COMPETITION AMONG THE ROOT AND CEREAL STAPLES IN TROPICAL AGRICULTURAL DEVELOPMENT

By

Joseph P. Krausz

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I. Introduction

Many of the nations of the third world are enmeshed in a dilemma of trying to balance food production, population growth, and employment levels in the face of rapid technological and sociological change. Populations in most developing nations are rapidly increasing and are expected to do so at least into the foreseeable future. In general, world food production has exhibited significant and rapid increases within the past decade, largely as a result of the recent technological achievements of the Green Revolution. But the spectacular increases in food production are often viewed as merely providing time for the development and implementation of population control measures. However, the mere availability and distribution of contraceptives has proven not to be the only significant factor in successfully controlling population growth (1). Of probably greater importance is the desire and motivation of a nation's people to want to reduce the sizes of their families. This necessary motivation can emerge only when the security previously provided by a large family is no longer necessary and is replaced by improved financial security resulting from full employment with favorable incomes. Therefore, development programs for the less developed nations should concentrate on increasing employment while enhancing food production.

Since a large proportion of the people of most developing countries are engaged in small-scale agriculture, a program of rural development might best serve to alleviate the imbalances between food, population growth, and employment. In planning such a program, careful consideration should be given in determining what crops might best be recommended to the peasant farmer to increase both his crop yield and his income.

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Most of the technological advances in agricultural production which have recently emerged from the efforts of the international agricultural institutes have been largely related to cereal production, especially wheat, rice, and maize. These efforts have largely been spearheaded by scientists from North America and Western Europe, bringing with them their wealth of knowledge in cereal technology. The root crops, definitely secondary staples in temperate zones, have also been allocated a secondary position in the thinking and priorities of many specialists in tropical agricultural development. The tropical root crops have traditionally been regarded as inferior foods and less worthy of attention than the cereals.

It should be noted that the above concept has been inferred from a serious lack of information. Relative to the amount of research done on the staple cereals, the more important root crops have received almost nil. Therefore, before drawing premature conclusions, it would seem advisable to thoroughly compare the potentials for increasing food production of the staple tropical cereals (rice, maize, sorghum, millet) with those of the tropical root crops (cassava, sweet potato, yam, cocoyam, Irish potato), with special reference to those regions where the two staple food groups are in competition.

Two regions where tropical cereal and root crops are important in total agriculture production are Central West Africa and the Caribbean. These two areas, with special reference to Ghana, Nigeria, Jamaica, and Trinidad, were chosen as areas of investigation whenever specific information was sought. Fairly reliable agricultural statistics are available for these regions, and both are seeking increased agricultural production with the domestic production of the staples largely in the hands of peasant farmers. Under these conditions, Central West Africa and the Caribbean islands seemed to be very suitable regions from which to obtain data for the following study.

II. Basic Production Characteristics of the Principal Staples

Rice

There are essentially two broad types of rice: upland, and irrigated or paddy rice. Upland rice matures in approximately three to four months as compared to five or six months for irrigated or lowland rice, but its yields are considerably less. Essential cultivation operations for lowland rice include land leveling, repair of waterways, bundling of seedlings, plowing, puddling, seed sowing and seedling transplant, weeding, herbicides, fertilizers, harvesting, and threshing (2, pp. 17-21). The above package of practices is very tedious and labor consuming, especially when transplanting is included. The need for a reliable source of irrigation water, intensive land preparation, and a sufficient supply of inexpensive labor place serious restrictions on the number of small farmers who can economically produce rice in many regions of the tropics.

Soil structure plays an important role in lowland rice production. A heavy clay with an impermeable hardpan is important for water retention, while a more permeable soil demands excessive water. Soil fertility, though less of a factor than soil structure, can be an important limiting factor. In Sierra Leone, lack of soil fertility is the major problem in limiting rice production and has led to a shift to other crops, especially manioc, as fertility decreases (3, p. 97).

Maize

Maize is relatively demanding in its soil requirements as compared to the other tropical cereals. In meeting this demand, it withdraws heavily many of the soil nutrients and rapidly reduces soil fertility. The serious problem of leaching, especially important in tropical regions with abundant rainfall, is particularly more serious with corn than with the other grains.

Maize has considerable drought tolerance, sharing with the millets and sorghums some ability to enter a dormant state when moisture levels are limited and to resume growth when levels become acceptable once again. At the other extreme, maize yields poorly in soils which often become waterlogged.

Relative to rice, maize is quite easy to cultivate and does well under primitive agricultural methods. It is often one of the major crops planted in shifting cultivation. Generally, an economic yield can be obtained without the careful seedbed preparation required of rice.

Millet and Sorghum

Both of these cereals are noted for their drought tolerance and low water requirements. This characteristic , along with relatively short growing seasons, make them most suitable for dry regions where rainfall occurs only during a short wet season. This hardiness also extends to their soil requirements, for they tolerate soils of medium fertility. Both cereals are easily cultivated and are well adapted to primitive agricultural systems.

