Government of the Republic of Trinidad and Tobago

Ministry of Agriculture,Land and Fisheries

Cassava Production

A Farmers' Guide

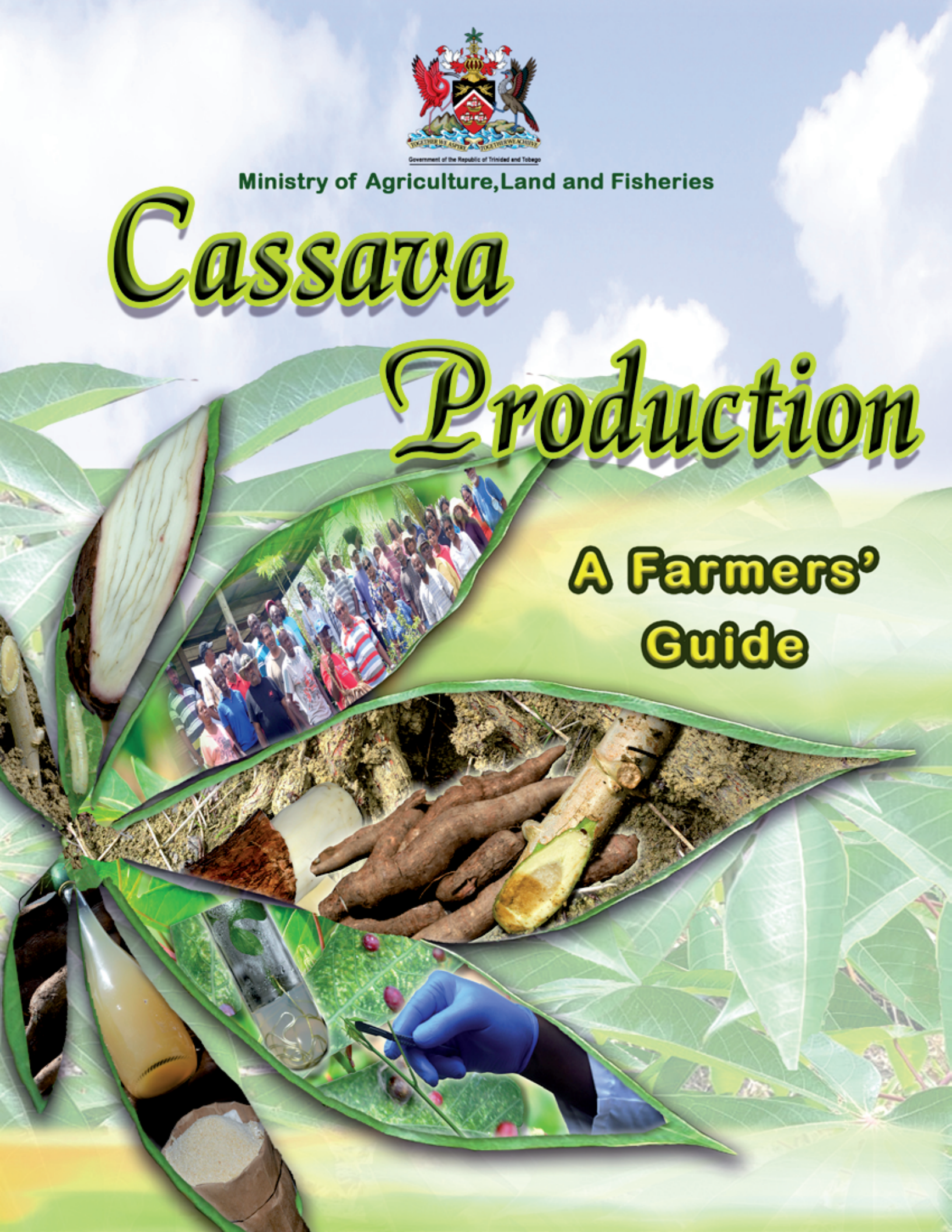

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Table of Contents

List of Figures ii
List of Tables ii
Acknowledgements iii
List of Acronyms iv
Introduction 01
Agronomic Practices for Cassava 02
- *Land Preparation* 03
- *Identifying Varieties of Cassava* 05
- *Selecting a Variety* 06
- *Planting Material* 07
- *Market* 10
- *Planting* 12
- *Fertilising* 14
- *Irrigation* 15
- *Weed Control* 17

