Hunt Institute for Botanical Documentation
5th Floor, Hunt Library
Carnegie Mellon University
4909 Frew Street
Pittsburgh, PA 15213-3890
Telephone: 412-268-2434
Email: huntinst@andrew.cmu.edu
Web site: www.huntbotanical.org

INDEX FOR THE THIRD INTERNATIONAL

SYMPOSIUM ON TROPICAL ROOT CROPS

1

NAMES AND PROFESSIONAL ADDRESSES OF THE DELEGATES

Third International Symposium on Tropical Root Crops

at

The International Institute of Tropical Agriculture

IBADAN, NIGERIA

2 - 9 December 1973

Abraham, Abraham
FAO Regional Office
Box 1628
Accra, Ghana

Adesuyi, Samuel Adeniran
Nigerian Stored Products Research Institute
Federal Ministry of Trade
Ibadan, Nigeria

Adetunji, S.A.
Agricultural Research Council of Nigeria
Moor Plantation
Ibadan, Nigeria

Adeosun, David Ola Olu
Commonwealth Development Corporation (Nigeria) Limited
47, Marina
Box 2012
Lagos, Nigeria

Agboola, Akinola A.
Dept. of Agronomy
University of Ibadan
Ibadan, Nigeria

Amon, B. O. E.
Agric. Research Council of Nigeria
PMB 5382
Ibadan, Nigeria

Agbo, Fabian M.O.
Federal Agric. Research & Training Station
Umudike, Umuahia
Nigeria

Andersen, Pinstrup Per
Cali. Colombia A.A. 67-13

April, Jay
University of Colorado
Boulder, Colorado
U.S.A.

Arinze, Anthony
Dept. of Botany
University of Lagos
Nigeria

Ange Alphonse Joseph
Centre Orstom
B.P. 193
Yaounde, Cameroun

Azih, Victor
Federal Dept. of Agric. Research
Moor Plantation
Ibadan, Nigeria

Ayanaba, A
IITA
Ibadan, Nigeria

Ayensu, Edward S.
Dept. of Botany
Smithsonian Institute
Washington D.C. 20560
U. S. A.

Ballestrem Conrad Count
P. O. Box 220, National Horticultural Res. Station
Thika/Kenya

Black, William
National Agricultural Laboratories
P. O. Box 30028
Nairobi, Kenya

Bourke, Richard Michael
DASF Keravat
ENB, Papua
New Gunea

Ballaux, Jean-Claude
IITA
Ibadan, Nigeria

Booth Robert
Tropical Products Institute
56-62 Grays Road
London WC1 x 8LU

Blom,Marijke Van
NEDECO
P. O. Box 973
Kano, Nigeria

Bot, Markus Gyang
c/o M.N.R. Riyom P. O. Box Vom
B/P State, Nigeria

Barrios, Jose Rafael
Facultad De Agronomia
Universidad Central - Maracay - Venezuela

Bruno, Fassi
c/o FAO, Rome

Chan, Seak Khen
c/o Mardi, Sudang Sg. Besi
West Malaysia

Caesar Kund
Tec. Univ. of Berlin
Germany

Cock, James H.
c/o CIAT AA67/13
Cali, Colombia

Correa, Heliv
IPEACO - Caixa Postal 151
35700 Setehagoas, MC, Brazil

Clarke, W.
Human Geography, Avstralian
National University, Canberra

Doll, Jerry
CIAT, A.A. 6713
Cali, Colombia

deVries, Cornelis Anthonie
Royal Tropical Institute
Amsterdam, Holland

Doku, Emmanuel Victor
Crop Science Dept.
University of Ghana
Ghana

Donald, Gilbert Coursey
TPL. 56/62 Groups Inn R1
London WC1

Enyi, Brown
University of Papua
P.O.Box 4820
New Guinea

Ene, Leonard Samuel
Federal Agric. Research & Training Station
Umudike, Umuahia, Nigeria

Ezumah, H. C.
IITA
Ibadan, Nigeria

El-Fouly, Mohamed M.
National Research Centre
Cairo-Dokki, Egypt

Enyinnaya, Anosike M.
Federal Agric. Research & Training Station
Umudike, Umuahia, Nigeria

Ekandem, Moses Joseph
Federal Dept. of Agric. Research
PMB 1032
Uyo, ECS, Nigeria

Eueuson, John
Agric. Dept.
Queenland University
Queenland

Flach, Michiel
University of Agric.
Wageuigew, The Netherlands

Ferguson, Theodore
Dept. of Soil Sci.
U.W.I. St. Augustine
Trinidad

Getahum, Amare
P.O.Box 138
Dive-Dawa, Ethiopia

Guzman, Adrina Guillen
Ministetcio de Agricultla
Ministerio de Agricultura
Managua, Nicaragua

Godfrey-Aggrey, Wilhelm
Njala University
PMB Freetown
Sierra Leone

Gramacho, Ivan Da Costa Pinto
CEPLAC-Cx Postal 7
Itabuna-Bahia-Brazil

Hutagalung, Rudy I.
Faculty of Agric.
University of Malaya
Kuala Lumpur, Malaysia

Haynes, Patrick H.
Koronivia Research Station
Nausori, Fiji

Hersh, Gilbert Van
University of Colorado
Boulder, Colo. U.S.A.

Howland, Audrie
IITA
Ibadan, Nigeria

Hojo, Yoshio
ARI 70, Kitamoto
Saitama, International Institute of Agric. Science
Japan

Hussain, Zahed
Tropical Institute University of Gotting
W. Germany

Hahn, S. K.
IITA
Ibadan, Nigeria

Hernandez, Teme
L.S.U.
Baton Rouge, U.S.A.

Heys, Gilbert
c/o Shell-BP
P.O.Box 230
Warri

Hozyo, Yoshio
Abai 70, Kitamoto Saitama
International Institute of Agric. Sci
Saitama, Japan

Idusogie, E. O.
United Nations Food and Agric. Organization
P.O.Box 1628
Accra, Ghana

Iruobe, Francis
Food Specialities (Ltd)
PMB 1164
Ikeja, Lagos

Jong, Seungkeun
Crop Experiment Station
Suwon, Korea

Javadia, Virendra Singh
Dept. of Entomology
University of Udaipur
India

Jean Cpaude Favier
Center Orstom-B.P. 193
Yaounde, Cameroun

Jennings, Derek I.
Scottish Horticultural Research Institite
Invergowine, Dundee, U.K.

Kawano, Kazro
CIAT A.A.67-13
Cali, Colombia

Kang, B.T.
IITA
Ibadan, Nigeria

Kande, Beya
IITA
Ibadan, Nigeria

Kunar, Dhananjay
University Hill
P.O.Box 35060
Dares-Salaan, Tanzania

Kinross, Keith John
Massey Ferguson Division
BEWAC Ltd.
P.O.Box 385
Ibadan, Nigeria

Kavadia, Virendra
Insect Toxicologist
Dept. of Entomology
University of Udaipur
Udaipur, India

Lozano, J. Carlos
CIAT, Apartado Aereo
67-13, Cali, Colombia

Look, Graham F.
Pans Office Copr. College House
Wrights Lane
London W8

Lal, Rattan
IITA
Ibadan, Nigeria

Lawson, Theoadre L.
IITA
Ibadan, Nigeria

Machenzie, Eric
CB70 Vanga, B.P. 4728
Kinshasa II
Republic of Zaire

Marrewijk, Gijsbert Van
IVP, Sawickse Allee 166
Wageningen

Mohi Eldin Mohmed Elbereir Kamal
213 Box
Khartoum, Shambat

Mamicpic, Noel G.
Dept. of Agronomy
Col. of Agric.
Laguna, Philippine

Njoku, Eni
University of Nigeria
Nsukka, Nigeria

Nestel, Barry
IDRC Apartado Aereo 53016
Bogota

Nwoke, Festus
Dept. of Botany
University of Nigeria
Usukka, Nigeria

Nwosu, Nelson Amadi
Federal Agric. Research and Training Station
Umudike, Umuahia, Nigeria

Nangju, Dimyan
IITA
Ibadan, Nigeria

Njuguna, Simon K.
P.O.Box 30028
Nairobi, Kenya

Nartey, Frederick
Institute of Plant Physiology
Farimagsgade 2A, 1353
Copenhagenk, Denmark

Nwigwe, Chinenye
Federal Agricultural Research Station
Unuahia, ECS, Nigeria

Okigbo, Bede N.
IITA
Ibadan, Nigeria

Okereke, O.U.
IITA
Ibadan, Nigeria

Olorunda, Ayodele Olu
University of Ife
IAR & T
PMB 5029, Moor Plantation
Ibadan, Nigeria

Oyolu, Dr. & Mrs. C.
University of Newcastle Upon Tyne
Dept. of Plant Science
NE1 7RU, Newcastle

Okusanya, Funnso
Federal Dept. of Agric. Research
Ibadan, Nigeria

Osarollor, Gomba Humphrey
Shell-BP
P.O.Box 263
Port Hartcourt
Nigeria

Okeke, Godson
Federal Agric. Research & Training Station
Umudike, Umuahia
Nigeria

Ogundana, S. K.
Federal Agric. Research
Ibadan, Nigeria

Okoli, C.
IITA
Ibadan, Nigeria

Otoo, John Alex
Crops Research Institute
P.O.Box 3785
Kumasi, Ghana

Oke', Olusegun
University of Ife
Ile-Ife, Nigeria

Okonkwo, Samuel
Dept. of Botany
University of Nigeria
Nsukka, Nigeria

Okonkwo, George
Deputy Chief Res. Officer
Federal Agric. Res. & Training
Umudike, Umuahia
Nigeria

Oppong, Angelina
Crops Research Institute
P.O.Box 3785
Kumasi, Ghana

Okoli, Obinani
F.A.R.T.S
Umudike, Umuahia
Nigeria

Phillips, Truman
School of Agric. Economics
University of Guelph
Guelph, Onitario

Plarre, Werner F. K.
IITA
Ibadan, Nigeria

Plucknett, Donald L.
Office of Agric. ITAB
Agency for International Dept.
Washington D.C. 20523

Posthumus, Adam C.
Centre for Plant Physiological Research
Bornesteeg, Wageningen
The Netherlands

Roland, Dumont
IRAT
110 rue de l'universite
Paris, France

Rosanow, Michael
c/o H.V.A. - Amsterdam
P.O.Box 10328
Amsterdam

Rawal, Kanti
IITA
Ibadan, Nigeria

Robinson, K. L.
IITA
Ibadan, Nigeria

Roa, Gonazlo
Agric. Engr. Dept.
University Del Valle
Apartado Aereo 21-88
Cali, Colombia

Rankine, Looyd B.
Faculty of Agric.
Kingston, 7 Jamaica

Rabson, Robert
FAO/Mean Joint Div. Food & Agric.
IAEA, Vignna, Austria

Spora, Ngale Lyonga
IRAT Bambui Station Bamenda, Cameroon

Silvis, Henk
P.O.Box 913
Khartoum, Sudan

Suchamel, Dale
M.O.N.R, Riyom,Via Vom
Beune-Plateau.State, Nigeria

Singh, Shiv Raj
IITA
Ibadan, Nigeria

Sebasigari, Kabony
IITA
Ibadan, Nigeria

Sadik, Sidki
IITA
Ibadan, Nigeria

Thompson, Anthony Keith
P.O.Box 913
Khartoum, Sudan

Terry, Eugene
IITA
Ibadan, Nigeria

Thurston, H. David
Dept. of Plant Pathology
Cornel University
Ithaca, N.Y.

Williams, Robert
IITA
Ibadan, Nigeria

Wudiri, B.B.
Institute for Agric. Research
Ahmadu Bello University
Zaria, Nigeria

Wmanah, Effiong
Federal Dept. of Agric. Research
Moor Plantation
Ibadan, Nigeria

Wilson, Lawrence
U.W.I. Dept. of Biol. Science
St. Augustine, Trinidad

Wiew, H. Chris
IITA
Ibadan, Nigeria

ADDITIONAL NAMES AND ADDRESSES

Awani, Napoleon
Cadbury Nig. Ltd.
Iseri Road
Ikeja, Lagos, Nigeria

Alvarez-Luna, Eduardo
CIAT, Ap. Aereo 67-13
Cali, Colombia

Atanda, Oluremi Ademola
Agricultural Research Council of Nigeria
PMB 5382
Moor Plantation
Ibadan, Nigeria

Blom, Peter Van
NEDECO
P.O.Box 973
Kano, Nigeria

THE STORAGE OF FRESH CASSAVA ROOTS

by

R.H. Booth

Tropical Products Institute (T.P.I.), 56-62 Gray's Inn Road, London WC1

INTRODUCTION

It is well known that cassava roots cannot be kept in the fresh state for more than a few days after harvest. This presents serious problems in the marketing and utilization of the crop and results in heavy losses. Most of the literature relevant to the storage of cassava, both in the fresh and dried state, has recently been reviewed by Ingram and Humphries (13). They concluded that "Knowledge of techniques for preserving and storing fresh cassava is still rudimentary and few reliable data exist". Similarly, little reliable information is available as to the nature of the rapid post-harvest deterioration which prevents storage in the fresh state. This has been reported as decay or rotting, dark bluish or brownish discolouration, dark or vascular streaking and/or softening of the affected areas. Several workers (1, 6, 10, 17, 21) have isolated and identified many micro-organisms from deteriorated cassava and in some cases these organisms have in turn been shown to cause decay and

.../...

discolouration. Other workers (3, 14, 18, 19, 20) have suggested that both discolouration and softening are the results of physiological or enzymatic reactions. Ingram and Humphries (13) concluded that "It appears that the spoilage arises from a combination of physiological and pathological factors".

The importance of mechanical damage as a major factor in post-harvest loss of all tropical root crops has recently been emphasized (5). Averre (3) reports that vascular streaking of cassava roots commences at cut surfaces and several workers (4, 24) have emphasized the need for careful handling of roots intended for storage.

While extensive mechanical damage can only be reduced by imporved harvesting and handling methods, a process of wound healing which occurs in several other root crops, potato (7), sweet potato (16) and yams (11, 23) has been shown to reduce storage losses of slightly damaged produce. This process, generally referred to as curing, is stimulated by conditions of relatively high temperatures and humidities and involves first suberisation followed by the development of a wound periderm that is effective in retarding water loss and acts as a barrier against infection.

It has long been known that cassava roots can be preserved for a few days using several simple techniques such as reburial, placing under water, and coating in mud. There are, however, few recorded instances, with the exception of the use of high

.../...

cost systems, such as refrigeration (9, 21) and waxing (14, 22), of successful long term storage of fresh cassava roots. The normal practice in much of the tropical world is to leave the cassava in the ground until required, a practice which, it has been estimated, occupies 3/4 million hectares of land unnecessarily (13). While refrigeration and certain waxing techniques maybe of use in limited situations, such as export marketing or for experimental purposes, it is not considered that at present they can be extensively applied to practical on-farm or local market storage.

There are reports in early ethnographic literature (12) that Amazonian Indians successfully stored fresh cassava during the annual flood period by buring the roots in the soil. Further, it is reported (2) that M. de Reine in 1741 successfully stored fresh cassava roots in a trench resembling a European potato clamp for periods of up to twelve months in Mauritius. In the Philippines, Baybay (4) showed that cassava roots could be stored for up to twenty-five days in a trench. It has also been reported (2, 22) that roots piled up and covered with straw alone or with straw and soil situated inside a building could be stored for periods of one to two months. Similar structures have also been used to store sweet potatoes under tropical conditions (15). Conditions of above ambient temperature and relative humidity have been shown to develop in European potato clamps (7, 8).

.../...

The present paper records observations on the nature and occurrence of the rapid post-harvest deterioration of cassava roots and reports a simple inexpensive on-farm method which is being developed for curing and storing cassava roots at C.I.A.T.

DETERIORATION OF CASSAVA ROOTS

As a result of post-harvest observations, two distinct phases in the deterioration of cassava roots have been identified.

A. Primary Deterioration

It has been observed that the initial cause of loss of acceptability is internal discolouration which normally develops within one to five days after harvest. This internal discolouration is first evident as fine blue/black vascular streaks as reported by Averre (3) and described and illustrated by Montaldo (18), who also reported that there are considerable varietal differences in the rate of development of the condition. With time this streaking increases in intensity and spreads to non-vascular tissue where a more diffuse brown discolouration accompanied by dry white lesions occurs. This discolouration renders the roots completely unacceptable both for human consumption and for most industurial purposes and will be referred to as "primary deterioration" (Fig. 1).

B. Secondary Deterioration

At a later stage pathogenic rotting, fermentation and/or

.../...

softening of the roots occurs, the roots already having become unacceptable because of primary deterioration. Thus, this type of root deterioration will subsequently be referred to as "secondary deterioration". However, in West Africa, softening can sometimes render cassava partially or completely unacceptable even when little or no discolouration occurs (Coursey, private communication). Montaldo (18) has indicated that in those varieties which are least susceptible to discolouration, useful life is terminated in about a week by desiccation.

C. Occurrence of Deterioration

A strong association has been observed between the onset of primary deterioration and the occurrence of various forms ofmechanical damage. Because of the nature of harvesting operations, cassava roots are always damaged, frequently severely. Roots are often cut during the digging operation, and tips of roots regularly broken-off and shoulders bruised as they are pulled out of the ground. Severance of the roots from the plant creates a further lesion, while transport from the field can often result in mechanical damage by bruising. It is at these sites of mechanical damage that discolouration has been observed to commence, and only minor differences among varieties have been found. The importance of mechanical damage in post-harvest deterioration has been confirmed in artificial wounding tests in which primary deterioration was observed to commence at the sites of damage.

.../...

The extent of the root damage that occurs during harvesting depends on several factors, probably the most important being soil type, variety and the care with which the operation is undertaken. Roots grown in sandy soils can be harvested with greater ease and with less damage and thus have a greater storage potential than those roots produced in heavy soils. Varieties of cassava differ widely in root shape, size, distribution through the soil and in their means of attachment, some varieties having more sessile roots than others. These factors, some of which may be modified by cultural practices, all influence the final amount of root damage. Table 1 illustrates the effect which severity of damage has on water loss and deterioration of freshly harvested roots.

The deterioration index in this and other tables is arrived at by totalling the deterioration score for each root within a treatment and expressing it as a percentage of the total possible score for that treatment. Deterioration score: 0=n0 deterioration, 1=1/4 deterioration, 2=1/2 deterioration, 3=3/4 deterioration, 4= complete deterioration.

