ROOT CROPS MANAGEMENT TECHNOLOGY

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INTRODUCTION

The food situation in most of the countries in the world is far from satisfactory. As a matter of fact, most developing countries are experiencing underproduction and severe food shortages due to unprecedented adverse climatic changes, rapid increase in population and rising prices of agricultural inputs. Against this background, it becomes imperative for all concerned to search and develop alternative sources of food aside from conventional grain crops.

The United Nations' Food and Agriculture Organization has calculated that food requirement standards in terms of calorie intake ranges from 2223 calories per capita in the Far East to 2560 calories per capita in North America. Based on the above standard, FAO has estimated that for developing countries current food consumption provides only 96 percent of calorie requirements, Figure 1. It has been predicted that the demand for food beginning in the 1980's will increase more rapidly in developing than in developed countries.

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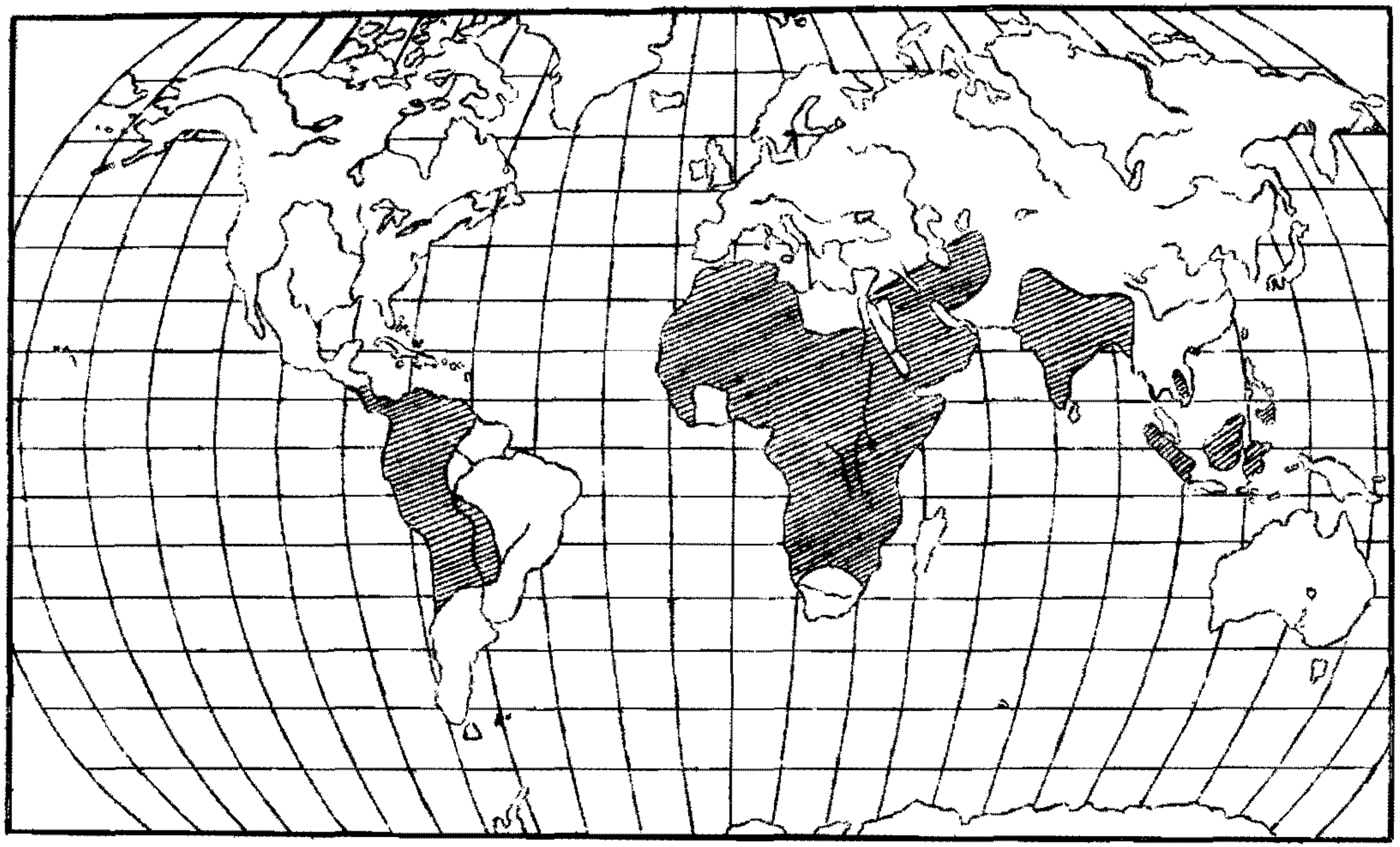

Regions with more than 100 calories deficit per day

Figure 1. Areas of the world with more than a 100-calorie/day deficit.

This means that agricultural production must grow more rapidly in these countries if the demand for food is to be met satisfactorily. Unfortunately, projections indicate that growth of agricultural production in developing countries will not match demand. It appears therefore that in the coming years developing countries will have the essential task of trying to meet consumption demands and nutrition requirements. A crucial element in this supply and demand balance is the ability of the country to produce sufficient calories — and in this regard the root and tuber crops are important crop commodities that can supply the needed calories.

Experience in many countries of the world especially in the tropics of Asia and the Pacific demonstrate that roots and tuber crops like cassava, white and sweet potatoes, yams (Dioscorea), Aroids, etc. not only can provide the cheapest source of high energy foods, but that they are also comparatively easy to cultivate and are adapted to our environment in the tropics.

Most root and tuber crops are thought to be of recent introductions to Asia either from the African or American continents. They are often regarded as relics of primitive agriculture probably because of the important role these crops play in existing primitive societies and on the rudimentary husbandry they require, particularly vegetative propagation, (Leon, 1976 and Darlington, 1969). But as has been pointed out, the contrasting of agricultural systems based on the differences between seed and clonal propagation is a simplification of a problem that is too complex to be reduced to the duality of planting materials.

Root crops are classified as such because the roots and tubers of these particular plant species are storage organs that developed probably as a result of selective pressures by the environment. The storage organs permit the accumulation of nutrients elaborated by the aerial parts of the plant. By growing underground, they maintain the nutrients with minimal loss. Once the temporary branches or foliage have dried, new shoots develop from the storage organs. By harvesting roots and tubers before the plants have flowered, man has interrupted this process, and thus kept the plants in a kind of permanent juvenile stage. In most of the root crops, the storage organs are primarily carbohydrate sinks. While it can also serve as reproductive organs thereby making this double function of foremost importance in their propagation, it is in the ability of the metamorphosed root to act as a reservoir of carbohydrate that these crops deserve the attention of researchers, scientists and policy makers.

The following paper attempts to describe the potential and status of root crop technology in some countries in Asia. It also ventures to analyze the constraints and problems of the industry and seeks to explain why it is in such a static system. Finally, it offers some strategies on how the industry can be improved. Because of the dearth of information relative to most root crops grown in the Region[3/], examples used are biassed for cassava and sweet potato — the two most important root crops in the humid tropics.

CURRENT STATUS

A. Crop description and origin

A brief description of some of the important root crops is given in Appendix A.

B. Production Statistics

A large variety of roots and tubers are grown in Asia especially in the humid tropics. In the countries of the South Pacific Islands roots and tubers form the staple diet of the people. Being rich in carbohydrates, they supply a large number of calories in the diet of the rural masses. In the years of food scarcity and high prices of traditional food grains, the demand for roots and tubers increases rapidly among low income groups.

The reported statistics on the area and production of several of these crops are neither complete nor comprehensive and are far less reliable than those of other crops. However, FAO reports world data in respect to white potatoes, sweet

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[3/] In subsequent discussion, Region refers to Asia and the Pacific area.

potatoes, cassava, yams and other roots not elsewhere specified, Tables 1 to 5. Data on Tables 1 to 5 show the extent to which these crops are cultivated in Asia in relation to other countries of the world.

In 1975, the total area and production of roots and tubers in the Asia and Pacific region were 21 million hectares and 203 million tons respectively. Countries producing more than 100,000 tons of roots and tubers were Bangladesh, China, India, Indonesia, Malaysia, Papua New Guinea, Philippines, the Socialist Republic of Vietnam, Sri Lanka and Thailand. The region contributed 40 and 35 percent to world area and production respectively (Figure 2). Average yield in the region was 9.5 tons per hectare against the world average of 11 tons. Within the region, the yield varied between 4.8 tons per hectare in the Philippines and 14.6 tons per hectare in Thailand, underscoring the production potentials of these crops.

Both white and sweet potatoes are grown in Bangladesh. Yields are low and considerable scope exists for expanding the production of tuber crops in Bangladesh.

White potatoes, sweet potatoes and cassava are the important tubers and root crops in India, but their yields are relatively low. Considerable work is being done on these crops at the Central Potato Research Institute at Simla and the Central Tuber Crop Research Institute at Trivandrum.

Table 1. World production of white potatoes, 1975.

Country	Area 1000 ha	Production million tons	Production % of total	Yield t/ha
USSR	7912	88.5	30.4	11.2
Poland	2585	46.5	16.0	18.0
China	3846	40.0	13.7	10.4
USA	509	14.3	4.9	28.2
Germany (Dem. Rep.)	636	13.4	4.6	21.1
Germany (Fed. Rep.)	415	10.8	3.7	26.2
France	311	7.2	2.5	23.2
India	594	6.2	2.1	10.4
Spain	376	5.2	1.8	13.7
Netherlands	151	5.0	1.7	33.1
UK	205	4.5	1.6	22.1
Czechoslovakia	249	3.6	1.2	14.3
Yugoslavia	315	3.2	1.2	10.1
Italy	178	3.0	1.0	17.1
Japan	140	3.0	1.0	21.4
Rumania	311	2.9	1.0	9.3
Turkey	187	2.3	.8	12.5
Canada	107	2.1	.7	19.9
Peru	280	1.9	.6	6.7
Hungary	133	1.7	.6	12.6
102 countries producing less than 1.7 million tons		26.0	8.9	
TOTAL		291.3	100.0	

Source: FAO Production Yearbook, 1975.

Table 2. World production of sweet potatoes, 1975.

Country	Area	Production		Yield
	1000 ha	million tons	% of total	t/ha
China	12036	114.8	84.1	9.5
Indonesia	385	3.0	2.2	7.8
India	215	1.8	1.3	8.4
Brazil	150	1.7	1.2	11.3
Korea Rep.	80	1.5	1.1	18.8
Japan	69	1.4	1.0	20.6
Burundi	161	1.3	.9	7.8
Vietnam Dem. Rep.	198	.9	.7	4.7
Bangladesh	67	.7	.5	10.8
Philippines	160	.7	.5	4.4
Uganda	140	.7	.5	4.7
Rwanda	86	.6	.5	7.5
USA	48	.6	.5	12.8
Cameroon	129	.6	.4	4.3
Kenya	57	.6	.4	9.7
Argentina	41	.4	.3	10.2
Papua New Guinea	92	.4	.3	4.4
Thailand	36	.3	.2	9.2
Korea Dem. Rep.	40	.3	.2	8.0
Madagascar	66	.3	.2	4.7
90 countries producing less than .3 million tons		3.9	2.9	
TOTAL		136.6	100.0	

Source: FAO Production Yearbook, 1975.

Table 3. World production of cassava, 1975.

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

Source: FAO Production Yearbook, 1975.

Table 4. World production of yams, 1975.

Country	Area	Production		Yield
	1000 ha	million tons	% of total	t/ha
Nigeria	1350	15.00	74.3	11.1
Ivory Coast	200	1.70	8.4	8.5
Ghana	160	.80	4.0	5.0
Yogo	100	.75	3.7	10.7
Benin	59	.61	3.0	10.3
Ethiopia	62	.27	1.3	4.4
Sudan	88	.26	1.3	3.0
Papua New Guinea	11	.17	.8	14.9
Japan	8	.14	.7	17.9
Jamaica	12	.13	.7	11.5
Guinea	15	.06	.3	3.7
Venezuela	10	.05	.2	4.7
Upper Volta	8	.05	.2	6.0
Dominican Rep.	3	.03	.1	10.7
Philippines	7	.03	.1	4.2
17 countries producing less than .03 million tons		.16	.8	
TOTAL		20.20	100.0	

Source: FAO Production Yearbook, 1975.

Table 5. World Production of taro (coco yam), 1975.

Country	Area 1000 ha	Production million tons	Production % of total	Yield t/ha
Nigeria	320	1.80	40.0	5.6
Ghana	150	1.40	31.0	9.3
Japan	35	.50	11.1	14.3
Papua New Guinea	26	.22	4.9	8.4
Ivory Coast	230	.20	4.4	.9
Madagascar	14	.09	2.0	6.4
Philippines	17	.08	2.0	5.1
Egypt	2	.05	1.2	26.0
Yogo	6	.04	.9	6.7
China	3	.02	.5	9.1
Benin	3	.02	.5	6.7
Solomon Is.	1	.02	.3	17.4
West Samoa	4	.01	.3	3.6
Sierra Leone	2	.01	.2	6.7
9 countries producing less than .01 million tons		.03	.7	
TOTAL		4.50	100.0	

Source: FAO Production Yearbook, 1975.

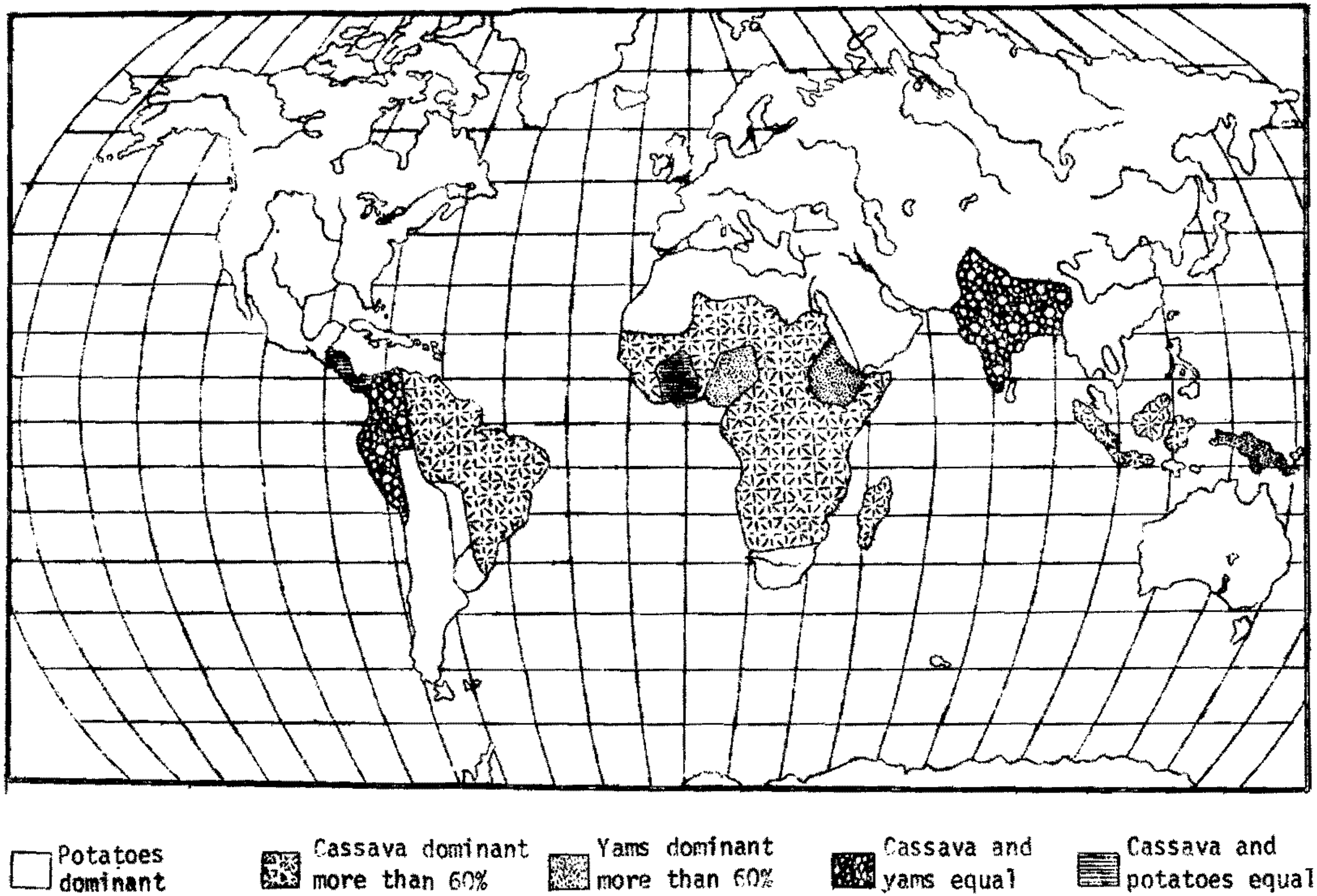


Figure 2. Map of the world showing areas of importance for specific root crops.

