GROUP II:

"DEVELOPING THE REGION'S ROOT CROPS, FRUITS AND VEGETABLES"

THE DEVELOPMENT POTENTIAL FOR ROOT CROPS IN THE CARIBBEAN REGION

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Introduction

The root crops of importance in the Caribbean region are: yams (*Dioscorea* spp.) sweet potato (*Ipomea batatas* (L.) (Lam)), cassava (*Manihot esculenta* (Crantz), Irish potato (*Solanum tuberosum* L.) and the edible aroids which include dasheen (*Colocasia esculenta* (L.) Schott var. *esculenta*), eddoe (*Colocasia esculenta* (L.) Schott var. *antiquorum* (Schott) Hubbard and Rehdner) and tannia (*Xanthosoma sagittifolium* (L.) (Schott). Other root crops of localised or minor importance are arrowroot (*Mananta arundinacea* L.), ginger (*Zingiber officinale* Rosc.) and topee tambu (*Calathea allonia* Aubl).

The major root crops listed above are important as carbohydrate foods. It is estimated that over 350,000 tons of root crops are produced in the Caricom region annually. Other carbohydrate foods of importance in the region are: wheat (flour and other wheat products), rice, corn, banana, plantain and breadfruit. Of the three cereals listed, rice is the only one produced in large quantities in the region and most of this production is confined to Guyana, which produced about 190,000 tons in 1972 [26]. Small quantities of rice are produced in Trinidad (11,000 tons) and Belize (4,000 tons) [26]. It is estimated that the Caricom Caribbean region currently imports over 170,000 tons of rice and 200,000 tons of corn annually. All the wheat and wheat products used in the region are imported; Barbados imported $2.5 million, Belize $2.1 million and Guyana $0.9 million in 1973. Jamaica imported $25.4 million cereal and cereal products in 1973 [25]. The above figures indicate that the Caricom Caribbean is a net importer of large quantities of cereals and this of course adversely affects the balance of payments situation in most territories.

Of the 400,000 tons of bananas estimated to be produced in the Caricom Caribbean region in 1973, 232,640 tons were exported [26]. All plantains and breadfruits grown are consumed locally; production figures for the region as a whole are not available but they are expected to represent a relatively small proportion of the total carbohydrate consumption in the region.

The region has a large carbohydrate gap as indicated by the large cereal import bill and it has the choice of either to continue importing or to increase the production and consumption of carbohydrate foods that can be grown locally. In this paper the potential of one group of these carbohydrate foods - the root crops - will be examined.

Some Root Crop Production Statistics

Statistics on the production of root crops in the Caribbean region are scarce and the available information is often conflicting. For example, FAO Production Year Book of 1972 gives a production figure of 160,000 metric tons for yams and sweet potato in Jamaica whereas the Agriculture Planning Unit of the Ministry of Agriculture, Jamaica, estimated production of these two crops in 1972 at 172,000 metric tons. However, FAO Production Year Books contain the most complete of available data and these are presented in Table 1. Yams and sweet potato data are combined and no data are available on dasheen, eddoe and tannia.

Table 1. The Production of Root Crops in the Caribbean Region in 1972

Countries	Yams and Sweet Potato ('000 metric tons)	Cassava
Caricom Countries:		
Antigua	-	-
Dominica	0	-
Grenada	0	-
St. Kitts/Nevis/Anguilla	0	-
St. Lucia	2	-
St. Vincent	4	-
Belize	-	-
LDC's Total	6	-
Barbados	23	1
Guyana	5	14
Jamaica	160	10
Trinidad & Tobago	20	4
MDC's Total	208	29
Caricom Total	214	29
Non-Caricom Countries:		
Cuba	260	220
Dominican Republic	90	174
Guadeloupe	28	4
Haiti	90	135
Martinique	38	3
Puerto Rico	09	5
Surinam	*	2

Source: FAO Production Year Book, 1972.
Notes: - None or negligible quantity
* Data not available.

The production figures given in Table 1 indicate that among the Caricom territories, Jamaica is by far the major producer of yams and sweet potato. The production of 160,000 tons of yams and sweet potato in Jamaica represents 75 per cent of the total production of these two crops for the Caricom territories. Other Caribbean territories producing large quantities of yams and sweet potato are Cuba, Dominican Republic and Haiti. Barbados produced 23,000 tons, Trinidad and Tobago 20,000 tons and Guyana 5,000 tons in 1972. Among the Lesser Developed Caricom Countries (LDC's) the production of yams and sweet potato is greatest in St. Vincent where 4,000 tons were produced in 1972. St. Lucia produced 2,000 tons and negligible amounts were produced in the other territories in 1972.

Cassava is produced in much smaller quantities than yams and sweet potato combined. Guyana (14,000 tons), Jamaica (10,000 tons) and Trinidad (4,000 tons) are the only Caricom countries producing significant quantities. Very large quantities of cassava are however produced in Cuba, Dominican Republic and Haiti.

Production data on the edible aroids are not available. Spence (1970) [22] estimated roughly that the production of edible aroids in Latin America and the Caribbean may be in the order of 3 million tons. The author estimates that annual production in the Caricom territories is no more than 100,000 tons.

Data on the production of root crops in Jamaica in 1972 are presented in Table 2. Yams are by far the major root crop grown in Jamaica and is followed by cassava (bitter and sweet), dasheen, sweet potato, tannia and Irish potato. Yams represent 86 per cent of combined yam and sweet potato production in Jamaica and are, therefore, the single most important root crop produced in the Caricom region.

Table 2. Production of Root Crops in Jamaica in 1972.