Table 1 Effect of severity of damage on fresh weight loss and deterioration of cassava roots stored at ambient conditions[1] in the laboratory.

Time in storage (days)	Fresh weight loss[2] (%)		Deterioration Index[2] (%)	
	Slightly[3] Damaged	Severely[4] Damaged	Slightly[3] Damaged	Severely[4] Damaged
1	2.9	3.5	2	15
2	7.4	10.1	27	32
4	12.4	15.9	62	65
7	17.9	21.5	57	67
11	22.1	34.2	72	75

1 - ambient conditions : temperature 20°C ± 4°C

2 - 3 x 10 roots per sample

3 - Roots with no obvious gross physical damage

4 - Roots with obvious physical damage.

D. Nature of Deterioration

An indication as to the possible cause of primary deterioration resulted from trials using surface sterilants. It has been observed that the onset of primary deterioration can be delayed when roots, portions of roots, or root slices are surface sterilized. For example, 10 mm thick transverse root slices untreated or dipped for thirty seconds in sterile distilled water and stored on moist filter paper in petri dishes became completely discoloured within twenty-four hours.

.../...

Similar root slices dipped for thirty seconds in calcium hypochlorite (>2.0%) or commercial alcohol (>40%) showed no such deterioration for between two and four days, depending on the concentration of surface sterilant used (Table 2).

<u>Table 2</u> Effect of calcium hypochlorite and commercial alcohol on the deterioration of cassava root slices.

Treatment[1]	Deterioration Index (%)					
	0	1	2	3	4	days
Undipped Control	0	100	100	100	100	
30 sec. dip in sterile distilled water	0	100	100	100	100	
30 sec dip in 1.0% com. alcohol	0	100	100	100	100	
" " " " 5.0% " "	0	75	100	100	100	
" " " " 10.0% " "	0	50	75	100	100	
" " " " 20.0% " "	0	25	50	75	100	
" " " " 40.0% " "	0	0	12	25	30	
" " " " 60.0% " "	0	0	0	0	2	
30 sec dip in 0.1% Ca hypochlorite	0	81	100	100	100	
" " " " 0.5% " "	0	25	50	75	100	
" " " " 1.0% " "	0	0	12	50	60	
" " " " 2.0% " "	0[2]	0[2]	0[2]	2[2]	12[2]	
" " " " 3.0% " "	0[2]	0[2]	0[2]	0[2]	2[2]	
" " " " 5.0% " "	0[2]	0[2]	0[2]	0[2]	0[2]	

1 - 4 x 4 slices per treatment

2 - slight discolouration because of phytotoxicity

.../...

As a result of these observations and those on the importance of mechanical damage, it is suggested that the rapid primary deterioration that occurs following the harvest of cassava roots may be the result of injury invasion by epiphytic microorganisms naturally present on the root surface. While these organisms, at present uncharacterized, do not normally cause rotting or decay of undamaged roots, they may enter wounds produced by mechanical damage and stimulate the onset of discolouration which subsequently spreads throughout the root.

STORAGE OF CASSAVA ROOTS

In view of the reported success of early workers in storing cassava roots in structures similar to potato clamps, investigations into this type of storage were initiated. Several clamp units were built on the C.I.A.T. station from November 1972 to June 1973. Each clamp was built by first placing a circular bed of rice straw of 1.5 m diameter and of sufficient thickness so that when it was later compacted it was approximately 150 mm thick on a suitably well drained piece of ground. On this straw the freshly harvested roots were heaped in a conical pile. For each unit 500 roots weighing approximately 300 kilos were used. This quantity was selected as representative of roots that one man can readily harvest in a day and also as it formed a convenient experimental unit. Unselected roots were used and so there

.../...

was therefore a large variation in root size and a substantial proportion of roots were mechanically damaged. Because of the heavy soils on the C.I.A.T. station, ahrvesting damage was particularly severe. The pile of roots was then covered with straw which compacted to a layer 150 mm thick. The whole clamp was then covered to a thickness of 100-150 mm with soil dug from around its circumference so as to form a drainage ditch (Fig. 2).

Storage clamps were opened and the roots examined after periods of one, two and three months (Table 3). During cooler periods or during periods of frequent but light rainfall, the roots were successfully stored, with an acceptable level of loss, for two months. During such periods the temperature inside the clamps was between 30°C and 35°C. Thsi temperature was found to remain constant throughout the storage periods whereas the temperature of the soil cover fluctuated with the day and night variations. A large proportion of the stored roots were successfully cured, and there was visible evidence of the wound healing after one month in storage (Fig. 3). After two months storage, the bulk of the roots remained undeteriorated (Fig. 1). However, a few of the stored roots although remaining undiscoloured, had softened in the centre. After three months storage, the percentage of unmarketable roots increased considerably as did the amount of central softening in otherwise undeteriorated roots.

.../...

During long, hot and dry periods when the temperature of the stored roots inside the clamps rose to more than $40^{0}C$, high percentage losses occurred after one month. Also, during periods of prolonged heavy rainfall when water penetrated the units, wetting the roots, heavy losses resulted.

Table 3 Results of clamp storage at different temperatures.

Time in storage (months)	Undeteriorated roots[1] (%)	
	Temperature of stored roots	
	$30 - 35^{0}C$	$40^{0}C$ and above
1	85 - 90	5 - 25
2	70 - 75	0 - 5
3	40 - 60	0

1 - Average of five clamps within each temperature range. Each clamp contained 500 roots which weighed approximately 300 kilos.

The main causes of loss in all cases were pathogenic rots, fermentation and softening at the centre of the roots. Little loss because of primary deterioration was observed. On several occasions roots at harvest time were seen to be coated with hyphae of *Corticium rolfsii* Curzi which, during storage, rapidly invaded wounds before effective curing could take place and resulted in considerable decay. The other organisms associated with rotting and fermentations have not yet been identified.

.../...

All the clamps in the main series of experiments were constructed using readily available rice straw. However, additional storage clamps built using dry sugar cane leaves, dry maize stems and leaves, and dry grass gave similar results. Also, two larger units of similar cross-sectional design and size but elongate instead of conical were built to accomodate one and two thousand roots, respectively. These gave similar results to the smaller clamps.

QUALITY OF STORED ROOTS

Tests were undertaken on numerous root samples after varying periods in storage to assess the acceptibility of stored roots. The majority of undeteriorated roots passed local freshness tests, such as nature and firmness of the skin, flesh moisture, and latex exudation after cutting.

Uncooked stored roots consistently tasted considerably sweeter than freshly harvested roots of the same variety, even after one month in storage. This sweetening was, however, less noticeable in cooked samples. Preliminary results indicate that there is a conversion from starch to sugars during storage.

In a few samples a slightly longer cooking period was required to soften the stored roots than was required for freshly harvested roots. Roots which had softened internally during prolonged storage frequently regained an acceptable texture and edible quality during cooking. The biochemical changes that occur during storage and the effect of these

.../...

changes on the eating quality of roots are being investigated.

It has also been observed that after successful curing the shelf-life of the roots subsequent to removal from storage was considerably longer than that of freshly harvested roots kept under the same conditions (Table 4).

Table 4 Comparison of shelf-life of fresh uncured roots (A) with that of roots that had been cured and stored in a clamp for eight weeks (B)

Laboratory storage (weeks)	Deterioration Index[1] (%)	
	A	B
1	45	10
2	80	7
3	100	20

It is considered that during curing not only does wound healing occur but also suberisation and/or thickening of the root skin. This slows down water loss and renders the roots more resistant to further damage. Individual, successfully cured roots have been stored for up to eight weeks at ambient conditions in the laboratoray after which they were of acceptable eating quality.

Thus, in most cases, even after three months storage, undeteriorated roots were acceptable, although quality differences could be detected between the stored and fresh

1 - 3 x 10 roots per sample

roots. The effect of these differences on the marketability, human acceptability and animal feeding qualities of the stored roots is at present being investigated.

C O N C L U S I O N S

Although this project is still at an early stage of development, some fairly definite conclusions are beginning to emerge.

1. Internal streaking and discolouration are the primary causes of the loss of acceptability of harvested cassava roots.
2 Mechanical damage is a crucial factor in the rapid post-harvest deterioration of cassava roots.
3. Cassava roots can be cured, during which process wound healing occurs and delays the onset of normal deterioration.
4. The curing process proceeds satisfactorily in cassava roots stored in structures similar to potato clamps which are inexpensive and easy to build with readily available materials. In such clamps, unselected roots have been stored with acceptable levels of loss for up to two months under the conditions prevailing at C.I.A.T., Colombia, during cool seasons.
5. The exact design of the clamps may need to be mofified to suit local conditions. In regions or seasons of

.../...

prolonged high temperatures clamps may need to be provided with shade and means of increased ventilation. Similarly, under conditions of prolonged heavy rains shelter may be needed.

6. During the reported storage trials internal quality changes associated with an increase in sweetness, add a softening of the root core occurred.

7. Following successful curing, cassava roots have a longer shelf-life than freshly harvested roots.

GENE BANK

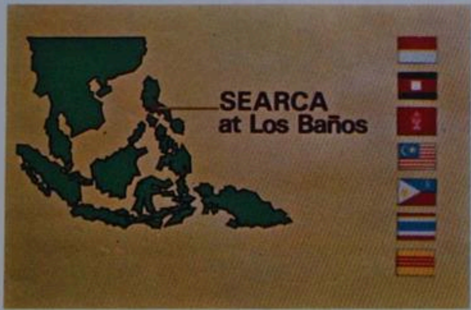
FOR

ECONOMIC CROPS

IN

SOUTHEAST

ASIA



REGIONAL EVALUATION OF HIGH-PROTEIN CROPS

3

XV CONGRESSO INTERNACIONAL DE ECONOMISTAS AGRICOLAS
XV INTERNATIONAL CONGRESS OF AGRICULTURAL ECONOMISTS
20 a 29 de agosto de 1973 - August - 20/29 - 1973 - Sao Paulo - Brasil

FARMER'S WIVES IN AGRICULTURAL DEVELOPMENT: THE NIGERIAN CASE

by

A. U. PATEL and Q. B. O. ANTHONIO

DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENTION
UNIVERSITY OF IBADAN
IBADAN, NIGERIA

Brazilian Organizing Committee: Rubens Araujo Dias, Chairman - XV Congress - IAAE - Rua Anchieta, 41 - 2.º andar - 01016 - Sao Paulo - Brazil

SEARCA IN THE SEVENTIES

for Dr. D. J. Rogers — with regards Kanti — 8

Systematic Germ Plasm Collection of Grain Legumes
in West Africa

Kanti M. Rawal
Botanist
International Institute of Tropical Agriculture, Ibadan

Plant breeders must meet the threat emerging from the geometrically increasing world population and the consequent, impending food crisis. They need new genetic inputs to carry out their large scale breeding programs which are initiated in light of these new objectives.

Rapid regional development can bring about the erosion of genetic resources in two ways. First, the native farmer ceases to grow indigenous agroecotypes adapted to local environmental conditions with the introduction of new, high yielding varieties developed through carefully manipulated breeding programs. Second, with the sophistication of communication systems, particularly road-transport, the agricultural innovations spread rapidly, thus transforming present subsistence agriculture into cash-produce economy of marketable commodities. As a consequence, the farmer mostly grows that variety of a crop which the consumers far away from him prefer. He may, however, continue to grow some of the previous variety for his own consumption. The result is slow but inevitable extinction of genetic resources of crops, since the population size of his own variety will gradually shrink. The varieties farmers grow have come into existence through many generations and cycles of selection specifically directed by the farmer towards his preferences and by nature towards adaptations to the habitat.

Exploration, collection and use of genetic variability in most of our crops, with a few exceptions, have been haphazard and often aimless. A systematic collection program requires well-planned and aim-oriented strategy with plenty

Presented at Grain Legume Improvement Workshop, October 1973.

of international and inter-displinary coordination. A sound, logistical support is an essential prerequisite for the implementation of such a program since the germ plasm of most of our major crops is scattered over a wide geographic range and often into remote, not easily accessible areas.

The collector needs to be well informed about the range of variability in the crop he is going to collect, prior to his expedition. He must also be familiar with the wild and weedy forms of the crop and with the related species. Knowledge about variation in the cultivated major crop species is gained by visiting various agricultural research stations, whereas that about other related non-cultivated forms is obtained by studying regional Floras and herbarium specimens. This information enables him to reach the right place at the right time. When planning, he should acquire some knowledge of taboos associated with the crop. Some appraisal of local traditions is necessary to facilitate field work. Even rudimentary understanding of local language does help but an interpreter is indispensable for collection in the remote areas. Interpreters are not difficult to find if the collector gets in touch with the local agricultural officers, volunteers from foreign countries, or educational institutions.

Market samples usually misrepresent geographic origins. The West African is as much or even more mobile than man from any other part of the world. The crops grown by the subsistence farmers might not be on the sale at the markets in that area. Since every farmer grows his own requirements, the surplus would naturally have to be shipped out into the areas where the production of the crop is not higher than the demand. As a corollary, the principal markets where a crop is sold are not necessarily located in the area where that crop is predominantly cultivated. For example, more than 80% of cowpea production in Nigeria is from the region north of 10^{o} latitude. At least 40% of the total production is sold in the markets of Western State alone. (Carswell, 1972).

Field collections provide valuable information regarding the ecology of the crop and the prevalent gene flow among its wild, weedy and cultivated forms. Knowledge of the geographic distribution of diseases and pests gained during the field-work provides useful information for plant protection measures. Sampling procedures for field collection cannot be standardized without prior knowledge of variation in the crop in relation to geography. The number of sites to be sampled and the number of samples per site to be collected would depend largely upon the collector's own familiarity with the crop. Separate envelopes containing single plant harvests facilitate subsequent evaluation of the germ plasm.

Short interviews of farmers, with the aid of an interpreter, provide very useful information about local agronomic practices and ethnobotany of the crop. The collector could gather useful data about reasons underlying farmers' special techniques and practices. He could also learn about local preferences and utilitarian criteria determining such preferences. These preferences indicate the direction of selection pressure that the farmer is exerting on a particular cultivar he grows.

With these objectives the systematic collection of cultivated grain legumes in West Africa was initiated at IITA in 1972. During a period of 57 days of active field collecting from October to December almost 14,000 miles were covered in

Nigeria. The germ plasm collections belonging to various grain legume species made in two expeditions are listed in Table 1. They were evaluated for various botanical and agronomic characteristics in 1972-1973.

Table 1. Germ plasm collections of Nigerian grain legumes in 1972

	Species	No. of Accessions
1.	Vigna unguiculata	
	a) cultivated	394
	b) wild and weedy	49
2.	Sphenostylis stenocarpa	42
3.	Voandzeia subterranea	22
4.	Phaseolus lunatus	16
5.	Cajanus cajan	5
6.	Mucuna sloanei	5
7.	Canavalia ensiformis	3
8.	Kirstingiella geocarpa	2
9.	Lablab niger	1

Symbiont rhizobia on the various grain legumes were collected from 60 sites during these expeditions. Both rhizobial nodules and soil around the roots were obtained ~~from~~ for microbial nitrogen fixation studies.

Local collaboration was developed with the Agricultural Extension Service of the Northern States through the Institute of Agricultural Research, Samaru. They provided additional seed samples of grain legumes grown in the area supervised by their field staff which exceeds 250 men distributed throughout the six northern states of Nigeria.

Detailed morphological analysis of Vigna unguiculata collections indicated extensive gene flow between the cultivated and weedy forms in Northern Nigeria. The roadside weedy V. unguiculata is recognized by the Hausa people as WAKEN BEYI BEYI (forbidden beans) and WAKEN GIZO (the bean that grows by itself). Waken Gizo is a common name for all introgression variants which are often harvested and consumed but never sown.

In the future this systematic germ plasm collection program will be extended to cover the complete range of geographic distribution of Vigna unguiculata and other legumes for lowland humid tropics.

ROOT CROP PRODUCTION IN A FIJIAN VILLAGE

By

S. CHANDRA[*], J.P. EVENSON[**]
and A.J. DE BOER[***]

Paper to be presented to the III International Symposium on Tropical Root and Tuber Crops, Ibadan, Nigeria. December, 1973.

* Satish Chandra, Fiji Department of Agriculture.

** J.P. Evenson, Department of Agriculture, University of Queensland.

*** A.J. DeBoer, Department of Agriculture, University of Queensland.

INTRODUCTION

The aim of this paper is to present data on land use productivity, labour utilization and energy relations in root crop production in village agriculture in Fiji. The data was collected weekly for 12 months by the senior author and trained enumerators in the 1970-71 cropping season in the Naduri - Emuri village. This village is nucleated in native land located on the banks of the Sigatoka River in the lower valley in the south-west Viti Levu. The main root crops grown, in order of importance, are cassava, sweet potatoes and yams and these are almost wholly used for subsistence. Other less important crops grown in this village are maize, tomatoes and water melon, which are marketed and form the basis of cash income.

The data was collected from nine sample farms out of a total of 21 farms in the village. The sizes of the sample farms ranged between 1.42 ha and 4.05 ha and comprised a total area of 23.89 ha. The parameters that were recorded were:-

(1) area of crop

(b) yield

(3) manhours and animal hours used in the following farm tasks:

- (i) Land preparation
- (ii) planting
- (iii) hoeing
- (iv) harvesting

(4) seasonal distribution of operations

(5) percentage of yield sold commercially

(6) transportation and marketing costs and,

(7) selling price of the goods

Prior to the beginning of this study a detailed soil survey of all the village farms at the scale of 1:25,000 was carried out. Also a complete census of the sample farm population was taken which included such parameters as sex, age, employment status, short-term migrations and any other relevant information regarding each individual on the farm. The ownership of draught animals (usually horses) and farm implements was also noted. Other cropping comparisons derived from this survey to be published elsewhere (5).

DESCRIPTION OF THE AREA

Meteorological data recorded at the Sigatoka Research Station, which is located only four kilometers from the Naduri-Emuri Village, is representative of the study area. The annual rainfall is 190 cm., distributed unimodally with a moderate dry season in the winter months. Between May and October inclusive 53.84 cm of rainfall is obtained. The mean monthly temperature ranges from 26.5°C in January to 22°C in July. The most sunshine is obtained in December at 6 hrd/day and least in June at 4.5 hrd/day.