Cassava

Cassava is a very hardy crop that will adapt to a wide range of growing conditions, soil types, and fertility levels. It is particularly noted for its ability to yield on soils of extremely low fertility, and is often grown where all other crops have failed.

Cassava cultivation is relatively simple with very little necessary land preparation and a simple planting technique of merely inserting stems into the soil. However, demanding labor is required at harvest time in digging the deeply embedded roots from the soil. Cassava is very popular with many subsistence farmers because of its ability to yield more calories of food per unit input of labor than probably any other crop--certainly far more than any of the dry-land cereals (4, p. 261).

Sweet Potato

Sweet potatoes require a well-drained soil and grow best in a warm growing season. Optimum moisture requirements are about 30-50 inches of rain per year (3, p. 118). This is slightly lower than most of the other root and tuber crops, and once the plants are established, they can tolerate drought moderately well. A relatively short growing season of 3-6 months is needed for maturing.

Yams

The genus Dioscorea contains a wide range of species used as food, of which about 5 or 6 species are widely used. Yams require a warm, humid climate, but are grown in areas with annual rainfall as high as 412 inches and as low as 46 inches (3, p. 112). Despite their favoring of humid conditions, yams definitely possess considerable drought resistance.

Of the several tropical root crops, yams are more particular in their soil fertility and soil structure requirements; a well-drained, rich, loamy soil being the most favorable. Also quite demanding are the labor and maintenance requirements of production. Hilling the soil around each plant is often practiced to insure a pulverized soil favorable for tuber development, and staking each plant is necessary for satisfactory yields.

Cocoyams

In this work, cocoyam will refer to both aroids from the genera Colocasia and Xanthosoma. The former are variously known as taro, eddoe, or dasheen, while the latter are often called tannia or yautia. Cocoyams are found as an important crop only in warm, humid forest areas because of their need for high annual rainfall and a long wet season. They thrive well on imperfectly drained soils and are not damaged by occasional flooding. Shady areas are not deleterious to cocoyam production, and they can be grown within the shade of other taller crops. The growth period is variable but lies close to that required for yams, about 7-10 months.

III. Aspects of Production

Necessary Inputs and Cost of Production

Keeping in mind that the major emphasis of this paper is to compare the production potentials of the tropical roots and cereals relevant to rural or characteristically small farm production, we must investigate the necessary inputs of production and the ability of the small farmer to supply these inputs. Some of the input considerations might include land, irrigation, fertilizers, pesticides, cultivation requirements, and labor.

Much labor is required to produce lowland rice, the only type which gives consistently good yields. Land preparation, irrigation, and considerable amounts of labor definitely restrict the distribution of rice production to areas where these three needs can be obtained inexpensively. Yam production is also characterized by high labor inputs, which is one of the major limiting factors in its production. Conventional production techniques require a package of practices including trenching, manuring, ridging, planting, staking, and harvesting--all carried out by hand in most tropical countries.

In contrast to yams and rice, cassava production has relatively low labor requirements until harvesting and processing, and for this reason, along with its yielding ability, cassava has often become very popular with peasant farmers.

Jones states that maize production per hectare probably requires about as little labor as a hectare of cassava, but much more labor is often spent in processing the crops than in producing them (5, p. 264). Jones quotes Geortay's estimates of processing labor requirements for the forest region of the former Belgian Congo: 35 man-days to prepare one ton of corn, 53 man-days to prepare one ton of rice, and 15 man-days to peel, soak, and dry one ton of cassava (5, p. 264).

Labor and cost of production estimates for food crops in most developing countries are rare and often of questionable accuracy. To complicate matters, estimates are often given in terms of cost per acre, per ton, or per thousand calories. Because of this, the establishment of a reliable cost of production hierarchy is complicated by the differences in yield and caloric values of the staples, thus making their relative positions dependent on the denominator employed. Despite the scarcity of reliable data on production costs and the variations in regional and local production conditions, Johnston has compiled considerable data from Western Central Africa and suggests the following general cost of production hierarchies (highest to lowest) (3, p. 144):

Per Acre	Per Pound	Per 1,000 Calories
1 yams	1 rice	1 yams
2 sweet potatoes	2 millet	2 rice
3 cocoyams	3 sorghum	3 millet
4 cassava	4 maize	4 sorghum
5 rice	5 yams	5 cocoyams
6 sorghum	6 cocoyams	6 maize
7 maize	7 sweet potatoes	7 sweet potatoes
8 millet	8 cassava	8 cassava

Present and Potential Yields

Data on yields of food crops for many tropical countries are highly variable, depending upon a multitude of factors. Experimental yields are often far beyond those obtained by farmers, and even farmers' yields vary greatly due to location, climate, cultural practices, crop variety, and the method used to determine yields.