Crop	Production (metric tons)
Yams	148,656
Sweet potato	24,064
Irish potato	12,656
Cassava - bitter	17,066
- sweet	9,817
Dasheen	25,527
Coco (tannia)	16,306
Total root crops	254,092

Source: Files, Agricultural Planning Unit, Ministry of Agriculture, Jamaica.

The Nutritional Value of Tropical Root Crops

Data on the nutritional value of tropical root crops presented in Tables 3, 4 and 5 show that the root crops have high moisture and carbohydrate contents and low protein contents (on a fresh weight basis) and contain moderate amounts of minerals and vitamins. When protein content is expressed on a dry weight basis (Table 4) values for yams and some cultivars of dasheen and tannia are comparable to protein levels in cereals such as rice (7 per cent), corn (8 per cent), wheat (10 per cent). Cassava, sweet potato and some cultivars of dasheen are very low in protein content. Splittstoesser *et al* (1973) [23] considered most yams and some of the aroids to be marginally sufficient as protein sources since foods containing 5 per cent utilizable protein can sustain health if eaten in sufficient quantities.

Minimum amounts of essential amino acids found in root crop protein are compared with essential amino acids in the FAO reference protein (Table 5). Cassava contained the lowest essential amino acid contents and many cultivars are deficient in all the essential amino acids. All the root crops

Table 3. Nutritive Value of Root Crops per 100 Grams of Edible Portion

Items	Units	Yams[a]	Irish potato[a]	Sweet potato[a]	Cassava[a]	Dasheen[a]	Tannia[b]
Food energy	Calories	105	82	117	146	104	133
Water	g	72.4	78	76	62.5	72.5	65
Carbohydrate	g	24.1	18.9	27.3	34.7	24.2	31
Protein	g	2.4	2.0	1.3	1.2	1.9	2.0
Fat	g	0.2	0.1	0.4	0.3	0.2	0.3
Calcium	mg	22	8	34	33	23	20
Iron	mg	0.8	0.7	1.0	0.7	1.1	1.0
Vitamin A	I.U.	traces	traces	500	traces	traces	traces
Thiamin B_1	mg	0.09	0.10	0.10	0.06	0.15	1.1
Riboflavin B_2	mg	0.03	0.03	0.05	0.03	0.03	0.03
Niacin (Nicotinic acid)	mg	0.5	1.4	0.6	0.6	0.9	0.5
Vitamin C	mg	10	10	23	36	5	10

Sources: a Jacoby (1965)
b Doku (1967).

Table 4. Crude Protein Content of Some Root Crops (dry weight basis)

Species	Number of cvs. tested	Range of % protein	Average % protein
Dioscorea:			
alata	26	6.56 - 11.22	8.33
bulbifera	6	6.66 - 11.06	9.79
esculenta	6	7.85 - 13.06	9.42
rotundata	5	6.34 - 8.06	7.21
trifida	3	6.69 - 7.63	7.23
Manihot esculenta	6	1.47 - 5.18	3.08
Colacasia esculenta	4	1.75 - 11.72	6.52
Xanthosoma sigittifolium	6	5.03 - 8.94	6.52
Ipomoea batatas	3	2.13 - 2.69	2.34

Source: Splittstoesser *et al* (1973).

tested were deficient in sulphur containing amino acids but leucine, phenylalanine and threonine are present in all root crops except cassava in sufficient excess to supplement other plant proteins (Splittstoesser *et al*, 1973). These data suggest that where cassava is used as a food it should be adequately supplemented with other protein sources.

Table 5. The Minimum Amount of Essential Amino Acids in Some Root Crops as Compared to the FAO Reference Protein

Species*	g Amino Acid/100 g Protein**								
	Lycine	Methionine	Half-Cystine	Tyrosine	Valine	Isoleucine	Leucine	Thereo-nine	Phenyl-alanine
Dioscorea:									
alata (26)	4.7	1.5(26)	0.1(26)	2.2(5)	4.2	3.6(6)	7.5	3.5	5.5
bulbifera (6)	3.4(2)	0.6(6)	0.3(6)	2.4(1)	5.5	4.2	5.6	4.1	5.5
esculenta (6)	3.6(6)	1.3(6)	0.3(6)	2.6(2)	4.0(1)	2.7(5)	6.4	3.9	4.2
rotundata (5)	5.3	1.4(5)	0.1(5)	2.8	4.6	4.1(1)	7.5	3.9	6.0
trifida (3)	4.6	1.2(3)	0.1(3)	2.9	4.9	3.9(2)	8.2	4.4	5.2
Manihot esculenta (6)	2.9(2)	0.7(6)	0.0(6)	0.8(6)	2.5(2)	1.5(6)	2.6(2)	2.3(2)	1.5(2)
Colocasia esculenta (4)	4.2	1.1(4)	0.1(4)	2.4(3)	5.5	3.3(3)	7.7	4.5	4.0
Xanthosoma sagittifolium (6)	3.7(6)	0.9(6)	0.6(6)	1.5(5)	6.0	3.1(6)	6.3	4.2	4.2
Ipomea batatas (3)	4.6	1.5(3)	0.0(3)	1.2(3)	6.9	4.8	7.7	4.8	4.5
FAO Reference Protein	4.2	2.2	2.0	2.8	4.2	4.2	4.8	2.8	2.8

Notes: * Number in parenthesis is the number of cultivars analysed.
** Number in parenthesis indicates the number of cultivars which were below the FAO minimum.

Source: Splittstoesser *et al* (1973).