The nine sample farms are located on the flood-plains of the Sigatoka River and all the soil types here belong to the alluvial Sigatoka Series (2). There are two distinct levels of alluvial terrace. The upper terrace, which stands at 11-13 m above normal river level, is larger and more important agriculturally and has soil textures ranging between sandy loams and clay loams (3). The lower terrace which occurs as isolated patches between the upper terrace and the Sigatoka River generally has loamy sands. The upper terrace is usually preferred for cassava and yams; the lower terrace for sweet potatoes.

CULTURAL PRACTICES

Each farm operates as a family enterprise, the labour force consisting of family members of both sexes. The total population of the nine sample farms was 47 of whom 25 were available for productive farm work. During the course of the survey it became evident that the working efficiency of women was as high as that of men and therefore a standard manhour could be adopted. Horses were the only drought animals used on these farms.

In this village four major tasks are associated with root crop production: land preparation, planting, hoeing and harvesting. Land preparation is defined as all tasks from the time the land is first ploughed from a weed fallow or a previous crop to the time the soil surface has been made suitable for planting. Planting includes all tasks involved in the preparation of vegetable parts and tubers and the actual act of planting. Hoeing is only carried out in cassava and yams in the early stages of their growth. This task involves the erradication of weeds by hoe or kinfeand also iincludes the removal of weeds by hand from near the crop plants. Harvesting covers all tasks involved in the transfer of a crop from the ground to the farm house.

Sweet potatoes are usually grown on lo mounds. Cassava is generally grown on continuous ridges but some farmers prefer mounds. The mounds for sweet potatoes amd yams are normally spaced about 0.75 m apart within the rows and 1 m apart between the rows. Sweet potatoes are almost always propagated by plant stems cut in 0.3 m lengths. When Cassava is grown in mounds about four to five such stems are used per mound. The mounds are usually spaced 1 m apart within the rows and 1.25 m apart between the rows. Depending on the food requirements of the individual households, one or two such pounds of cassava and sweet potatoes are harvested daily or every few days.

CROP PRODUCTION

Cassava is by far the most important crop grpwn by the sample farmers (Table 1).

Table 1

Crop Production

Crop	Total Area cropped (ha)	$ Total cropped area	Mean Plot Size per Farm (ha)	No. of Farmers that grew Crop	Yield ha-1 (kg)	Edible Yield ha-1 (kg)	$ Total Kcals. Contributed by crops
Cassava	6.40	44.9	0.71	9	9432	8489	66.8
Sweet Potatoes	1.05	7.4	0.15	7	8422	7580	11.1
Yams	0.24	1.7	0.08	3	5895	5310	2.2
Sub-total	7.69	54.0	-	-	-	-	80.1
TOTAL	14.26	100.0	-	-	-	-	100.0

Over 90% of the root crops produced by these farmers are used for subsistence and the remainder marketed at infrequent intervals. Their diet is supplemented by green beans, cabbages, egg plants and bananas. About 80% of the food energy produced by these farmers is contributed by root crops of which cassava contributes 66.8%.

LABOUR UTILIZATION

Table 2 shows the extent of labour usage by the root crops in the nine sample farms:

Table 2

Labour Utilization

	Total Manhours Used	$ Total Manhours Used	Manhours ha^{-1}	Total Horse Hours Used	% Total Horse Hours Used	Efficiency Ratio (E)*
Cassava	2989	58.3	467	640	40.6	71
Sweet Potatoes	376	7.5	358	105	6.7	82
Yams	69	1.3	287	24	1.5	77
Sub-Total	3434	66.9	446.34**	769	48.8	76**
All other Crops	1699	33.1	257**	806	51.2	28**
TOTAL	5133	100.0	359**	1575	100.0	53**

* The efficiency ratio (E) is defined as the calorific output of the crop divided by the calorific input, excluding photosynthesis (Black, 1971).

** Area weighted mean.

About two-thirds of the total manhours worked are devoted to the root crops. Less draught animal hours are required per unit area in root crops than in the major cash crops such as maize, timatoes and water melon.

In the latter crops horses are used for inter-row cultivation in the early stages of the crop growth. Once the land preparation has been completed draught animals are not required in root crops.

Cassava and sweet potatoes have no seasonality in an agronomic or cultural sense and are planted and harvested all the year round. Yams, on the other hnad, are generally planted between September and January and harvested between January and May.

Figure 2 shows the comparison between the total monthly manhours required in root crops with those required in all the other crops.

Insert Figure 2

Apart from maize which is generally grown throughout the year, all the other crops such as tomatoes, water melons and green beans are planted and harvested in the winter months. This pattern of labour utilization is reflected in Figure 2. The lowest total manhours work is recorded for the month of March which is the wettest month.

Figure 3 shows the breakdown of the to al manhours used in root crops into specific tasks.

Insert Figure 5

Of the total manhours used for root crop production 52.6% went into the harvesting process as it remains a manual operation. Such a high input is worthy of closer research attention for both agricultural engineers and breeders to ptoduce either a more hand harvestable plant or suitable mechanical methods of harvesting.

The Energetics of Root Crop Production

The 'Efficiency Ratio' (8) which is the calorific output of the crop as yield divided by the calorific input excluding photosynthesis is extremely high in the root crops examined here compared with the mean of all other crops grown (Table 2). More detailed comparisons have been made elsewhere (4).

This substantiates Coursey and Haynes' (6) statement that tropical root crops are more efficient energy convertors than most other crops, especially cereals. The root crops grown also have much more even monthly labour requirements than the other crops which show a more pronounced seasonal pattern, and therefore have a damping effect on fluctuations of seasonal labour requirements.

ENERGETICS AND ECONOMIC DEVELOPMENT

The process of economic development depends, to a large extent, upon the substitution of capital for labour; this in turn has a pronounced effect upon the energetics of the food producing system. Using a combination of village and experimental data, the relationship between biological efficiency and increased capital inputs is examined for three Fijian root crops using four sets of production technology - hand labour only (1), hand plus horses (II), hand, horses and chemical fertilizers (III), and hand, chemical fertilizer and tractors (IV).

In the simplest production system using all hand labour, it took 617 manhours to produce 9200 kgs. of cassava root, or

$$617\ (M) + 0(H) + 0(F) + 0(T) = 9200 \text{ kgs.}$$

where

M = manhours of hand labour per hectare

H = hours of draft power provided by horses per hectare

F = kgs. of chemical fertilizer per hectare

T = hours of tractor power per hectare

Each of these inputs as well as the resulting output were converted to kcals of energy. For human labour, draft power and tractors, only direct energy expenditures actually used in root crop production were considered, while estimates of fertilizer energy inputs were made using estimates of energy required to produce N, P, and K (7).

Crop output was measured as edible root and takes no account of energy used in transport or processing.

The resu ts of this energy budgeting exercise are presented in
root
Table III for the three major/crops grown in Naduri-Emuri.

Table 3

'Efficiency Ratios' for Three Crops and Four Production Technologies

	Production Technology			
	I	II*	III	IV
Cassava	100	71	5.6	5.5
Sweet Potato	119	82	9.2	8.8
Yams	147	77	8.1	7.7

* Weighted by output

** This is the present production technology used by the sample farmers and corresponds to the E ratios given in Table 2.

As Table 3 indicates, the efficiency of energy use declines most rapidly when chemical fertilizer is used (Stage III) and then only slightly when tractors are used. This is partly a function of energy estimation problems and partly a result of tractors only replacing a single task, land preparation.

A revealing pattern emerges when we look at these E ratios plotted against (a) energy use per hectare and (b) the average groww value of production per man-hour, an indicator of economic development. Figure 4 shows the effect of the wholesale substitution of chemical energy for man power while Figure 5 illustrates the decreasing biological efficiency of the system as fewer man-hours are required to produce a crop.

CONCLUSION

These results again illustrate the care with which recommendations for wholesale change must be made, especially in a world where the terms of trade are turning progressively against petroleum based products. To maintain soil fertility while also maintaining a reasonably efficient system from a biological point of view, emphasis needs to be placed on the use of renewable resources and on agronomic practices requiring minimum amounts of fossil fuel based inputs (7).

REFERENCES

1. Black, J.N. (1971) Energy Relations in Crop Production - A Preliminary Survey. Proc. Applied Biologists: 272-278.

2. Chandra, S. (1971) Soils of the Sigatoka Valley. Unpubl. Fiji Dept. Agric. Repl. 41 pp.

3. Chandra, S. (1972) Agriculture, Land Use and Smallholder Farming Problems in the Sigatoka Valley. Fiji Agric. J. 34, 1: 21-25.

4. Chandra, S., De Boer, J. and J.P. Evenson (In Press a). "Economics and Energetics: Sigatoka Valley, Fiji".

5. Chandra, S., Evenson, J. and J. De Boer (In Press b). "Energetics of Crop Production in Two Smallholder Villages in the Sigatoka Valley, Fiji".

6. Coursey, D.G. and Haynes, P.H. (1970) Root crops and their potential as food in the tropics. World Crops 22, 4: 261-265.

7. Gifford, R.M., and R.J. Millington (1973). "Energetics of Food Production with Special Emphasis on the Australian Situation", paper presented at the UNESCO Man and the Biosphere Program, National Symposium on Energy and How We Live (Adelaide, 1973).

CASSAVA AS A DIVERSIFICATION CROP

From the above analysis it can be concluded that there will be a growing demand for cassava products, and that global supply, given past trends, will meet future demand. Therefore, <u>prima facie</u>, any producing country which is attracted to cassava as a diversification crop must be prepared to provide cassava products at competitive prices and at suitable quality and quantities. The potential exporter of cassava should realise

(1) that the price of cassava products must be competitive. In the EEC this means a cif Rotterdam price of approximately $75.00/ton;

(2) that supplies of cassava must be readily available throughout the year - consumers do not wish to stock-pile large quantities of cassava products;

(3) that Thailand may continue to expand exports, and thereby capture an even larger proportion of the European market;

(4) that if Brazil can either increase production by a few percentage points or divert a small percentage of production to export markets*, Brazil and Thailand could meet total export demand.

Notwithstanding these reservations, it appears that there is scope for a number of** developing countries to now consider cassava as a diversification crop. Furthermore, the current interest in cassava trade may also highlight the possibilities of promoting cassava because ot its potential import-saving ability. The use of cassava as an input to indsutry and animal rearing instead of other starches or grains, especially those which must be imported, could free LDC resources for more productive uses. Cassava may soon cease to be criticised for what it is not, and become valued for what it is.

---

*Note that Brazil produces 30,000,000 tons of cassava a year (25% of world production). Therefore, a 10% increase in output or a similar diversion of production to exports would produce an additional 1,2000,000 tons of pellets (35% of the low EEC projection, Table 3).

**The demand for cassava as an animal ingredient may increase dramatically if Japan becomes a user of cassava. Present estimates are that Japan could easily consume 1 million tons of pellets a year once cassava is used in compound animal feeds.

References Chapter 1

(1) Smith, C. Earle Jr., "The New World Centres of Origin of Cultivated Plants and the Archaeological Evidence", Economic Botany, Vol. 22(3).

(2) Jones, William O., Manioc in Africa, Stanford University Press, 1959.

(3) Rogers, D.J., and Appon, S.B., "Cassava (Manihot esculenta Crantz), "The Plant World Production and its Importance in World Food Supply", A Literature Review and Research Recommendations on Cassava, University of Georgia, March 1972, pp. 1-14.

(4) Agricultural Commodity Projections 1970 - 1980, Volume II, Food and Agriculture Organisation of the United Nations, Rome, 1971.

(5) Production Year Book 1971, Food and Agriculture Organisation of the United Nations, Rome, 1972.

(6) Coursey, D.G., and Haynes, P.H., "Root Crops and their Potential as Food in the Tropics", World Crops, July/August, 1970 pp. 261-265.

(7) Abbott, John C., "The Efficient Use of World Protein Supplies", Monthly Bulletin of Agricultural Economics and Statistics, Vol. 21, June, 1972, pp. 1-8.

(8) Phillips, Truman P., Cassava: A Study of Utilisation and Potential Markets, International Development Research Centre, Ottawa, September, 1973.

(9) Chronica Cassava Toxicity: (eds. Barry Nestel and Reginald MacIntyre), IDRC - 010e, International Development Research Centre, Ottawa, May, 1973.

(10) Bangkok Bank Monthly Review, Vol. 14, No. 4, April, 1973.

(11) Esselman, W., "Development of Future Mixed-Feed Consumption in the Common Market", Paper presented at the Eighth European Mixed-Feed Congress, Rotterdam, 19 May, 1972.

(12) Ferris, John., Josling, Timothy., Davey, Brian., Weightman, Paul., Lucey, Denis., O'Callaghan, Liam., Sorenson, Vernon., The Impact on U.S. Agricultural Trade of the Accession of the United Kingdom, Ireland, Denmark and Norway to the European Economic Community, Research Report No. 11, Institute of International Agriculture, Michigan State University, 1971.

PRESENT AND POTENTIAL LABOR ABSORPTION IN CASSAVA PRODUCTION IN COLOMBIA

By

Per Pinstrup-Andersen and Rafael O. Diaz

High and increasing rates of unemployment resulting in severe poverty among large segments of the population is a common problem for a large number of developing countries. The problem is generally caused by a combination of high rates of population growth and the inability of the economy to absorb the resulting expansion of the labor force. A strong rural to urban migration trend accelerates urban unemployment since industry and commerce frequently are unable to provide the necessary additional jobs. It is not uncommon to find urban areas with an annual population growth rate of 7-8 percent, with about half of this growth resulting from rural to urban migration, while the annual growth in urban employment opportunities may be only 3-4 percent.

Creation of more productive jobs at a faster rate than what is presently encountered is essential to reduce poverty. Even to maintain proverty at its present level the rate of employment generation must be accelerated considerably.

Additional jobs may be created in the rural as well as the urban sector. More jobs in the rural sector tend to reduce rural to urban migration provided that earnings and working conditions in the rural sector are sufficient to satisfy the aspirations of the potential migrant. However, there have been few cases of rapid expansion of rural employment during recent past. Since the economic growth of Western Europe and North America included a rapid reduction of the rural labor force, governments of developing countries frequently consider a rapid reduction of the rural labor force necessary to accelerate economic growth. This, of course, would be true only to the extent that sufficient productive jobs are made available in the urban sector. Furthermore, individual farmers tend to replace labor by machinery in order to increase labor efficiency and reduce the problems associated with maintaining a large labor force. Farm machinery is frequently imported, hence domestic agricultural labor is replaced by foreign labor services and the mechanization does not create additional jobs in industry and commerce to absorb the displaced farm workers.

Recently, a number of developing count es have become concerned about the enquiry issues of economic growth. Income distribution and productive employment have been added to the efficiency goal to establish a new social objective function. Included in this new political trend, governments look for ways to increase labor absorption in agriculture while gaining time to expand urban employment.

This paper deals with a small fraction of the complex problem of labor absorption in agriculture. The paper attempts to analyze present and potential labor absorption in the production of cassava in Colombia. The specific objectives of the paper are:

1. To estimate present labor use in cassava production in Colombia.
2. To compare labor use in cassava production to that of other major agricultural products.
3. To estimate how certain new technology applied in cassava production may influence labor absorption.

The analysis is limited to the production process. No attempt is made to estimate labor absorption in processing and marketing of cassava.

The employment problem in Colombia.

The total population of Colombia was estimated at 22.6 million for 1970. Twenty nine percent of the population was considered economically active. Of the economically active, 2.5 million or 38 percent were engaged in agriculture. Past population growth of 3.2 percent per year along with a massive rural to urban migration resulted in an urban population increase of 5.4 percent annually during 1951-64, while the rural population increased at a rate of 1.3 percent. During the same period, the three largest cities grew at 7 percent per year (5). Employment creation has been insufficient to meet the increase in the labor force and unemployment is increasing.

Despite the rapid outmigration, it is estimated that only 70 percent of the present agricultural labor force is employed. This figure takes into account unemployment as well as under-employment.

The Colombian labor force is projected to grow at a rate of 3.5 percent annually for a period of at least 15 years, while employment during the last two decades rose by only 2.2 percent. It is estimated that agriculture will need to provide employment for 50.000 additional persons annually during during the period 1970-85 (5). What is the contribution that cassava production can make to help fulfill this need?

Cassava in Colombia

Although cassava occupies a considerable area in Colombia (Figures 1 and 2), the crop has received little attention from researchers and public agencies engaged in agricultural development. Yields are low, and no significant improvement has been noted during the last 10 years (Figure 2). The production increases encountered have been due almost exclusively to expanded area. A linear trend shows an annual increase of 3.760 ha.

Cassava is typically grown on small farms and a considerable amount of the production is consumed by the producer and his family, hence does not enter the market place. Because of the past lack of interest for the crop on the part of decision makers in research and public policy and because of its utilization as a subsistence crop, reliable statistical information on cassava is extremely scarce.

In order to obtain more information on the cassava production process, a survey was carried out among 300 producers in 19 departments of Colombia. Major emphasis was placed on obtaining reliable information on production costs and input use. This paper reports the major findings with respect to labor use.

About 30 percent of the sample farms used machinery for land preparation. No other activities were mechanized. Considering the impact of mechanized land preparation on labor use and cost of production, the sample farms were divided into two groups according to whether land preparation was mechanized or not.

Estimated labor use in cassava production.

Table 1 shows the estimated labor use by production activity. Total annual labor use per hectare was estimated at 81.7 man days for producers using mechanized land preparation and 111.6 man-days for producers that prepared the land manually. Weeding was found to be the major labor absorbing activity. Almost 60 percent of the total labor use among farmers with mechanized land preparation was used for weeding. Manual land preparation and harvesting were other important consuming activities.

In order to assess the general applicability of the results reported in Table 1, comparisons are made with results from similar studies in other regions. Total labor use per hectare in cassava production in the coffee zones of Colombia was estimated to be similar to that estimated for producers preparing land manually (Table 2). The distribution of labor on production activities was quite different. More labor was spent on harvesting and less on weeding in the coffee zones. Estimates from Northeast Brazil show a considerable variation among regions. However, the average labor requirements are similar to those estimated for Colombia. Labor requirements in the production of cassava in Jamaica were estimated to be considerably larger than those estimated for Colombia and Brazil.