To obtain an overall estimation of yield potential of the cereals and root crops, the average world production figures of these tropical crops can be obtained from the FAO Production Yearbooks. DeVries has used the 1963 FAO production figures, based on three-year averages, to compare the yields of various tropical staples (6, pp. 241-248). In order to make the yields comparable, they were expressed in calories per unit of land area per period of vegetation (Table 1). As mentioned above, yield data for tropical food crops are highly variable, and it is from such data that the average world production figures are obtained for the tropical staples. Therefore, the value of the estimates in Table 1 are limited, and only very general trends should be observed. Furthermore, the period of vegetation can also show considerable variation depending upon the variety of a particular crop used. The vegetative period data used in Table 1 are the average periods to maturity.

Despite the limitations mentioned, deVries notes some important trends (6, p. 242):

> The Root crops produce much more bulk than the grains (col. 1) but mainly because of their high water content, their energetic food value (col. 2) amounts to approximately 30% of the grain crops per unit of weight. If the differences in percentage edible (col. 3) are incorporated, the differences in caloric production per unit of surface area appear to be smaller (col. 4). This tendency is even stronger after incorporation of the average period of vegetation (col. 5); the crops now tend to more or less the same level of production (col. 6).

The potato has been included because it is also grown in subtropical regions and mountainous tropical regions. Its world production is an average 11.1 tons per hectare or 75,000 kcal. per hectare per day of vegetation, which is much higher than any other crop (6, p. 242). However, these high world average figures reflect the very intensive cultivation of many temperate regions such as the potato belts of Eastern Europe. To estimate the average yield of tropical and subtropical regions, Simmonds uses the average yields of Kenya and Jamaica which are incorporated into Table 1 (7). The same situation exists with maize, which is grown intensively in the corn belt of North America. Should the production only of developing countries be considered, the average production for maize would not be as high as the FAO figures indicate but more close to 1.4 tons per hectare or 37,000 kcal. per hectare per day, which is similar to the figures for wheat and rice (6, p. 243).

Taking into account the above considerations, we see that the root crops as a whole tend to have a higher level of production than the cereals taken as a whole (42×10^3 vs. 32×10^3 kcal. per hectare per day).

TABLE 1. AVERAGE WORLD PRODUCTION OF A NUMBER OF TROPICAL STAPLES*

Crop	Tons/ha. (1)	Cal/100g (2)	Edible portion (3)	Cal/ha. x 10^3 (4)	Period of Vegetation (5)	Cal/ha-day x 10^3 (6)
			(percent)		(days)	
Rice	2.0	352	70	5.0	150	33
Wheat	1.2	344	100	4.1	120	34
Maize	2.1(1.4)**	363	100	7.6	135	56(37)**
Sorghum	1.0	355	90	3.2	135	24
Cassava	9.1	153	83	11.6	330	35
Sweet potato	6.5	114	88	6.5	135	48
Yam	8.0	104	85	7.1	280	25
Colocasia	5.8	113	85	5.5	120	46
Potato	11.1(10.0)**	70	80	5.6	120	75(47)**

* C. A. deVries, J. D. Ferwerda, and M. Flach, "Choice of Food Crops in Relation to actual and Potential Production in the Tropics," Neth. J. Agric. Sci., Vol. 15, 1967.

** Estimates for tropical conditions since large and efficient production of maize and potato are in temperate regions and considerably lower yields are obtained in the tropics.

In considering the future potential of the various tropical root and cereal crops, it would seem advisable to consider potential crop improvement through breeding. Rice, maize, and wheat have received considerable attention in breeding programs while the several tropical root crops have received relatively nil. Therefore, to estimate the relative potential for yield improvement in the various crops, the maximum yields obtained can be compared with the world average yields. For the purpose of estimating maximum yields, figures were obtained by deVries from the following research organizations:

Agricultural Experiment Station, Bogar, Indonesia
International Rice Research Institute, Los Baños, Philippines
Central Rice Research Institute, Cuttack, India
Institut Nationale pour l'Etude Agronomique du Congo.