Appropriate agronomic practices have also been developed resulting in several high yielding varieties of cassava. Associated agronomic practices are also being developed under the All India Co-ordinated Research Scheme for Tuber Crops.

In Indonesia, cassava, sweet potatoes and other root crops are extensively grown. Total production is over 14 million tons of which cassava alone accounts for 12.9 million tons. With further efforts in research and development, cassava among the root crops, has the best potential for export.

Cassava and sweet potato are the important root crops in Malaysia. Research is being undertaken on the following aspects: mechanical harvesting, weed control, time of planting and plant breeding to improve yield and nutritive content of some tuber crops. Most of the work is coordinated by the Malaysian Agricultural Research and Development Institute supported by the Colleges and Ministry of Agriculture.

In the Philippines, the most important root and tuber crops are sweet potato and cassava, and to a lesser extent, gabi (<u>Colocasia</u> spp.) and yam or "ubi" (<u>Dioscorea alata</u>). White potatoes are also grown on higher altitudes and at a limited scale. A summarized hectarage and production of these crops is given on Table 6 while individually and by regions, the data are shown on Tables 7 to 11. These statistics show that yield of root crops in the Philippines are among the lowest in Asia.

Table 6. Area and production of rootcrops in the Philippines, 1975.

Root Crops	Area	Production	Yield
	ha	mt	t/ha
Sweet Potato (*Ipomoea batatas*)	195,730	986,017	5.0
Cassava (*Manihot esculenta*)	119,310	679,322	5.7
Gabi (*Colocasia* spp.)	25,970	92,706	3.6
Pao (Galiang) (*Cyrtosperma chamissonis*)	3,920	19,591	5.0
Tugui (*Dioscorea esculenta*)	1,290	3,611	2.8
Ubi (Yam) (*Dioscorea alata*)	4,910	21,578	4.4

Source: Bu. of Agric. Econ., 1976.

Table 7. Area planted and production of cassava by region, Philippines, 1976.

Region	Area	Production	Yield
	ha	1000 mt	t/ha
PHILIPPINES	117,970	620.93	5.3
Ilocos	2,240	18.93	8.5
Cagayan Valley	990	3.12	3.2
Central Luzon	860	2.90	3.4
Southern Tagalog	8,180	36.08	4.4
Bicol	19,360	148.62	7.7
Western Visayas	7,790	39.16	5.0
Central Visayas	23,920	89.93	3.6
Eastern Visayas	29,340	163.41	5.6
Western Mindanao	3,230	15.91	4.9
Northern Mindanao	16,650	63.88	3.8
Southern Mindanao	5,410	42.00	7.8

Source: Bu. of Agric. Econ., 1977.

Table 8. Area planted and production of sweet potato by region, Philippines, 1976.

Region	Area	Production	Yield
	ha	1000 mt	t/ha
PHILIPPINES	192,270	781.20	4.1
Ilocos	12,030	81.99	6.8
Cagayan Valley	7,960	35.38	4.4
Central Luzon	6,850	31.64	4.6
Southern Tagalog	8,610	31.34	3.6
Bicol	19,360	121.70	6.3
Western Visayas	6,780	43.02	6.3
Central Visayas	27,850	76.96	2.8
Eastern Visayas	54,080	186.23	3.4
Western Mindanao	2,500	11.44	4.6
Northern Mindanao	37,710	106.22	2.8
Southern Mindanao	8,510	44.29	5.5

Source: Bu. of Agric. Econ., 1977.

Table 9. Area planted and production of gabi (Colocasia) by region, Philippines, 1975.

Region	Area	Production	Yield
	ha	1000 mt	t/ha
PHILIPPINES	25,970	92.71	3.6
Ilocos	640	4.20	6.6
Cagayan Valley	260	0.86	3.3
Central Luzon	300	2.46	8.2
Southern Tagalog	1,640	11.53	7.0
Bicol	3,210	9.71	3.0
Western Visayas	120	0.70	5.8
Central Visayas	8,070	10.92	1.4
Eastern Visayas	7,550	24.50	3.3
Western Mindanao	240	0.67	2.8
Northern Mindanao	3,390	11.48	3.4
Southern Mindanao	920	7.32	8.0

Source: Bu. of Agric. Econ., 1976.

Table 10. Yam (Ubi): Area, production and yield by region, Philippines, 1975.

Region	Area	Production	Yield
	ha	mt	t/ha
PHILIPPINES	4,910	21,578.2	4.4
Ilocos	110	460.8	4.2
Cagayan Valley	150	602.6	4.0
Central Luzon	70	270.5	3.9
Southern Tagalog	410	1,887.1	4.6
Bicol	40	240.0	6.0
Western Visayas	40	224.9	5.6
Central Visayas	3,070	11,451.8	3.7
Eastern Visayas	360	1,718.6	4.8
Western Mindanao	110	453.3	4.1
Northern Mindanao	270	2,132.1	7.9
Southern Mindanao	280	2,136.5	7.6

Source: Bu. of Agric. Econ., 1976.

Table 11. White potato: Area, production and yield by region, Philippines, 1975.

Region	Area	Production	Yield
	ha	mt	t/ha
PHILIPPINES	3,290	20,423.9	6.2
Ilocos	2,440	17,585.6	7.2
Cagayan Valley	60	164.2	2.7
Central Luzon	NA	NA	NA
Southern Tagalog	NA	NA	NA
Bicol	40	180.0	4.5
Western Visayas	NA	NA	NA
Central Visayas	60	69.0	1.2
Eastern Visayas	NA	NA	NA
Western Mindanao	10	26.0	2.6
Northern Mindanao	440	1,270.4	2.9
Southern Mindanao	240	1,115.7	4.7

Source: Bu. of Agric. Econ., 1976.

NA : Data not available.

Of the above root and tuber crops, cassava seems to have the brightest prospect in the Philippines especially as a source of low-cost energy. Presently, cassava is used largely for food, starch manufacture and to a lesser extent, for livestock feed. The crop is generally grown in small farms from less than one to two hectares in size. Most of the produce are consumed mainly as immediate food, while in large plantations the tubers are processed into starch for commercial purposes.

In Sri Lanka, cassava, sweet potato and yam are cultivated in the wet zone of the country. The area under these crops has increased considerably because of their importance in supplementing the available food supplies.

Cassava is the most important root crop in Thailand and its cultivation has expanded recently under the stimulus of exports as livestock feed. About 80 percent of the Kingdom's planted area is in the Central Plain. Two provinces, Rayong and Chonburi account for nearly 90 percent of the Central Plain planted area and 70 percent of the Kingdom's output. The importance of these two provinces is attributed to their relatively high precipitation even in the dry season and the sandy loam soils.

C. Research

1. National Level

Except for India, up-to-date information regarding the current status of root crop research at the national level is not readily available in respect to many countries in the Region. Some countries like the Philippines and Malaysia have recently reorganized their national research system (Appendix B) and it is too early to assess the progress they have made in improving the industry. With respect to cassava however, Thailand is an exception — primarily because of the support the private sector has given to the industry. One difficulty is the lack of delineation and classification for these crops. Thus, sweet potato and taro which are considered very important crops in the Pacific Islands, are not accorded the same importance in Thailand. These confusion further serve to underscore the need for current information on root crop production, research and development.

2. International Institutes

Beginning with the International Rice Research Institute (IRRI), which was set up at Los Baños in the Philippines in 1962 jointly by the Rockefeller and Ford Foundations in cooperation with the Government of the Philippines, there were at the end of 1975, nine international research institutes supported by the Consultative Group on International Agricultural Research (CGIAR) dealing with a crop or group of crops and/or livestock. The names of these institutes, their locations, the area covered by them and the commodities handled are given in

Appendix C. In addition, six Asian countries together with the USA and the Asian Development Bank established in 1971 the Asian Vegetable Research and Development Center.

Of the ten institutes, the International Laboratory for Research on Animal Diseases (ILRAD) and the International Livestock Center for Africa (ILCA) deal exclusively with livestock. The remaining eight are mainly crop-oriented, although the International Center for Tropical Agriculture (CIAT) has a program on beef cattle and swine. Most of these institutes are placing emphasis on multiple-cropping programs and/or farming system, although they still continue to be crop-oriented.

Of the Institutes listed above, CIAT, CIP and ICRISAT have a global mandate. CIAT puts special emphasis on Latin America, and IITA on Africa. CIP has a mandate for both tropical and temperate regions. ICRISAT attends to problems in the dry semi-arid tropics and has relay stations in Africa. ICARDA covers the Near East and North Africa. IRRI, AVRDC and ICRISAT are located in Asia. All, but AVRDC are supported by the CGIAR.

Root and tuber crops are primary commodities being researched at four of these international centers:

a) Centro Internacional de Agricultura Tropical
   or CIAT: cassava

developed. Too, CIAT has since organized the largest germplasm bank for cassava in the world. It now contains in excess of 2500 entries encompassing the greatest genetic and morphological variability available up to the present.

D. Production Practices

1. Soil and climatic requirements

One of the favorable features of the whole group of root and tuber crops is the great diversity of types that are available for cultivation which makes it possible to grow one root crop or other under any ecological situation.

Root crops adopt to a wide variety of soil types and climate. Except for some varieties of white and sweet potato which can be harvested in six months time or less, root crops in general mature in a year.

Root crops can grow under a wide range of climatic environment in the tropics. Except for the white potato which is adapted in higher altitudes and cool areas, most tuber crops perform best in a warm humid climate with a well distributed rainfall of 1000 to 2000 mm per year. Cassava is a special case in that except during the early stage of development, it can withstand periods of prolonged drought and is therefore a valuable crop in regions of low or uncertain rainfall.

Root crops can grow well in soil types ranging from light to heavy. Most grow best on sandy loams or loamy sands (about 50-80 percent sand, 0 to 50 percent silt and 0 - 20 percent clay), which are moist, fertile and deep. Poorly drained, heavy and rocky soils are among the most unfavorable conditions for proper size, shape and development of tubers — including ease in harvesting. Cassava, for example cannot thrive on water-logged soils. On the other hand, the Aroids like the Colocasia and Cyrtosperma possess special adaptation to be able to grow under wet soil conditions.

2. Cultural practices

In most of the small farms in Asia and the Pacific region, root crops are generally cultivated under subsistence type of agriculture. Root crop husbandry is generally labor intensive especially in the planting and harvesting operations (in most root crops these are simultaneous operations) since vegetative or asexual propagation is the rule rather than the exception. Thus in lands probably freshly opened by slash-and-burn methods with virtually no intertillage, weeding or bedding is undertaken. With the exception of large progressive plantations (cassava commercial plantations in Indonesia, Malaysia, Thailand, etc.) attempts to modernize, in the sense of increased use of fertilizers, herbicides, pesticides and machineries, have failed. In the past, the failure could be due to the small size of most farms and the uneconomic cost of agricultural inputs. Another contributing factor is the unavailability of appropriate technology and infrastructure.

On the other hand progressive plantations in the region do practice improve methods of husbandry viz: use of adapted varieties, crop protection, cultural management, cropping system and even mechanical harvesting. The improved production system for cassava is a good example. Cock (1977) has pointed out that in spite of its great yield potential and certain attributes that make it easy to fit into a farming system, world cassava yields at 10 t/ha are far below those that might be expected. The reasons for these low yields include: poor agronomic practices, poor varietal selection and control of insect pest and diseases. In consideration of the above, a package of practices for cassava production would probably include the following:

a. Weed Control

Adequate weed control can markedly improve yields. Data from CIAT demonstrate that cassava yields can be reduced to less than 2 t/ha when no weed control is used (Doll, 1974). Table 12 and Figure 3 shows this graphically. Thus to maximize yield, weeding operation must begin 15 to 30 days after planting and continue

Table 12. Effect of hand weedings at different times and frequencies on the fresh root yield of cassava (CMC-39) at 380 days after planting.

No. of hand weedings	Frequency of hand weedings (days)	Fresh root yield	
		tons/ha	Percent of maximum yield*
4+**	15, 30, 60, 120, UH***	18.0	86
3+	30, 60, 120, UH	16.0	76
2+	60, 120, UH	11.0	56
1+	120 UH	7.0	33
4	15, 30, 60, 120	19.5	92
3	15, 30, 60	12.9	61
2	15, 30	13.3	63
1	15	5.8	28
2	30, 60	16.3	77
2	15, 45	15.4	73
0	Weedy check	1.4	7
0	Chemical control****	21.1	100

* Percentage of the yield of cassava weeded with herbicides.
** The "+" indicates additional weedings.
*** UH = until harvest, as needed.
**** Alachlor + fluometuron were applied in pre-emergence, and directed applications with a shielded nozzle were made of paraquat as needed in postemergence.

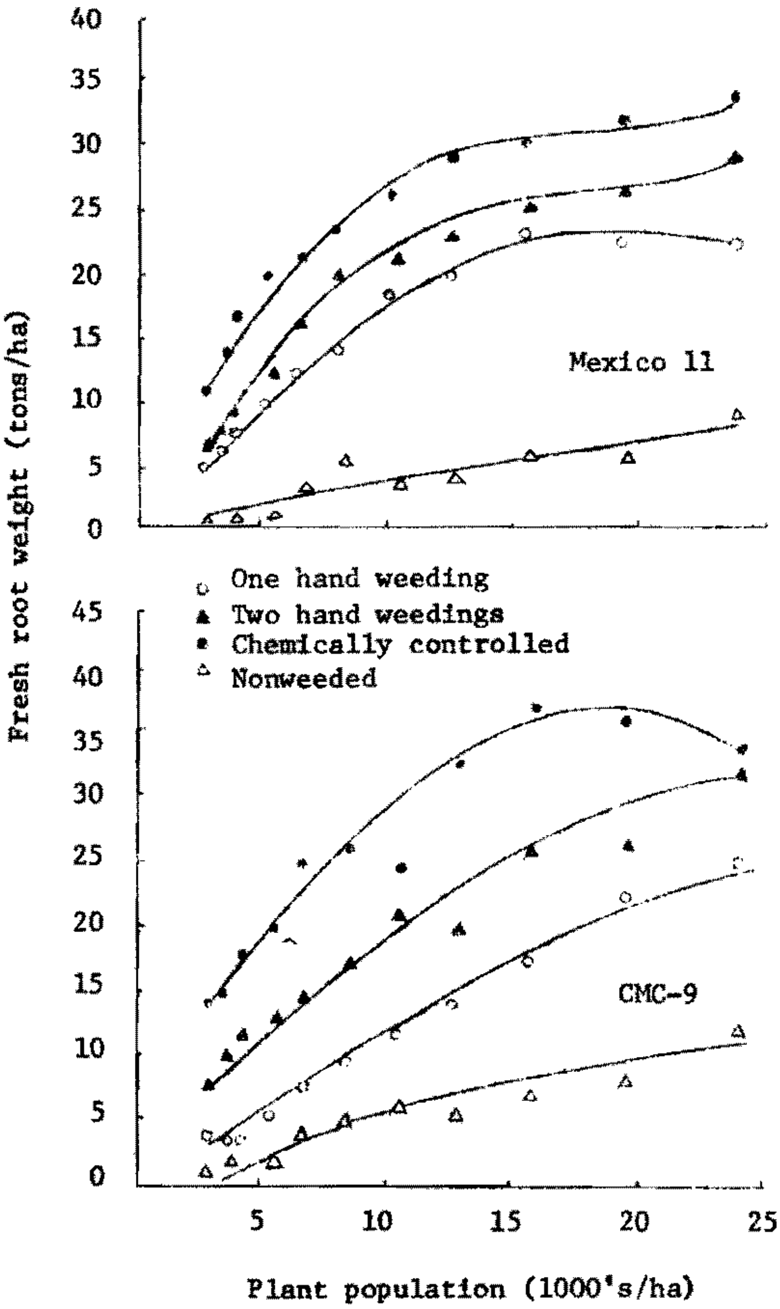


Figure 3. Effect of cassava population and weed control system on fresh root weight 10 months after planting for Mexico 11 and CMC-9.

until a canopy has formed. Weeding after 120 days do not increase production. One weeding is not sufficient, whereas two well-spaced weedings is capable of producing 75 percent of the maximum yield. The highest yield could be obtained by chemically weeding the cassava, never allowing weeds to compete with the crop.

b. Varietal Selection

There is no substitute for an improved adapted variety. New, improved varieties of cassava (as well, as sweet and white potatoes) are now exhaustively tested by the Centers at various ecological conditions. Most of these varieties are currently entered in the regional trials and some of them could very well be recommended as country varieties in the near future. Further, for cassava there is ample evidence that different varieties grown under similar conditions have very different yielding ability (Galang, 1931; Lambourne, 1937; Arraudeau, 1969; Sarmiento, 1969; CIAT, 1972; 1973) and that these variations are large enough to be highly important to the grower. In a recent trial at CIAT with very low level of disease and pest incidence, yields of varieties varied from 16 to 46 t/ha per year. Thus, simple selection opens the way in some instances to very large yield increases.

c. Fertilization

The literature is full of reports that due to its high nutrient requirement, cassava is a soil-depleting crop especially with respect to potassium. This is not surprising, for any crop that yields well particularly on poor soils, will deplete the nutrient reserves in that soil (Cock, 1974). On the other hand, past studies (Birkinshaw, 1926) have shown up to 15 cassava crops being harvested continuously in the same farm with no significant decrease in the productivity of the soil. Nonetheless, the use of fertilizer to obtain high yields is essential, particularly if the crop is planted on poor soils (De Geus, 1967). In Latin America, farmers frequently say that excessive nitrogen actually decreases yield due to excessive top growth (Figure 4). At CIAT, fertilizer trials using up to 300 kg/ha of N have not shown any negative nitrogen response. Although reports on the favorable responses of fertilizers to increasing cassava yields are numerous, the low value of cassava and the high price of fertilizers in some region, makes it uneconomical for the farmers to apply it. It is however, obvious that yields can be increased by the judicious use of fertilizers.