Table 1. Estimated labor use in the production of cassava in Colombia by activity

Activity	A 1/		B 2/	
	Man days per ha/yr	%	Man days per ha/yr.	%
Land preparation	-	-	28.4	25.4
Planting	8.0	10.0	11.0	9.9
Re-planting	1.6	2.0	2.0	1.8
Weeding	48.1	59.0	43.7	39.2
Application of fertilizers	3.9	5.0	7.3	6.5
Application of insecticides	1.2	1.0	4.2	3.8
Harvesting and packing	18.9	23.0	15.0	13.4
Total	81.7	100.0	111.6	100.0

1/ 'A' refers to producers that use mechanical land preparation.

'B' refers to producers that do not use mechanical land preparation.

Table 2. Labor use per hectare and per ton of cassava produced in Colombia, Brazil and Jamaica

	Man-days per ha/yr.	Yield (ton/ha)	Man-days per ton
Colombia: 1/			
Mechanized land preparation	81.7	11.7	7.0
Manaual land preparation	111.6	10.8	10.3
Colombia: 2/			
Coffee zones	105.0	-	-
Northeast Brazil: 3/			
Alagoas	96.0	10.7	9.0
Maranhao	69.0	10.0	6.9
Sergipe	165.4	13.9	11.9
Average	110.0	11.5	9.6
Jamaica: 4/			
Mandeville	191.5	15.9	12.0
Santa Cruz	186.0	6.3	29.5

1/ Data estimated in this study.

2/ From: Fondo de Desarrollo y Diversificación de zonas cafeteras. Cultivos y Empresas de sustitución para zonas cafeteras marginales, 1968, p. 35.

3/ From: Feasibility of manioc production in Northeast Brazil. University of Georgia, 1971, p. 45.

4/ From: Rankine, Lloyd B. and Marlene Hee Houng. A preliminary view of cassava production in Jamaica. Occasional series No. 6. Department of Agricultural Economics, University of the West Indies, Trinidad. December, 1971.

The labor needed to produce a ton of cassava was estimated to be 7 man-days if machines were used for land preparation and 10 man-days if the land were prepared manually. Labor needs per ton of cassava produced appear to be very similar for Colombia and Northeast Brazil while they are somewhat larger for Jamaica (Table 2).

Table 3 compares the labor use per hectare for 10 major crops in Colombia. Among the 10 crops, cassava occupies a fifth place in terms of labor use per unit of land exceeded by sugarcane, coffee, plantain and potatoes. Cassava provides twice as many jobs as corn per unit of land and three times as many as wheat. About one third of the farm value fo the cassava production was estimated to be labor costs as compared to 58% for sugarcane and 20 percent for irrigated rice.

Assuming that the labor use per hectare reported in Table 3 is valid for the total national production, the total annual labor absorption in cassava production was estimated to be approximately 60.000 man-years (Table 3). This amounts to approximately 2.4 percent of the total agricultural labor force. It is interesting to note that cassava absorbs more labor than cotton, the latter traditionally being considered a major labor consuming crop.

Potential labor absorption.

We now turn to the question of the future role of cassava production as a labor absorbing activity. The analysis will be divided into two parts. First, we will attempt to estimate the demand for labor as a function of the adoption of new technology assuming constant cassava prices. Then we will remove this assumption to iclude the effect of product market relationships. Throughout the analysis, we assume an unlimited supply of labor, i.e. increasing demand for labor will have no impact on wages. This assumption

Table 3. Estimated labor absorption in the production of various crops in Colombia

Crop	Area (1.000) (Ha.)	per ha/yr.[1] (man days)	Total labor absorption: Man-years (1.000)[2]	Percent of total agr. labor for [3]	Labor costs in % of output value [1]
Coffee	1.069	134	572.8	22.9	38.1
Sugarcane	398	145	230.8	9.2	57.5
Corn	542	56	121.6	4.9	39.1
Plantain	240	120	115.2	4.6	35.0
Rice	273	68	74.4	3.0	20.5
Cassava	155	96	59.6	2.4	31.2
Cotton	238	62	59.2	2.4	28.9
Potatoes	80	115	36.8	1.5	26.4
Beans	92	68	25.2	1.0	-
Sorghum	104	15	6.4	0.3	18.5
Wheat	61	31	7.6	0.3	25.5

1/ Samuel R. Daines, et al. Summary Results of Employment, Income Distribution and Small Farm Analysis. Analytical Working Document No. 2, Colombia Agriculture Sector Analysis, AID, Bogotá, 1972.

2/ Assuming that a man year is equal to 250 man-days.

3/ Total agricultural labor force in Colombia 1970 was estimated to be approximately 2.5 million (Economic growth of Colombia, problems and prospects, World Bank country economic report, Washington, 1972.)

appears valid for the relatively small demand changes to be dealt with in this analysis, in view of the present employment situation in Colombian agriculture, as previously discussed.

Labor demand and new technology assuming constant cassava prices.

Virtually no technological changes has occurred in cassava production in Colombia with the exception of some mechanization of land preparation. Hence the analysis attempts to predict changes in labor demand if new technology were adopted (ex ante)rather than evaluate what happened in the past (ex post).

Three levels of technological development will be considered:

1. No new technology will be adopted. Area and yields will continue along past trends.

2. Mechanical technology will be adopted for land preparation 1/. Areaand yields will continue along past trends.

3. Improved biological technology will be adopted. Area will continue along past trends but yields will increase.

1. No new technology. Past trends in cassava area show an annual increase of 3.760 ha. while yields have been constant (Figure 2). Assuming constant factor and factor product proportions, each additional ha. would require an additional 96 man days per year (Table 3). Hence, assuming that 250 man days equal a man year, the demand for labor would increase by 1.444 workers annually. This amounts to 2.9 percent of the estimated additional needs for employment in agriculture (50.000 workers) as previously discussed.

1/ Mechanical technology refers to traditional four-wheel tractors and implements. Intermediate size machinery such as two-wheel garden tractors are not considered because of lack of data.

Present employment in cassava is only 2.4 percent of total agricultural employment. Hence an expansion of the cassava area along past trends would provide more than its share to employ the additional labor force. To the extent that the new cassava area originates from subsitution between cassava and other crops, labor requirements for the production of foregone crops would decrease. For example, substituting cassava for corn will increase labor demands for cassava by 96 man days/ha and reduce it for corn by 56 resulting in a net increase of 40 man days/ha. However, it may be expected that the majority of the net expansion of the cassava area comes from land not previously used for crops.

2. Mechanical technology: A large portion of the cassava area is found on hill sides where mechanization would not be feasible. Although its extension is not known, there is a considerable area where present manual land preparation could be replaced by mechanical means. Such replacement would save approximately 30 man days per ha. (Table 2). Figure 3 shows the relationship between increasing mechanization of land preparation and the reduction in labor use. We may speculate that about 10 percent of the total cassava area is apt for mechanical land preparation but presently prepared manually. A change from manual to mechanical means on this area would displace about 1,860 workers. Assuming a continuation of past trends in area, the additional employment due to area expansion will be offset by mechanization.

3. Biological technology: Assuming that a new biological technology adopted by the farmers (high yielding varieties, resistance to certain diseases, etc.) results in increasing yields, its major impact on labour requirements per unit of land will be felt through increasing harvesting and packing costs. If new

varieties must be accompanied by increasing fertilizer use or improved cultural practices, labor requirements for these activities may change as well. On the other hand, insect resistant varieties may reduce labor requirements for insecticide application. This analysis is limited to the impact on harvesting and packing labor requirements. Changes in labor requirements for other activities would probably be relatively small and would depend on the specific characteristics of the biological technology, hence cannot be estimated in this general analysis.

Labor requirements for harvesting and packing as a function of yield was estimated for the farmers included in the sample previously mentioned. A simple linear regression equation was used for each of the two activities. The results were as follows:

$$L_1 = 6.3986 + 1.2781\ Y\ ,\ R^2 == 0.6817$$

$$L_2 = 0.0220 + 0.5059\ Y\ ;\ R^2 = 0.8255$$

Where L_1 = labor requirements for harvesting (man days/ha.)

L_2 = labor requirements for packing (man days/ha.)

and Y = yield (tons.ha.)

Hence, each unit increase in yields (ton/ha.) would require an additional 1.28 man days/ha. for harvesting and 0.51 man days/ha. for packing or a total of 1.8 man days-ha.

Based on this estimate we then proceeded to estimate the change in labor requirements as a function of the level of yield increase among adopters of new biological technology and adoption rates. The following equation was developed:

$$L = \frac{(\% \quad Ya)}{100} \quad (\% \; Aa) \quad \frac{(Yn)}{100} \quad \frac{(b_1 + b_2)}{250} \; An$$

where:

L = changes in total labor requirements (man years)

$(\% \quad Ya)$ = percent change in yields on farms adopting new technology [2]

$(\% \; Aa)$ = percent of total cassava area where new technology was adopted

Yn + average national yields before adoption (ton/ha.)

b_1, b_2 = coefficients of the above regression equations

An = total cassava area (ha.)

Substituting 1969 average national yields and cassava area for Yn and An and using the estimated values of the b coefficients, the equation becomes:

$$L = 0.6747 \quad (\% \quad Ya) \quad (\% Aa)$$

Hence, the impact of the adoption of new biological technology on labor requirements can be estimated directly from the equation on the basis of yield increasing effects and rate of adoption. Figure 4 shows the relationship between rate of adoption nad labor requirements for selected levels of yield increases. If, for example, adoption of a certain new biolcgical technology increases yields on adopting farms by 100 percent and the technology is being adopted on 10 percent of the cassava area, the estimated increase in labor requirements is 675 man years. If the technology is adopted on 50 percent of the area, labor requirements increase by 3.374 man-years.

A certain increase in labor absorption may be brought about by a number of combinations of yield increases (   ) and adoption rates (Aa). Figure 5 shows this relationship for selected levels of labor absorption.

As an illustration of the use of the curves presented in Figure 5, assume that the desired level of increase in employment in cassava production is 1.000 man-years. This level may be reached by any combination of yield increase and adoption rate shown by the curve labelled L = 1000 man years, for example a yield increase of 100 percent on 15 percent of the area.

Assuming a continuation of past trends in area, the additional labor demand estimated above should be added to that estimated here.

Labor demand and new technology considering market impact.

In the previous section we estimated the impact of new technology on labor demand assuming constant cassava prices. We may conclude that, under this assumption, the adoption of yield increasing biological technology will increase labor demand. Furthermore, assuming a continuation of past trends in cassava area, a considerable increase in labor demands will occur even without the adoption of new technology. An expansion of mechanical land preparation could severely reduce labor demands. However, a large portion of the cassava area is found on relatively steep slopes, not suited for mechanized land preparation.

As yield increasing technology is adopted and area is expanded, more cassava will be produced. If the increase in the quantity produced exceeds the increase in the quantity demanded at the current price, a downward pressure on the price will result. The price decrease likely to result from supply expansions can be estimated from the price flexibility of demand 3/.

3/ The price flexibility of demand is defined as the percentage change in the price of a commodity for each one percent change in the supply of the commodity in order that the market may be cleared.

The majority of the cassava grown in Colombia is used for direct human consumption. The price flexibility for cassava for direct human consumption is such that supply expansions beyond normal demand increases will result in price declines proportionally larger than the supply expansions, hence total revenues to the producer sector will decrease as production is increased. This implies that traditional resources (land and labor) must move out of cassava production as new technology is adopted. Hence, if the cassava producers were to depend exclusively on the demand for direct human consumption, large supply expansions caused by the adoption of yield increasing biological technology would most likely result in a reduction in labor demand. While the farmers adopting the new technology would expand labor demands at least initially, the expansion would probably be insufficient to counteract the reduction in labor demands among non-adopting farmers, a proportion of whom would not be able to cover costs at the lower prices. The adopters, however, can stand a considerable price fall. The additional production brought about by the new technology adds little to total costs per ha. 4/ and the cost per ton is severely reduced.

There are a number of reasons why cassava prices may not fall as drastically as indicated above in the case of large production expansions. The government, may establish support prices to protect the producer. Furthermore, if prices are allowed to fall, new markets, such as cassava for livestock feed, will appear. This will slow down the rate of price decrease. The price flexibility for the direct human consumption market is no longer valid and further production expansions may well increase returns to the producer sector hence allow for a net increase in labor demands.

4/ Each additional ton/ha. is expected to add the cost of 1.8 man day, while the average current labor use, to produce 10 tons was estimated at 96 man days/ha. Furthermore, the new technology itself may carry a cost.

Summary and Conclusions

The present paper analyzes the present and potential labor absorption in cassava production in Colombia. Present labor absorption is estimated to be about 60.000 man-years, or 2.4 percent of the total agricultural labor force. Accounting for 40-60 percent of the total labor requirements, weeding is the most labor consuming activity in cassava production followed by land preparation.

The potential labor absorption was analyzed as a function of increasing cassava area and the adoption of mechanical as well as biological technology. If past trends continue, additional cassava area will require an annual increase of 1.444 workers or 2.9 percent of the expected annual increase in the agricultural labor force. Mechanized land preparation reduces labor requirements per ha. by about one-third. Hence, extensive mechanization could have a very significant negative impact on labor demand.

While new biological technology is expected to increase labor demand among adopters, the increase is relatively small (1.8 man-day/additional ton produced) and may well be offset by labor reductions among non-adopters if cassava prices are permitted to adjust to large supply expansions resulting from the new technology. Ther marginal cost associated with adoption of yield increasing biological technology is extremely low. Hence, the adopters will be able to absorb a considerable price fall and still maintain a reasonable net return. As prices,fall, however, the non-adopters will find their net returns reduced and losses may occur. This will cause a reduction in labor and land dedicated to cassava among non-adopters. New uses fcr cassava, such as livestock feed and industrial processing are likely to become economically sound as prices fall. When this occurs, the price amy stabilize as production expands resulting in increasing revenues to the producer sector, which in turn allows for additional employment.

Based on this study we may draw the following conclusions:

1. Cassava production makes a significant contribution to agricultural employment in Colombia.

2. Increasing the cassava area along past trends to meet increasing demand may be expected to absorb a considerable number of agricultural workers.

3. Adoption of yield expanding biological technology will increase labor demands among adopters.

4. The impact on labor demand among non-adopters will be neutral if cassava prices remain constant, and negative if prices fall.

5. The net effect on labor absorption in the producer sector could be positive, neutral or negative depending on the extent to which cassava prices decrease.

6. As the cassava production is expanded and prices decrease, new markets for cassava are likely to be economically feasible. Hence, prices will not fall to the extend indicated by the price flexibility of demand for direct human consumption.

7. Extensive mechanization of land preparation is likely to have a considerable negative impact on labor demands.

8. The social objective of creating employment may conflict with private objectives of maximizing profits. This paper has dealt with the issue of labor absorption within a framework of profit maximizing firms. It is quite clear from this analysis that while biological research may have a considerable positive impact on productivity hence increase consumer real income through reduced food prices and/or increase producer real income through higher net returns, it may at the same time have an adverse impact on employment. It is important that these trade-offs among goals be fully understood by government policy makers so that corrective measures may be introduced if needed to meet overall development objective.

Bibliography

1. Daines, Samuel R., el. al. Summary Results of Employment, Income distribution and small farm analysis. Analytical Working Document No. 2, Colombia Agriculture Sector Analysis, AID, Bogotá, 1972.

2. Rankine, Lloyd B. and Marlene Hee Houng. A preliminary view of cassava production in Jamaica. Occasional series No. 6. Department of Agricultural Economics, University of the West Indies, Trinidad, 1971.

3. Changes in Agricultural Production and Technology in Colombia. U.S. Department of Agriculture, Economic Research Service in cooperation with the Ministry of Agriculture and the Central Planning Agency of Colombia.

4. Cultivos y Empresas de sustitución para zonas cafeteras marginales. Fondo de Desarrollo y Diversificación de zonas cafeteras, 1968.

5. Economic growth of Colombia, Problems and Prospects. World Bank Country Economic Report. John Hopkins University Press, Baltimore, 1972.

6. Feasibility of manioc production in Northeast Brazil. University of Georgia, 1971.

7. Ministerio de Agricultura, Programas Agricolas. Oficina de Planeamiento del Sector Agropecuario, January and December, 1972.

THE SAGO PALM; A POTENTIAL COMPETITOR TO ROOT CROPS

by

M. FLACH

Introduction

Sago is the starch the sago palm accumulates in its trunk as a reserve. The pith of a sago trunk has the composition as given in table 1; it closely resembles cassava roots and therefore can be used for the same purposes, i.e. for human food, for preparation of industrial starches and probably also as an animal feed.

Table 1. Composition of cassava roots and sago pith (4)

	tapioca root		sago pith	
	fresh	dry matter	fresh	dry matter
Moisture	62.4%	-	80.0%	-
Soluble carbohydrates	35.5%	94.4%	18.5%	92.5%
Protein	0.4%	1.1%	0.3%	1.5%
Fat	0.2%	0.5%	0.1%	0.5%
Fibre	0.8%	2.1%	0.3%	1.5%
Ash	0.7%	1.9%	0.8%	4.0%
Convertible to chips (at 14% moisture)	43%		22.8%	

Rasped and dried sago pith already for a long time has been used as a feed for pigs and poultry, while refuse from starch factories is used as a feed for pigs and also for cattle. It is likely that rasped, dried and pelletized sago pith will be completely acceptable for the animal feed industry. However, this needs to be proven in experiments.

Botany

The palm genus Metroxylon consists of some six species. The name is derived from Greek, i.e. metra meaning pith and xylon meaning xylem. The genus is indigenous in the lowlands of southeast Asia and Melanesia; there it occurs between 10° N and S up to a height of 700 m. Most species are found on and around New Guinea which probably is the gene centre. The economically most important species are M. sagu ROTTBOL and M. rumphii (WILD.) MARTIUS. The latter name was given in honour of RUMPHIUS (1755) who, in his 'Amboinsch Kruyd-boek' gave the first description of the palm accompanied by a drawing. The main difference between the two species is that M. sagu has no thorns, whereas in M. rumphii leaf sheath and petiole are covered with sometimes 8 cm long sharp thorns, BARRAU (1) favours the idea that they should not be considered to be separate as they appear to cross readily. This was proven in our department: the offspring of two unthorned palms in Singapore Botanical Gardens also gave a few thorned palms.

Under natural conditions the palm occurs in fresh water swamps in the tropical rain forest zone. Single palms occur outside this natural habitat and appear to do well, provided they are tended properly. Probably in its natural habitat the palm possesses a competitive advantage. The best natural stands occur in clayish fresh water swamps, high in organic matter; peat soils clearly are less well suited. Although sago occurs in swamps, permanent inundation appears to present a disadvantage.