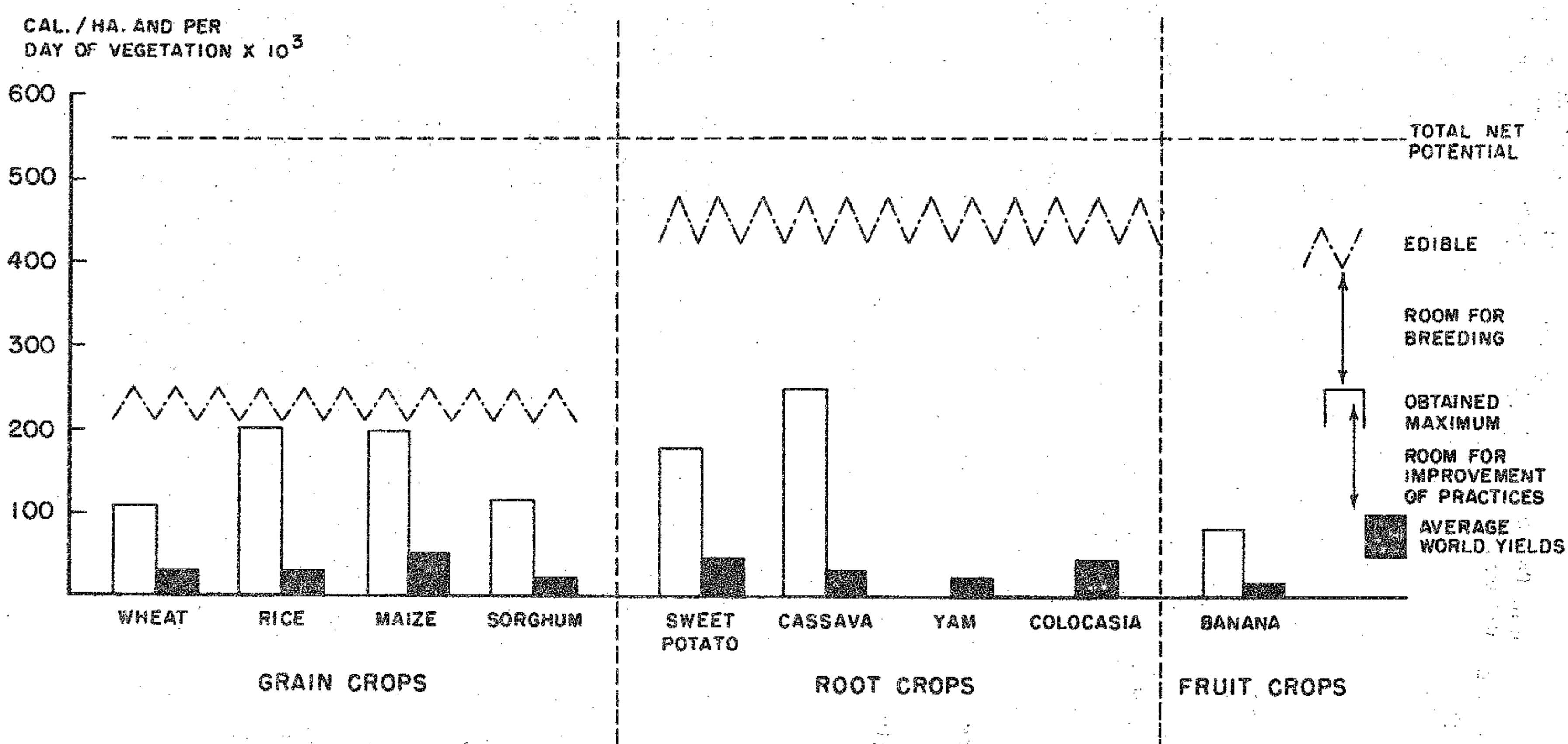
Figure 1 shows deVries' findings with an estimation of potential increase in yield still possible through breeding. Since the cereals are generally approaching their potential genetic optimum for yield because of the extensive breeding work already done on them, the difference between their maximum obtained yields and the optimum potential improvement through breeding are much less than the difference in most of the tropical root crops which have received relatively little breeding work. Also, the grains are somewhat limited by the size that the heads can attain. As the size of the grain heads increase, a corresponding increase in stalk size must also occur to support the increased head weight. Since, within a fairly narrow range, each plant species can produce only a limited amount of photosynthate, increased grain yield will be curtailed genetically by the necessary corresponding partitioning of photosynthate to the supporting stalk. This is not the case with the root crops which have no need for increased support of the economic structure of the plant as size is increased through breeding. Taking these considerations into account, Figure 1 shows that the root crops probably have a much greater yield potential than the cereals and that the root crops are far behind in breeding and selection.

Marketing Aspects of Production

Transportation

The bulkiness of the root crops is a definite disadvantage as compared to the relative compactness of cereals. However, both crops are sufficiently bulky to require a substantial system of bulk transportation to be moved any considerable distance from farm to market. The peasant farmer's task often involves getting his produce to one of the small local markets to be sold by himself or disposed of to other salesmen. If roads are sufficient, middlemen or jobbers often follow a route among many farmers or collection points where they gather the peasants' produce in hopes of selling it in some distant urban market. If such an organized transport system exists, the burden of transportation is greatly reduced

FIGURE 1. AVERAGE WORLD YIELDS, MAXIMUM OBTAINED YIELDS IN SELECTED TROPICAL EXPERIMENT STATIONS, AND ESTIMATED POTENTIAL YIELDS TO BE REACHED THROUGH BREEDING AND RESEARCH



Source: C. A. deVries, J. D. Ferwerda, and F. Flach, "Choice of Food Crops in Relation to Actual and Potential Production in the Tropics," <u>Neth. J. Agric. Sci.</u>, Vol. 15, 1967.

for the individual peasant farmer. The jobbers often travel considerable distances, as shown by Poleman's study of Ghana's food economy (8, pp. 167-169). He shows that the demand of the Accra market exerts a pull upon sources of staple crops far beyond the Coastal Savanna. About 55 percent of the tonnage of the major staples (maize, cassava, and plantain) arrive from areas over 50 miles from Accra, and about 30 percent travels more than 100 miles or more (8, p. 169). Bulky fresh cassava and dried cassava products were shown to move considerable distances, more than might be expected for such bulky root crops. But such transportation of the bulky root crops requires a system by which the peasant farmer can get his crop to one of the trucking jobbers.