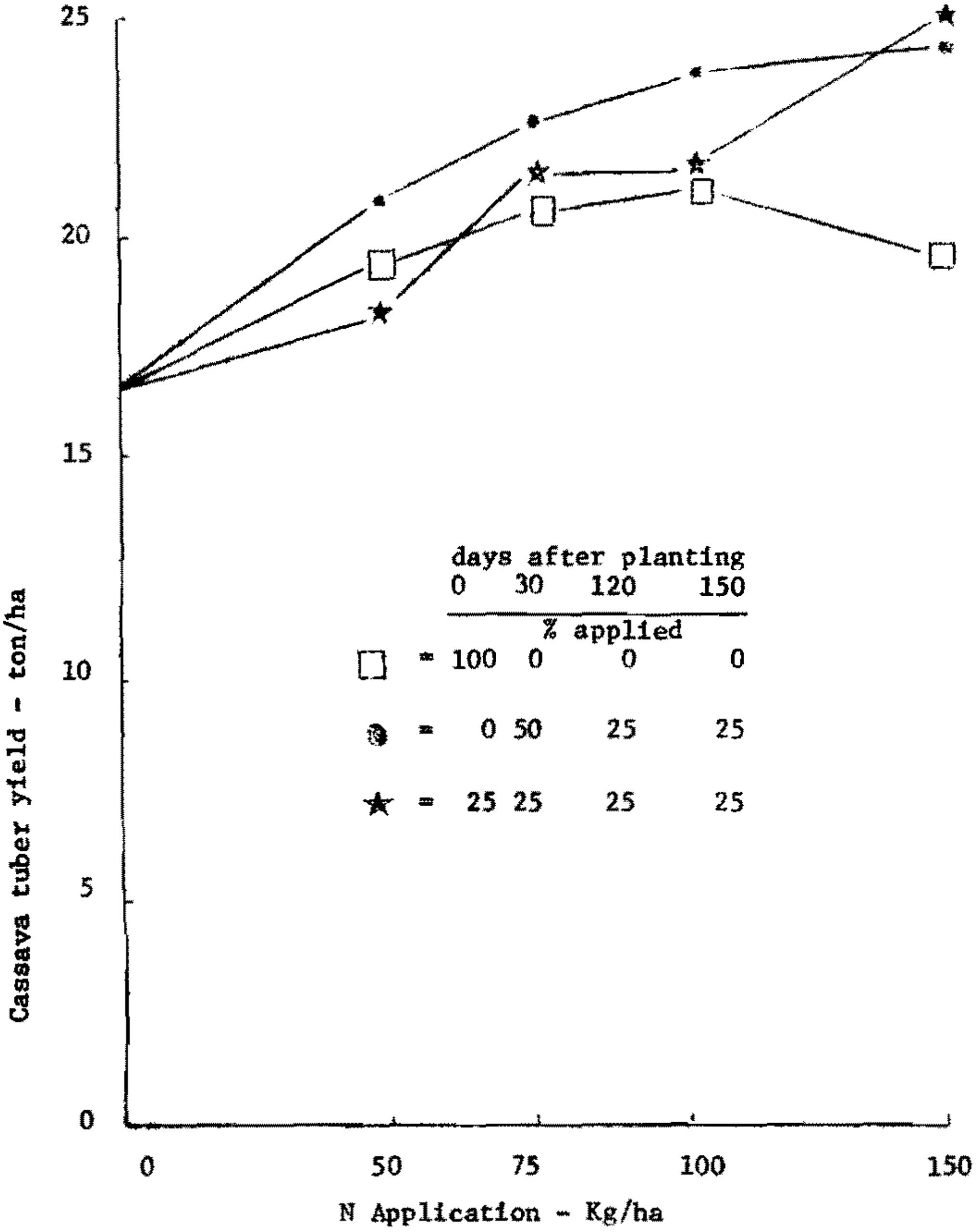


Figure 4. - Cassava response to various levels and times of application of urea-nitrogen at Carimagua.

d. Pest and disease control

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

The spread of pests and diseases is usually facilitated through the planting materials. Cassava is vegetatively propagated by planting pieces of stem cuttings; consequently, cassava pathogens can be disseminated easily by the movement of planting materials from infected to uninfected areas. It is in recognition of this, that the treatment of cassava stakes before planting in a mixture of insecticide and fungicide ("the cassava cocktail") should become a standard practice, considering that the cost of such a treatment is insignificant, Table 13.

Table 13. Cost of treating cassava cuttings with certain pesticides and zinc sulfate.

Product	Concentration g/ha	Cost (Aggregate) US $
Dithane M-45	333.0	0.43
Manzate 80	187.5	0.65
Vitigran	300.0	1.15
Malathion E.C.	750.0	2.93
Zinc sulfate*	6000.0	6.21

*Use only when there is a deficiency of zinc.

In sweet potato the sweet potato weevil has been considered as one of the most important insect pest attacking the tubers. Damaged by the weevils lowers significantly the marketable value of the roots and even renders it unfit for human consumption. A good fraction of the entomology and pesticide chemistry work at AVRDC deals with screening and evaluation of insecticides for sweet potato weevil control. Several of these insecticides have shown promise and perhaps can form part of the recommendation in the near future, Tables 14 and 15.

Table 14. Comparative effect of different insecticide treatments on sweet potato yield, weevil control, and pesticide residue; 1975, AVRDC.

Insecticide (formulation)	Rate (kg a.i./ha)	Total yield	No. of weevils		Pesticide residue	
			roots	stem	roots	tips
		(t/ha)			-----(ppm)-----	
Heptachlor	4	48	7	3	0.017	0.04
DDT	4	47	26	2	0.010	1.07
Toxaphene	4	44	33	12	nd	nd
Chlordane	4	41	102	4	0.004	0.46
Lindane	4	37	132	11	0.009	0.79
Dieldrin	4	37	43	6	0.007	1.14
Heptachlor	2	36	42	12	0.005	0.01
Chlordane	2	35	50	40	0.003	0.22
Dieldrin	2	34	45	11	0.003	1.15
Control		40	103	29		
LSD 5%		12	100	20		

Table 15. Comparative effect of nine insecticides on sweet potato yield, weevil control, and pesticide residue; 1975, AVRDC.

Insecticide (formulation)	Rate (kg a.i./ha)	Total yield	No. of weevils		Pesticide residue in leaves
			roots	stem	
		(t/ha)			-----(ppm)-----
Furadan	1	12	6	4	0
Monitor	1	11	24	4	
Surecide	1	10	7	5	1.9
Hostathion	1	10	9	4	0.2
Lannate	1	10	9	8	
Azodrin	1	9	18	11	
Dursban	1	9	21	6	
Diazinon	1	9	24	14	
Gardona	1	9	29	13	
Control		8	37	6	
LSD 5%		3	19	8	

E. Post-Harvest Handling, Marketing and Utilization

1. Storage of harvested tubers (Cassava)

Cassava roots have a very high perishability. Deterioration of roots after harvest is either physiological or microbial. Physiological deterioration is characterized by a dry brown to dark necrosis, normally appearing in the form of rings around the periphery of the cortex. This deterioration appears within the first 48 hours of harvesting, depending on varietal susceptibility. Microbial deterioration commonly starts as vascular streaking, followed by soft rot, fermentation and maceration of the root tissues. This type of deterioration which does not occur in any special order, is normally noticeable 5 to 8 days after harvesting, depending on the soil microbial flora able to metabolize cassava roots and on the intensity of damage to roots at harvest. Studies at CIAT (1976) and elsewhere (Booth, 1976; 1977) show that physiological deterioration can be prevented either by pruning the plants two to three weeks before harvest or by packing the roots in polyethylene-lined paper bags after harvest, Figures 5, 6 and 7. Microbial deterioration can be prevented by dip-treating the roots with broad spectrum fungicides such as Manzate, Figure 8.

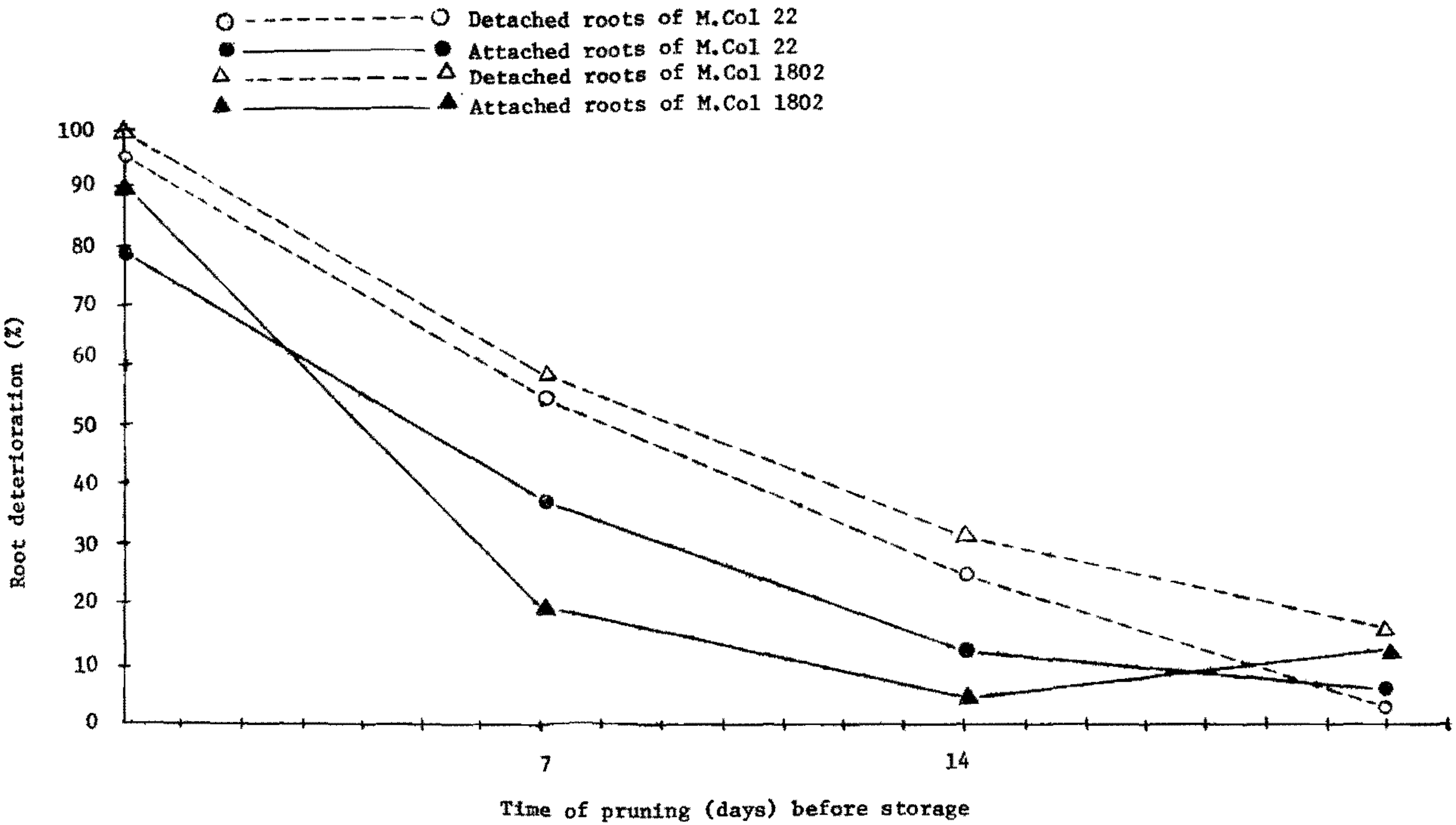


Figure 5. Pruning effect on cassava root deterioration after 20 days of storage

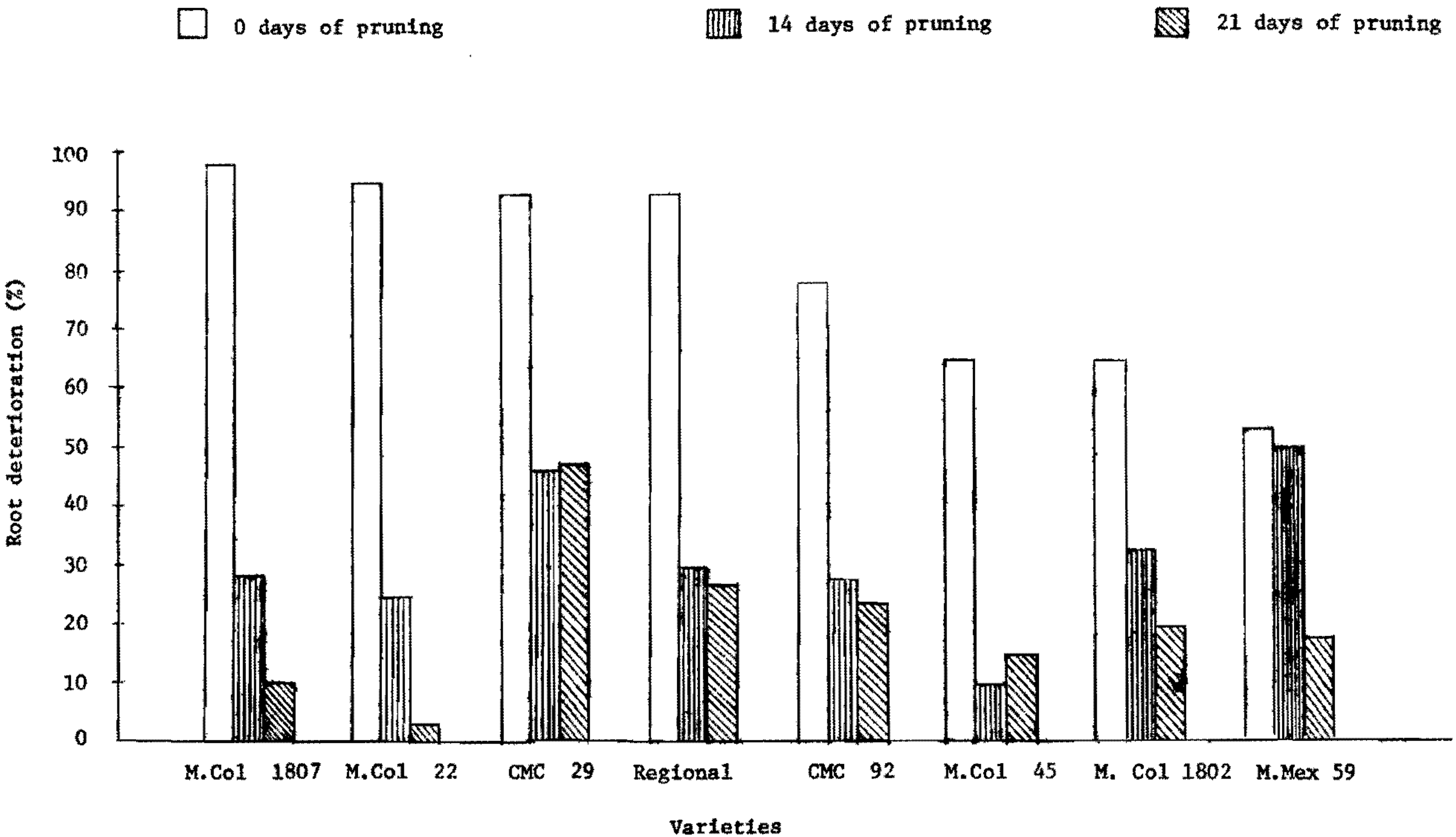


Figure 6. Root deterioration of eight cassava varieties pruned 0, 14 and 21 days before harvesting and stored for 20 days.