In technical terms the palm is a once-flowering and tillering perennial. The trunk acts as a sink in which the palm collects its superfluous carbohydrates as starch, which is used for flowering and fruiting after which the trunk dies. Mostly already in the first year the palm forms a number of buds in the axils of lower leaves which develop into shoots or tillers. Such tillers may develop into new stems. (photo 1)

The crown of the palm consists of some 6-15 feathered leaves each composed of leaf sheath, petiole and approx. 20 pairs of leaflets of 60-180 cm (6). The rachis is on the upper side concave whereas it is convex on the underside. On the trunk the leaf sheath may reach a width of 30 cm. The oldest leaves break at their leaf sheath; later the leaf sheath also drops and a leaf scar remains on the stem.

Appearance of the inflorescence is preceeded by a number of smaller leaves and announces the end of the life cycle of the trunk. The terminal inflorescence, resembling an enormous antler, consists of a primary axis dividing into secondary and tertiary axis. The tertiary axis bear the small flowers in pairs, a male and an apparently complete flower together (photo 4). Male flowers open and shed their pollen before the complete flowers open; in the latter the stamens probably are not functional. The palm therefore probably is an obligatory cross pollinator. In male and in complete flowers the six stamens have grown together into a tube. In the complete flowers the half inferior ovary contains three ovules out of which only one develops. This results in a beautiful scaled fruit with only one seed (photo 3).

The palm possesses a large number of mostly superficial primary roots from which often pneumathodes grow above ground level. Also the trunk may be covered with roots. Each tiller develops its own root system, provided it does not grow to far above the soil. After the first trunk has disappeared, the connexion between its tillers may be severed. Tillers may produce their trunks at considerable distances, sometimes even a few meters from the original trunk (photo 1). The height of a flowering trunk without its inflorescence may vary from 10-15 m. Usually at its base the stem has a girth of 35-50 cm, slowly increasing till 50-60 cm and tapering off again till approximately the girth at its base. At harvesting the average trunk weighs over 1000 kg.

The palm may be propagated from seeds (photo 3). In harvested wild stands however, the palm as a rule is not permitted to produce ripe seeds, because then the product to be harvested is used. Only low producing palms will receive the opportunity of giving ripe seeds. This results into negative mass selection. In cultivation however, the palm is propagated by means of tillers or suckers, mostly from selected mother trees.

Yields of wild stands

In wild condition as on New Guinea and in the Moluccas palms are harvested as their first young fruits are formed. This apparently is the moment with the highest starch production per stem. It is however, very difficult to obtain data on production per unit of surface and time under such conditions. Wild stands show large variations in numbers of stools per hectare of which also the age may vary. Moreover the age of harvested trunks is only vaguely known. Best estimates on possible yields of very nearly pure wild stands are 40-60 stems per ha and year (14). At 1000 kg pith per trunk and a starch content of 18.5% this would result in 7-11 tons of waterfree starch or 28-44 x 10^6 kcal per ha and year.

It is amazing that such potentials, high even if compared to modern methods of cultivation, have not been realized, especially if one considers that

PHOTO 1 FREE GROWING SAGO PALM STOOL IN WET RICE FIELD (SARAWAK)

PHOTO 2 WELL MAINTAINED SAGO PLANTING CLOSE TO BATU PAHAT (W.MAL.)

PHOTO 4

FLOWERS OF THE SAGOPALM; ABOVE COMPLETE FLOWER; UNDER MALE FLOWER

PHOTO 3

FRUIT, SEED AND SEEDLINGS OF THE SAGO PALM

Indonesia possesses several hundreds of thousands hectares of nearly pure stands. According to all reports the transport of the harvested stems to a factory was the main difficulty. In a high producing wild stand transport of 40-60 tons of raw material per ha and year to a central point is required for processing. This raw material, containing 80% moisture, has to be transported in a swampy area, without roads and mostly also without navigable waterways. The indigenous population has a very simple solution to this problem. The trunks are harvested and processed in the swamp. Only the wet starch is taken out of the swamp.

Only in 1957 systematic research in this field was started by a Dutch company in New Guinea. Trunks were cut and rasped in the wild stands. Rasped pith with its contents of starch was mixed with clear water and pumped through a pipe line towards a floating factory and refined there. In 1962 results appeared promising, but the experiments were ended because of the political situation.

Yields under semi wild conditions

The situation in the semi wild cultivation in Sarawak differs in a few aspects from the situation in Indonesia. In Sarawak most sago areas are established on peat soils instead of on mineral soils. On peat soils the palms have less leaves; the leaves show all kinds of deficiency symptoms and growth is slower. A palm grown on mineral soil may reach maturity after 8-10 years, whereas a palm on peat soil is said to reach maturity after 15-17 years (3). Yields from good sago land are reported at a level of some 60 stems per ha and year. The quality of the soil is believed to influence the size of the trunks also.

There is another difference between the sago area in New Guinea and the area in Sarawak. In Sarawak the sago area shows a fairly dense network of small rivers and creeks. Although transport even of one-meter logs from the site of felling to the river is difficult, transport in the water is fairly easy. This resulted into the establishment of a number of sago starch factories. These factories produce second quality starch because in the processing they have to use water coloured by peat. Refuse of starch production is not utilized but washed into the river.

Yields under cultivation

RIDLEY (7) already mentions the existence of sago plantings around Batu Pahat, Johor, West Malaysia. NICHOLSON (5) gives an accurate description which, as I could see for myself in 1971, still holds true. Such cultivation existed also on the island Benkalis and in the Lingga archipelago, east of Sumatra in Indonesia (9; 8). Whether cultivation is still practised there remains uncertain. But cultivation is still extended around Batu Pahat. Official estimates amount to 2000 ha while in the last few years at least 100 ha were planted.

In the Batu Pahat area the palm is planted in clayish soils in coastal areas, under tidal influence but above the salt water line. This results in twice daily flooding and draining of the plantings with fresh water. The palm is planted by means of carefully selected well sized suckers at 6 x 6 m (277 suckers per ha). Around the palms the soil is kept clean weeded; the plants are regularly and carefully pruned in order to ensure an even spread over the surface.

After eight years of growth the first trunks may be harvested (photo 2). Each stool of palms, derived from one planted sucker, produces one trunk per two years. So an estimate of 130 trunks per ha and year on good sago land -- clayish soil, high in organic matter - is realistic. This would lead to a production of 24 tons of waterfree starch or 96×10^6 kcal. It was observed that the trunks are harvested before the inflorescence develops in the growing point. This probably is the moment with the highest production per unit of surface and time. Trunks are cut as low above ground level as possible and transported to the processing plant as rafts consisting of one-meter logs. For this purpose the whole area is provided with a dense network of interconnected small canals connected with the river. This network also enables the area to flood and drain easily.

This continuous flooding and draining of the sago area probably also provides the nutrients for the sago palm, as no fertilizer is used. From data of WOODMAN et al (13) it was calculated that the pith of the palms he used for analysis contained the nutrients given in table 2. It is assumed that these figures also apply to Batu Pahat, because of lack of better figures. All nutrients in other plant parts are assumed to be returned to the soil, approximately in situ.

It stands to reason that in an area flooded and drained twice daily the nutrient contents of the soil are in equilibrium with the nutrient contents of the fresh water that floods the soil. Data on the river running through the area is not available, contrary to a survey on the nearby Malacca river (10). A comparison of these data with the nutrient contents of sago pith is given in table 2. It is assumed that the area is flooded twice daily with a layer of 10 cm water above ground level.

Table 2. A comparison of nutrient contents of harvested sago pith and nutrient contents of flooding river water

Nutrient	Nutrient contents of pith of 130 trunks per ha and year	Total of nutrients flowing over the soil in aqueous solution in kg per ha and year	Percentage to be withdrawn from the aqueous solution in order to maintain the yields
N	80 kg	763- 903	10.5- 8.9
P_2O_5	30 kg	161- 301	18.6-10.8
K_2O	160 kg	1,883-2,772	8.5- 5.8
CaO	100 kg	1,834-2,030	5.5- 4.9
MgO	40 kg	1,295-2,296	3.1- 1.7

The conclusion can be drawn that the sago cultivation as described could be considered to be a kind of water culture. This probably is the explanation for the continuous high yield level without the addition of fertilizer. As application of fertilizer in such a situation is very difficult, it might also be a limiting factor to an increasing yield level.

It is amazing to note that this interesting and high yielding culture hardly received any attention in research. This level of production was reached by the farmers themselves without any outside influence. It is therefore of interest to calculate whether yields still could be higher and research is worth-while.

Potential Production

If all other conditions are optimal the dry matter production of a crop is determined by photosynthesis and thus by sunlight. In the tropics theoretically one can grow a crop the year round. In the region between 10° N and S gross photosynthesis amounts to on the average 400 kg of carbohydrates per ha and day on a day without clouds. On a clouded day, however, photosynthesis reaches only 220 kg carbohydrates (12). Roughly 30% of the carbohydrates produced the plant uses for respiration. Assuming that in the humid tropics the sky will be half clouded on the average, production of carbohydrates could be roughly estimated at 200 kg per ha and day. Of course, depending on the cloudiness production could be higher or lower. As an average however, the figure given serves well.

A comparison of potential production of rice, cassava and sago palm under the circumstances mentioned is given in table 3. In this table the percentage of usefull dry matter in rice and cassava is based on data given by de VRIES (11). Usefull d.m. production of the sagopalm was estimated by means of comparison with the oil palm (2). A sago palm is estimated to consist of crown and roots 50 kg, bark of trunk 200 kg, pith 1000 kg. Its 20% d.m. contains starch at 18.5% of 1000 kg fresh pith or 74% of total d.m.

It appears from the comparison that the sago palm wins in potential production from both cassava and rice. Two factors can be distinguished, i.e. a more favourable d.m. distribution, which is important for both cassava and sago palm, and secondly a longer period of closed canopy, by means of which the sago palm also wins from cassava. The latter point shows clearly the advantage of sago palm, that it closely resembles the climax vegetation in the humid tropical lowlands, actually even is part of it. Moreover the present yields of the sago palm theoretically may be doubled.

Table 3. A comparison of the potential production of rice, cassava and sago palm

	rice	cassava	sago palm
Assumed duration of growth	120 days	270 days	30 years
Estimated period before closed canopy is reached	50 days	90 days	4 years
Estimated d.m. prod. a. before	$\frac{50 \times 200}{2}$ kg	$\frac{90 \times 200}{2}$ kg	$\frac{4 \times 365 \times 200}{2}$ kg
b. after closed canopy	70 x 200 kg	180 x 200 kg	26 x 365 x 200 kg
Estimated d.m. prod. per day of vegetation	158 kg	166 kg	186 kg
Percentage usefull d.m.	40%	80%	74%
Usefull d.m. per day of vegetation in kilocalories	252×10^3	531×10^3	550×10^3
Production per day in % of rice prod.	100%	210%	218%
Part of increase over rice due to			
a. longer period of closed canopy	-	5%	18%
b. more favourable d.m. distribution	-	105%	100%
Potential crop yield in practical terms	8.500 kg polished rice per harvest	97 tons of fresh roots per harvest	270 tons of debarked pith per year of full production

Main advantages and disadvantages of the crop

It is fairly easy to mention a few distinct advantages of this crop over all other starchy crops:

(I) It is perennial crop fitting into the climax vegetation.

(ii) The crop is especially suited for swampy areas which at the moment cannot be used without expensive measures for water control.

(iii) The crop is a relatively simple one as regards maintenance and care. One man could probably easily tend 5 ha.

(iv) Harvesting of the crop is not confined to a season; neither is harvesting limited to a strict physiological growth phase.

(v) Harvested stems can be kept in water during some weeks without great losses.

In other words the sago palm is a relatively simple crop, suitable for small scale farming and well adapted to continuous production of either animal feed or starch, in regions where other uses of the soil are limited.

There is, however, in addition to the problem of transport of harvested produce, one other problem which presents a clear disadvantage. i.e. the long -- 8 years -- period from planting to first harvest. This is the main economic problem for a rapid expansion of sago cultivation throughout the tropical belt of the world. The evidence presented here gives some support to the thought that this period could be shortened by means of fertilization. In peat soils, which are characterized by being acid and poor in nutrients, the palms take 15-18 years untill maturity. On good mineral soils maturity may be reached after 8-10 years. Therefore with heavy fertilization it might be possible to harvest earlier; but fertilization may prove impossible because of the flooding.

If earlier harvesting proves impossible, other means are available to reduce the economic disadvantage of the long juvenile period. If virgin swamp forest is used for planting, one could start clearing by means of poisoning the large trees and later on the undergrowth could be cut progressively. In this way the cost of clearing would be reduced.

There may be another possibility to reduce the economic effect of the long juvenile period. In the first four years after planting much unused space is available between the suckers. If the finally remaining palms are planted at 6 x 6 m, one then could plant one additional sucker in the centre of each square. The latter suckers then could be left to grow into one or maybe two trunks each. In the first few years one could then harvest approximately double the usual number of trunks, in this way compensating the losses of the eight-years' juvenile period.

Conclusion

The sago palm appears to be a hitherto neglected starch crop with a high yield potential and suited for marginal soils. Due to its unique possibilities, a research effort directed to this crop could lead to important results aiding in a solution to the world food problem. It is suggested that this crop be included in the ones of interest to the International Society for Tropical Root Crops, despite it not being a root crop.

References:

1. Barrau, J. (1959). The sago palm and other food plants of marsh dwellers on the South Pacific islands. Econ. Bot. 13, 151 - 162.
2. Ferwerda, J.D. (1962). Die Oelpalme. Tropische und subtropische Weltwirtschaftspflanzen II, 344 Enke; Stuttgart.
3. Johnson, R.M. & W.D. Raymond (1956). Sources of starch in colonial territories I: the sago palm. Col. Plant and Animal Prod. 6, 20 - 32.
4. Lim, H.K. (1967). Animal feeding stuffs. Mal. Agric. J. 46, 63 - 79.
5. Nicholson, G.P. (1921). Le sagoutier en terrains marécageux (Malacca). Bull. Econ. Indoch. 24, 159 - 200.
6. Oijen, L.A.T.J.F. (1909). Sagoe en sagoepalmen. Bull. Kol. Mus. Haarlem no. 44, 12 - 69.
7. Ridley, H.N. (1895). Sago. Agric. Bull. Malay Penins. 4, 62.
8. Reep, C. (1907). Sagocultuur op Benkalis. Tijdschr. Binnenl. Best. 32, 393 - 394.
9. Scheffer, R.H.C.C. & K.F. Holle (1873). Een sagoboom op Java. Tijdschr. Ind. Mij Nijverh. & Landb. 18 : 397.

10. Tan, Y.T. & G.A. Prowse (1972). A chemical survey of the Malacca river.
Mal. Agric. J. 48, 185 - 221.

11. Vries, C.A. de, J.D. Ferwerda & M. Flach (1967). Choice of food crops in relation to actual and potential production in the tropics.
Neth. J. Agric. Sci 15, 241 - 248.

12. Wit, C.T. de (1965). Photosynthesis of leaf canopies.
Agric. Res. Rep. 663; Centre Agric. Publ. & Doc.; Wageningen.

13. Woodman, H.E., A.W. Menzies, A.W.M. Kitchin & R.E. Evans (1931). The value of tapioca flour and sago pith meal in the nutrition of swine.
J. Agric. Sci 21, 526 - 546.

14. Zwollo, M. (195). Rapport sago onderzoek Inanwatan.
Report available in the Archives of the former Directorate Netherlands New Guinea; the Hague.

THE COMPARATIVE ETHNOBOTANY OF AFRICAN AND ASIAN YAM CULTURES

By

D.G. COURSEY

Tropical Products Institute, 56/62 Gray's Inn Road, London, England.

Introduction

At a Symposium attended mainly by agricultural scientists and other biologists, a discussion of the prehistory of the development of yam cultivation may to some appear out of place. But, conversely, if there is to be concern with the present strains of root crop production in the world, and with the development of such production in the future, to the highest optimal level, it is appropriate and indeed necessary to understand something of the past. This is especially true when dealing with root crops rather than with some of the better-known crop plants. Agricultural science, wherever in the world it may be applied, was initially a development of Western Europe and has been much influenced by European modes of thought: these in turn were influenced by cultural concepts ultimately derived from the so-called "Neolithic Revolution" of South-Western Asia of 7 to 10 millenia ago, where the process occurred that brought seed-propagated grain crops and a number of animal species, but not vegetatively-propagated root crops, into domestication by man. Various authors (7, 16, 40) have drawn attention to the interpenetration that has occurred between scientific thought and the folk ethnocentricism of Western Europe, and the confusion so generated when tropical food production systems are being considered: it is in this context that the culture history of man in relationship to tropical root crops is of great importance.

One outcome of this interpenetration is the frequently made supposition that any non-grain-using or pre-grain-using culture is necessarily at a very low order of evolution; that only grain-based cultures are based on a symbiotic relationship between man and plant; and that these must be constrasted sharply with the hunter/gatherer cultural level at which it is supposed that man is purely parasitic on his environment. It may therefore seem surprising that in connection with the cultivation of yams there are two major areas in the world to which, quite independently, the term "la civilisation de l'igname" has been applied. The first of these is that part of West Africa between Central Ivory Coast and the Cameroun where root crops, especially yams, are the dominant staples (32, 14, 18). The other is that part of the Indo-Pacific area based on Melanesia, but extending into Micronesia and Polynesia where yams and other vegetatively propagated crops are important (23). Yam cultivation in this area has been considered in detail by Burkill (8, 9) and by Barrau (4, 5, 6, 7).

This paper examined some aspects of the culture history of the man/plant relationship in these two areas, and attempts to draw some more general conclusions.

Botany

The African and Asiatic species of Dioscorea have long been isolated genetically from each other: probably since the Miocene and in any case since long before man's appearance in the world. The differences between Asiatic and African species are, however, far less than between Old World and New World Dioscorea, where divergence occurred much earlier in geological history, and there are close morphological parallels between many African and Asiatic species, even in the wild state (14).

Man has thus domesticated different species of yam in the two continents (see Table 1) but there are a number of parallels between the domesticates in the two areas. Particularly striking is the fact that in each continential area yam utilisation tends to be dominated by a single cultigen. In Asia the cultigen D. alata is of the greatest importance, though D. esculenta (a species which has no parallel in Africa) and some others are also widely grown. In Africa the extremely similar cultigen D. rotundata is dominant in cultivation, even though several other species are also cultivated in the earlier times a greater variety was probably utilised.