The Economics of Root Crop Production

Table 6 shows data on labour utilisation, yields, production, cost, and gross and net returns of yams, sweet potato, dasheen, eddoe, tannia and Irish potato in some Caricom Caribbean territories collected by Rankine (1972) in the Caribbean wide study of over 800 root crop farms in 1970. In general it was found that the cost of producing and marketing root crops was relatively high when compared to the prices received. In Jamaica and St. Vincent farms growing yams and sweet potato were operating at a loss. Yam and sweet potato farmers in Barbados and St. Kitts were at the break-even point and realised only a small profit. Farmers producing aroids and Irish potato operated at a loss in all territories.

The high cost of producing root crops, is mainly due to (a) the low yields obtained, and (b) the high cost of the large number of man-hours utilised in the production system as shown in Table 6. Figure 1 shows the relationship between the cost of production and yield for yams and sweet potato and demonstrates quite clearly that the cost of production is very high when yields are low. The potential for higher yields and lower labour utilisation are two important factors which must be considered.

Yields

The data presented in Table 7 show that there is a vast difference in the yields obtained on experimental plots as compared with the yields normally obtained in commercial fields. With the exception of Guyana and Belize the available cultivable land is limited in the Caricom Caribbean region and hence increasing production by increasing the area of land cultivated to root crops appear not to be a feasible proposition outside of these two countries. Root crops are not important in Belize and only relatively small quantities are cultivated in Guyana. Since root crops are bulky and expensive to transport, increased production should ideally occur within the territory where the crop is to be consumed. It must be noted however, that the use of dehydrated root crop products may facilitate intra and extra regional trade in these commodities. The important consideration is therefore the potential for increasing yield per unit of land area. This can be achieved by (1) improving the genetic material by developing high yielding cultivars, (2) improving management practices, and (3) reducing the incident of pests and diseases.

Potential for Cultivar Improvement

Of the five species of edible yams, *Dioscorea alata, D. rotundata, D. cayenensis, D. Esculenta* and *D. trifida*, grown in the Caribbean, only one, *D. trifida* produces viable seeds freely in the region. To date, hybridisation among cultivars within the other four species has had little or no success and unless these species can be induced to flower and set seeds readily cultivar improvement through breeding may not be possible. Some mutation breeding has been tried but with no success. Cultivar improvement of these four species is therefore limited to selection of superior cultivars or clones from among the existing germ plasm. Martin (personal communication) in Puerto Rico has screened a world-wide collection of yams and has found that two of the leading Caribbean cultivars - the Negro yam of Jamaica and the White Lisbon yam of the Eastern Caribbean are among the best in the world. Ferguson (1974) has suggested that some improvement may be made be selecting from among existing cultivars.

Table 6. The Economics of Root Crop Production in the Caribbean; Yield, Man-Hours, and Cost and Returns during 1970.

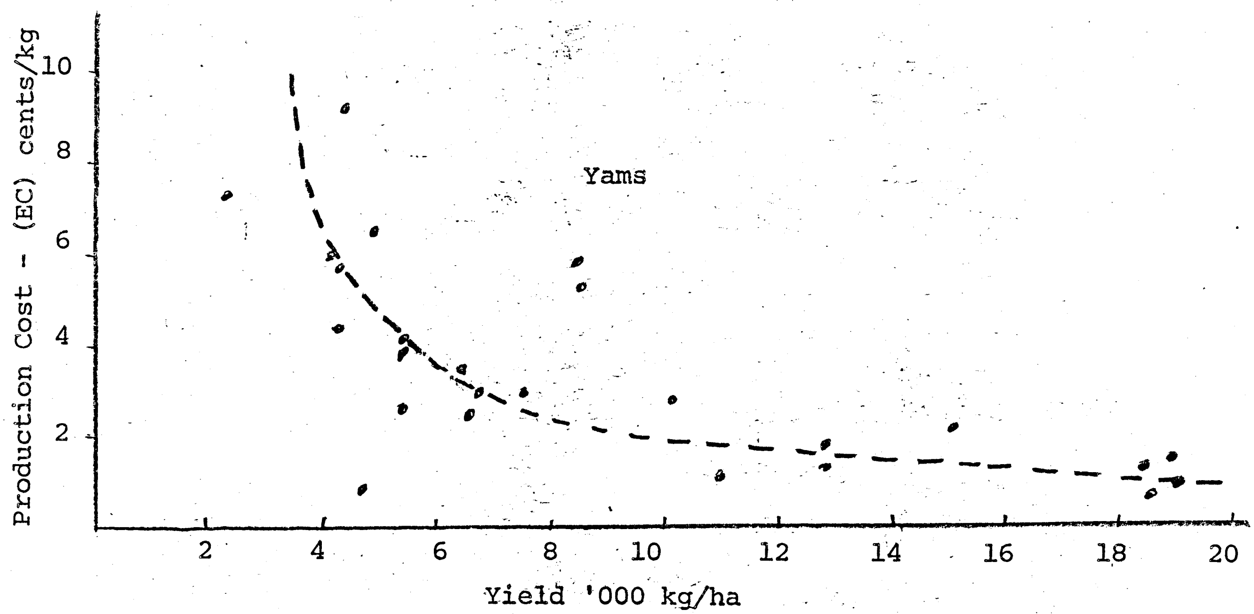
	Jamaica	St. Vincent	Barbados		St. Kitts		Nevis
			Estates	Small farms	Estates	Small farms	
Yams:							
Yield (tons/ha)	8.90	5.63	6.96	11.64	2.84	7.37	5.87
Man-hours (ha)	2,829	3,646	75	1,060	536	1,097	1,477
Cost (¢/kg)	37.5	36.4	13.4	18.1	19.8	13.2	17.6
Gross returns (¢/kg)	27.6	25.4	14.3	18.7	24.2	22.0	30.9
Net returns (¢/kg)	-9.9	-11.0	0.9	0.6	4.4	8.8	13.3
Sweet Potato:							
Yield (tons/ha)	3.64	3.97	8.59	11.22	0.94	3.07	2.29
Man-hours (ha)	1,173	1,000	393	738	207	654	1,306
Cost (¢/kg)	35.7	12.6	7.1	10.8	19.8	13.2	37.5
Gross returns (¢/kg)	19.8	12.1	8.8	19.2	19.8	17.6	22.0
Net returns (¢/kg)	-15.9	-0.5	1.7	8.4	0.0	4.4	-15.5
Aroids and Irish Potato:	*Dasheen*		*Eddoe*	-------	*Tannia* -----		*Irish potato*
	Jamaica	St. Kitts[2]	St. Vincent	St. Vincent	St. Kitts[2]	Nevis	Jamaica
Yield (tons/ha)	12.92	2.02	5.84	4.40	2.17	2.13	3.79
Man-hours (ha)	2,265	941	2,471	2,307	593	1,316	1,785
Cost (¢/kg)	14.6	30.9	24.2	21.4	30.9	46.3	19.8
Gross returns (¢/kg)	17.2	30.9	19.8	28.7	28.7	28.7	10.5
Net returns (¢/kg)	-2.6	0.0	-4.4	-1.6	-2.2	-17.6	-9.3