Pest and Disease Management of Cassava 19
- *Shoot Fly* 20
- *Thrips* 21
- *Chinch Bug* 22
- *Super Elongation Disease* 23
- *Brown Leaf Spot (BLS)* 24
- *Cassava Bacterial Blight (CBB)* 25
- *Anthracnose* 26

Harvesting of Cassava 27
- *Factors Affecting Ease of Harvest* 27
- *Harvesting Methods*
  a) *Pre-harvest* 28
  b) *Manual Harvesting* 28
  c) *Mechanically - Farmer Modified* 29
- *Mechanical Planters / Harvesters* 29
- *Harvesting Methods* 30
- *Steps for A Good Shelf-life* 31

Post-harvest Treatment of Cassava 32
- *Microbial Damage* 32
- *Physiological Deterioration* 33
- *Moisture Loss* 34
- *Refrigeration* 34
- *Steps to Ensure a Good Shelf-life* 34

Value-Added Cassava Products 35
- *Value-Added Cassava Products* 36
  a) *Fries and Logs* 36
  b) *Chips* 36
  c) *Farine* 36
  d) *Flour* 37
  e) *Cassareep* 37
  f) *Casava Wine* 38
  g) *Cassava (Tapioca) Starch* 38

Varieties of Cassava 39
- *Selling to the Fresh Market* 40
- *Selling to A Processor* 41
- *Producing Cassareep, Wine, Vinegar* 42
- *Prducing Flour and Farine* 42
- *Producing Starch* 43

Cassava Value Chain 44
- *Cassava Value Chain* 44
- *Components of the Cassava Value Chain, Their Needs and The Supporting Bodies* 45

Summary 46
Photo Credits 47
References 48

List of Figures

Figure 1: Annotated drawing of a cassava leaf demonstrating the features used in the identification of varieties..... 05

Figure 2: Diagram showing regime for fertilizer application in the life of the cassava crop..... 14

Figure 3: A graphical representation of the cassava value chain components and their roles and relationships..... 44

List of Tables

Table 1. List of distinguishing characteristics of ten varieties of cassava..... 06

Table 2. Tuber characteristic required for different markets..... 10

Table 3. Comparative chemical content per kg of some cassava varieties (figures are rounded off)..... 11

Table 4. A comparison of chemical component levels in eleven varieties of cassava and the value-added products that are best suited for production..... 39

Table 5. The components of the cassava value chain, their needs and the supporting bodies..... 45

Acknowledgments

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List of Acronyms

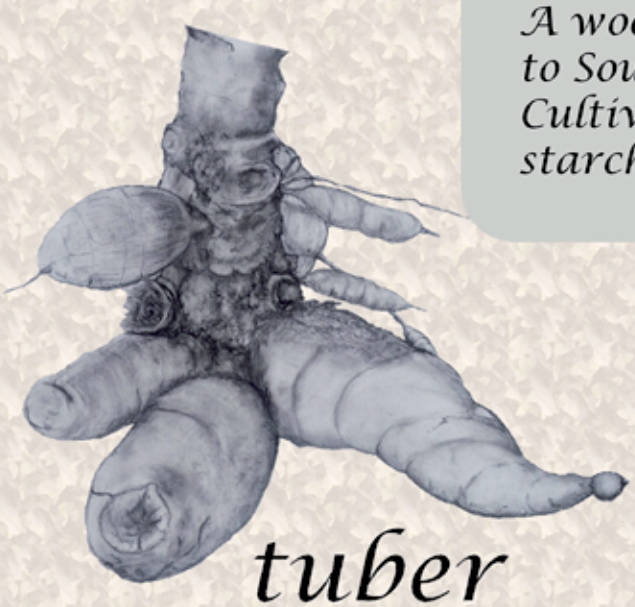
ADB	Agricultural Development Bank
BLS	Brown Leaf Spot
CARDI	Caribbean Agricultural Research and Development Institute
CARIRI	Caribbean Industrial Research Institute
CBB	Cassava Bacterial Blight
CDB	Caribbean Development Bank
CIDMATVD	Cassava Industry Development – Market Assessment and Technology Validation and Dissemination project
ExporTT	National Export Facilitation Organization of Trinidad and Tobago
FAO/UN	Food and Agriculture Organization of the United Nations
MALF	Ministry of Agriculture, Land and Fisheries
NAMDEVCO	National Agricultural Marketing and Development Company Limited
NEDCO	National Entrepreneurial Development Company Limited
UWI	The University of the West Indies
WASA	Water and Sewerage Authority