Table 1

Principal African and Asian Yams Utilised as food

African	Asian
D. rotundata Poir.	D. alata L.
D. cavenensis Lamk.	D. esculenta (Lour) Burk
D. praehensilis Benth.	D. nummularia Lamk.
D. bulbifera L.	D. bulbifera L.
D. dumetorum (Kunth) Pax	D. hispida Dennst.
	D. pentaphylla L.

What is perhaps most significant is that both the dominant species, D. alata and D. rotundata are cultigens - i.e. artefacts of man, which are known in the wild state only as escapes from cultivation. The Asiatic species is believed to have originated from spontaneous hybrids between D. hamiltonii Hook and D. persimilis Prain et Burk., two closely related species whose natural ranges overlap in Northern Burma and Thailand (8, 9). The ancestry of the African cultigen is less clearly understood but is believed (3, 15) to have originated from D. cavenensis and a savanna species, probably D. praehensilis, with a possibility of a second savanna species D. abyssinica Hochst also contributing to its ancestry.

Both cultigens belong to the section Enantiophyllum of the genus Dioscorea whose members are characterised by the formation of a single large tuber with only limited formation of subsidiary tubers. Both have been in vegetative propagation under domestication for sexual reproduction and fertile seed is only very rarely formed, although it is known in both species.

Asian Yam Cultures

In his early work on the origins of cultivated Asiatic yams, Burkill (8) assumed that the emergence of cultivated forms was comparatively recent; that domestication occurred subsequently to the introduction of grain-based agriculture into both India and China; and that the pressures generated between these two grain-based cultures on the aboriginal peoples of the S.E. Asian peninsula provided the initial stimulus for yam domestication, at a date only about 2000 to 3000 BP. Although there is every reason to accept the hybrid origin of D. alata, and that it is in tropical, as opposed to equatorial, regions where large-tubered forms of plant are most likely to occur (as the fluctuation in seasonality between wet and dry makes a large, and more esculent, organ of dormancy necessary) the dates suggested for domestication are far too recent.

The original concept of a separate origin of agriculture in the S.E. Asian region can be attributed to Haudricourt and Hedin (25) and after being more widely popularised by Sauer (36) was developed substantially further by Barrau (5, 6, 7). These writers hypothesize that vegetatively propagated crops were brought into symbiotic association with man in S.E. Asia area independently of the S.W. Asian "Neolithic Revolution" and probably at a much earlier data. The aroid <u>Colocasia</u> <u>esculenta</u> (L.) Schott was probably the first plant to be domesticated in this area and was brought into cultivation by littoral or riverain people dependent on fishing as their major nutritional base; this crop was subsequently developed in cultivation particularly in the moister areas (5). The yams, essentially plants of somewhat drier conditions than <u>Colocasia</u> are associated with regions of higher seasonality of rainfall, i.e. the savannas rather than the forests, and were suggested as somewhat later, but still exceedingly early, demesticates, although it has been suggested (13) that they were the first plants ever to be cultivated, These concepts are now beginning to receive some firm archaelogical support. Though no recognizable fragments of either aroid or yam material have so far been isolated in excavations, both artefacts and other plant material strongly indicate a positive symbiotic association between plant and man of an essentially horticultural nature at dates around 10,000 BP in various parts of S.E Asia. Most of the available evidence which has recently been reviewed (12, 38) suggests an entirely separate and earlier agricultural revolution, quite independent of the "Neolitic Revolution" of S.W. Asia.

On most of the S.E. Asian mainland and many of the neighbouring islands the cultivation of vegetatively propagated crops such as aroids and yams is now of distinctly secondary importance although these crops are still known and used. Displacement was initially by rice (which may have been originally (12) a weed in flooded Colocasia fields); by dry land grain crops of more recent introduction; and, in the last few decades by cassava. But before this displacement occurred these crops were carried by the Polynesian migrations, archaelogically dated as originating on the coasts of the South China Sea between 4000 and 3000 BP, to the furthest reaches of the inhabited Pacific Ocean; and in many parts of this area they are still of very great importance.

It is in Melanesia, the area based on New Guinea and extending through the Solomons, New Caledonia and Fiji, that the cultivation of root crops, in particular yams, has survived to the present day as the core of the agricultural complex: it was parts of this area which were designated by Haudricourt as "la civilisation de l'igname". Within this large and climatically diverse region, there are variations, depending basically upon ecological factors between specific areas as to whether yam or Colocasia is favoured, and the whole production system of the area has also been modified within recent centuries by the introduction of the sweet potato (Ipomoea batatas (L) Lamk.) which made possible extensive colonisation of the New Guinea highlands where the climate is too cold for either yam or Colocasia to grow well. Throughout the area, the yam more than any other crop is not only the major nutritional base but is also the focus of the human socio-cultural system. In most of

Melanesia, one may find a complex of ritual and socio-religious beliefs associated with almost every phase of the cultivation, storage and handling of yams. Although other species are also respected for their value as food, these cultural associations relate mainly to the cultigen D. alata. It is not possible here to go into detail, but reference may be made to the practice of growing giant tubers of D. alata, (frequently more than 2m long and weighing more than 50 kg) under very carefully ritually controlled conditions (26, 29); to the highly complex system of ritual exchanges of yams between inidivduals and groups: to the sexual taboos associated with yam cultivation, which can even insist on total celibacy during the entire growing season; and the role played by giant yams in formalized ritual conflicts (29, 30, 39). The concept of a close spiritual relationship between man and yam appears in the writing of all these workers, but even more strongly in the legends recorded in New Guinea (2) where iseas of an actual transubstantiation between man and yam, associated with the mythical origins of the human race, occur.

The antiquity of yam cultivation in Melanesia is not clearly established. Most of the little archaeology so far done has concentrated on the highland areas of the Ipomoean culture where human occupation may not be of very high antiquity. Recently, however, evidence has been produced for the existence of horticultural systems closely similar to those of the present day at dates around 5000 BP in New Guinea (34). These dates would be consistent with the origin of the yam and Colocasia-based agricultural systems deriving from earlier cultures of mainland S..E. Asia.

In addition, there exist in several parts of Asia, small, isolated groups of people who are culturally and ethnically distinct from their neighbours, and who utilise yams as their major staple. Notable amongst these are various Indian hill tribes such as the Kadar; the Veddas of Sri Lanka; the Andaman Islanders; the Semang and Malaya and various aboriginal groups in the Philippines (16). These people are at an early level of cultural evolution and have often been described by ethnographers as being completely non-agricultural. However, as pointed out by Burkill (10) referring specifiaally to the Andamans "They make D. glabra a crop plant to the small extent that the elders issue a taboo on the digging of the yams in the season of new growth" and, as has been pointed out elsewhere (7, 16, 18), ritual practices associated with this "protection" of the wild yam may be regarded as an incipient stage of horticulture.

The food plants of the Australian Aborigines, at least in the Northern part of the continent, are similar to those of tropical Asia, New Guinea etc. (21), and even amongst these people, there are what might be termed proto-agricultural rituals and concepts, similar to those of some of the relict Asian groups.

African Yam Cultures

Though yams are cultivated and utilised to some extent through most parts of Africa, ecologically suitable for their growth, the main concentration occurs in the West African "Yam Zone". Here the cultigen D. rotundata is the principal species although various other species are also grown. It is, however, with the cultigen D. rotundata that the greater part of the human cultural aspect of yam growing is associated: in fact in more than one West African language, the name applied to this species signifies some such concept as "proper yam" (3).

A major ehtnobotanical difference between the African and S.E. Asian areas is that in Africa no aroid crop, adapted to swamp or at least high moisture conditions was deomesticated to any substantial degree, comparable to the domestication of Colocasia in Asia. Today, Colocasia is widely known in Africa (together with the recently intorduced Xanthosoma of American origin), but it is an introduction only of the last millenium or two. Some wild African aroids (Amorphallus and Anchomanes spp) are occasionally eaten but they have never been developed to any extent as cultivated plants. In contrast therefore to the Asian situation where aroid cultivation developed in the more humid areas, the yam cultivation in the areas of seasonal humidity, in Africa one must look for the origins of root crop agriculture mainly in the savanna areas and in association with the yam.

Against this however must be considered the biological origin of D. rotundata. One of ts parents, D. cavenensis, is itself a forest species and other parent or parents savanna species. It is only reasonable therefore to assume that D. rotundata arose initially at the forest/savanna ecotone, and as we have discussed elsewhere (3, 15), this yam may be regarded as a derivation from natural hybrids which arose where the natural zones of the parent species overlapped (that is at the forest/savanna ecotone), and that some of these hybrids, although poorly adopted to survival in the wild state, were capable of surviving under the protection of man.

Today an enormous range of cultivated forms exists which shade imperceptibility from pure D. cayenensis on the one hand to something very close fo an improved form of D. praehensilis at the other end. Although a considerable number of these cultivated forms have benn studied (41) and others recently collected and established in Puerto Rico, the cultivated material in existence in West Africa, has never been exhaustively studied. Serious erosion of the genetic resources is taking place both through the displacement of yam cultivation by rice and cassava and also by the spread of the particularly favoured varieties of yam. In Ghana, for example, it is believed that some 80% of yam production is accounted for by two particular cultivars. High priority should be given to fully collecting and cataloguing the existing West African cultivars before they are lost for ever (14, 17).

As in Melanesia, so in West Africa, yams are not only a major nutritional base but, at least until recently a focus of human culture. Comments on the importance of yams and their social and even religious significance have been made spasmodically by visitors to West Africa since the 16th Century, but little attention has been devoted to the subject by ethnographers or anthropologists, and little reliable information appears in the literature.

It is nevertheless clear that prior to the impact of Western education and ideologists, the farming cycle concerning the yam was also the basis of the human social calendar, dominated by the annual ceremony held to open the yam harvest (18, 33). Other events in the farming year were also associated with social, cultural or religious festivities, few of which have been well documented. Yam played many roles beyond that of food: it was an essential constituent of sacrifices or other offeringa in the traditional religious systems; in at least parts of the Yam Zone of West Africa the yam is associated with particular deities in the traditional religious systems (2, 33); a man's social position may be related to his competency as a yam farmer; theft of yams may be regarded as a more heinous crime than theft of other goods, even of greater value.

These and other philosophical concepts related to African yam cultivation have been discussed elsewhere (14, 18) but, just as there is a need physicallu to collect the African yam cultivars, before they are lost, there is a need for ethnological study of traditional concepts and practices relating to yam cultivation before they too finally disappear. Many traditional customs confined to the older generation. Such a study should be of great value in understanding the development of production systems, and be a guide towards the future development.

Although no rigid archaeological evidence exists to date, yam cultivation or at least the systematic utilisation of yams may well be of very high antiquity in Africa. It far antedates the earliest European contacts ca. 600 BP, while traditions strongly suggest that it also antedates the introduction of iron, approximately 2000 BP. Many writers have assumed that agriculture of any sort in Africa can only have arisen subsequent to trans-Saharan Neolithic contacts with the middle east: while there is little doubt that such factors influenced and accelerated the development of the existing agricultural system (1), the beginning of the evolution may well be considerably older and of purely African origins. The collection of wild yams has been related (19) to African artifacts dated ca. 50,000 BP, while an analysis based on both climatic changes, and changes in the human population that are archaeologically recorded by appearance of microlithic industries in West Africa suggests a major cultural change approximately 10000 BP, associated with the appearance of the organized production of yams based on the selection and protection of natural hybrid yams at the rain forest/savanna ecotone (3, 15).

Origins of the Yam Cultures

Current views on the processes of plant domestication (22), indicates that, whereas grain and similar crops were domesticated in the sub-tropical areas if S.W. Asia and middle China, in closely circumscribed areas that can be regarded as Centres of Origin in the Vavilovian sense, the tropical and equatorial crops were domesticated rather over wide, diffuse areas or "Non-centres" in sub-Saharan Africa and in South-East Asia. These broad areas were originally culturally discrete from the more northerly Centres, although as history proceeded, cultural interaction took place between each centre and its equavalent "Non-Centre". Yams in both Africa and Asia are domesticates of the "Non-Centres".

Although different yam species weredomesticated in the two areas, the parallelism of evolution that has occurred is extremely marked, not only in the morphology of the plants th mselves, but also in the cultural complexes that have been built up around them. In particular, the protocultural phase of evolution which we have hypothesised elsewhere (18) as being a major step in the origins of African yam cultivation finds close conceptual parallels in the ethnographic present amongst the much less advanced Negrito and similar relect peoples of

Asia. Indeed, there appear to be very close similarities in the man/plant interrelationships wherever yams are a major staple food anywhere in the Old World. The fact that these relict groups, whose cultures are of much higher antiquity than those of major civilisations (Indian and Chinese) of Southern Asia, have similar practices, even where they have survived in isolation, is, together with the emerging archaeological evidence, highly suggestive that the first steps towards yam domestication in Asia were taken by the remote ancestors of these people, when they were much more widely spread through tropical Asia than they are today. The presence of customs related to these amongst the Australian aborigines, who first reached the continent 30,000 BP and whose stone tools resemble very early African and pre-Aryan Indian artefacts (2') is also suggestive of an extreme antiquity for at least the beginnings of the man/yam symbiotic relationship. The work of Davies (19) and the writer (15) has indicated, rather more speculatively, similarly extreme antiquity for the initiation of similar man/yam symbiosis in the African "Non-Centre".

While recognising the separateness of the African and Asian "Non-Centres" of plant domestication, it does appear that some form of cultural continuum existed in extremely early times right across the tropical Old World from West Africa at one extreme to New Guinea at the other. The man/yam relationship developed into a true agriculture only at the two extremities of this continuum, probably under the influence, in the later phases, of cultural contact with the grain-based civilizations further north in S.W. Asia and in China (1). Nevertheless, some progress towards agricultural or horticultural evolution took place in many other intervening areas right across this hypothesized continuum, as what might be termed the "Mesolithic Revolution", based on the "protection" or partial domestication of vegetatively-propagated plants, as indicated by the existence of concept ally similar yam-related customs in West Africa, Melanesia and among the various relict groups.

The hypothesis of such a cultural continuum is supported from an unexpected direction, by ethnomusicology. Sophisticated, computer-based statistical taximetric techniques have been used to analyse the traditional music patterns of a great number of different ethnic groups and classify them according to their degree of similarity. In this study, it was found that higher orders of correlation exist between the music of Africa, Melanesia and the relict Indian groups, all within this hypothesized continuum, than would be expected between such widely separated groups. The "hypothesis that a continuous ring of gardening cultures once linked Oceania to Africa" was suggested, though "only traces of this ancient human distribution seem to have survived the incursion of higher cultures" between the two extremes (31).

Some General Conclusions

Man has not only modified plants for food production, but since he initiated food production systems, has become himself the product of an artificial system, human culture itself, being in part an artefact of man's relationships with his crop plants and domestic animals. It could even be said that domestication is a reciprocal process, and that man has been domesticated by his crops just as he has domesticated them. The consequences for man of the evolution of various food production systems have not been explored except in the most general terms and there is a great need for a study of the cognitive and conceptual aspects of these effects on human culture (37). Attention has already been drawn (24) to differences in cultural behaviour between societies with grain-based agricultural systems derived from the S.W. Asian "Neolithic Revolution" and those with vegecultural systems based on root and tuber crops of the S.E. Asian area - the latter derived from the hypothesized "Mesolithic Revolution". The former, dealing with crop plants which require a direct, active and selective approach by man have lead to an "intercentionist" type of mentalith and ultimately to the type of cultural system that is now dominant in the world, a concept which was anticipated as early as the writings of Rosseau (35). On the other hand, the indirect, less positively active relationships between man and vegetatively propagated crop plants such as the yam leads to a "non-interventionist" attitude of mind and an altogether clower integration of man as part of the overall ecosystem rather than as something above, and separate, from it.

The whole question of the cultural effects of differing types of man/plant relationship needs further attention, especially so in those surviving cultures where root crops such as the yam are the predominant food plant. As Campbell (11) has said, "Ritual is.......the DNA of society, the encoded informational basis of culture..........the memory core of human achievement".

So, we return conceptually to our opening comments and suggest that studies of the surviving yam cultures from the points of view of the prehistorian and also of the ethnologist may well be rewarding in improving out understanding of the crop plants concerned and so optimising their future use. There may even be an unexpected spin-off in terms of a broader understanding of the basis for human culture, in its relationship to food production systems.

Bibliography

1. Alexander, J. and Coursey, D.G. (1969) The origins of yam cultivation. The Domestication and Exploitation of Plants and Animals. P.J. Ucko and G.W. Dimbleby (edit.) Gerald Duckworth, London. pp. 405-425.

2. Arinze, F.A. (1970) Sacrifice in Ibo religion. Ibadan University Press.

3. Ayensu, E.S. and Coursey, D.G. (1972) Guinea yams. Econ. Bot. 26, 301-318.

4. Barrau, J. (1963) Plants and the Migrations of Man in the Pacific. B.P. Bishop Museum, Hawaii.

5. Barrau, J. (1965) L'humide et le sec. J. Polynesian Soc. 74, 329-346.

6. Barrau, J. (1965) Histoire et prehistoire de l'Oceanie Tropicale. J. Soc. Oceanistes, 21, 55-78.

7. Barrau, J. (1970) La region indo-pacifique comme centre de nise enculture et de domestication des vegetaux. J. Agric. Trop. Bot. appl. 17, 482-503.

8. Burkill, I.H. (1924). A list of oriental vernacular names of the genus Dioscorea. Gdns' Bull., Straits Settl. 3, 121-244.

9. Burkill, I.H. (1951) The rise and decline of the Greater Yam in the service of Man. Advtmt. Sci., Lond. 7, 443-448.

10. Burkill, I.H. (1953). Habits pf Man and the history of cultivated plants in the Old World. Proc. Linn Soc., Lond. 164, 12-42.

11. Campbell, B.G. (1966) Human evolution. Aldine. Chicago

12. Chang, K.C. (1970) The beginnings of agriculture in the Far East. Antiquity, 44, 175-185.

13. Cipriani, L. (1966) The Andaman Islanders. Weidenflet and Nicholson, London.

14. Coursey, D.G. (1967) Yams. Longmans, London.

15. Coursey, D.G. (1972) The origins and domestication of yams in Africa. Wenner Green Foundation for Anthropological Research, Burg Wartenstein Symposium No. 56, The Origin of African Plant Domesticates.