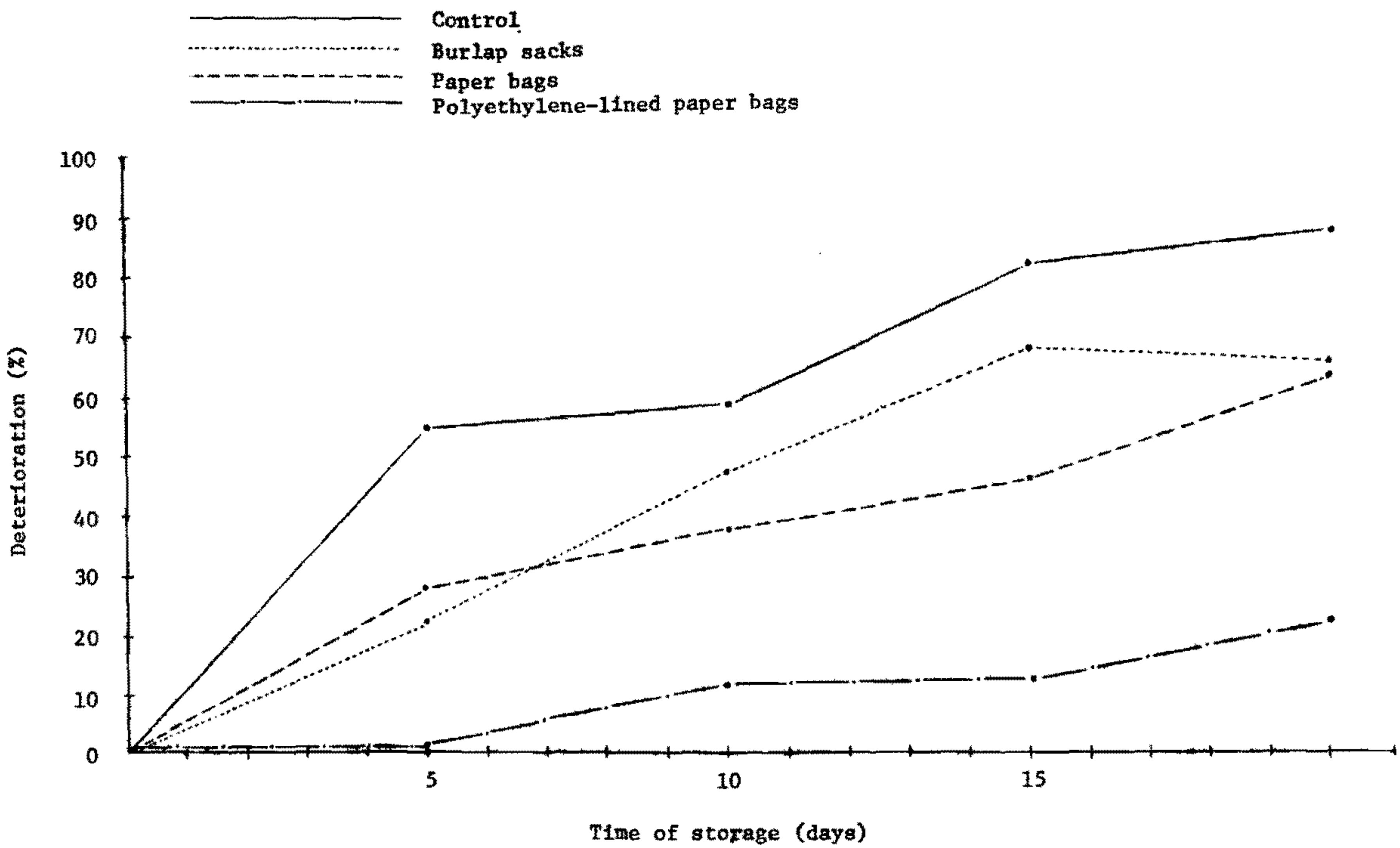


Figure 7. Effect of storage in bags on cassava (var. M.Col 113) root deterioration.

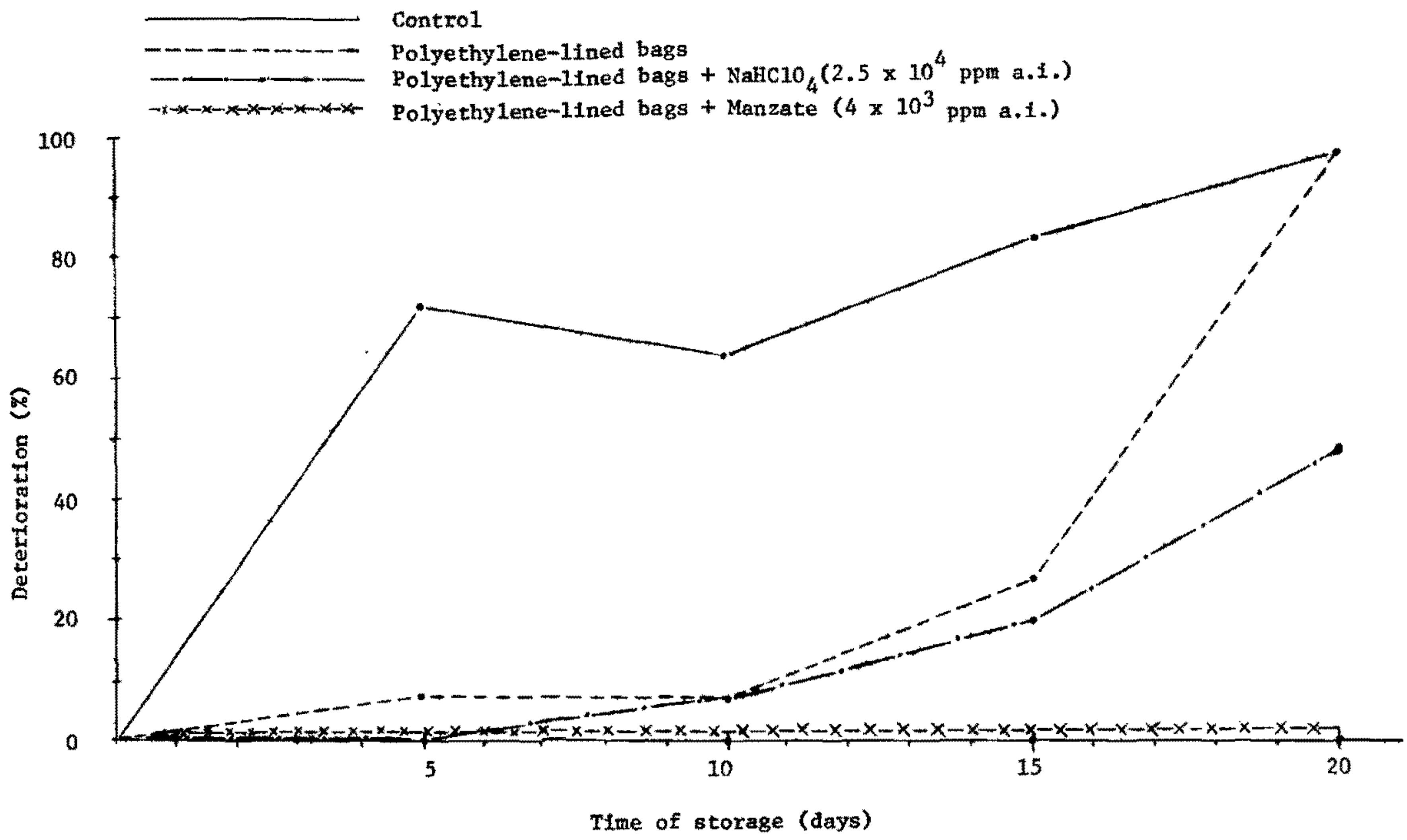


Figure 8. Effects of polyethylene-lined paper bags and chemical treatments on deterioration of stored roots.

Other practical ways of storing cassava is by the clamp method or by using moistened sawdust. The clamp method has been proven effective by experiments in some parts of Asia. A clamp is built in well drained ground by first placing a circular bed of straw approximately 1.5 m diameter and 15 cm thick. On this straw bed the freshly harvested roots are heaped in conical piles, for each unit between 300-500 kg of unselected roots are used. The pile of roots is then covered with soil to a thickness of 10-15 cm while the soil around the clamp is dug to form a drainage ditch. Under clamp conditions, 75 percent of the roots survive storage for about one month, Figure 9.

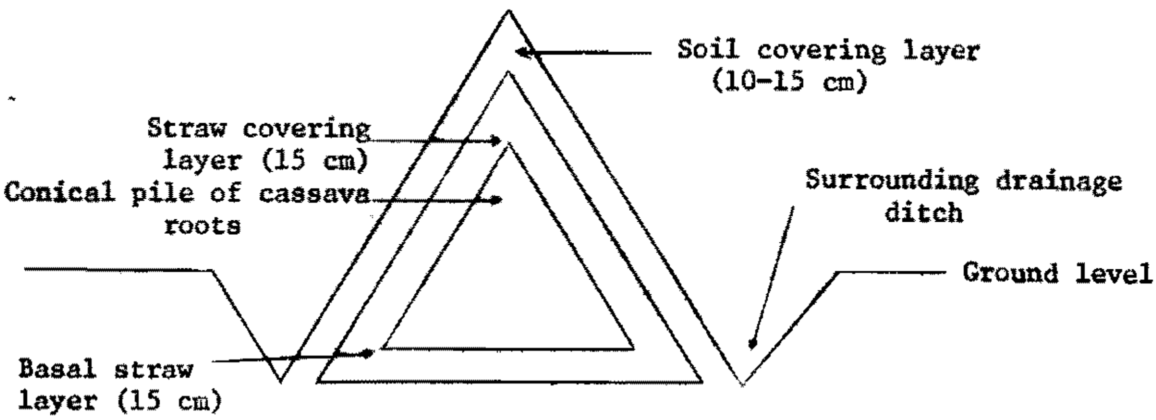


Figure 9. Cross-section through cassava clamp.

Storing cassava roots in boxes at ambient temperature surrounded by damp (45-55 percent moisture) sawdust or any suitable substitute is another way of curing. Under these conditions 85 percent of the roots survive storage for two months or more. This type of storage is suitable when transporting cassava roots.

2. Marketing (Sweet potato, Philippines, Santos, 1977)

As with production statistics, data on marketing of rootcrops in the region is scanty or unavailable. In some cases the reason is simply the lack of records on the transactions between the producers and the buyers. The following data is presented, more to show the problems of a particular commodity in a particular country, rather than to serve as a typical marketing picture in the region.

Sweet potato in the Philippines is classified both as a vegetable and as a root crop. It is grown all year round and is raised for home consumption as well as for commercial purposes.

a. Pre-sale practices and costs

Harvesting. Sweet potatoes are harvested as soon as they reached maturity to obtain good quality tubers. Farmers with small areas of sweet potatoes usually practice selective harvesting by digging with bolos, scythes, knives or other pointed tools and picking only the tubers large enough to be harvested. Thus two to three harvests per crop over a three-month period or so are typical. Farms with large areas of sweet potatoes usually harvest by first cutting and removing the vines, plowing, and then harrowing prior to picking up the roots. Harvesting costs range from ₱2.12 to ₱6.48 per 100 kilos (US$ 0.30 to 0.90 with 1 US$ = ₱7.30), Table 16.

<u>Hauling</u>. Farmers mostly carry or use animal-drawn sleds and carts in hauling sweet potatoes from the farm to the house. Hauling costs range from ₱0.46 to ₱2.47 (US$ 0.06 to 0.34).

<u>Cleaning, sorting, grading and packaging</u>. Some farmers clean sweet potatoes either by trimming small roots or by washing with water to improve the appearance of the tubers. They are then sorted to remove the diseased and badly bruised tubers before packaging them for market. Grading is done by sorting the tubers by size. Burlap sacks or baskets are generally used for packaging the roots. For these operations, cost varies from ₱0.17 to ₱1.83 per 100 kilos, Table 16.

<u>Delivery and selling</u>. Producers use several different methods like boats, trucks or by man, in delivering the tubers to their outlets. The average costs of delivery and selling (Table 16) reflects the

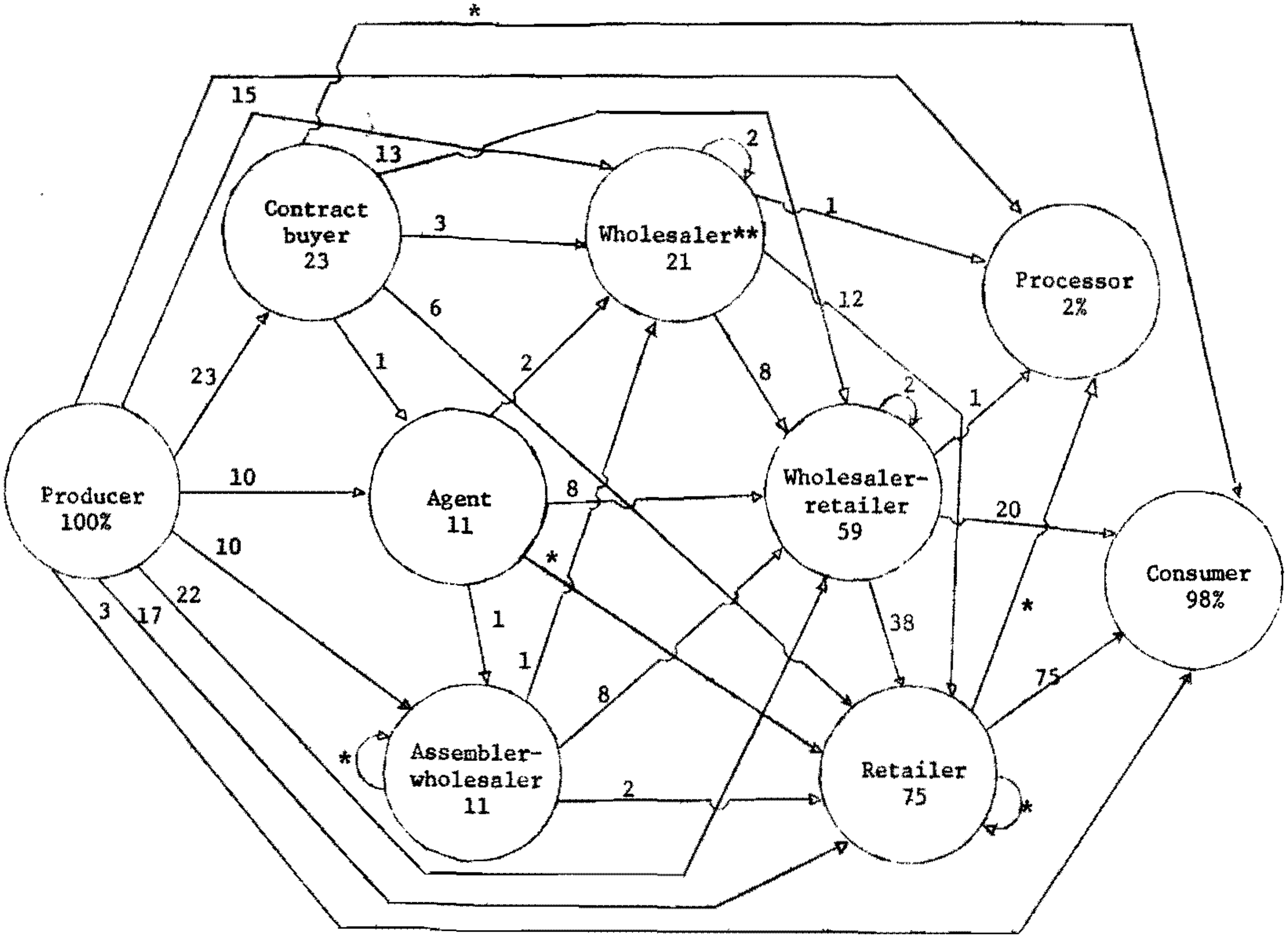
Table 16. Pre-sale practices and costs, 504 sweet potato farms, last harvest, Philippines, 1974-76.