leaf

fruit

flower

Cassava, yucca, manioc. A woody shrub native to South America. Cultivated for its edible starchy tubers.



tuber

Manihot esculenta

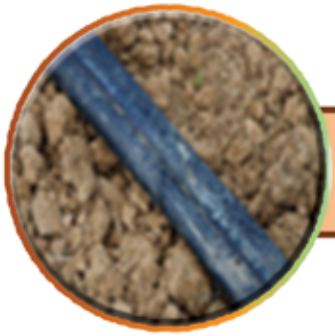
Introduction

This manual is being written for the commercial cassava producer who wants to stream line production to better meet market demand and to optimise profits. It is also intended to be a resource for frontline extension officers who advise farmers, as they require detailed technical information on varieties, agronomy, post-harvest treatments and processing.

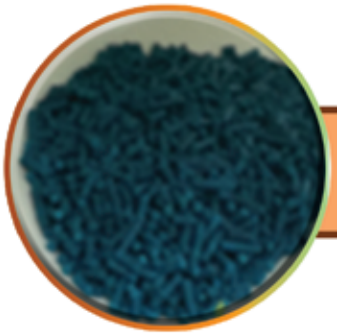
Most of the information comes from a project initiated in 2016 by the Food and Agricultural Organisation of the United Nations (FAO/UN) in collaboration with the Ministry of Agriculture Land and Fisheries (MALF), and Funded by the Caribbean Development Bank (CBD) called "The Cassava Industry Development Market Assessment and Technology Validation and Dissemination "(CIDMATVD). The project was designed to assess the markets for cassava, validate existing and new technologies related to cassava production and processing, and, most critically, share this information with the farming community in Trinidad and Tobago. It built on an assessment conducted by the Root Crop Unit of the Research Division of the Ministry of Agriculture from 2010 to 2017 of the agronomic and biochemical characteristics of 11 promising cassava varieties. Three of the varieties, CM 2772-3, MPER 183 and CM 3306-4, along with the most popular local variety MMEX, were used in the Farmer's Field School Initiative that formed a critical part of this project. Extension Officers in MALF and The Tobago House of Assembly Department of Agriculture were trained by Staff of the Extension Training and Information Services Division of MALF in the logistics and techniques of conducting a Farmer's Field School. These front line officers were then able to use this training to guide three groups of farmers, one in Couva, another in Penal and a third in Louis D'Or in the Cassava Field Schools.

It is no secret that Trinidad and Tobago imports most of the food it consumes. In fact the food import bill for 2019 was $5,670,000,000.00 US dollars, 1 billion of which was spent on calorie dense cereals, most of which can be replaced by locally grown starches like cassava. It must be noted that cassava products cannot simply be substituted for wheat flour in most recipes so there will need to be a comprehensive programme to encourage householders to use the locally grown cassava in place of the imported wheat and potatoes. As a country T&T can definitely grow enough cassava to support the caloric needs of its population of 1.4 million. In fact with 100 grams of cassava providing 129 kcal, less than 18,000 hectares of land can grow enough cassava to provide 100% of the caloric requirements of the population for one year. Since cassava will not be the only food in a diet it is more realistic to project 10,000 hectares per year to provide the bulk of starches for the population. Arable land in Trinidad and Tobago comes in at 25,000 hectares in 2016 so availability of land will not be a limiting factor.
It is the aim of this publication to use the information gathered from the CIDMATVD to provide a comprehensive practical guide to farmers who wish to take advantage of the opportunity to move cassava production out of an ad hoc, subsistence level enterprise and into the realm of commodity that can replace imports and genuinely feed a nation.