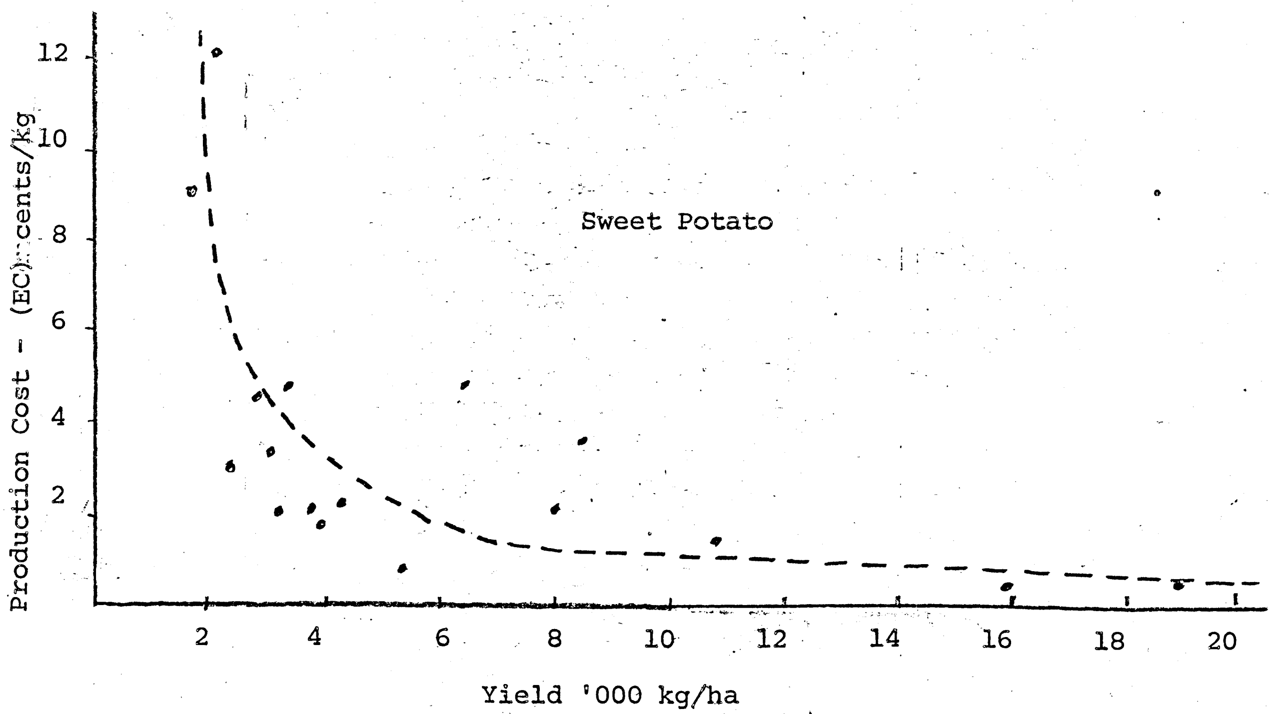
Source: Compiled from data presented by Rankine (1972).
Notes: 1 Small farms only.
2 Eastern Caribbean currency (EC$1 = US$0.50).

Table 7. The Yields of Root Crops under Commercial and Experimental Conditions in the Caribbean

Crop	Commercial (tons/ha)	Experimental (tons/ha)
Yams	2 - 15	20 - 65
Sweet potato	1 - 10	9 - 32
Cassava	1 - 10	15 - 45
Dasheen	2 - 15	15 - 38
Eddoe	2 - 7	10 - 30
Tannia	1 - 7	10 - 38
Irish potato	2 - 10	10 - 35

Figure 1. The Relationship between Production Costs and Yields for Yams and Sweet Potato on Small Farms in the Caribbean during 1970





Source: Rankine (1973).

D. trifida (cush-cush or yampie) has been subjected to some breeding in Trinidad (Henry, 1967) and Guadeloupe (Degras, 1969). In Guadeloupe cultivars which can yield over 40 tons per ha without staking have been developed (Degras, personal communication).