16. Coursey, D.G. (1972) The civilizations of the yam: interrelationships of man and yams in Africa and the Indo-pacific region. Archaeol. Phys. Anthropol. Oceania. 7, 215-233.

17. Coursey, D.G. (1973) Genetic erosion of yams in West Africa. Crop Genetic Resources in their Centres of Diversity. O.H. Frankel (edit.) FAO/IBP Rome, pp. 67-69.

18. Coursey, D.G. and Coursey, Cecelia K. (1971) The new yam festivals of West Africa. Anthropos, 66, 444-448.

19. Davies, O. (1968) The origins of agriculture in West Africa. Curr. Anthropol. 9, 479-482.

20. Golson, J. (1971) Australian Aboriginal food plants: some ecological and culture historical implications. Aboriginal Man and Environment in Australia. D.J. Mulvaney and J. Golson (edit.) Australian National University Press, Canberra. pp. 196-238.

22. Harlan, J.R. (1971) Agricultural Origina: centres and noncentres. Science, 174, 468-474.

23. Haudricourt, A.G. (1964) Nature et culture dans la civilization de l'igname: l'origine des clones et des clans. L'Homme, 4, 93-104.

24. Haudricourt, A.G. (1964) Aspects qualitifs des civilizations agricoles de la societe de communaute primitive. Congress of Anthropological and Entomological Sciences, Moscow, 5, 506-507.

25. Haudricourt, A.G. and Hedin, L. (1943) L'Homme et les plantes Cultivees Libraire Gallimead, Paris.

26. Haynes, P.H. and Coursey, D.G. (1969) Gigantism in the yam. Trop. Sci. 11, 93-96.

27. Igbozurike, M.V. (1971) Ecological balance in tropical agriculture. Geogrl. Rev. 61, 519-529.

28. Jones, R. (1968) The geographical backgrouns to the arrival of man in Australia and Tasmania. Archeol. Phys. Anthropol., Oceania, 3, 186-215.

29. Lea, D.A.M. (1966) Yam growing in the Maprik area. Papua New Guin. J. Agric. 18, 5-15.

30. Lea, D.A.M. (1969) Some non-nutritive functions of food in New Guinea. Settlement and encounter. F. Gale and G.H. Lawton (edit.) Oxford University Press, London.

31. Lomax, A. and Berkowitz, N. (1972) The evolutionary taxonomy of culture. Science, 177, 228-239.

32. Miege, J. (1954) Les cultures vivrieres en Afrique Occidentale. Cah. d'Outre-Mer, 7, 25-50.

33. Opoku, A.A. (1970) Festivals of Ghana. Ghana Publishing Corporation, Accra.

34. Powell, Jocelyn, M. (1970) The history of agriculture in the New Guinea highlands. Search, 1, 199-200.

35. Rosseau, J. - J. (1755) Discours sur l'origine et les fondements de l'inegalite parmi les hommes. Paris.

36. Sauer, C.O. (1952). Agricultural origins and dispersals. The American Geographic Society, New York.

37. Smith, P.E.L. (1972) The consequences of food production. Addison-Wesley Modular Publications, Module 31, 1-38.

38. Solheim, W.G. (1972) An earlier Agricultural Revolution. Scientific American, 226, 34-41.

39. Tuzin, W.F. (1972) Yam symbolism in the Sepik: an interpretive account. Southwestern J. Anthropol. 28, 230-254.

40. Uchendu, V.C. (1970) Cultural and economic factors influencing food habit patterns in sub-Saharan Africa. Proc. 3rd Int. Congress Fd Sci. Technol. 160-168.

41. Waitt, A.W. (1965) A key to some Nigerian variations of yam (Dioscorea spp.) Memorandum No. 60, Federal Department of Agricultural Research, Ibadan.

PHYSIOLOGICAL VARIABILITY IN THE MINERAL NUTRITION OF CASSAVA

by

D.A. Forno, C.J. Asher, D.G. Edwards and J.P. Evenson

INTRODUCTION

The importance of cassava (Manihot esculenta Crantz.) for food, as a potentially cheap source of carbohydrate for livestock and for industrial purposes is now well recognized. However, although considerable attention has been given to improving the overall agronomy of the crop and to the breeding of superior lines, relatively little attention has been given to the physiology of cassava. Morphological differences between cassava cultivars are well known (2). and provide visible evidence of the vast genetic diversity among cultivars. However much less is known about the physiological variation among cultivars, although the limited evidence available suggests that this may be substantial also (4). Large differences between cassava cultivars in their response to fertilizers, observed in Ghana (S.H. Evelyn, pers. comm.), provides further evidence for physiological differences in cassava.

In order to investigate physiological differences between cultivars in nutrient response, studies were commenced at the University of Queensland in early 1972. Since then considerable evidence has been obtained for physiological differences effecting the response of various local and imported*. cultivars to root remperature and to calcium and nitrogen nutrition.

In this paper, it is intended to illustrate the magnitude of these differences by reference to specific examples.

EXPERIMENTAL

Most of our work so far has been conducted using flowing solution culture techniques that permit precise control to be maintained over nutrient ion concentrations, pH and root temperature (1). For this purpose it is convenient to use small stem tip cuttings with much lower total nutrient contents than would be the case with the larger stem cuttings usually employed in field plantings of cassava.

We have found that stem tip cuttings, lateral buds and even detached leaves can be readily propagated in mist culture, and have constructed experimental mist propagators in which both root temperature and nutrient supply can be varied.

RESULTS AND DISCUSSION

Effect of substrate calcium concentrations on root development

Root development by stem tip cuttings grown in mist propagation chambers was markedly affected by the concentration of calcium in the rooting medium (Fig. 1). When no calcium was supplied, the root development of all three cultivars was greatly retarded and the roots were stunted with brownish-black tips.

---

* The authors gratefully acknowledge the assistance of Prof. D.L. Plucknett (University of Hawaii) and Dr. F.W. Martin (USDA Puerto Rico) in obtaining cassava cultivars of Puerto Rican origin.

In Ceiba, root growth appeared healthy at 15 µM calcium, but in Nina and UQ2, the roots still showed obvious symptoms of calcium deficiency. Further marked differences in response to calcium supply were noted at higher concentrations. Thus Ceiba was relatively insensitive to substrate calcium concentrations over the range 15 to 1500 µM, root yields increasing gradually throughout this range. However in Nina and UQ2, substantial increases in root yield were observed when the calcium concentration was increased from 15 to 150µM, while yields tended to decrease at higher calcium concentrations.

Effect of substrate temperatures on root development

When stem tip cuttings were supplied with 155µM calcium, large effects of temperature on root development were obtained in the root propagation chambers and there were again substantial differences in responses of individual cultivars (Fig.2). At 20°C, root growth was severely retarded in all three cultivars, and increasing the temperature to 25°C caused a four to nine fold increase in root yields.

At 25°C, Nina produced its best root growth, whereas for UQ2, best growth was obtained at 30°C. For Ceiba however root growth was still increasing at 35°C. At this latter temperature, the root growth of Nina and UQ2 was retarded.

However, the data obtained in this experiment relate to optimum root temperatures for root initiation and development, rather than to optimum root temperatures for prolonged growth. Nevertheless, substantial differences may exist between cultivars in root temperatures required for optimum growth. For the following studies, the root temperatures of all cultivars were maintained at 25°C to avoid possible heat injury.

Effect of Calcium concentration on growth of rooted cuttings

In a flowing culture experiment conducted at a range of controlled calcium concentrations, large differences were found in the responses of individual cultivars. Figure 3 shows the results for two cultivars studied. In the three lowest treatments (0.3, 3 and 10 μM Ca), the growth of both Nina and UQ5 was severely retarded and root growth was particularly stunted. However above 100 μM, there was little effect of calcium concentration on the growth of Nina, but for UQ5, yields continued to increase up to 1000 μM. Further increases in calcium concentration caused substantial yield reductions of UQ5. However since calcium was supplied as calcium chloride, the large yield depression in UQ5 may have been due to a greater sensitivity of this cultivar to high chloride concentrations.

Effect of nitrate and ammonium nitrogen concentrations on the growth of rooted cuttings.

Quite large differences were observed between cultivars in response to nitrogen, but the response to various nitrogen concentrations depended upon whether nitrogen was supplied as nitrate or ammonium. Much higher concentrations of nitrate than ammonium nitrogen were needed for maximum growth (Figs. 4 and 5). When nitrogen was supplied solely as the ammonium ion, the growth of Ceiba was best at 29 μM, and was depressed at higher concentrations. In contrast to this, UQ2, responded to ammonium concentrations up to 490 μM (Fig. 4).

The response to nitrate however was somewhat different. Although the growth of both Ceiba abd UQ2 was severely retarded at low nitrate concentrations (0.5 to 5 μM), Ceiba was much more responsive to intermediate concentrations of nitrate than UQ2. Thus an increase in nitrate concentration from 16 to 52 μM resulted in a 30 percent increase in the growth of Ceiba but only a 2 percent increase in the growth of UQ2. By contrast, at high concentrations the situation was reversed, thus there was a 47 percent increase in the growth of UQ2 between the 560 and 5050 μM nitrate treatments, compared with only a 15 percent increase in the growth of Ceiba.

CONCLUSIONS

The existence of major differences in the response of cassava cultivars to the supply of particular nutrient elements poses problems when attempting to base fertilizer recommendations for one cultivar on the results of fertilizer trials conducted with other cultivars. Evidence presented suggests that, as has been found for other crops (3), responsive and non-responsive cassava cultivars may exist, and if so, should be managed accordingly.

Furthermore, the existance of such differences between cultivars suggests that care should be taken in plant breeding programmes with cassava to select under nutritional conditions as close as possible to those under which the crop is likely to be grown. Thus it would seem unwise to select under high fertility conditions, cultivars intended for use on poor soils with small or zero fertilizer input, and equally unwise to select under low fertility conditions, cultivars intended for cultivation under intense management systems. The possibility exists that with a further knowledge of physiological variation in cassava, it may be possible to select for specific nutrient responses in future cassava breeding programmes.

A Review of Cassava Mosaic Virus Research in Nigeria

By

B. A. O. Okusanya and M. J. Ekandem
Federal Department of Agricultural Research, Moor Plantation,
P.M.B. 5042, Ibadan, Nigeria.

INTRODUCTION

Cassava mosaic was originally described in 1894 by Warburg in East Africa under the name Krauselkranheit. Golding (1936(a)) recorded Jones's original report of the disease in Ijebu-Ode (1926), Ibadan (1929) and Ilorin (1932). It was then considered that mosaic was spreading inland from the coast (Golding, 1936(b)). A survey of the spread of cassava mosic conducted by West in 1945 revealed that it has spread to Umuahia in the East and Zaria in the North. Since then, the disease has been observed to be prevailent throughout the whole country. The disease was also recorded in West Africa - in Ghana (Dade, 1930), and in Sierra-Leone (Deighton, 1926). In fact, it is known in all cassava-growing areas of the world, (Jennings, 1970), in Brazil (Costa, 1940), in Indonesia (Muller, 1931) and in India (Alagianagalingam et al, 1966).

The cassava mosic "virus" is the major cause of reduction in the yield of the crop. Golding (1936(a)) reported that only 3% of the cassava plants at Moor Plantation, Ibadan, Nigeria was infected. But 33% and 43% reduction in yield have been recorded in two cassava varieties - "Karagba" and "Atu" respectively (Golding, 1936(b); Beck and Chant, 1958). In the Belgian Congo, 20% reduction in yield has been reported (Muller, 1931), while up to 76% and 95% loss were recorded in Zanzibar (Tidbury, 1937; Braint and Johns, 1940). It now appears that every widely grown cassava variety seems to live with the virus.

Studies on the cassava mosaic virus have been undertaken individually by various research workers in the Federal Department of Agricultural Research, Moor Plantation, Ibadan., which is situated 630 feet above sea level at latitude 6°N, longitude 4°E in the humid forest zone of Southern Nigeria. Golding, Squire, Cotterel and Mound have worked extensively on the vector, while West, Chant, Beck, Robertson, Ekandem, Barbee and Okusanya worked on the cassava plant and /or the virus.

An attempt is made to review the progress and problems on the cassava mosaic virus complex in Nigeria.

SYMPTOMATOLOGY

The infected cassava plant shows various degrees of mosaic patterns with small diserete chlorotic areas which cover only part of the lamina. These areas alternate with islands of deep green tissue along the leaflets. In severe cases, the mature leaves are distorted and constricted with considerable reduction in leaf size coupled with the shortening of the internodes of the stem. The plants thus appear stunted.

For ease of scoring in the field, the virus symptoms on cassava leaves have been classified (Chant and Beck, 1959; Ekandem and Waitt, 1964) as follows:-

Class 1. - Symptomless

Class 2. - Mosaic patterns without distortion of the lamina; chlorotic areas discrete, and bounded by the veins of the leaf.

Class 3. - Mosaic pattern with distortion of the lamina.

Class 4. - Mosaic pattern with constriction of the leaf lobes either locally or along their length; the lamina having a crinkled appearance and the leaf margins rolled backwards.

Class 5. - Mosaic pattern with distortion and constriction (Classes 3 and 4).

Class 6. - Chlorotic areas regularly arranged between the veins, (lines of small spots between the veins).

Symptom expressions vary within plants of the same variety in that they show different combinations of these class symptoms. It has been observed, however, that symptom expressions tend to be milder on plants with green or yellow petioles. In Nigeria, the distortion and constrictions of the lamina are acute when the rainfall is heavy (June - August). Symptoms appear on leaves produced subsequent to infection and never on the already mature leaves.

TRANSMISSION

The spread of cassava mosaic virus in the field could be due to primary and secondary infection. Primary infection is brought about by vegetative propagation from infected plants, because the virus is systemic in its host and is therefore carried-over in infected planting materials to successive crops. Secondary infection is initiated by the transmission of the disease in the field by an insect vector (Storey and Nichols, 1938). In Nigeria, the whitefly, Bemisia nigeriensis Corb. (Aleyrodidae) is the known vector of cassava mosaic virus (Golding 1936(a), 1936(b); Chant, 1958). Chant has shown that reduction in yield was only significant with primary infection.

The virus has been transmitted by grafting infected scions on to healthy stocks (Deighton, 1926; Pascalet, 1932; Storey, 1934; and Chant, 1957). But the reports of successful mechanical transmission of the virus by Kufferath and Chesquiere (1932) and Lefevre (1935), have not been reproduced or repeated even with modern reagents and techniques. Up till now, all attempts to transmit the virus by sap inoculation have been unsuccessful.

Golding (1936(b)) first demonstrated that the whitefly, B. nigeriensis Corb. transmitted the virus from infected cassava plants to healthy ones. During his comprehensive studies on the virus-vector relationship, Chant (1958(b)) showed that whiteflies become viruliferous after a minimum feeding period of 4 hours on infected plants, and that the percentage of successful transmissions increased with the length of feeding time. The virus can be transmitted by the viruliferous whiteflies within 15 minutes, although the percentage of successfully inoculated plants increased with increased feeding time. A single viruliferous whitefly can transmit the cassava mosaic virus and the number of transmissions increases with the number of whiteflies. Chant (1958(b)) further demonstrated that the minimum time in which healthy whiteflies can become viruliferous and transmit the virus is 8 hours, this period, being independent of whether the length of infection feed was 4 hours or 6 hours.

Whiteflies only survived for 15 hours when removed from the host plant, but when enclosed on cassava plants, some could remain alive for 10 - 12 days while the majority died after 4 - 5 days. Under experimental conditions, if batches of infected whiteflies (200 per plant) are transferred every 12 hours from plant to plant, the number of whiteflies is greatly reduced (10 - 30 per plant) after the fourth transfer (48 hours); but there was no evidence of loss in infectivity or attenuation of the virus at these stages. Hence it may be concluded that viruliferous whiteflies remain capable of transmitting the virus for at least 48 hours after the acquisition period after a minimum infection feed of 4 hours (Chant, 1958(b)).

Studies on the vector

The taxonomic identity of the whitefly (Bemisia sp.) is highly obscure. It has been shown that variations in the form of whiteflies are not genetically determined, but actually host induced. Such taxonomic problem of host-induced variation is not uncommon in the aleyrodidae family. It is not yet known whether cassava mosaic virus is related to other viruses transmitted by other species of whitefly. B. tabacci has been shown to transmit cotton leaf curlvirus (Storey, 1930), and okro mosaic virus. As with B. nigeriensis, the virus persists in B. tabacci. B. nigeriensis transmits cotton leaf curlvirus in Nigeria, but it cannot transmit this virus from cotton to cassava. Both B. tabacci and B. nigeriensis have been observed breeding on tomato, sweet potato, cowpeas, cotton, tobacco and pepper (Cotterell, 1956; Squire, 1957). Hence, the two species, Bemisia nigeriensis Corb; and Bemisia tabacci Genn. are regarded as synonymous (Mound, 1961).

Behavioural pattern

The degree to which the whiteflies have adopted itself to the growth habit of the cassava plant suggests a long and intimate association. Whiteflies lay eggs in great numbers near the growing tip of the plant. By the time the eggs hatch, the leaf has expanded thus providing ample food and shelter for the larvae and pupae. At the same time, the adult whiteflies, mainly females, congregate and feed on the most nutritious new young, succulent leaves and rest on the lower part of the leaves. An alternative explanation of this preferential feeding of adult whiteflies on the apical leaves of cassava is that the cuticle of the older leaves is too thick for easy piercing.

The emergence of the adults from their pupal cases takes place in the early morning sunlight. As the insolation rises, the whiteflies become increasingly active as a result of increasing light intensity rather than temperature (Mound, 1961). Adult whiteflies fly away from the host plant during the morning so that there is an apparent reduction in the number of adults on the plant by noon.

A strong attraction of the whiteflies to yellow paint has been demonstrated by Mound (1961). The sensitivity to the yellow colour by the whitefly seems to be of great importance in host selection, if not in host acceptance. Counts of adult whiteflies on different cassava varieties clearly indicate that plants with yellow petioles attract more insects than those with darker peticoles. Correlated counts of mature pupae also confirmed that cassava plants with yellow peticles carry a population about five times more than plants with reddish petioles (Mound, 1961).