Item	N. Viz-caya	C. Luzon: Pang. and Tarlac	C. Luzon: Bata-an	S. Luzon	Bicol	W. Visa-yas	C. Visa-yas	E. Visa-yas	N. Mindanao: Lanao del Norte	N. Mindanao: Agusan del Norte	C. Mindanao: Davao	C. Mindanao: Cota-bato
	Pesos per 100 kilos											
Harvesting:												
Digging	1.56	-	-	0.03	4.26	0.19	2.58	1.72	0.51	4.61	3.08	0.16
Plowing, harrowing, picking, trimming, cutting, assembling	4.92	3.39	5.22	5.19	-	3.51	-	0.40	4.10	-	0.12	2.21
Hauling:												
Man-carried	0.24	-	0.05	0.50	0.69	0.04	0.48	0.16	-	0.42	0.79	0.01
Carabao, cow with sled or cart	0.47	1.10	0.37	0.13	0.90	2.42	0.52	0.30	1.06	0.82	1.02	0.86
Other*	-	-	0.78	0.29	-	0.01	0.03	-	-	-	0.33	-
Cleaning	1.78	-	-	-	0.08	-	0.22	***	-	-	0.71	0.80
Sorting, grading, packaging	1.53	0.32	1.83	0.37	0.43	0.61	0.29	0.17	0.88	0.43	0.77	0.89
Delivery and selling:												
Man-carried	0.06	-	-	-	-	0.01	0.08	0.05	***	-	-	-
Carabao with sled, cart	-	0.02	-	-	0.31	0.18	0.51	0.15	0.91	0.16	-	0.31
Bus, mini-bus	-	0.20	-	-	0.66	0.54	-	-	-	-	-	0.16
Jeep, trailer	2.90	0.03	0.06	1.08	0.14	-	1.80	0.45	0.51	4.19	3.53	-
Tricycle	-	-	0.06	-	0.07	0.08	0.05	-	***	0.13	-	0.60
Other**	-	0.15	-	0.67	0.14	-	-	0.10	0.57	0.50	-	1.79
TOTAL	13.46	5.21	8.37	8.26	7.78	7.59	6.56	3.50	8.54	11.26	10.35	7.79

* Includes horses, trucks, trailers, tricycles, bicycles and jeeps.
** Includes horses, calesa, boats, pump boats and trucks.
*** Less than ₱0.005.

Table 17. Net farm price in selling sweet potatoes, 504 sweet potato farms, Philippines, 1974-76.

Area	Average selling price	Cost: Pre-sale practices	Cost: Invest-ment	Cost: Total	Net farm price
		Pesos per 100 kilos			
Nueva Vizcaya	47.00	13.46	0.99	14.45	32.55
Central Luzon:					
Pangasinan and Tarlac	40.00	5.21	7.18	12.39	27.61
Bataan	28.00	8.37	0.50	8.87	19.13
Southern Luzon	50.00	8.26	2.48	10.74	39.26
Bicol	30.00	7.78	1.11	8.89	21.11
Western Visayas	31.00	7.59	15.21	22.80	8.20
Central Visayas	30.00	6.56	1.66	8.22	21.78
Eastern Visayas	21.00	3.50	0.78	4.28	16.72
Northern Mindanao:					
Lanao del Norte	25.00	8.54	0.78	9.32	15.68
Agusan del Norte	54.00	11.26	0.40	11.66	42.34
Southern Mindanao:					
Davao	37.00	10.35	0.84	11.19	25.81
Cotabato	21.00	7.79	5.78	13.57	7.43



* Less than 0.5 percent.
** Includes financier-wholesalers.

Figure 10. Market channels for sweet potatoes, Philippines, 1974-76.

wholesalers. Contract buyers, agents and assembler-wholesalers sells the bulk of the volume handled to wholesaler-retailers; wholesaler and wholesaler-retailers sells more than half of the volume handled to retailers while a minimal portion are sold to processors. Retailers, as expected sells to consumers.

d. Marketing problems and possible solutions

Lack of standard sales unit. The tubers are usually sold at wholesale either by the can, sack or pile basis. The weight of a sack or can of sweet potatoes varies widely depending upon the size of the sack or container. There is no standard quantity in a pile. In such a system, the farmer (producer) is deprived of a good price for his product and the consumer who buys by the pile cannot chose the best quality roots he wants. A standard unit of sale, say the kilo would not only improve marketing procedures but would also make price information more meaningful.

Lack of market intelligence. Generally, producers are not aware of prevailing prices in major market outlets. The farmer/producers therefore have no alternative but accept the prices offered to them by buyers operating within the area. This information shortfall can be remedied either by setting up a price information system (through the local extension services, etc.) or through the creation of a cooperative marketing organization.

Poor quality tubers. Insect and rodent infected farms yield low quality products. Poor and good quality tubers are usually mixed together, packaged and sold. This practice downgrades product quality resulting in low prices. Low quality tubers should not be sold and control measures for rodents and insects infecting sweet potatoes should be used. Control information and assistance should be provided by appropriate agencies.

Proliferation of channels

Lack of good transportation facilities

3. Utilization (Cassava, McCann, 1976)

Cassava is well-suited as an agro-industrial crop, i.e. one that is grown primarily for processing into industrially useful products. With a yield potential now of about 40-50 t/ha even on rather infertile soils with limited inputs and without irrigation, cassava is the highest known yielder of starch and is in the top rank of crop biomass producers.

The importance of cassava as an agro-industrial crop has been further enhanced by the recent change in the world energy price structure. All of the chemicals that can be produced from cassava starch are currently manufactured from petrochemicals derived from oil. Although cassava processing also requires significant amounts of energy (usually in the form of heat and electricity), this can be provided from crop residues. For example, the leafy tops could be burned to provide steam or combined with tuber waste streams to provide methane by anaerobic fermentation.

In Figure 11, some possibilities for a cassava agro-industrial system are given. Although all of these industries could ultimately be integrated in the one area, it is unlikely that this would ever be achieved. Development is most likely to occur on an individual basis commencing with the least capital intensive process that is economically viable. Many of the processes in the chart could be developed on either a medium large scale or village scale, the appropriate level depending upon the socio-economic structure of each country. Some of the possible products of the system are as follows:

a. Leaf protein

Cassava leaves are rich in protein, B-carotene (the vitamin A precursor), and vitamins B_1, B_2 and C. The leaf and leaf stem may contain up to 30 percent crude protein so that a yield of 15 percent crude protein may be possible from the foliage.

A leaf protein concentrate (LPC) can be extracted from cassava tops using a screw press or a belt press process similar to that developed by Pirie (1971). Considering the widespread problem of protein malnutrition in most developing countries, the potential for using LPC from cassava deserves immediate attention.

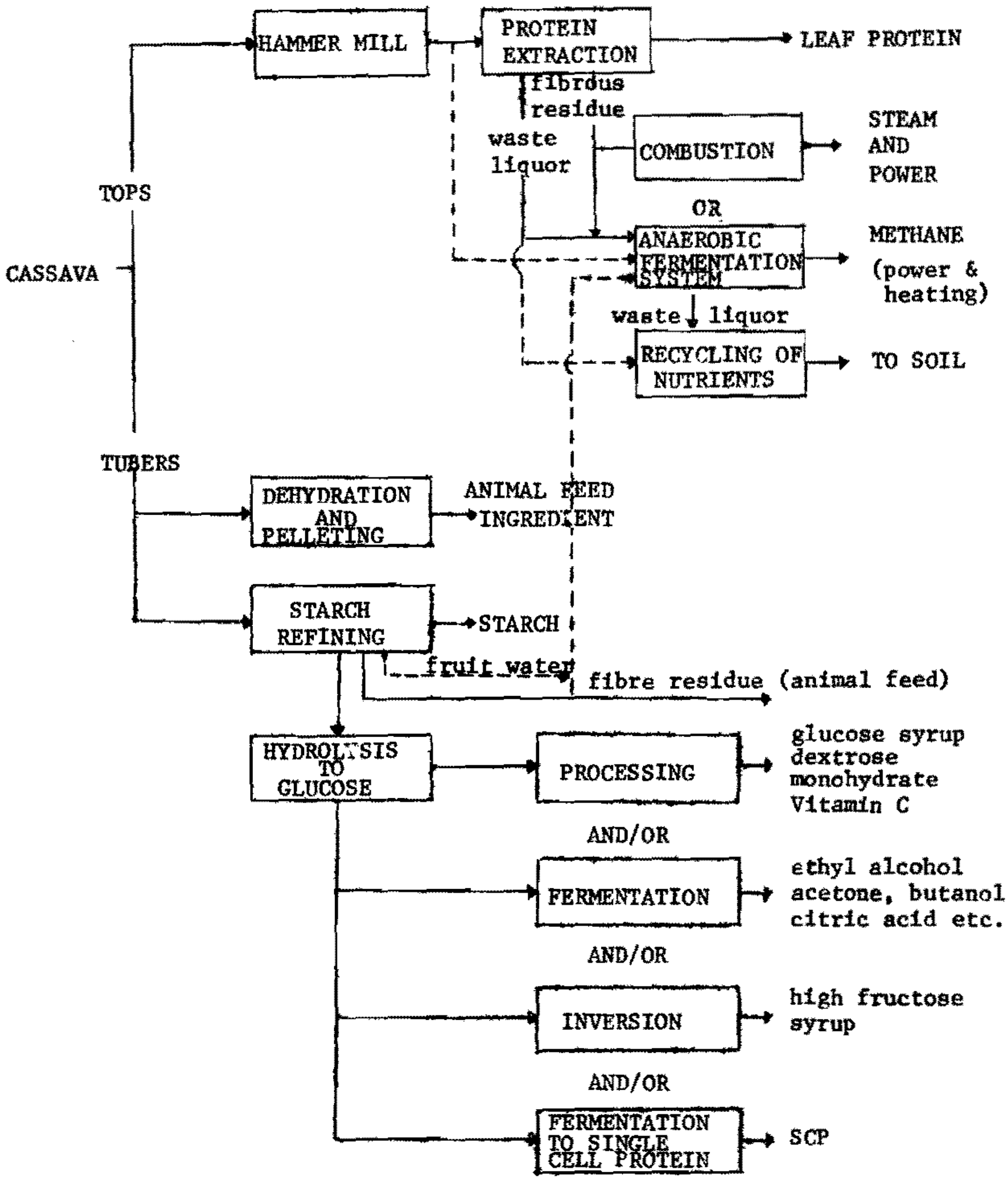


Figure 11. Cassava agro-industrial system.

b. Starch

Perhaps the greatest potential for cassava as an agro-industrial crop lies in the production of starch. The cassava starch market has never attained its full potential possibly because of alternative uses as a subsistence food and animal feed ingredient. Cassava starch however can be blended with other starches that would make it ideal for use in a whole variety of convenience foods. As well, cassava starch is ideal for paper sizing and enzyme hydrolysis to glucose and subsequent fermentation.

c. Ethyl alcohol

Cassava starch can be readily converted to ethyl alcohol in a two-stage process. First the starch slurry (unrefined) is hydrolyzed to glucose either by an enzyme or acid process or a mixture of both. The glucose solution is then diluted to about 10-18 percent concentration and converted to ethyl alcohol by the anaerobic action of yeast (*Saccharomyces cerevisiae*). Purification of the alcohol is then accomplished by distillation to yield either industrial alcohol (95%) or absolute alcohol, which maybe used as solvent or fuel substitute. Butanol and acetone can go via a similar process but using a different microorganism.

d. Sugars

Glucose sugar (dextrose) can be produced from cassava starch by hydrolysis. Currently most of the glucose produced is made from corn or wheat starch, but if high yields of cassava become available, cassava starch could be an important raw material, since the preferred source is largely a matter of economics.

e. Single Cell Protein (SCP)

One of the problems with cassava when used as human food is its low protein content (1-2 percent crude protein). When used as a staple food, protein-deficiency diseases such as "kwashiorkor" have been reported to occur. (Cassava is primarily a carbohydrate and therefore should not necessarily be viewed as a protein source. To attribute the occurrence of "kwashiorkor" to high cassava consumption seems unjustified because "kwashiorkor" is primarily a protein deficiency and not a calorie excess, Phillips, 1974.) One way of increasing the protein content is to partially ferment the tuber mash using yeasts on fungi, as in "gari" fermentation. This is probably the simplest and cheapest way of increasing protein content in developing countries. Another approach is being examined at Sydney University (MacLennan, 1975) whereby yeast is grown on hydrolyzed starch and harvested as a concentrated source of protein (45-55 percent).

F. Comparative Costs and Returns (Cassava, Philippine data, Philippines Recommends for Root Crop, 1977)

In order to exploit the markets for root crops, it has to be sold at a price that is competitive. To some degree this depends on the use to which the crop is put. Thus, in the case of cassava, the Thai farmer who grows most of the crop that reaches the world market obtains US$ 11-12 for the farm-dried chips from a ton of fresh cassava whereas for fresh cassava for human use, the Jamaican farmer obtains 2-4 times this price (Rankine and Houng, 1971), and, at certain times of the year, the Colombian farmer may obtain 6-10 times the price obtained by his Thai counterpart. However, generally speaking the farm gate price for fresh roots seems to lie in the range of US$ 35-40 per ton.

It is difficult to cost cassava production since the main inputs are family labor and land, and in subsistence farming areas, the land maybe communally owned. Brannen (1972) reviewed some of the literature on production costs and found that the usual cost of producing cassava was about US$ 6 per ton. The major production cost was labor. In various surveys the man-hours used to produce a ton of cassava appeared to range from 50 to 150 and to average about 100 (Andersen and Diaz, 1973; Brannen, 1972; Rankine and Houng, 1971; Raeburn et. al., 1950).

Growing a cassava crop under Philippine conditions entails simple farm operations such as land preparation, planting, replanting, weeding, cultivation and harvesting. For small scale production (2 ha or less) it requires 51 man-days to operate a hectare of land. For the plantation type it needs 55 man-days per hectare to accomplish all the farm operations.

With good management, using recommended cultural operations and high yielding adapted varieties, a yield of 40 tons fresh cassava tubers per hectare is easily attainable. Under Philippine condition, a 30-ton per hectare harvest using recommended practices would deliver a good profit to the producer.

A 10 ton per hectare yield of cassava in small scale plantings, a net return of ₱1,662 or US$ 227.00 Table 18 can be expected, while a 20-ton per hectare yield of cassava in the plantation or commercial scale can give a net return of ₱2,926 or US $400.00 Table 19, with interest or land rental cost excluded.

G. Research Developments and Highlights

As was pointed out earlier, except probably for India, national or country research programs for root crops in the region, are all of recent development. It is not surprising therefore that a good fraction of the studies conducted at national centers are validations of technologies "borrowed" from international institutes. The intention is of course to modify these technologies for use under Asian conditions. Let us now examine

Table 18. Cost and return of cassava production per hectare (Small Scale Production).