The island of Nevis in the West Indies is an example of where such a system is lacking. About 90 percent of the island's root crops are grown by peasant farmers who usually cultivate less than three-fourths of an acre of root crops at any one time, despite a potentially rapid increase in demand from the growing local and Caribbean tourist industry. The reason for the lack of increased production is the inability of the majority of the peasants to get their root crops over the mountainous terrain to the one major public highway where government trucks provide for transport to market (9, pp. 46-52).

Processing of the root crops into various dried forms greatly reduces their bulk and increases storing ability, making them more competitive with the less burdensome dried cereals.

Processing and storage

In general, the root crops have a relatively inferior storage ability compared to the small grains. For this reason their supply often fluctuates tremendously with the seasons. The grains, on the other hand, are easily dried and almost immediately ready for storage right after harvest. The grains encounter a different type of storage loss than the root crops. They are often heavily infested with insects and rodents which inflict tremendous losses, while the major storage losses for the root crops involve weight loss through respiration and metabolism, premature sprouting, and fungal and bacterial rots.

It has been estimated that if losses in stored grains were eliminated, there would be saved a quantity of carbohydrates sufficient to feed 250 million people each year (10, p. 197). In the tropics, losses are often particularly severe, because most of the grains are stored in the farmers' own granaries consisting of dried earthen bins or padded underground pits. Increased rainfall and high humidities significantly are correlated with increased losses, and it is in the high moisture regions of Western Central Africa where the root crops give the grains their greatest competition. Although the cereals are usually stored only for the period between harvests, properly stored grains occasionally are held several years. However, losses generally increase with length of time in storage.

Considerable effort has been made to try to increase the storage life of the root crops. Above ground storage life varies with conditions but are generally a matter of days for the vulnerable sweet potato and fresh cassava to several months for the hardier yam. Under dry, well-ventilated conditions, yams can occasionally be stored from harvest to harvest (3, p. 115).

Yams can also be stored very effectively by leaving the crop in the soil until needed. Although this increases the cost of harvest for yams, it has proven a very effective means of storage for cassava. Cassava roots can be successfully left in the ground for approximately two years without loss in quality (3, p. 108).

Without refrigeration, cocoyams store only a week or two under most tropical conditions, but if they are dried, they store satisfactorily at room temperature for considerable periods (11, p. 267).

Drying and processing of the root crops greatly increase their competitive storing ability with those of the cereals. Cassava can be chipped and sun dried, increasing storage life up to 3 to 6 months (12, p. 141). These can easily be ground into flour, also with good storing quality. Gari consists of fermented cassava gratings which form a granular meal that compares favorably with the cereals as a transportable and storable product. The same is true for the slightly more bulky "kokonte" or dried sliced roots.

Despite the high demand for yam in the fresh state, yam flour and flakes have been tested and show considerable promise in storage ability (13, p. 85). Cocoyam flour and a fermented mash called "poi" are processed products aiding in storability. Converting sweet potato into flour not only increases storage life but has been shown to be a satisfactory substitute for wheat flour at a rate of 15 percent in bread and 20 to 30 percent in pastries (14, pp. 115-125).

Although the grains have a definite storage superiority over the root crops, processing of the root crops greatly increases their storage quality, and with further research, the differences in storage ability may be reduced considerably.

IV. Aspects of Demand

Consumer Preferences and Relative Prices

Consumer preference is an essential aspect of demand for the staples, but many factors come into play to determine which staple crop a certain people will prefer. Although price relationships are important, various social, cultural, and traditional factors also can greatly influence demand. The Central West African countries of Ghana and Nigeria are a fine example of this. In this region, yams were virtually the only staple crop before the introduction of cassava, corn, and cocoyam from the Americas and Asia. Yams have assumed, through time, a very significant role in the cultural and traditional life of the people in the rural areas, and are usually preferred above all other staples despite the relative high cost (15, pp. 80-81).