Possibilities for crop improvement by breeding in sweet potato is much better than in yams. Although the sweet potato has much variation in foliage and tuber characteristics the sterility-incompatibility complex of the cultivated sweet potato and related species greatly limits the genetic base and techniques available for hybridisation. Recently, Charles *et al* (1973) outlined various approaches which may be used to overcome cross and self-incompatibility problems and thus facilitate inbreeding and more rapid hybridisation among sweet potato cultivars and related species. At present there is little or no breeding of sweet potato in the Caribbean and this is an area warranting immediate attention.

Cassava is a highly heterogenous crop with considerable possibilities for intra and inter-specific hybridisation. Good progress has been made in the breeding of cassava for yield and disease resistance in India and the two recently established agricultural research institutes, Centro Internacional de Agricultura Tropical (CIAT) in Colombia and the International Institute for Tropical Agriculture (IITA) in Nigeria, have major breeding programmes on cassava. It is anticipated that vastly improved cultivars may be available in the next few years. In the Caribbean there has been little effort to improve the available cultivars and the potential for improvement through improved genetic material is good.

Of all the root crops grown in the Caribbean the edible aroids have had the least scientific attention. Gooding and Campbell (1961) collected and described some 15 West Indian tannia cultivars. Apart from some small efforts by Campbell and Gooding (1962) in Trinidad and Bully (personal communication) in Dominica the author is not aware of any systematic effort at screening dasheen and eddoe cultivars in the Caribbean. The edible aroids rarely set seeds and crop improvement by breeding is therefore not very attractive. Campbell and Gooding (1962) reported some seeds set in Dominica. There is some room for improvement by selecting superior cultivars from among local (especially cultivars from Dominica) and introduced cultivars.

The Irish potato which originated in the Andean region of South America is now grown extensively in temperate and sub-temperate countries and in the highland region of some tropical countries. In the Caribbean, it is an important cash crop in Jamaica where it is grown at the higher altitudes. Currently, efforts are being made to establish this crop in Guyana. It has been tried with very little success in many of the other Caricom territories. Cultivar improvement of this crop has been limited mostly to selection from among European and North American cultivars. To date there has been little serious effort to breed Irish potato cultivars for the lowland tropics.

Potential for Improving Yield Through Improved Management Practices

Most of the root crops produced in the Caricom region are grown by small farmers. Most of these farms are below 10 hectares and the vast majority are less than 2 hectares. Barbados is somewhat of an exception in having a substantial proportion of their root crops produced on sugar cane plantations. Rankine (1970) found that the average root crop worker in the Caribbean is 45 to 60 years old and that he has been involved in root crop production for more than 20 years. The techniques used in production are more often than not traditional (Ferguson, 1974) and highly labour intensive (Table 6) thus resulting in low labour productivity. *The low level of management used by farmers is perhaps the greatest limiting factor in root crop production in the Caribbean region.*

Improved practices can be used for the production of yams in all Caribbean territories. Where these practices are applied high yields normally result. In a recent study in Barbados by Rankine and Ferguson (1975) yields of yams of over 25,000 kg per hectare were achieved on farms which applied a package of recommended practices. Yam yields in Barbados normally averaged about 8,000 kg per hectare. For high yields it is important that:

(1) the land is well prepared and ridged (or mounded);
(2) healthy planting material of a good cultivar is used;
(3) the optimum seed rate (sett weight x spacing) is used;
(4) the crop is kept weed free especially for the first one-third of the life of the crop;
(5) fertilizers are applied in the correct quantities and at the right time;
(6) where necessary yams are staked early using the most suitable technique; and
(7) crop rotation is practised to avoid a build up of diseases and especially nematodes.

Different species and cultivars of yams vary in their agronomic requirements. For example, the White Lisbon yam (*D. alata*) has different fertilizer requirements to the Chinese yam (*D. esculenta*); setts of about 1.5 kg are used for the Negro yam (*D. rotundata*) and Yellow yam (*D. cayenensis*) which are normally planted at a spacing of 1.75 m x 1 m whereas setts of 113 gm and a spacing of 1 m x 0.75 m are recommended for the White Lisbon yam: the staking of White Lisbon yam is recommended for Trinidad but it is not recommended for the drier islands of Barbados and St. Kitts; some cultivars are best planted in December/January (e.g. Portuguese, Negro, Lucea) whereas others are best planted in May (Yellow, White Lisbon, Cush-Cush); etc. It is clear that before specific recommendations could be made for the growing of yams, information on cultivars, local soil and climatic conditions and the agronomic techniques most suited for the cultivars must be known. Knowledge of the agronomic requirements of *D. rotundata* and *D. cayenenis* cultivars is scanty.

Although the sweet potato has been subjected on more research investigation than yams in the Caribbean our understanding of the behaviour of the sweet potato in the field is not as complete as yams. The sweet potato is a very unpredictable crop and it is very sensitive to imbalances among soil moisture, soil nutrient levels, soil physical conditions and other aspects of cultural management. We very often hear of farmers complaining of the poor yield of tubers from crops which had very luxurious foliage growth. It is very often difficult to make recommendations for sweet potato cultivation because of the multitude of cultivars grown (all of which may have differential response to different factors) and the lack of knowledge of the behaviour of these cultivars in different locations. However, some information on management techniques which can substantially increase yields is available. In general most cultivars tend to give reasonable yields when grown on sandy soils. Yields are far less predictable when the sweet potato is grown on the heavy clays. We need to select or breed cultivars that can perform well on most soil types and under varying moisture regimes. The UWI variety 049 once yielded well under varying conditions. Recently yields from this cultivar have however been very low. Another UWI variety, A26/7, has performed well when grown under a wide range of soil and rainfall conditions in the Eastern Caribbean and it is now considered to be among the best of named cultivars in the Caribbean. We need to identify more broad-based cultivars and to identify their local management requirements.