Activity	Man/Man-Animal days1/	Value (₱)
1. Land preparation		
Plowing (twice)	10	300
Harrowing (twice)	8	240
Furrowing	3	45
2. Planting		
Planting materials ₱20/3000 stakes, total of 12000 stakes)		80
Planting	10	150
Hauling seed pieces	2	30
Cutting seed pieces	1	15
3. Replanting (10% of planting cost)		28
4. Weeding and cultivation (once)	20	300
5. Harvesting at ₱10/ton (15 tons)		150
TOTAL COST OF PRODUCTION		1338
Production (10 tons) valued at ₱0.30 per kg.		3000
Net Return before interest and rentals		1662

1/Rate per man-day is ₱15.00.
Rate per man-animal day is ₱30.00.

Table 19. Cost and return of cassava production per hectare (Plantation/Commercial Type).

Activity	Man/Man-Animal days[1/]	Value (₱)
1. Land preparation		
Plowing (twice)	10	300
Harrowing (twice)	8	240
Furrowing	3	45
2. Planting		
Planting materials, ₱20/3000 stakes, total of 12000 stakes		80
Planting ₱15/thousand)		180
Hauling seed pieces (for distant planting areas at ₱8/ thousand)		96
Cutting seed pieces	1	15
3. Replanting (10% of planting cost)		38
4. Weeding and cultivation		
First Off-barring	1	30
First Hilling-up	1	30
Weeding (twice)	30	450
5. Fertilization		
Fertilizers, 6 bags 14-14-14 at ₱67.20/bag; 2 bags K_2SO_4 at ₱96.00		596
Application	2	30
6. Clearing prior to harvesting	2.5	38
7. Harvesting ₱10/ton (20 tons)		200
8. Hauling Cost ₱25/truckload		250
9. Miscellaneous		240
10. Contingencies (10% of subtotal)		296
TOTAL COST OF PRODUCTION		3074
Production (20 tons) valued at ₱0.30/kg.		6000
Net Return before interest and rentals		2926

occur in Asian farms when the crop is planted. In these trials, tuber yields of as high as 18-20 t/ha were realized Tables 20 and 21. Again, these are impressive yields considering that the only inputs involved were minimal land preparation and planting of improved/selected sweet potato cuttings.

In cassava the emphasis is to select varieties which could be adapted to regions of acid, infertile soils since there are more than 300 million hectares in the Latin American tropics and Asia with these characteristics. On the CIAT farm where the soil is fertile, several hybrid selections gave root dry-weight yields of 15 tons/ha/yr or more, outyielding a local cultivar by 100 percent. This is without any application of fertilizer, fungicide, insecticide or irrigation (Table 22). On the soil of the Llanos Orientales of Colombia, which is so acid (pH 4.3), so high in aluminum (exch. Al 3.5 me/100 g, 85% saturation) and so low in phosphorus (1-2 ppm Bray II) that the majority of food crops can be grown only with a heavy application of lime and phosphorus, several hybrid selections gave root dry weight yields of 10 tons/ha/yr with a moderate application of lime and phosphorus, outyielding a local cultivar by 50 percent. On the southern coast of Colombia, which is one of the cassava producing centers of that country, several hybrid selections yielded more than 12 tons/ha/yr

Table 20. Yields of the ten highest yielding sweet potato cultivars in a dry season minimum input trial; 1975, AVRDC[a].

AVRDC Acc. No.	Varietal Name	Marketable Yield	Flesh color of root
		t/ha	
6	Tainung 31	18	white
18	Taiwan-2	17	white
93	PI 315342	14	white
117	PI 344129	14	white
54	PI 318548	14	yellow
154	Tainung 10	14	yellow
58	Tainan 14	13	white
115	PI 344123	13	yellow
106	PI 318859	12	yellow
5	Tainung New 10	12	white
171	Tainung 63 (Check)	4	orange

[a] 194 cultivars were planted and harvested after 155 days

Table 21. List of the ten highest yielding sweet potato breeding lines in a dry season minimum input trial; 1975, AVRDC[a].

Selection	Pedigree (or varietal name)	Marketable yield	Flesh color of root
		t/ha	
278-1	Tainung 27/HDK 8	20	yellow
277-1	Red Tuber Tail/OK 6-3-118	18	yellow
276-1	Red Tuber Tail/OK 6-3-106	17	white
0122-2	B 6708	16	orange
272-8	Red Tuber Tail/All good	15	yellow
015-10	HDK 6	15	orange
010-2	HDK 8	14	yellow
276-2	Red Tuber Tail/OK 6-3-106	13	yellow
137-1	Tainung 57/Acadian	12	white
272-4	Red Tuber Tail/All good	12	white
171	Check (Tainung 63)	4	orange

[a] 495 breeding lines were planted and harvested after 155 days.

Table 22. Selected results of yield trials in three locations.

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

in root dry weight notwithstanding five months of dry season. These selections have outyielded local cultivars by more than 100 percent. A hybrid selection such as CM 308-197 did well in all of these locations, always exceeding the yields of corresponding local cultivars by 50-150 percent (Table 22). This is indeed way above current yields at the farm level of only 3 to 5 tons/ha/yr in root dry weight.

2. Breeding technique (Cassava)

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

At CIAT, studies on the relationships between single row and population trials have shown that there is no correlation between root yield data obtained in single-row trials and those obtained in population trials, Figure 12. Since the valid yield data should come from replicated population trials, the root yield data obtained in single-row trials have virtually no meaning. However, harvest index data obtained in single-row trials are highly correlated with those in population trials, Figure 13. In population trials, harvest index is highly correlated with the root yield, Figure 14. As a

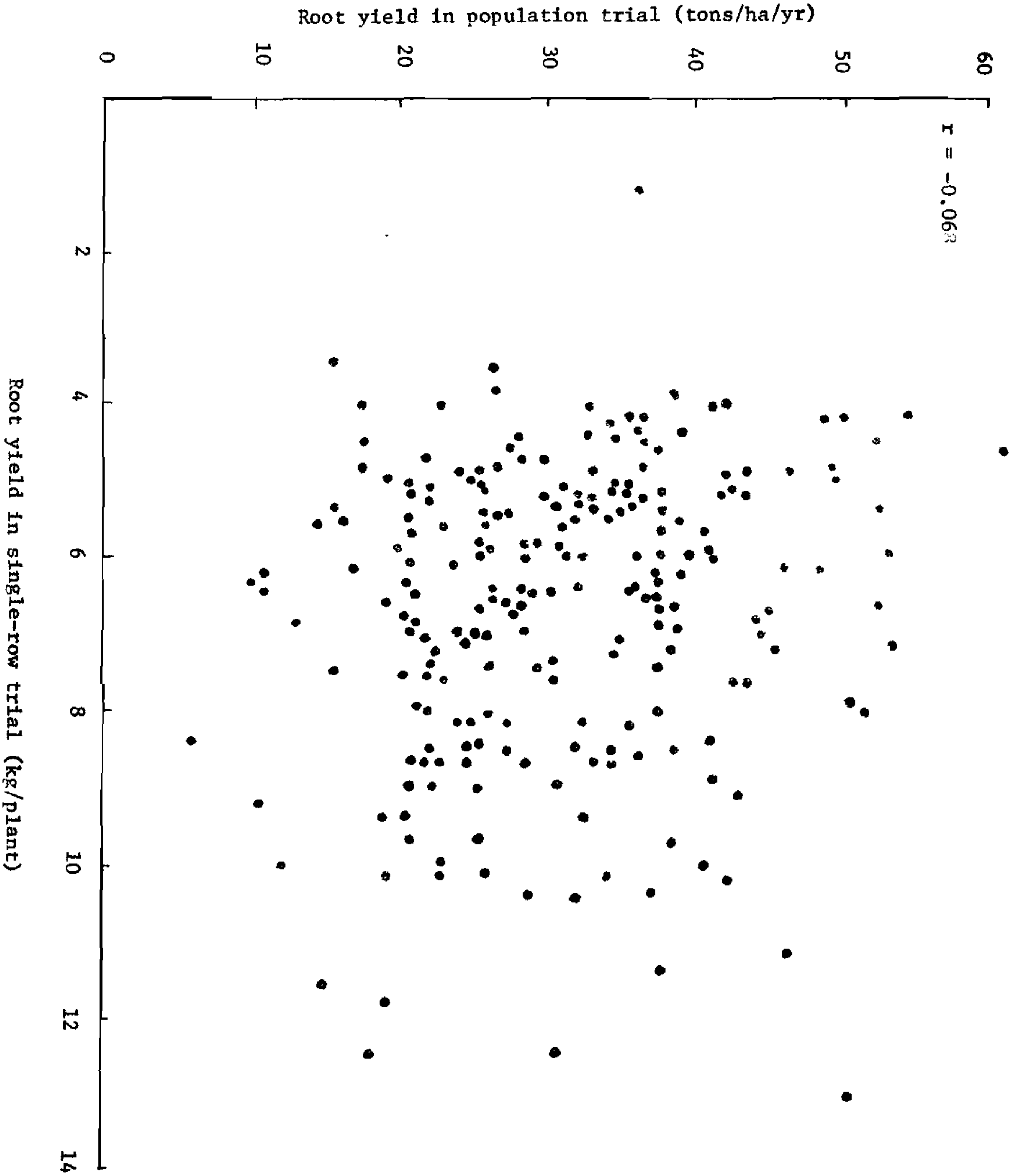


Figure 17. Relationship between root yield data weight in fresh weight in single-row trial and that in population trial at CIAT.

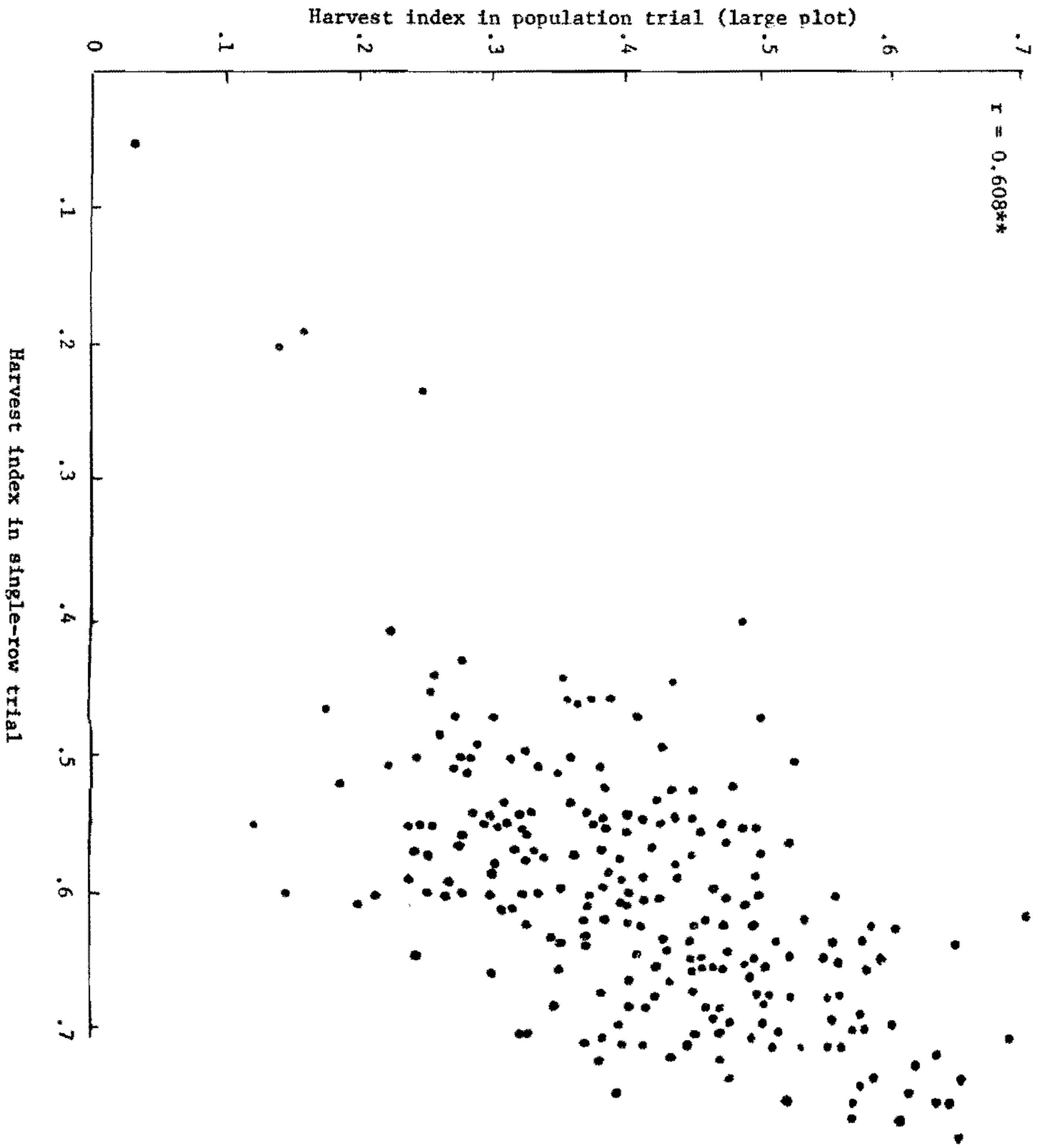


Figure 13. Relationship between harvest indices in single-row trial and population trial at CIAT.

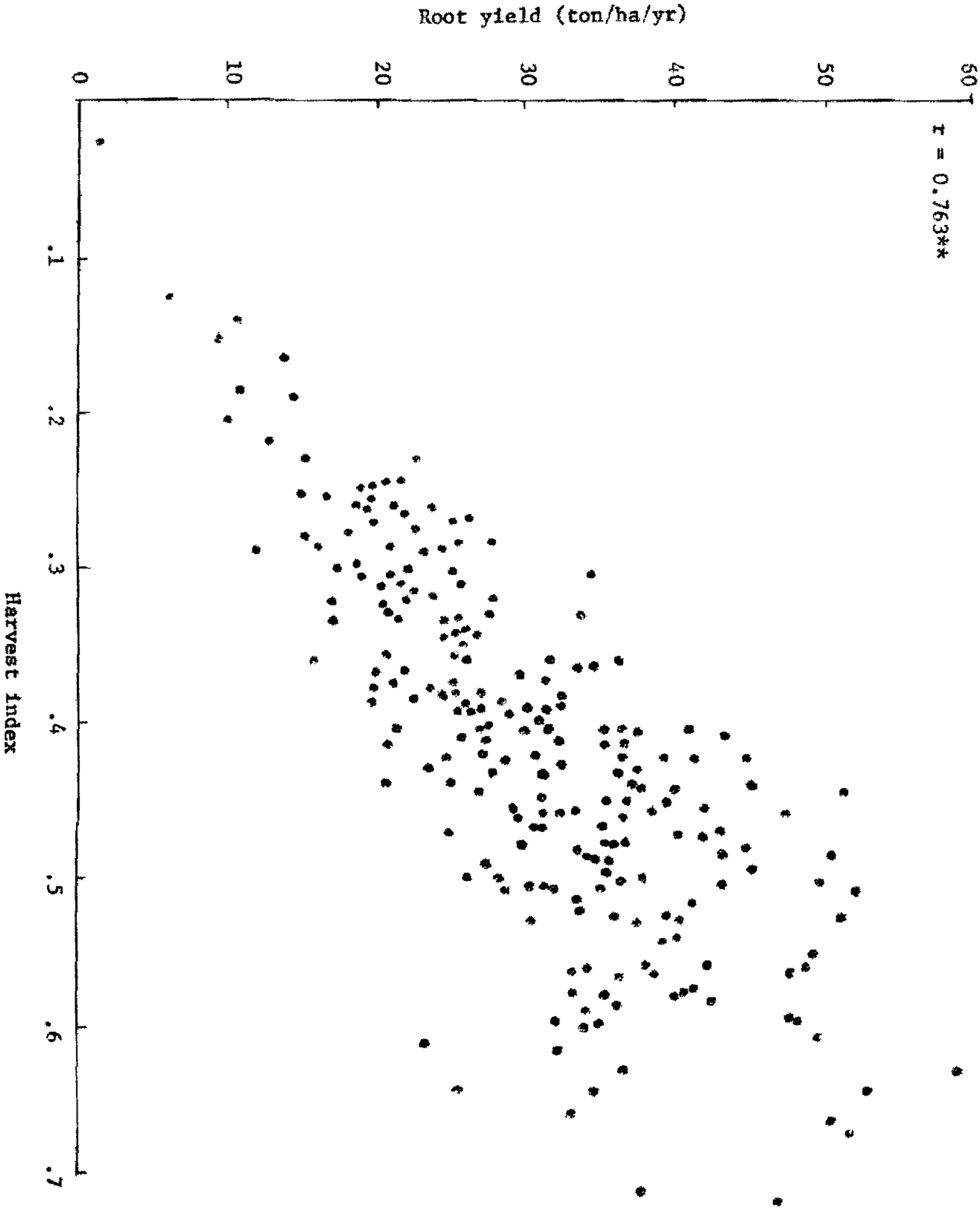


Figure 14. Relationship betwen harvest index and root yield (fresh weight) in population trial at CIAT.

consequence, in the single-row trials havest index is a better indicator of true yielding ability than the yield itself. This occurs as a result of competition between genotypes. Genotypes with high vegetative vigor and low harvest index can occupy a larger space resulting in higher root yield in seedling in single-row trials. However, when these types are planted in populations, they do not yield well.