The importance of yams in the food preferences of the people of Ghana and Nigeria can be seen from the following data showing the relative price ratios of yams to other major calorie sources (15, p. 81):

Area	Price Ratios per Unit Caloric Value		
	Yam/Cassava	Yam/Maize	Yam/Rice
Ghana	1:1.7-3.8	1:3.0-5.5	1:1.0-1.9
Nigeria			
East	1:3.2-5.3	1:2.6-3.2	1:1.1-1.6
West	1:3.0-4.8	1:1.8-3.3	1:1.1-1.6
North (Kabba Province)	1:2.2	1:2.5	1:0.7

The above ratios indicate a strong preference for yams, since relatively high prices are paid for this crop and large quantities are consumed. Most of the data were obtained from urban and semiurban districts, and if the figures for prices from small rural markets were included, the ratios would probably be higher than those above. Rice compares most favorably with the yam, but because of the restrictions and limitations that most peasant farmers in Ghana and Nigeria would face in trying to grow rice, yam production would seem more favorable from demand considerations.

A gradual displacement of yam by cassava is beginning to occur in some regions as the trend toward urbanization increases and the growing urban proletariat (often at a low wage scale) seeks easily prepared, inexpensive food (15, p. 81). In some rural areas yams are an almost universal food despite their cost, but in the large towns of Western Africa it is becoming known as a "rich man's food."

Relative prices can give some objective information indicating consumer preference. To obtain price data on a very broad basis, I used the average community prices as quoted by the U.S.D.A. Economic Research Indices of Agricultural Production for Africa and the Near East and for the Western Hemisphere (16; 17). The price averages quoted were the average prices received by farmers for the period 1961-1965 and were expressed in dollars per metric ton. Because of the large weight differences between the root crops and the cereals, the relative prices would be much more meaningful if expressed in price per unit caloric value. Besides, when a consumer purchases a staple food, he is buying it for its food value (calories) and not for its sheer mass. For this reason, I converted the U.S.D.A. figures to price per 1000 calories based on the caloric values stated in Table 1. The only exception is the caloric value for millet which I obtained from Johnston (3, p. 160). Table 2 lists the prices per 1000 calories for the major staples of Ghana,

TABLE 2. AVERAGE PRICES OF VARIOUS STAPLES RECEIVED BY FARMERS FOR 1961-1965, RANKED IN ORDER OF PRICE PER 1 000 CALORIES

Country	Crop	Price per Metric ton	Price per 1 000 Calories
		(U.S. dollars)	(U.S. dollars)
Ghana	Yam	73	.070
	Rice	149	.042
	Cocoyam	46	.041
	Millet	131	.038
	Sorghum	130	.037
	Maize	87	.024
	Cassava	37	.024
Nigeria	Yam	61	.059
	Cocoyam	50	.044
	Rice	103	.029
	Millet	70	.020
	Sorghum	70	.020
	Cassava	29	.019
	Maize	53	.015
Jamaica	Potato	85	.121
	Yam & Sweet Potato	60	.055
	Cassava	70	.046
	Rice	130	.037
	Corn	65	.018
Trinidad	Yam & Sweet Potato	58	.053
	Cassava	64	.041
	Rice	91	.026
Dominican Republic	Potato	59	.085
	Sweet Potato	55	.048
	Rice	160	.046
	Cassava	42	.027
	Maize	60	.017

U. S. Dept. of Agr., Econ. Res. Ser., Indices of Agricultural Production in Africa and the Near East, (For. Agr. Econ. Rept. 265), 1971.

U. S. Dept. of Agr., Econ. Res. Ser., Indices of Agricultural Production for the Western Hemisphere, (For. Agr. Econ. Rept. 264), 1971.

Nigeria, Dominican Republic, Jamaica, and Trinidad. Aside from the inherent errors of the data, the price relationships show something of the prices consumers are willing to pay for the various staples. This gives us an indication of consumer preference with certain limitations relative to the quantity consumed. We see for Jamaica and the Dominican Republic that the Irish potato draws a very high price relative to the other staples, however, the qualities consumed are relatively small. Thus we must not overemphasize the present consumer demand by the present price. In contrast to the potato, the yam in Ghana and Nigeria also commands a high price but is also consumed in large quantities, thus indicating a strong present consumer preference. The high Irish potato prices received by farmers in Jamaica and the Dominican Republic, do, however, indicate a potentially favorable crop for increased peasant production.

We can see from Table 2 that in Ghana and Nigeria maize, cassava, millet, and sorghum consistently are the lower cost staples while yam, cocoyam, and rice command higher prices. In Jamaica and Trinidad, corn, cassava, and rice generally tend to have lower prices than potatoes, sweet potatoes and yams. In the Dominican Republic the same hierarchy is true with the exception of rice commanding a relatively high price. The difference lies in the fact that the Dominican Republic is attempting to be self-sufficient in its rice production while Jamaica and Trinidad import considerable quantities from their commonwealth neighbor, Guyana, at relatively low cost. The Dominican Republic's rice production probably is not as efficient as that of Guyana where the extensive, well-irrigated, lowlands are excellent for rice production, and also the government of Dominican Republic has placed price supports on rice production causing higher prices (18, p. 15).