Agronomic Practices
For Cassava



LAND PREPARATION



VARIETY SELECTION

PLANTING

FERTILISING

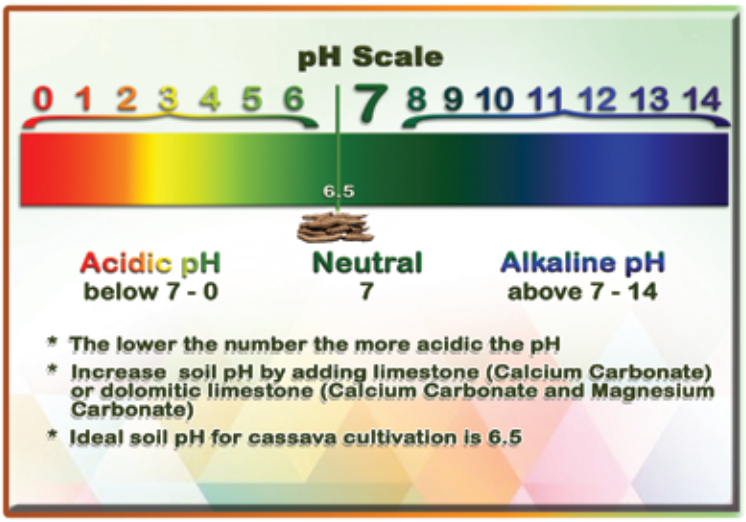
IRRIGATING

Land Preparation

The first step in land preparation is getting a soil test done. The soil test tells you the soil pH and the nutrients present in the soil. The soil pH is most essential since the plants' capability to use fertilisers and to withstand disease attacks are influenced by soil pH.

The soil pH is a measure of how acidic or alkaline the soil is. The scale goes from 0 to 14; 7 is neutral pH where soil is neither acid nor alkaline. Above 7 going to 14 soil is alkaline and below 7 going to 0 soil is acidic. The more acidic a soil is the lower the pH; the more alkaline a soil is the higher the pH.

If a soil is too acidic or too alkaline, plant nutrients cannot be taken up by the plants despite being present in the soil. Soils in Trinidad and Tobago tend to be acidic and in some cases highly acidic, which encourages the growth of some micro-organisms, increasing the risk of disease. Under acidic conditions, levels of aluminum in the soil can become toxic which hinders root development and eventually yield. The ideal pH for cassava cultivation is 6.5, if the soil is too acid, it can be corrected by applying limestone.



pH scale

Applying limestone

If the soil test reveals an acidic soil, a recommendation will be made of the amount of limestone in tons per hectare needed to increase the pH. This will usually be added when the land is being prepared.

The soil test will also give the nutrient profile of the soil which will guide fertiliser application.

The land must be cleared of any vegetation prior to ploughing; the methods used will depend on the type of vegetation. Trees have to be cut and the roots dug out, grass can be cut, or sprayed with a weedicide. Once the overlying vegetation is cleared the land is ploughed, and rotovated. At rotovation limestone and some Phosphorus Fertiliser may be added to the soil.

Ploughed field

Ridges and furrows may be formed after rotovation. Some farmers may prefer to plant on cambered beds rather than form ridges however, harvesting the tubers is a lot easier if the cassava is planted on ridges especially if the soil is a clay. If the crop is to be planted and harvested with a mechanized planter/harvester, the field should be flat with a gradient of no more than seven degrees.

Cassava planted on ridges and furrows

Identifying Varieties of Cassava

After land preparation' it is time to choose a variety to plant, however, it can be difficult to tell one variety from another. Sometimes even the seller of the planting material is unsure of the characteristics of each variety and consequently which variety he/she is offering for sale. The situation is exacerbated if the farmer has several varieties planted on the farm. The graphic below shows the identifying traits that are used to tell one variety from one another without the need for genetic analysis (Figure 1).