Harvest index is an indicator of the balance between leaf and stem growth and root growth. There exists an enormous genetic variation in this character and it is highly heritable (Kawano, 1977). Thus harvest index is a highly effective character for use as an indicator for the selection of cross parents, seedling selections and single-row-trials. At CIAT materials which have a harvest index lower than 0.60 and 0.55 in seedling and single-row trials, respectively are already eliminated.

3. Physiology: Plant type (Cassava)

The production of any crop depends on the total dry matter production and the proportion of that dry matter deposited in the useful parts of the plant. An efficient plant is one that has a correct balance between the source of production - the leaves, and the product sought - in the case of cassava, the roots. Crop growth rate (CGR) in most crops increases as leaf area index (LAI) increases up to a certain level, above this level CGR may stay constant or decline. In the case of cassava, studies at CIAT by the cassava physiologist have shown that CGR increased with LAI to about 110 g m^{-2} wk^{-1} at LAI 4; above this level it declined repidly (Figure 15). Root growth rate showed a marked decline from 45 g m^{-2} wk^{-1} at a LAI of 3 to 3.5 to less than 20 g m^{-2} wk^{-1} at a LAI of 4.2 (Figure 16). These data confirm the hypothesis that the optimum LAI for root growth in cassava is 3 to 3.5 during the bulking period.

The identification of an optimum leaf area index for root yield (CIAT, 1975) maybe the most significant contribution of cassava production physiology to the breeders' work up to the present. The optimum LAI found that exists between 3 to 3.5 stays phenotypically constant over a wide range of temperature variation, although the genotype which attains the optimum LAI may be different under different temperatures (CIAT, 1976; Kawano, 1977). This important piece of work leads to a conclusion that to obtain the highest yield, a cassava population must reach the optimum LAI as soon as possible and maintain it as near as possible until harvest time. Analysis of the components of leaf area suggests that long leaf life and late branching are the most important among others (CIAT, 1975; 1976).

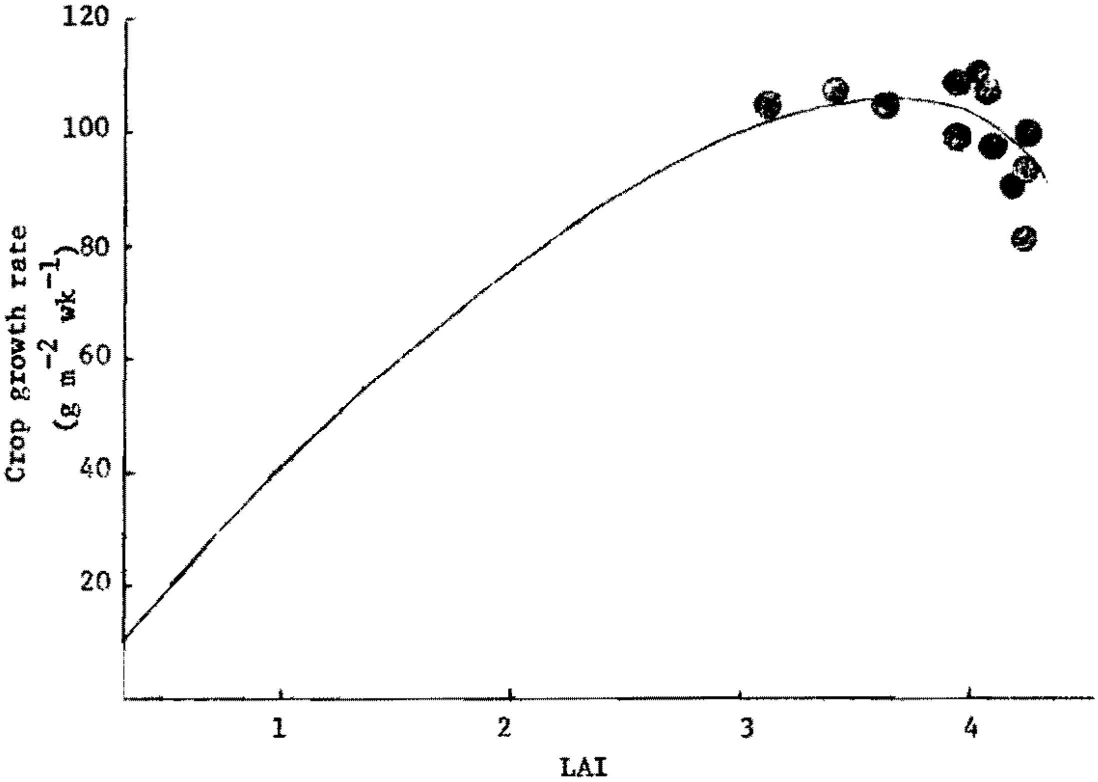


Figure 15. Crop growth rate of M Col 113 as a function of LAI.

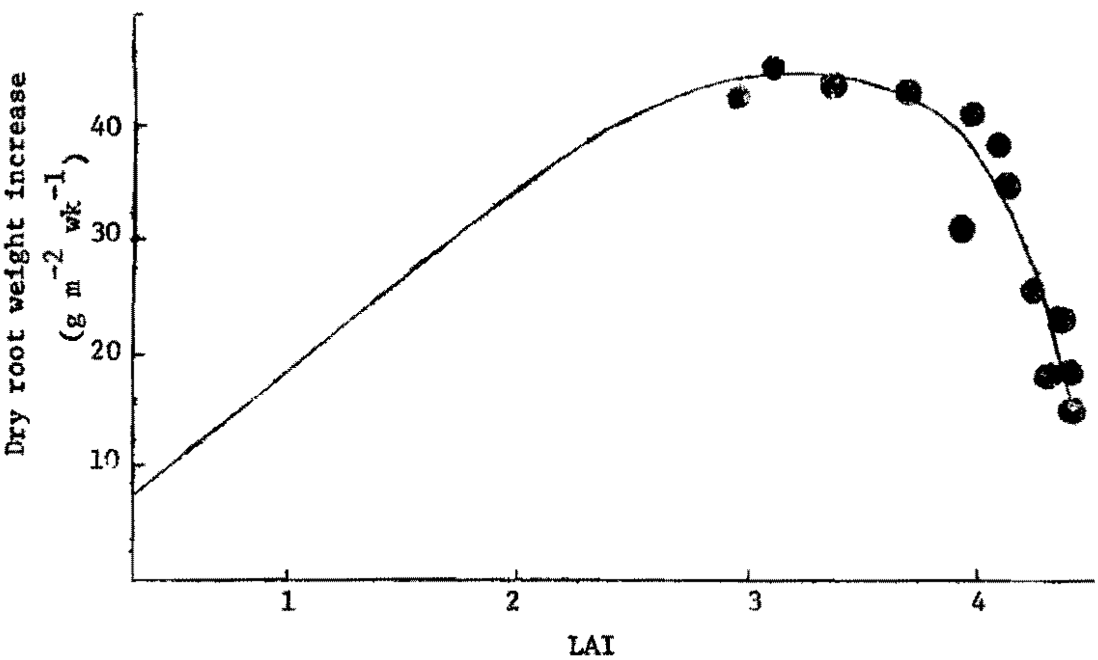


Figure 16. Root weight increase as a function of LAI in M Col 113.

4. Rapid propagation (Cassava)

Cassava like most root crops is propagated vegetatively. Vegetative propagation is a much slower rate of multiplying elite varieties for commercial production. A mature cassava plant will give about 10 to 30 normal sized (25 cm) stakes after one year; thus the propagation rate is only 10 to 30 times per year. This rate of propagation is not sufficiently rapid to give large short-term increases in planting material from new varieties or to supply disease-free stock for commercial planting. A simple rapid propagation method that requires minimum facilities to function has been developed and is now being perfected. The technique lies in inducing stake sprouting, re-growth of new shoots from the cut base of the first shoot, and shoot rooting. This method can provide approximately 36,000 cuttings per year from only one mature plant. This method is illustrated in the following picture slides.

PROBLEMS AND RECOMMENDATIONS

The potentialities of root crops as a major source of food, feed and industrial products is well documented. The industry can contribute significantly to the economy of developing countries in the region. These crops are no longer "strangers" to the Asian farmer nor are they exacting in their soil and climatic requirements.

In spite of this, the industry is in such a stagnant state. It is beset with many problems hampering the exploitation of its vast potentials. Some of the problems and possible solutions can be summed up as fo lows:

A. Sociological attitudes towards root crops

Root crop husbandry has not gained the acceptance as a type of profitable farming among the people in the rural areas. Because of their basic agronomic charateristics and cultural adaptability, they are accepted as crops that do not need much care and attention. In most national agricultural development programs, root crops rate lower priority than other crops. Appreciation of the less known qualities of the crop must be developed to gain the people's respect and encourage more farmers to produce them.

B. Lack of high yielding varieties adaptable to the various ecological conditions of the region. It has been recognized that the existing germplasm of root and tuber crops in the region is very narrow. It is common to observe in farmer's backyards and farms that the same variety of cassava or sweet potato have been cultivated for generations.

C. Low yield, inferior quality and hence decreasing production trend.

D. Lack of technology in processing and utilization.

E. Absence of storage technology.

F. Limited and uncertain market outlet.

G. Lack of trained manpower in the industry.

H. Absence of credit programs and minimal government support

In the light of these problems and recognizing the need to develop the root crops industry in the region, the following recommendations are suggested:

A. Encourage present production improvements. Existing knowledge indicates that immediate yield improvement can be expected from the use of either input or management substitution technology. Examples of this would be the widespread use of high yielding, disease-resistant and adapted varieties. In view of the resources available to the government for massive aid schemes, the small farmer is most likely to opt for a technology which would not require big capital.

B. Improve root crop economic situation. Credit programs for growers especially where improvement in production, processing and storage is being undertaken, should be established and supported. Floor and ceiling prices and even typhoon insurance or (similar weather adversities) should be considered.

C. Expand substantially extension services to increase coverage of small-scale producers of root crops. Extension effort should be integrated up to the lowest management unit through the establishment of technical centers to hasten the spread of applicable technologies.

D. Support research on utilization of root and tuber crops. Increase utilization of root crops and its products should open up new market horizons.

E. Institute within the region a coordinated problem-oriented research program: variety testing, agronomic practices, crop protection, water management and economic studies. Also, at both the national and regional level, studies on consumption patterns, utilization and demands for root and tuber crops should be undertaken.

F. Specifically for research, the following studies are recommended for consideration:

1. Since the demand for root crops specifically cassava is a demand for carbohydrates, breeding and selection which improves starch yield per tuber, per unit land and per unit time should be given higher priority than breeding for a high protein content.

2. The great part of root crop cultivation is presently and presumably will continue to be small scale. Therefore three areas of concern are suggested: (a) varieties that will grow under small-scale, traditional production conditions; (b) development of appropriate cultivation methods designed to support

the use of improved but perhaps less hardy varieties; and (c) identification of production practices which are economically applicable to small scale production.

3. For the large or commercial type of plantation, the development of machineries suitable to large-scale production are also required, especially harvesting machinery.

4. Research into the development of root crop foods for human consumption should be supported. Research in this field should be done with a view to price and market acceptability.

5. Research into the storageability of root crops, to prolong shelf-life not only of the raw material but of the products as well.

6. Greater information is required in producer countries on the domestic markets for root crops. There is a need to bring producers, processors and consumers together to promote flows of information and to coordinate development of potential markets.

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BRIEF CROP DESCRIPTION: Botany and Origin

A. Sweet Potato

Sweet potato (Ipomoea batatas L.) originated in the Western Hemisphere, although the site of origin and the manner in which it was domesticated are still unknown. An early world traveler, sweet potato had reached New Guinea and New Zealand before the time of Columbus and played an important role in the colonization and welfare of the Pacific islands.

Its range has since been extended so that the species is well known throughout both temperate zones and the tropics. In 1974, the Food and Agricultural Organization estimated that approximately 84 percent of the world's production was on the Chinese mainland.

Sweet potato is normally a trailing vine, although climbing forms similar to typical morning-glories are known. It is a perennial crop, however, the succulent nature of its roots restricts sweet potato cultivation to relatively short growing seasons of three to six months. Unlike many root and tuber crops, sweet potato begins to store starch at a very early stage making early harvests possible. Sweet potato is one of the most efficient plants at converting the sun's energy into food.

Sweet potato is generally cultivated for the starch in its enlarged roots. However, the leaves and stem tips of its vines are frequently eaten as a highly nutritious and tasty green, leafy vegetable. Often considered a poor man's spinach, sweet potato tips have a rich protein content that helps fill the nutritional gap left by eating the low protein roots. In West Africa, sweet potato greens are particularly important, and varieties have been developed that are used only for the leaves, which are especially high in calcium and vitamin A.

Sweet potato ranks high in calories produced per hectare per day at a lower cost per calorie than cereals. Sweet potato has an amazing potential for feeding people, is relatively free from disease problems, and generally produces high and dependable yields with a minimum of costly energy-consuming inputs such as fertilizers and pesticides compared to those needed for high yields of cereals.

The sweet potato plant can use the nutrients that remain in the soil after preceding crops, and it resists environmental extremes such as drought. It can be grown in paddy fields during the dry season in many tropical countries, thus increasing the food production of hungry nations.

B. White Potato

White potato (Solanum tuberosum L.) was cultivated in the highlands of the Andes in South America over 2,000 years ago. The Spanish conquistadores brought it to Europe around 1570. It spread rather quickly throughout Europe and became a popular, easily grown staple in Ireland. When, in 1845 and 1846, a blight fungus destroyed the Irish potato crops and the resulting famine caused the death or emigration of many Irish, the crop became known as the "Irish" potato.

White potato has since continued its travels, and the nutritious tuber is now considered to be the fourth most important food plant of man-after the cereals, corn, and rice. In tropical Asia, white potato is still not well known, but is believed to have considerable potential for the region if a truly tropical potato could be developed. Thus AVRDC, in cooperation with the International Potato Center (CIP) in Peru, is screening the world's germplasm of tuber-bearing Solanum species for clones capable of tuberization under lowland tropical conditions.

White potato has been referred to as a well balanced, well packaged food. Nutritionally, it is close to sweet potato in calorie production per hectare per day and second only to soybean in protein production per hectare. In addition, white potato is an excellent source of vitamin C and the vitamin B group. Its balanced protein-calorie composition, the nutritious quality of its protein, and its relatively rapid growth makes white potato an ideal food complement to cereal crops in multiple cropping systems.

C. Cassava

Botanically, the cassava plant is known as Manihot esculenta Crantz. It belongs to the family Euphorbiaceae.

The plant is known under a great variety of names and the following are the principal ones: ubi kettela or kaspe (Indonesia), manioca, rumu or yucca (Spanish America), mandioca or Aipin (Brazil), manioc (Madagascar and French speaking Africa), tapioca (India, Malaysia) and cassava and sometimes cassada (English speaking regions in Africa, Thailand, Sri Lanka).