POPULATION STUDIES ON THE VECTOR

Studies on the whitefly population clearly showed that there were marked seasonal fluctuations brought about by climatic and biological factors (Squire, 1960). The number of adult whiteflies has been found to be greatly reduced as a result of heavy rains, but no other direct relationship between weather and population level has been demonstrated. Generally, the level of whitefly population is dependent on the physiological condition of the host plants. The increase in the whitefly population on the onset of the rains, is due to the flushing of the cassava plants while the fluctuation is due to the activities of predators on the larvae, pupae and the adults (Squire, 1961). The population of whiteflies reaches a peak in February and then falls to a minimum (about 5 larvae per plant) in early April. A steady increase (about 24 larvae per plant) in June is followed by another decline. Chant (1958(b)) has shown that there was no correlation between rainfall and the whitefly population. This is not in agreement with the observations of Golding (1936(a)) and Mound (1961). Whitefly Predators and Parasites.

Squire (1961) has shown that the beetle, Serangium cinctum Wse (Coccinellidae) was an effective predator on whitefly larvae and pupae while the redspider mites Typholodromite sp, feed on the adults. They appear in large number in April causing a reduction in whitefly population until about the end of May (Squire, 1960). The wasp, Prospaltella sp. (Encyrtidae), has been found to be parasitic on whiteflies. Studies on the Prospaltella sp. of Bemisia on cassava, tobacco and cotton, showed that, in the field, the incidence was generally as low as 12.3% while in the insectary, once the parasite is established, its incidence on cassava is as high as 40.3% especially in December. The figure is generally lower on tobacco than on cotton and cassava (Squire, 1964).

Control of whiteflies on cassava

Whiteflies on cassava have been successfully controlled by the use of chemicals. Rogor 40 or Fostion ($\frac{1}{10}$ pint in 5 gallons of water) and Endrin have proved effective (Squire, 1960).

Identity of the causal agent of cassava mosaic

Nothing is known yet about the properties of the causal agent because the disease is not considered to be mechanically transmitted by inoculation of plant extracts, despite early claims by Lefevre (1935) and others. Kitajima and Costa (1964) have compared the mosaic infected plants from West Africa and Brazil. The disease differs from the cassava common mosaic found in Brazil, which is caused by a filamentous virus 495 x 15 nm, that is easily sap transmitted and has no known vector (Costa and Kitajima, 1972). The nature of the causal agent of African cassava mosaic disease is unknown. Electron microscopy studies (Murrant et al) revealed that flexuous filamentous particles of no characteristic modal length were found in leaf-dip preparations and exudates of latex from cassava, both from healthy plants and from plants with African cassava mosaic disease. No virus-like spherical, rod-shaped or bacilliform particles were found. These flexuous filamentous particles could probably be the same as those already observed by Plavsic-Banjac and Maramorosch (1973), but obviously are not the causal agent of the mosaic disease. Studies have, however, failed to reveal virus-lime or mycoplasma-like particles that could be the causal agent of African cassava mosaic disease (Murrant et al, 1973)

There are indications that there are several different strains of viruses which produce similar symptoms on cassava. Because of the variations in symptoms in the same cassava varieties, Storey and Nichols (1938(a)) divided the Tanganyinkan mosaic into severe and mild strains. In Nigeria, three distinct kinds of symptoms were found associated with the mosaic complex in the field. These were: mild or severe mottle, distortion and chlorosis; and green mottle. These symptoms were separated experimentally by serial whitefly transfers to disease free clonal material of variety 53101.

The causal agent of cassava mosaic in Nigeria seems to have a low temperature coefficient of inactivation. In East Africa the existence of several strains of the causal agent has been demonstrated (Storey and Nichols, 1938(b)) and a similar situation almost certainly hold in Nigeria where plants of the same clone display varying degrees of chlorosis and distortion of leaves. There is a possibility that some strains or groups of strains may therefore be susceptible to heat treatment than others. Such a difference could explain the persistence of the causal agent in some plants which remained infected after treatment in condition which cured other plants.

Studies on the effect of cassava mosaic on the cassava plant

(a) Effect of the virus on leaf area, yield and net assimilation rate (NAR)

Chant (1958(b)) has shown that cassava mosaic virus significantly reduced the leaf area, total fresh weight, total dry weight, and the yield of the cassava plant. When growing conditions are optimum, there is a highly positive correlation between leaf area and yield (root weight) in healthy plants. But no such correlation has been found in virus-infected plants when symptom expression of the leaves was at its maximum severity. During the dry season, when symptom expression was less marked, there was highly significant positive correlation between leaf area and root weight in both infected and healthy cassava plants. Primary infection of the cassava plant with mosaic virus causes a reduction of about 25 - 30% in the yield of the crop; the magnitude of the reduction varying with the variety, strain of the virus and the environment (Beck and Chant, 1958). The variations in the estimation of reduction in yield may be attributed to such factors as variations in the virulence of the virus strains; variations in the tolerance/resistance of the cassava varieties; and environmental influences on the host, virus and vector.

Infection with the mosaic virus has been shown to reduce the net assimilation rate (NAR) and although NAR decreased with advancing age of the plant, the decrease became proportionally greater in infected compared with the healthy plants (Chant, 1958(b); 1959).

(b) Effect of environmental factors on symptom expression

Shading has been shown to reduce the effect of cassava mosaic virus on the plant. When grown under the shade, only 19.5% of the total leaf area of infected plants was found to be chlorotic in contrast to infected plants grown under normal light intensity where 35.6% of the total leaf area showed symptoms (Chant, 1959).

The effect of nitrogen application on symptom expression of infected cassava plants was difficult to assess.

The variety with the highest percentage of symptomless leaves gave the best yield and greatest leaf area.

The variety with the lowest percentage of symptomless leaves and the highest percentage of leaves displaying crinkle and distortion gave a correspondingly lower yield and leaf area than either of other varieties. These facts tend to confirm the suggestion that a positive correlation exists between the leaf area and yield in cassava.

(c) <u>Effect of cassava mosaic virus on carbohydrate and nitrogen status, respiration rate and moisture content of infected cassava leaf.</u>

Infection with cassava mosaic virus is accompanied by a decrease in total carbohydrate content of cassava leaves. The diurnal fluctuation of total carbohydrate in leaves from mosaic-infected cassava plants is much less than that in comparable leaves from healthy plants (Chant, 1959). From the data available, infection with cassava mosaic virus results in an increased total nitrogen content of the leaves, total carbohydrate: nitrogen ratio and the crude protein content of the leaf (Chant, 1958 (b); 1959; Beck and Chant, 1958).

The respiration rate of infected mature leaves of cassava plants is 20% greater than that of comparable leaves from healthy plants (Chant, 1958(b). This phenomenon seems to be common with virus infection in plants.

The moisture content of mosaic-infected cassava leaves has been shown to be greater than in comparable healthy leaves. Mosaic infection has also been found to reduce the area / fresh weight ratio significantly in the evening. This presumably implies that leaves from plants infected with mosaic virus could be slightly thicker than comparable leaves from healthy plants.

(d) <u>Effect of cassava mosaic virus on the leaf and stem anatomy</u>

Anatomical studies on the effect of the virus on cassava tissue was first carried out by Pascalet (1932). Chant and Beck (1959) Working in Nigeria showed that the palisade tissue in the chlorotic area is undifferentiated. The Chloroplasts are fewer and tend to line the cell wall. The phloem in the midrib of infected leaves is restricted to small bundles and there is absence of starch grains in the parenchyma of infected leaves.

Nevertheless, the anatomical changes in the virus-infected plant are associated with decrease in photosynthetic rates and an increase in respiratory rates that result in an overall net loss in carbonhydrate and in yield (Beck and Chant, 1959).

<u>Differential hosts:</u>

Attempts to find differential hosts for the different isolates, by attempted whitefly transmission to species susceptible to other whitefly transmitted virus diseases, were unsuccessful. Ceara rubber, *Manibot glaziovii*, shows promise as a possible selective host (Robertson and Okusanya, 1967).

Control of Cassava Mosaic

None of the attempted Chemotherapeutic treatment has been sucessful for the control of the virus. Immersion of infected cuttings in warm or hot water failed to inactivate the virus. Heat theraphy (Kunkel, 1936) of the cassava cuttings has been successfully used by Chant (1959a). He showed that casava mosaic virus is inactivated by growing infected cuttings in an incubator at 35 - 39°C for 4 - 6 weeks, but healthy looking plants were susceptible to re-infection with the virus by the vector. Chant's experiments showed that treatments at 39°C gave a greater proportion of healthy plants than treatments at lower temperature, but fewer plants survived at the higher temperature. Young green cuttings direct from the green house could not stand the high temperatures of the incubator for more than 10 days, but similar cuttings taken from plants in the incubator became successfully established in the green house at normal temperature. When young green shoots produced during the heat treatment were removed after treatment and rooted separately, they gave healthy plants although their parent plants developed symptoms after some weeks in the green-house (Chant and Marden, 1958; Chant, 1959b).

With these difficulties in maintaining virus-free plants in the field, attempts were made to breed cassava varieties that are resistant to mosaic and high-yielding. In the Agricultural Development Programme in Nigeria, attempts at improving the cassava crop include breeding for resistance to disease, high yield and acceptability.

Faukner collected about 80 local varieties from various parts of Nigeria in 1932. They were all found to be susceptible to the mosaic virus. West and Beck later obtained seeds or cuttings of cassava reputed to be "resistant" or tolerant to the virus from Ghana, Sierra-Leone, Trinidad, Brazil, Puerto Rico, Bermuda, Kew, India, Natal, Amani, East Africa, Australia, Cameroons, Zaire and Malagasy. It is doubtful whether these were actually resistant. A number of these hybrid lines gave good yield within 12 months, from planting. After this, subsequent cuttings from them sprouted into plants with clear mosaic symptoms. They are, therefore, probably high-yielding mosaic-tolerant hybrids. The most promising ones were GC997^{B}, CH50 and CH128, all from Ghana (Ekandem, 1970) and were later introduced to Umudike farms in 1940.

From 1955 - 1958, about 40,000 clones were produced at Ibadan. The cassava breeding stock were then transferred to Umudike in 1961. Waitt in 1962 started the selections from numerous hybrids of high-yielding varieties. It is from his work that the high-yielding cassava varieties - 60444, 60447, 60506, 53101 and 44086 (sweet cassava) were later recommended to farmers. But, unfortunately, these were susceptible but tolerant to the mosaic virus.

S U M M A R Y

The cassava leaf mosaic was first recorded near Ijebu-Ode, Nigeria in 1926. The whitefly Bemisia nigeriensis Corb is the insect rector of the cassava mosaic. A single whitefly can transmit the disease and transmission, by viruliferous whitefly, to healthy plants can take within 15 minutes after a minimum infection feed of 4 hours. The whitefly population reaches a peak at the onset of the rains and it has been shown that cassava plants with red petioles support a very low population of whiteflies. Whiteflies breed easily on Ceara rubber, cotton, pepper, tobacco. Whiteflies on Cassava are effectively controlled by Rogor 40 and Endrin. The causal agent of cassava mosaic is inactivated by heat-treatment at a temperature between 35 - 39°C for about 42 days. Infection with cassava mosaic caused a reduction in yield (root weight), leaf area, total fresh weight, total dry weight, net assimilation rate of the cassava plant. Infection is also accompanied by a decrease in total carbohydrate content and an increase in nitrogen content, total carbohydrate: nitrogen ratio and crude protein content of the leaf. Shading reduces the effect of cassava mosaic on the plant. Respiration rate and the moisture content of infected leaves are increased. The anatomy of infected tissue is affected. Manihot glaziovii is an alternate host to cassava mosaic. There were no significant differences in the hydrogen cyanide content of peeled tubers from healthy and infected plants. Acquisitions based on M. glaziovii X M. esculenta crosses have given the highest percentage of mosaic resistant types and the highest proportion of resistant lines were derived from the variety 58308.

CONCLUSIONS

Thus far is the progress and set-back on the research on the cassava mosaic virus in Nigeria up to date. A lot of useful information and data have emerged through interrupted and unilateral efforts of research workers over the years. From these, it is clear that no one specialist in his own line could solve the problem posed by the pathogen on the host; this could be achieved only through a combined effort.

There are still numerous problems posed by the virus-complex. These could be elucidated by turning to serology and electron-microscopy to gain further information on the number of viruses or virus strains causing the mosaic disease. This is because the cassava brown streak virus, which is sap-transmissible, causes leaf chlorosis or mosaic on cassava leaves, but has up till now been reported only in East Africa. Such facts will be needed before any meaningful breeding programme for resistance against mosaic virus could be embarked upon.

With the right agronomic and cultural practices, it appears most cassava plants, in all cassava-growing areas, have apparently learnt to live with the virus. The very existence of this important foodcrop could be threatened in the future should in case a more virulent strain develop.

Alagianagalingan, M. N. and Ramakrishnan, K. (1966).
Cassava mosaic in India.
S. Indian Hort., 14, 71.

Beck, B. D. A. and Chant, S. R. (1958). A preliminary investigation on the effect of mosaic virus on Manihot utilissima, Poho. in Nigeria.
Trop. Agric. Trinidad, 35, 59

Braint, A. K. and Johns, R. (1940). Cassava investigations in Zanzibar.
E. Afri Agric. J., 5, 404.

Chant, S. R. (1957). Annual Report of the Agricultural Department, Nigeria, 1955-56 (publ. 1957)

Chant, S. R. (1958r). Studies on the transmission of cassava mosaic virus by Bemisia spp. (Aleyrodidae).
Ann. Appl. Biol., 46, 210.

Chant, S. R. (1958b). Cassava mosaic virus in Nigeria. Ph. D. Thesis, University of Edinburgh, Scotland, U.K.

Chant, S. R. (1959). Ann. Rept. Fed. Dept. of Agric. Res. Ibadan 1957 - 58. Govt. Printer, Lagos. (publ. 1959).

Chant, S. R. (1959 (b)). A note on the inactivation of mosaic virus in cassava (Manihot utilissima Pohl.) by heat treatment. Emp. J. Expt. Agric., 27, 55.

Chant, S. R. and Beck, B. D. A. (1959). The effect of cassava mosaic virus on the anatomy of cassava leaves.
Trop. Agric. Trinidad, 36, 231.

Chant, S. R. and Marden, J. A. (1958). Method for the rapid propagation of vassava cuttings.
Trop. Agric. Trinidad, 35, 195.

Costa, A. S. (1940). Observacoes sobre O Mosaico comum e o mosaico dos nurvuras da mandioca (Manihot utilissima) em agna aquecida a diversas temperaturas.
Rev. Agric., Piracicaba 14, 227.

Costa, A. S. and Kitajima, E. W. (1972). Cassava common mosaic virus.
C. M. I./A. A. B. Descriptions of Plant Viruses, 90, 4 pp

Cotterell, G. S. (1956). Annual Report of the Agricultural Department, Nigeria. 1956-57.

Dade, H. A. (1930). Cassava mosaic.
Gold Coast Dept. of Agric. Year Book 1930 (Bull.23), 245. (publ. 1931).

Deighton, F. C. (1926). Mycological Section. Issued with Ann. Rept. Lands and Forests Dept. Sierra-Leone, for the year 1926. (publ. 1927).

Ekandem, M. J. and Waitt, A. W. (1964). A method for scoring the leaf symptoms of cassava mosaic virus disease.
Tech. Memo. Fed. Dept. Agric. Res. Moor Plantation, Ibadan No. 62.

Golding, F. D. (1936(a)) . Bemisia nigeriensis corb, a vector of cassava mosaic in Southern Nigeria.
Trop. Agric., 13, 182

Golding, F. D. (1936(b)). Cassava mosaic in Southern Nigeria.
Eleventh Bull. Agric. Dept., Nigeria, 1.

Jennings, D. L. (1970). A cassava mosaic in East Africa.
Proc. 2nd Int. Symp. Trop. Root and Tuber Crops, 1, 64.

Kitajima, E. W. and Costa, A. S. (1964). Elongated particles found associated with cassava brown streak.
E. Afr. Agric. For. J., 30, 28

Kufferath, H. and Chesquiere, J. (1932). La mosaique du manioc.
Comptes rendus - Soc. de Biol., CIX, 1146

Kunkel, L. O. (1936). Heat treatments on the cure of yellows and other virus diseases of peach.
Phytopathology, 26, 806

Lefevre, P. (1935). Quelques considerations sar la Mosaique du Manioc.
Bull. Agric. Congo Belge, XXVI, 442.

Mound, L. A. (1961). Ann. Rept. of Fed. Dept. of Agric. Res. Ibadan. 1959-60 Govt. Printers, Lagos. (publ. 1961).

Muller, H. R. A. (1931). Mosaic disease of cassava. Inst. Voor, Plantenzietkten Bull., 54, 17.

Pascalet, M. (1932). La mosaique ou lepre du Manioc. Agron. Colon., 21, 117

Plavsic-Banjac, B. and Maramorosch, K. (1973). Cassava mosaic virus. Phytopathology (abstract), 63, 206.

Robertson, D. G. and Okusanya, B. A. (1968). Quarterly Rept. Fed. Dept. of Agric. Res. Ibadan. 1967 (publ. 1968)

Squire, F. A. (1957). Annual Report of the Federal Dept. of Agric. Res. Ibadan, Nigeria. 1957-58. Govt. Printer, Lagos.

Squire, F. A. (1960). Ann. Rept. of Fed. Dept. of Agric. Res. Ibadan. 1958-59. Govt. Printers, Lagos. (publ. 1960).

Squire, F. A. (1961). Ann. Rept. Fed. Dept. of Agric. Res. Ibadan. 1959-60. Govt. Printer, Lagos. (publ. 1961).

Squire, F. A. (1964). Ann. Rept. Fed. Dept. of Agric. Res. Ibadan. 1961-62. Govt. Printer, Lagos. (publ. 1964).

Storey, H. H. (1930). Plant Pathologist Report. 2nd Ann. Rept. E. Afr. Agric. Res. Stat., Amani. 1929-30.

Storey, H. H. (1934). Report of the Plant Pathologist. Rep. E. Afr. Agric. Res. Sta. 1934-35 (publ. 1935).

Storey, H. H. and Nichols, R. F. W. (1938 (a)). Studies of the mosaic of cassava.
Ann. Appl. Biol., 25, 790

Storey, H. H. and Nichols, R. F. W. (1938 (b)). A field experiment in the transmission of cassava mosaic.
E. Afr. Agr. J. 3, 446

Tidbary, G. E. (1937). A note on the yield of mosaic-diseased cassava.
E. Afr. Agric. J., 3, 119

Warbury, O. (1894). Die Kuttur pflanzen Usamboras Mitt dtsch. Schutzgab, 7, 131.