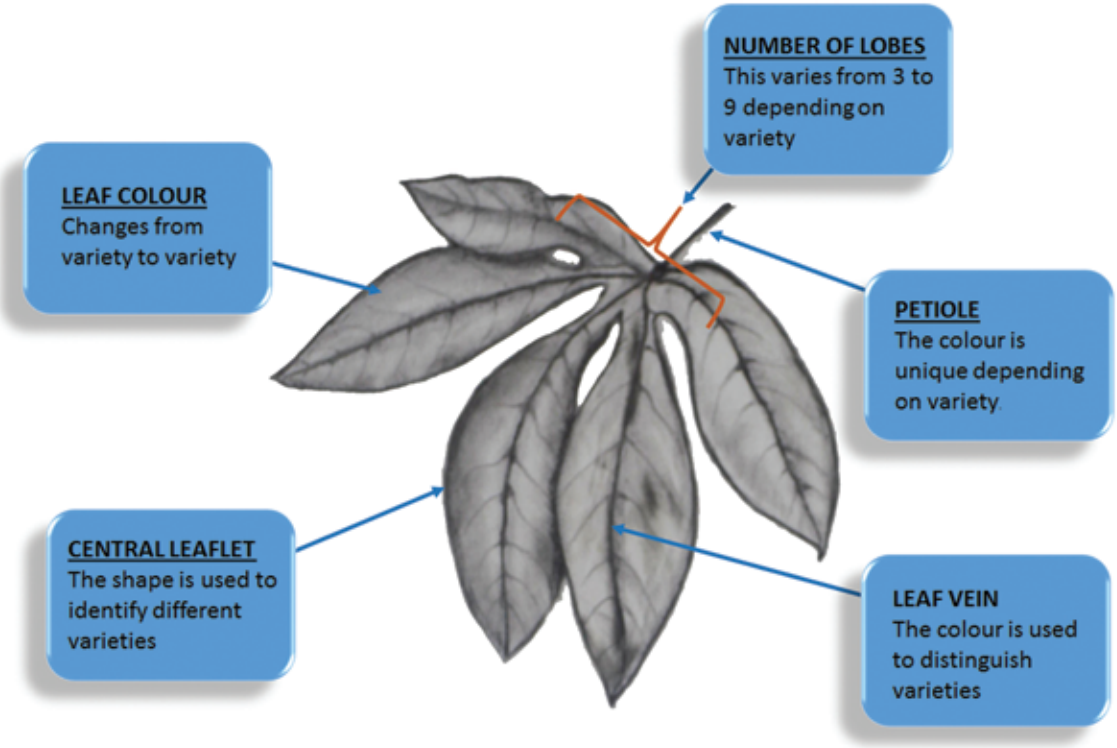
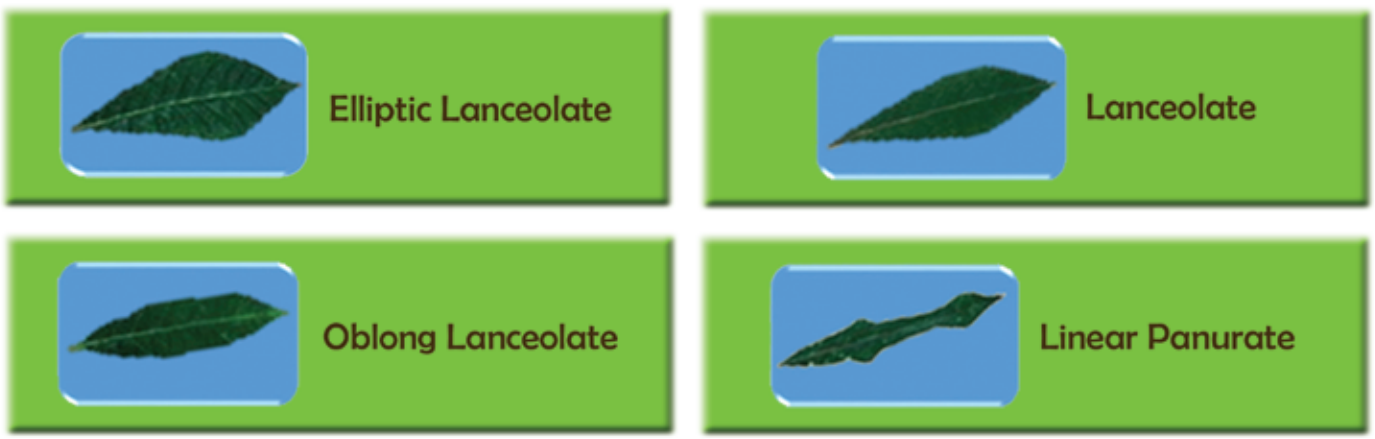