Cassava is well known as a crop which can yield tubers under poor soil conditions where most other cultivated crops will fail to grow. Cassava yields are however much higher on the more fertile soils. The cassava crop is relatively easy to grow and appears to have some potential in the region. In the Caribbean we have done very little research in identifying superior cassava cultivars and in determining their agronomic requirements. We therefore do not have the necessary agronomic information or proven high yielding cultivars for the rapid development of this crop. Any expansion programme must be preceded and/or accompanied by a few years of developmental research. We can draw greatly on the experiences of CIAT and IITA and in recent times there has been increased momentum in cassava research at the UWI.

It was stated earlier that there has been little research in the Caribbean on the aroids; and this includes the agronomy of aroids. The system of growing dasheen in the Caribbean lacks the sophistication used in Hawaii and other Pacific islands. Dasheen in the Caribbean is still a crop that is grown in drainage ditches, streams, low wet areas of fields and in naturally existing swamps. In Hawaii dasheen (or taro as it is known in the Pacific and South-east Asia) is grown in flooded fields which are prepared in similar way to flooded rice fields. There is good potential for increasing the production of dasheen in Trinidad and in Jamaica; it may however compete with rice for suitable lands. In Dominica the dasheen grows well because of the high rainfall; the possibility of expanding production in this territory should be investigated. Yields are normally lower than dry land conditions. There is the need for more agronomic research on dasheen in order to identify systems of production most suited to the Caribbean region. Tannias and eddoes are dry land crops and although they are very important in some territories (e.g. St. Vincent) there has not been sufficient agronomic research on which to base recommendations for increased production.

The Irish potato has been well researched in Jamaica and precise information on production and management techniques are available to farmers in Jamaica.

Pests and Diseases

Pests and diseases very often reduce the potential for developing root crops. In yams a fungal leaf disease commonly known as anthracnose in Jamaica and leaf spot in the Eastern Caribbean greatly reduces the yield of many cultivars of *D. alata* and *D. trifida*. The causative agents are *Phyllosticta dioscoreae* and/or *Colletotrichum gloeosporioides;* some control by chemicals sprays is possible. The Internal Brown Spot of yam tubers is a very important disease in Barbados and has also been found in many other Caribbean territories (Mantell *et al*, 1974). It is believed to be caused by a virus and a team of pathologists at the U.W.I. are now actively working on overcoming this problem. Nematodes are apparently the most serious pest of yams in Jamaica (Rankine and Ferguson, 1975) and unless serious efforts are made to control this pest attempts to increase the production of yams in Jamaica may prove to be futile.

There are no very serious diseases other than some storage diseases affecting sweet potato production in the Caribbean. There are, however, two very important pests, *Eucepes postfasciatus* and *Megastes grandalis* both of which can be contorlled chemically; biological control is being tried in Barbados.

Cassava tends to have relatively few pests because of the high HCN content in leaves and tubers of most varieties. However, a shoot fly sometimes attacks plants in Trinidad. There are number of virus diseases which can only be controlled by the use of disease free planting material.

The aroids are relatively free from pests and diseases. The Irish potato on the other hand is attacked by a wide range of pests and diseases. Some of the important diseases of Irish potato in Jamaica are late blight caused by *Phytophthora infestans*, early blight caused by *Alternaria solani*, *Fusarium* and stem end rot caused by soil borne species of *Fusarium*, scab caused by *Streptomyces scabies*, black rot caused by the soil borne fungus *Roscellinia* spp., *Sclerotium* or southern wilt caused by *Sclerotium rolfsii* and virus diseases such as potato virus x, potato virus y, leaf roll virus and mosaic virus (Naylor, 1974). There is also a formidable list of insect and other pests attacking the potato and (Shah, 1974) has listed 16 as important in Jamaica. Frequent applications of fungicides and insecticides are required for good Irish potato production in Jamaica. The incidence of viruses is reduced through the importation of clean but expensive seed. In general, pests and diseases pose a serious limitation to the development of the Irish potato production in the Caribbean.

Potential for Improvement by Reducing Labout Input

In addition to low yields, it was shown earlier that the large number of man-hours utilised in the production of root crops contributes to the high cost of production. The operations requiring substantial amounts of labour are land preparation, planting, weeding, staking (yams only) and harvesting.

The obvious answers to reducing the labour input are mechanisation and the use of labour saving techniques. In areas where root crops are grown on relatively flat land e.g. in Barbados, St. Kitts and some parts of Trinidad, land preparation can be and is often mechanised. This operation involves ploughing, harrowing, rotavating (sometimes) and ridging. Fertilizer may be broadcasted and easily incorporated during land preparation. Most of the root crops grown in Jamaica, St. Vincent and the other Caricom territories are however grown by small farmers located on steep hillsides, where it is often impossible for tractors to work. In addition small farmers cannot normally afford to buy tractors and other expensive assessories and very often tractor services are not available. These are very serious constraints which will restrict the degree of mechanisation that is possible in the root crop industry in the Caribbean.