Elasticities of Demand

Income elasticities of demand as listed in the FAO Agricultural Commodity Projections are useful in indicating a general relationship between per capita quantity consumption of various commodities with corresponding one percent increase in income. These data are not only useful in demand projections, but give a general indication of consumer preference for particular commodities as the means of purchasing them increase. Data from the FAO commodity projections for 1975 and 1985 for Jamaica, Trinidad, and Nigeria are listed below, giving income elasticities of demand for several of the starchy staples (19, pp. 79, 80, 90):

Commodity	Jamaica	Trinidad	Nigeria
Wheat	0.3	0.2	1.1
Rice	0.4	0.2	0.6
Coarse grains	0.3	0.0	0.4
Starchy roots	0.2	-0.1	0.2

Although the starchy roots probably have considerable variability in their demand elasticities, they are bulked under a single grouping. Despite this, the general trend is clear, that in these three countries the root crops tend to have a lower income elasticity of demand. Therefore, as income increases in these countries, per capita consumption of the root crops increases less than that of the cereals. This is a well established general tendency in most developing countries.

Future Demand

Although per capita demand for the starchy root crops and the cereals are important considerations, possibly more important for production planning are considerations of total demand for particular crops. Total demand, a function of population and income growth, will be an important factor in determining which crops are to be recommended for production in rural development. With growing incomes, the future demand for the cereals would tend to increase more than the root crops. But populations are also expected to continue to rise in West Africa and most of the Caribbean islands with a corresponding rapid growth of urban centers. The increase in total population with proportionately fewer people remaining in the rural sectors will place an increasing burden on the peasant farmer to produce more food. He must not only increase production to meet the demand from population growth, but also to meet the growing demand of an ever expanding, nonfood-producing urban sector. Previously, we have noted that the root crops are better able to meet the needs of the peasant farmer for a crop that yields well with relatively few inputs, and also meets the needs of the low income classes for an inexpensive source of calories. Rapid urban growth in the developing world is not generally producing a new middle class with its increased demand for the more desirable (higher income elasticity) foods, but instead are harboring a growing mass of low income groups, who place high demand on inexpensive calorie sources.

Poleman's study of Ghana's food economy substantiates the importance of the inexpensive root crops in the diet of the booming city of Accra and other urban centers (8). It would seem that, despite the general preference for cereal staples over root crops, the situation of the urban centers would indicate a large demand for the root crops for some time into the future.

Several developments in root crop processing may also play an important role in their future demand. Baked goods made from wheat flour are a staple food in many of the tropical developing countries. Since wheat is a temperate crop, wheat imports are often very high for these countries, placing a large strain on their foreign exchange. Sweet potato flour has been shown to be satisfactory as a wheat flour substitute at a rate of 15 percent in bread and 20-30 percent in pastries (14, pp. 115-125). Implementing findings such as this may greatly increase demand for domestically produced root crops as well as reduce loss in foreign exchange.

Also worth mentioning are the potentials for cassava as animal feed both for domestic production and even as an export product. The European Economic Community is importing large quantities of cassava as a raw material for compound animal feeds. The total import value of cassava into the EEC in 1966 was $57.5 million and is expected to increase (20, p. 9).

As a feed, cassava roots are low in protein, but the leaves contain as much as 30 percent protein. The International Center for Tropical Agriculture (CIAT) in Colombia is investigating the incorporation of the leaf protein into an overall, complete feed with the roots supplying the main bulk. Developments such as these hold promise for increased demand for some of the root crops.

V. Effect of Society in Choice of a Staple Crop

The choice of food crops chosen and emphasized in rural development will largely influence the success of any program designed to increase rural employment and income and thereby reduce the mass migration to the urban areas. We have tried to briefly investigate some of the aspects of the various staple crops that would determine their value in rural agricultural production. In a recent study at the University of the West Indies in Trinidad, the operation of small farmers were shown to be economically feasible if the proper crops were chosen for production (21). The choice of crops was based on some of the criteria we have investigated thus far. From the data obtained, several hierarchies of the staple crops might be constructed to see an overall comparison among the various staple crops.

A cost of production hierarchy can be found on page 5, relating costs per acre, per pound, and per 1000 calories. Cost of production per pound has little direct meaning in comparing the bulky root crops with the lighter grains. Of greater concern for comparison are the cost of production per acre and the cost per unit of food value (calories). The peasant farmer seeks a crop that yields well on relatively small land area per unit of time of growing season (kcal./ha. per day). At the same time this cost of production must be low (cost/1000 calories). Below are the cost of production hierarchy for the cost of production per 1000 calories as reported on page 5 and a hierarchy for average production in the tropics in terms of calories per hectare per day from the data in Table 1:

	Cost/1000 calories (lowest to highest)		Kilocalories/hectare/day (highest to lowest)
1	cassava	1	sweet potato
2	sweet potato	2	Irish potato
3	maize	3	cocoyam
4	cocoyam	4	maize
5	sorghum	5	cassava
6	millet	6	rice
7	rice	7	yams
8	yams	8	sorghum

Since the peasant farmer is seeking high yielding crops with low costs of production, the crops on the upper range of the two hierarchies would be most suitable based on the above criteria. The most favorable crops appear to be sweet potatoes, cocoyams, maize, and cassava. The relatively high cost of production and lower yields make sorghum, rice, and yams less favorable.