The cassava plant is a perennial shrub which if allowed to grow indefinitely reaches the size of a small tree. At the age of about a year, when it is usually harvested, it is from two to three meters high. The stem which varies in color from pale or dirty white to brown, is marked by numerous nodes formed by the scars left by the fallen leaves. The leaves are fan-shaped, pale to dark green in color with about 5-9 lobes. The petiole varies from pale white to red in color.

Male and female flowers arranged in loose plumes are produced on the same plant. The triangular-shaped fruit contains 3 seeds which are viable and can be used for the propagation of the plant. The number of the tuberous roots and their dimensions vary a great deal in form with the different varieties. The roots may reach a size of 30-120 cm. long and 4-15 cm. in diameter and a weight of 1-8 kgms. or more.

Cassava known only under cultivation, is a complex of clones showing the widest morphological diversity in the Paraguay - South Brazil area. Clusters of closely related species to cassava are located in both North and South America (Rogers and Fleming, 1973), but no wild species have been suggested as a possible ancestor. The time and place of domestication are unknown. The most important trait for the use of cassava as a food is the HCN content in the roots, which has a wide range from high (bitter cassavas) to very low (sweet cassavas). There is a clear correlation in the geographic distribution of the two kinds: sweet cassavas occur in the western side of South America, Central America — Mexico, while bitter clones are planted mainly in the eastern side of South America and the Antilles, with an overlapping area in between (Renvoize, 1972). Cassava as early as the second and third millenia BC (Jennings, 1976), was more intensively used in South America than in Middle America. In the former area, the artefacts for the preparation of sauces, are typical of South America. Archeological information, such as representations in ceramics and early historical information, gives additional support to a more intensive use in South America. All this may point to a South American domestication and the fact that its spread towards the north was restricted to the sweet varieties.

Cassava was introduced early to Africa by the Portuguese. The first published report by Barre and Thevet is dated 1558

(Mauny, 1953). Further spread inside Africa was determined by its adoption first as a vegetable and later as a flour source in the Kingdom of Congo, which was an advanced state that influenced the rest of tropical Africa. The spread apparently was rather slow, but was favored by the resistance of cassava to locusts (Jones, 1959).

Cassava was introduced to India and Southeast Asia late in the nineteenth century.

D. Yams (*Dioscorea*)

The yams were probably domesticated in the Southeast Asia region. *D. alata* originated most probably in the area occupied by Burma and China where the rivers Irrawaddy, Salween, and Mekong ran closely and parallel to each other (Burkill, 1951). The yams grow large rhizomes deep in the soil to survive the dry season, and this characteristic may have attracted the attention of man since early times.

The greater yam was taken first to the Sunda Islands, to the east, quite possibly only as clones with shallow-growing tubers. Many mutants were concentrated or appeared in these islands, differing in tuber shape and size, and in other characteristics, and this area has the highest diversity of the species. It spread also to the Philippines and to all parts of Oceania, including New Zealand. Toward the west, it extended to west India, stopped by the Great Indian Desert. It spread toward

Africa, maybe taking the same route as taro, banana, and other Southeast Asian crops. It spread to East Africa and Madagascar, and later to central and west Africa. In the latter region, however, it did not become important because there were already native yams under cultivation. An historical expansion took place after 1500, when the Portuguese brought it to the west coast of Africa. It became the main food in the slave ships and was marketed widely as "Lisbon yams," especially from San THome. With the slaves, the greater yam arrived quite early, around 1530, in the Caribbean and Brazil, but in the New World its expansion was checked again by the African yams.

Dioscorea esculenta, the "lesser yam," was possibly domesticated in the same area as *D. alata*. Wild types have been reported from India and Guam. Before the arrival of the Europeans, it had spread from Southeast Asia to the Philippines and into Oceania but not beyond Tahiti, and north to China, where it is mentioned in the literature around 200 and 300 AD. It was taken by the Portuguese, along with *D. alata*, around the Cape to west Africa. By selection, superior clones with larger and fewer tubers and less thorny stems have been obtained in Southeast Asia and Oceania.

E. Aroids

Alocasia macrorrhiza (*A. indica*). This is a very primitive crop, possibly domesticated in India (Assam, Bengal), or in

Indochina; in India other species (e.g. A. cucullata) are cultivated and wild Alocasia is used as food. Its large trunk contains a fine starch, but because of the high oxalate content, it must be cut and baked on hot stones, or boiled. In Java and Tonga some cultivars are used only for their leaves. Alocasia spread only to the east towards Melanesia and Polynesia. It is of some importance in Tonga and Samoa and to all of Micronesia, especially the Marshall Islands, and was introduced into Brazil in the last century as cattle feed.

Amorphophallus campanulatus. This plant is found from India to Polynesia but with no clues as to the area of domestication. It is an ancient plant, low-yielding, and difficult to prepare for eating, with the result that it is being grown less and less. It is cultivated from India to Malaysia, and in Java as a backyard crop (Sastrapradja, 1970). In Polynesia, it grows wild and is occasionally gathered, but is unknown in Micronesia (Barrau, 1962).

Colocasia esculenta. This species is found wild from India to Southeast Asia, and has spread throughout the tropical world and to the fringes of the temperature regions.

Towards the east, the plant was spread by the Malayans and Polynesians to all the islands of Oceania, including Hawaii, Easter Island, and New Zealand. In this vast area, some hundreds of clones are known, but there is no complete survey of its diversity.

From chromosome counts, it has been established that there are two types, $2n = 28$ and $2n = 42$, with the former the predominant type from India to Japan and Polynesia. Type $2n = 42$ occurs in India, New Zealand, and the Philippines and seems to have originated in India. It has spread eastward in recent times, but is not found in Polynesia (Yen and Wheeler, 1968).

It reached China and the Lower Yangtze Valley and is mentioned in literature toward 100 BC. From China it moved into Japan. The introduction into the Philippines came possibly through the Sunda Islands.

The spread of C. esculenta to the west is poorly documented. It reached Egypt around 100 AD, either through Syria (and there is some linguistic support for this, Tackholm and Dar, 1950), or through the Sabean Lane, since it is found in Yemen from where it may have originated. From Egypt, it went through North Africa to Morocco and then to Spain and Portugal. It spread also from Egypt to Italy and to Cyprus, where it is an old and important crop.

When, where and by whom Southeast Asian crops were transported to Africa is still open to question. Indians or Indonesians settled south of Ethiopia around 500 AD, leaving instruments and practices, like certain types of boats along the coast of Zanj-and the lakes, and they brought in their crop plants from Malaysia. Madagascar is culturally linked with Indonesia, and many of the words for crops like Tacca, coconut, taro, are the same in the two areas.

The Malay sailors may have reached the coast of Africa with the favorable winds during the monsoon season. Propagation material of roots and tuber crops, brought in these trips, may have remained viable for weeks and very likely were established in Africa after many failures. Taro, bananas, greater and lesser yams, and sugar cane were adopted by the Bantu people and other tribes on the continent. Either by the geographic spread of the former ethnic group, or through diffusion into different tribes, these crops reached central Africa and later on west Africa. Taro was already in cultivation in Gambia and San Thome around 1500 (Mauny, 1953).

Taro was taken from west Africa to tropical America, probably in the early 1500s. However, it is difficult to establish its arrival because early descriptions confuse it with Xanthosoma. By the end of the 18th century it had spread from the Caribbean to Brazil, and early in this century to the southern coast of the United States. Again, very little is known of its diversity in this area. Superior clones, called "dasheen," are recent introductions but the native Xanthosoma, being more productive and resistant, has prevented the expansion of Colocasia esculenta in the American tropics.

Cyrtosperma chamissonis. This aroid was not domesticated on the continent since it is not cultivated in India and Malaysia. Its range extends from Indonesia to the north side of New Guinea; in Melanesia, the Solomons and Fiji, but not in New Caledonia;

in Polynesia, in the central part as far as the Marquesas, but not in Hawaii or Southeast Polynesia; throughout Micronesia, as it grows well in the low atolls (Barrau, 1962).

National Root Crops Research Program (Philippines)

Rationale

1. Status of the Root Crops Industry

Root crops industry provide a significant contribution to the Philippine economy as an important source of food, feed and industrial products.

The major root crops in the country are sweet potato, cassava, white potato, gabi, yams (ubi and tugui) and some of the "minor" root crops which include arrowroot, apulid, and other indigenous plants. The culture of root crops has been classified by Filipino agriculturists under subsistence farming. The crops are being commonly raised in small plots and primarily intended for home consumption.

Root crops occupied around 1,534,177.20 hectares with a total production of 355,510 mt and with an average yield of 4.34 mt/ha.

The potentials of the root crops industry is bright in view of the Philippines' favorable climatic and soil conditions. Moreover, a market for root crops can be found in both local and international sectors. The current principal world market for root crops particularly cassava flour is the European common market. The principal starch markets are USA and Canada.

In the country, root crops are a major substitute or supplementary energy food especially among the lower income segment of the population. However, the root crops industry is beset by a number of problems.

2. Commodity Industry Problems

   a. Lack of high-yielding varieties adaptable to the wide ecological range of the country
   b. Low yield and decreasing production trend
   c. Lack of technology in processing and utilization
   d. Absence of storage technology
   e. Limited and uncertain market in production areas

3. Objectives of the Root Crops Research Commodity

   Goal:

   To convert the present nature of the root crops industry from subsistence to a full-blown commercial venture.

   Specific Objectives:

   a. To establish a strong breeding program for the major root crops
   b. To devise a system of cultural management suitable for root crops
   c. To popularize and stabilize root crops production through the development of market channels and outlet.

Root Crops Production

Root Crops	$\frac{\text{Production}}{\text{Area}}$	$\frac{1,543,177.2}{355,510}$	= 4.34 mt
Irish potato	$\frac{\text{Production}}{\text{Area}}$	$\frac{20,484.7}{4,750}$	= 4.31 mt
Sweet potato	$\frac{\text{Production}}{\text{Area}}$	$\frac{781,201.7}{192,270}$	= 4.06 mt
Cassava	$\frac{\text{Production}}{\text{Area}}$	$\frac{620,932.4}{117,970}$	= 5.26 mt
Gabi	$\frac{\text{Production}}{\text{Area}}$	$\frac{93,275.4}{34.410}$	= 2.71 mt
Pau	$\frac{\text{Production}}{\text{Area}}$	$\frac{10,221.5}{3,250}$	= 3.15 mt
Tugui	$\frac{\text{Production}}{\text{Area}}$	$\frac{4,393.4}{1,220}$	= 3.60 mt
Ubi	$\frac{\text{Production}}{\text{Area}}$	$\frac{24,152.8}{6,390}$	= 3.78 mt

National Root Crops Research Program (Philippines)

Priority Rank	Area
1	Critical agronomic and socio-economic analysis of the rootcrops industry
2	Collection, establishment, maintenance and evaluation of germplasm
3	Hybridization and mutation breeding
4	Processing and Utilization
5	Plant-soil-water Relationship

6	Crop protection
7	Cropping system
8	Handling and storage studies
9	Extension studies
10	Design and development and improvement of tools and equipment for production and processing
11	Chemical and physiological studies
12	Seedpiece production technique

A. National Sweet Potato Research Program

1. Varietal Improvement
2. Cultural Management
3. Crop Protection
4. Processing and Utilization
5. Socio-Economics/Post Harvest Handling Studies
6. Sociology and Extension Studies

B. National Cassava Research Program

1. Varietal Improvement
2. Cultural Management
3. Crop Protection
4. Processing and Utilization
5. Socio-Economics/Post Harvest Handling Storage Studies
6. Extension/Sociology

C. National White Potato Research Program

1. Varietal Improvement
2. Cultural Management
3. Crop Protection
4. Socio-Economics/Post Harvest Handling Studies
5. Processing and Utilization

D. Ubi Research

On-going Projects:

1. Varietal collection and testing of ubi in Batanes
2. Induction and evaluation of beneficial mutation in asexually propagated ubi
3. Comparative effects of organic fertilizers on the yield of ubi
4. Field response of ubi to different levels of NPK
5. Socio-economic study of ubi
6. Agro-economic studies of ubi

E. Gabi Research

On-going Projects:

1. Collection, evaluation and selection of gabi (*Colocasia* sp.) and their production under improved cultural management

   Study 1. Variety testing of native and introduce Hawaiian gabi (Colocasia esculenta L. Schott) in the Philippines

Study 2. Cultural management techniques for lowland gabi under monoculture system

Study 3. Cultural management technique for upland gabi under monoculture multiple cropping and rotation system

2. Collection and testing of gabi under different ecological conditions
3. Test of promising varieties of lowland gabi
4. Varietal collection and screening of gabi in Batanes
5. Induction and evaluation of beneficial mutation in asexually propagated gabi
6. Comparative effects of organic fertilizers on the yield of gabi
7. Field response of gabi to different levels of NPK
8. Screening of gabi cultivars for resistance to leaf blight (*Phytophora colocasia*, Rac.)
9. Development of processing and feeding techniques for maximum utilization of gabi for animal feed at farm level
10. Agro-economics studies of gabi
11. Socio-economic study of gabi

F. Arrowroot Research

On-going Projects:

1. Induction and evaluation of beneficial mutation in asexually propagated arrowroot
2. Comparative effects of organic fertilizers on the yield of arrowroot
3. Field response of arrowroot to different levels of NPK

G. Tugui Research

<u>On-going Projects</u>

1. Socio-economic study of tugui

2. Varietal collection and screening of tugui in Batanes

3. Induction and evaluation of beneficial mutation in asexually propagated tugui

MAIN FEATURES OF INTERNATIONAL AGRICULTURAL RESEARCH INSTITUTES

	Name of Institute	Year of establish-ment	Location	Crops attended	Objectives
1.	International Rice Research Institute (IRRI)	1962	Los Baños, Philippines	Rice	Maintaining world collection of rice varieties. Varietal improvement, production technique, training programme for scientists and multiple cropping. Co-ordinate rice work in Africa through IITA and in Latin America through CIAT. Conducting co-operative varietal trials in rice-growing centres of southeast Asia. Assist with expertise to the centres.
2.	International Maize and Wheat Improvement Centre (CIMMYT)	1966	El Batan, Mexico	Maize, wheat, barley, triticale, sorghum	Main emphasis on the improvement of wheat and maize. Research on various aspects on the improvement of these crops. Training of personnel of the national institutes. Assistance to national governments with expertise and plant materials through international nurseries of these crops.
3.	International Institute of Tropical Agriculture (IITA)	1967	Ibadan, Nigeria	Rice, maize, cowpea, pigeon pea, lima beans, jack beans, cassava, sweet potatoes, yams	Development of farming system for the humid tropics of Africa. To develop rice and maize varieties through co-operation with IRRI and CIMMYT - major responsibility in the improvement of grain, legumes and root and tuber crops. Conduct co-operative programme in a number of countries in Africa. Training programme for the workers of the national institutes.
4.	International Centre of Tropical Agriculture (CIAT)	1972	Palmira Colombia	Cassava, field beans,	Development of agriculture. Major responsibility for the improvement of cassava and field beans on the international scale. For rice and maize, it has changed to local basis with backstopping from IRRI and CIMMYT. Other objectives concern small farm system, training and communication.

	Name of Institute	Year of establishment	Location	Crops attended	Objectives
5.	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	1972	Hyderabad, India	Sorghum pearl millet, pigeon peas, chick pea and groundnut	To improve the genetic potential for grain yield and the nutritional quality of the crops, develop farming systems which will help to increase and stabilize production in dry conditions and assist national and regional research programmes through training programmes and extension activities
6.	International Potato Centre (IPC)	1971	Lima, Peru	Potato	To improve the crop and maintain world collection, conduct training programme for staff and carry out co-operative trials in the various regions of the world.
7.	International Laboratory for Research on Animal Diseases (ILRAD)	1973	Nairobi, Kenya	-	To conduct basic and applied research, test the results in the field, conduct formal and on-the-job training of scientists etc. and assist other institutes.
8.	International Livestock Centre for Africa (ILCA)	1974	Addis Ababa, Ethiopia	-	To effect improvement in livestock production and train scientists in the field.
9.	International Centre for Research in Dry Areas (ICARDA)			Wheat, barley, food legumes	To strengthen research in the Near East and North Africa in conditions of winter rainfall followed by hot arid summers.

Source: Consultative Group on International Agricultural Research, International Research in Agriculture, 1974.