The mechanical planting of root crops in the Caribbean has only been tried on experimental and semi-commercial scales. A potato planter (modified) has been used for planting yams and potato at the Texaco Food Crops Demonstration Farm, Trinidad. In Barbados Chandler and Jeffers (1974) have developed a yam planter which has given very promising results. Vegetable transplanters (some modified) have been used for planting sweet potato, dasheen and cassava. The cane planter can also be used for planting cassava. These machines are all tractor mounted and can only be used on flat or gently sloping land.

Chemicals are available for weed control in all the major root crops. Chemical weed control is advantageous because fewer weedings are necessary and the cost per weeding is cheap. The application of pre-emergence herbicides can be done mechanically. Chemicals for use as herbicides in tropical root crops were recently reviewed by Moody and Ezumah (1974).

The labour and materials used in the staking of yams are normally very costly. The traditional practice is to use bamboo or sticks. Trellice systems, which may involve high initial capital outlay but are much lower in labour requirements, have been described by Haynes (1967), Campbell (1967) and Wholey and Haynes (1971). These systems are however suited to relatively large plots and flat terrain. Trellices tend to be more susceptible to wind damage than individual stakes. The ultimate objective should be to grow yams without any vine support as is done in Barbados and St. Kitts.

In general, the harvesting of root crops demands a very high labour input when the job is done manually. Mechanical harvesters are available commercially for Irish potato and sweet potato. However, the heavy soils on which these crops are grown very often restrict the use of these harvesters. A side lifter developed by the University of the West Indies has given encouraging results for yams and sweet potato in Trinidad and Barbados. In Barbados a locally built harvesting aide has been used quite successfully in the harvesting of yams and sweet potato (Chandler and Jeffers, 1974). Tubers of cultivated varieties of *(D. rotundata* and *D. cayenensis* yams tend to be large and cylindrical thus making them very difficult to harvest mechanically. Attempts at harvesting cassava mechanically have not been very successful because of the spreading habit of the tubers of most cassava cultivars. There is a need to develop cassava cultivars more suited to mechanical harvesting.

The mechanisation of root crop production in the Caribbean (also the tropics) is still in its infancy. Apart from mechanical land preparation which is widespread in Barbados and St. Kitts and practised to a limited extent in most other territories, the applications of the other mechanical operations are limited to research and demonstration farms, and the odd commercial farm. Two important requirements for mechanisation are (1) a fairly large uniform crop acreage, and (2) flat or gently sloping terrain. With the exception of Barbados, St. Kitts and limited areas in the other territories these conditions are difficult to find on existing root crop farms. It is recommended that careful consideration should be given to feasibility of setting up of highly mechanised root crop farms, perhaps on a demonstration basis. The soils and terrain in large areas of St. Kitts are ideally suited to mechanised root crop production and warrants special mention.

Some of the main forms in which root crops can be and are consumed in the Caribbean region are given in Table 8.

Table 8. The Utilisation of Tropical Root Crops

Form utilised	Yams	Sweet potato	Cassava	Tannia	Eddoe	Dasheen	Arrowroot
Fresh tubers[1]	*c	*c	*c	*c	*c	*c	-
Flours	*	*	*	-	-	*	-
Fermented food products	-	-	*	-	-		-
Instant products	*c	*	-	-	-	-	-
Breakfast foods	*	*	-	-	-	-	-
Infant foods	x	x	*	x	x	*	*c2
Livestock feeds	x	*	*	-	-	-	-
Industrial starch	-	*	*	-	-	-	*c2
Green leaves (spinach)	-	-	*	*c	*c	*c	-

Notes: * Utilised commercially or have good potential for commercial utilisation

x Experimental stage

\- Not known to be utilised in this form

c Produced and utilised in the Caribbean

1 For human consumption

2 Arrowroot starch which is easily digested and often used in infant and invalid food preparations. Produced mainly for export.

The major root crops are grown mainly for the consumption of fresh tubers. Most of the root crops are seasonal either because of their (annual) growth cycle (e.g. yams) or because of climatic variations such as rainfall (e.g. sweet potato). In general there tend to be periods of surplus alternating with periods of scarcity. Also tropical root crops do not as a rule store well for extented periods; cassava, yellow yam and dasheen will only keep for a few days, sweet potato for a few weeks and some varieties of yams for three months. Storage life of most root crops can be extended by cold storage but this is expensive because of the bulky nature of most root crops (70 to 85 per cent moisture) and the high cost of the energy required for cooling. The curing of tubers is perhaps the most practical way of keeping tubers and recent work by the Storage and Infestation Division of the Ministry of Industry, Commerce and Tourism in Jamaica has shown that the storage life of yams, sweet potato and dasheen can be extended substantially by curing. Clamps similar to those used for Irish potato have been shown to cure and extend the storage life of cassava at CIAT (Booth, 1973).

The fresh tubers of all the root crops listed in Table 8 are normally eaten boiled. Some such as the sweet potato may be baked. Fried chips (some after parboiling) may be prepared from yams, sweet potato, tannia, eddoe and dasheen. Yams and sweet potato can be canned.

Many cassava cultivars are toxic due to the presence of cyanogenic glucosides (mainly linimarin) which liberate hydrogen cyanide (HCN) on hydrolysis. Cassava cultivars are often classified as bitter (high HCN) and sweet (low HCN) but there are many cultivars having intermediate HCN levels that are neither bitter nor sweet. Detoxication of the poisonous or bitter cultivars is necessary before they can be eaten. The liberation of HCN either by solution in water or by volatilisation can be achieved by processes which involve maceration, soaking, boiling, roasting, fermentation or a combination of these processes (Coursey, 1973).