Now that we have determined which crops generally will yield best and cost less to produce, let us investigate what prices the farmers can receive, and thus get a feeling for which are the better income producing crops. This factor will be influenced by many circumstances including the region which we investigate. If we refer to Table 2 (page 13), we see that in Ghana and Nigeria, yams, rice, and cocoyams bring the higher prices per 1000 calories and cassava and maize, the lowest prices. With the exception of cocoyams, the crops which yield best and are least costly to produce bring a lower price to the farmer. Therefore, in the Ghana and Nigeria situation no clear and obvious "most favorable" group of staple crops can be recommended for peasant production as opposed to a "less favorable" group in terms of peasant income improvement. More information would be required of the particular soil, climatic, and local marketing factors before any recommendations could be made.

In the West Indian situation, as shown by the data for Jamaica and Trinidad, the situation is different. Here yams, sweet potatoes, and cassava command better prices for the farmer than do corn or rice (Table 2). But even here we see differences due to location and other factors such as price supports. Prices per 1000 calories are higher for rice in Dominican Republic than for cassava, probably due to price supports issued by the government.

The varied situation between that found in Central West Africa and that of the West Indies indicates the importance of investigating the many factors involved in any one region before drawing any conclusions as to which is best suited for increasing peasant incomes.

Should the root crops generally be seen as a more favorable choice in any particular region, I would possibly foresee criticism based on their low protein composition. It is true that the grains contain 7-11 percent protein per 100 grams edible proportion as compared to only 0.4-2.8 percent for the root crops. But determination of food quality should be done with calories, not weight, as the base, especially in comparing crops with such divergent moisture contents as the grain and root crops. Where this is done, protein composition differences are considerably smaller. Table 3 lists the various crops in order of their ability to produce protein efficiently, but also lists their protein content per 100 calories. Except for cassava and some sweet potato varieties, the root crops compete favorably with the cereals. When protein quality is taken into account, differences become even less distinct.

TABLE 3. PROTEIN PRODUCTION EFFICIENCY AND COMPOSITION OF THE VARIOUS TROPICAL STAPLES, RANKED IN ORDER OF PROTEIN PRODUCTION EFFICIENCY

Crop	Protein per 100 Cal.	Protein per ha./day	Utilizable Protein
	(grams)	(grams)	(percent)
Potato (world)	2.5	1875	5.9
Potato (tropical)	2.5	1225	5.9
Maize (world)	2.8	1568	4.7
Maize (tropical)	2.8	1036	4.7
Wheat	3.2	1088	5.9
Colocasia	1.8	828	-
Sorghum	2.9	696	-
Rice	2.0	600	4.9
Yams	1.9	475	4.6
Sweet Potato	0.35-2.5	192-1200	-
Cassava	0.5	161	0.9

Sources:

C. A. deVries, J. D. Ferwerda, and M. Flach, "Choice of Food Crops in Relation to Actual and Potential Production of the Tropics," Neth. J. Agric. Sci., Vol. 15, 1967.

D. G. Coursey and P. H. Haynes, "Root Crops and Their Potential as Food in the Tropics," World Crops, July-August 1970.

VI. Conclusion

Keeping in mind the general and variable nature of much of the data upon which conclusions were drawn, we have observed several important points in relation to choosing between staples for tropical peasant agricultural development. We have seen that the root crops tend to have slightly higher caloric yields per unit area per unit of time, and that the genetical potential still untapped through breeding is much higher in root crops than in the cereals. With few exceptions, the root crops have lower costs of production than most of the cereals, but the importance of this is largely related to the farmers' returns which, as we have seen, vary with the region under study.

Should incomes be expected to rise in a developing country, root crops would tend to be less preferred over most cereals. But the increase of urban centers perpetuates considerable demand for the generally low cost root crops.

In terms of storage and transportation, the cereals are far superior. Attempts at reducing the bulkiness of root crops and increasing their storage ability by processing and drying increase their competition with the cereals.

Although the cereals have been claimed as being better sources of protein, the differences are greatly reduced if we view protein composition in terms of calories and not weight.

In very general terms, the root crops appear to be superior to the cereals in terms of cost of production and yielding ability, and the latter seems to have considerable room for improvement. Protein deficiencies between the two staple crop groups are not as great as previously stressed. Finally, as breeding programs for the tropical root crops are initiated and expanded, I would recommend that they be accompanied by research on storability and processing. It seems imperative that the tropical root and tuber crops be given considerably more emphasis on present tropical agricultural development schemes than is presently being done.

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