Flours can be prepared from cassava, yams, sweet potato and dasheen. It should also be possible to prepare flours from tannia and eddoe. These flours can usually be incorporated into wheat flour for bread-making; Sammy (1974) has done much work on the utilisation of yams and sweet potato flours in baked products. In Brazil, 10 per cent cassava flour is incorporated into wheat flour used for bread-making.

Fermented foods from root crops are not used in the Caribbean. In West Africa the fermented cassava food, gari is a most important staple food and in Hawaii, poi, a fermented preparation from dasheen (taro) is a national dish.

The development and commercial production of instant yam is perhaps the most important development in the processing of root crops in the Caribbean. It is processed in the form of a dehydrated flake to which the addition of milk or water will result in mashed yam. The basic processes for making instant yam were developed at the University of the West Indies and the product is now produced commercially (at the pilot plant stage) by the Agricultural Development Corporation in Barbados. A similar product can be prepared from sweet potato.

The preparation of breakfast foods from yams and sweet potato (very much like cereal flakes) has been demonstrated by Sammy (1974) of the University of the West Indies. This researcher is also working on the preparation of infant foods using yams, sweet potato, dasheen, eddoe and tannia. Cassava is often used as a base for baby food preparations. One of the major uses of arrowroot starch is in the preparation of baby and invalid foods.

One of the important uses of cassava in some parts of Asia (Thailand and Indonesia) and West Africa and South America (Brazil) is in the preparation of dehydrating chips and pellets for export to Europe (mainly EEC countries) where they are used in livestock feed rations. In the Caribbean, livestock is fed with expensive North American grain. Unfortunately however, we are not in a position to utilise cassava as our carbohydrate source because we have not yet demonstrated economic production levels for this crop. More research and development on this crop is obviously needed. Sweet potato is used in livestock rations in Taiwan and the French islands of the Caribbean. However, the high cost of sweet potato production in the Caricom territories and its high demand for human consumption will limit its use. Yams are currently being examined for possible use as a livestock feed at the University of the West Indies. It is the author's opinion however that like sweet potato, yams are far too costly to be used as an animal feed. However, the by-products from processing and the use of discarded yams and sweet potato tubers may find limited use in livestock rations.

Cassava and sweet potato starches have found widespread use in industry. Cassava starch in addition to its use in the preparation of foods for human consumption can be utilised in the paper and textile industries, in the making of plywood and veneer and in the manufacture of adhesives. It may also be used as a flocculation agent in the bauxite industry. Sweet potato starch can be used for making starchy jelly and glucose.

In addition to the above listed products alcohol for human consumption (wine, beer etc.) and industrial alcohol (ethyl alcohol) can be made from most of the root crops. In Guyana casareep, which is used in cooking is made from cassava.

Finally the green young leaves of many root crops are utilised as a spinach. Leaves of dasheen and to a smaller extent tannia and eddoe are used for making the well known calaloo in Trinidad; this product is now canned and exported. The tender leaves of sweet potato and cassava are eaten in some root crop growing areas but not in the Caribbean. Sweet potato foliage can be used for feeding livestock.

Conclusions

In concluding this paper attention is drawn to Table 9, where some of the more important ideas discussed in this paper are summarised.

Yam yields are currently low and the immediate potential for increasing yield by breeding and selection is not very good as we already have some of the best cultivars in the world in cultivation. Yields and the high labour input can however be substantially improved through better management by applying better agronomic practices and limited mechanisation. Nematodes and diseases may reduce the potential for achieving high yields. Yams have good potential for utilisation as processed products for human consumption but appear to have little potential for use in industry and livestock feeds.

Sweet potato, unlike yams, has good potential for crop improvement through breeding and selection. The potential for mechanisation is good on flat terrain. There are many serious pests but few diseases. The potential for food processing is good but it has only fair potential for use in industry (as starch) and livestock feeds.

Current cultivars of Irish potato will do well only at the higher altitudes and have little potential for widespread cultivation. There however appears to be good potential for improvement by breeding and improved management. The potential for mechnaisation is good but the crop is attacked by a wide range of pests and diseases. Sufficient quantities of Irish potato are not produced to warrant processing, although the potential is good.

Table 9. Some Criteria Determining the Potential for Major Root Crops in the Caribbean Region

	Yams	Sweet potato	Irish potato	Aroids	Cassava
1. Potential for yield improvement by:					
(a) Breeding	Poor[1]	Good	Good	Poor	V.good
(b) Selection	Fair	Good	Poor	Fair	Good
(c) Management	V.good	Good	Good	Good	Good
2. Potential for reducing labour input by mechanisation etc.	Fair	Good	Good	Fair	Fair
3. Pests	Few	Some	Many	Few	Few
4. Diseases	Some	Few	Many	Few	Few
5. Potential for utilisation:					
(a) as processed foods[2]	V.good	V.good	Good	Fair[3]	Good
(b) in industry	Poor	Fair	Poor	Poor	V.good
(c) as livestock feeds	Poor	Fair	Poor	Poor	V.good

Notes: 1 Except
2 For human consumption
3 May have good potential but not yet demonstrated.

Although the aroids have had very little scientific attention the potential for crop improvement management appears to be good. Potential for breeding is poor and selection fair. Pests and diseases are however not serious on these crops. The aroids may have good potential for food processing but this has not yet been adequately demonstrated.

Cassava yields are currently very low but this crop has good potential for higher yields through breeding, selection and management. There is however the need to conduct the necessary research to demonstrate this potential in the Caribbean region. Apart from land preparation the mechanisation of planting and harvesting cassava has only fair potential. However cassava tubers have potential for use in industry and in livestock feed rations if competitive production costs can be achieved.

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