Figure 1. Annotated drawing of a cassava leaf demonstrating the features used in the identification of varieties.

Shape of the Central Leaflet Used to Identify Varieties



Selecting A Variety

The most important consideration in selecting a variety of cassava after is market demand since a commercial producer has to be able to sell he/she crop. Once the farmer knows which variety he/she wants to produce he/she needs to be able to tell different varieties from each other based on physical appearance to ensure he/she is getting the planting material he/she wants (Table 1).

Table 1. List of distinguishing characteristics of ten varieties of cassava.

VARIETY	SHAPE OF CENTRAL LEAFLET	PETIOLE COLOUR	LEAF COLOUR	NO. OF LEAFLET	COLOUR OF VEIN
CM 6119-5	Oblong-Lanceolate	Red	Dark-green	7	Green
CM 523-7	Lanceolate	Reddish-green	Dark-green	7	Reddish-green in less than half of the lobe
CM 3306-4	Oblong-Lanceolate	Greenish-red	Dark-green	7	Green
CG 1450-4	Lanceolate	Yellowish-green	Light-green	7	Green
BRA 383	Linear pandurate	Purple	Dark-green	7	Green
CM 2766-5	Lanceolate	Greenish-red	Dark-green	7	Green
MPER 183	Elliptic-lanceolate	Red	Dark-green	7	Green
CM 2772-3	Lanceolate	Greenish-red	Dark-green	7	Green
MCOL 1505	Lanceolate	Yellowish-green	Dark-green	7	Green
HMC 1	Lanceolate	Red	Dark-green	7	Reddish-green in more than half of the lobe

Source: *Root Crop Unit, Research Division, Ministry of Agriculture, Land and Fisheries, GORTT*

Planting Material

Types of planting material

There are four choices of planting material that can be used: Setts, one leaf – one bud, apical tips and tissue culture products. The cassava plant can also produce seeds which are mainly used by breeders when producing new varieties.

Setts

Setts are pieces of cassava stems approximately 30 cm long with 9 - 12 nodes that are planted in the field to produce new plants. They are harvested from the mid portion of vigorously growing plants 8 - 15 months old. It is important that setts come from plants that are free from pests and disease lest the problems are transferred to the new crop.

If there is a need for multiplication of the planting material, setts can be in the form of 2, 4 or 6 node pieces to produce new plants.
They are overwhelmingly the most common source of planting material for farmers and require no intervention from anyone else.

30 cm sett

ADVANTAGES	DISADVANTAGES
✓ Easy to obtain and ✓ Fastest way to move from planting	✓ Disease and pests can be spread. ✓ No guarantee that it is preferred variety. ✓ Over time there is genetic dilution of the preferred characteristics. ✓ Availability of setts is not consistent. Farmers only have for sale or for use after harvest and this mitigates against crop rotation.

One Leaf-One Bud and Apical Tips

The use of the one leaf - one bud and the apical tips are considered bulk multiplication methods because many plants can be produced from one parent plant. Theoretically each leaf and tip can produce a new plant.

A plug of stem tissue (bud) is cut off along with the attached leaf. This is initially sprouted in water before being planted in potting mix in propagating containers and cared for in a nursery shed.

A new plant sprouts from the leaf base; it is allowed to grow for 2 - 3 months and then hardened off and planted in the field.

The apical tip approximately 5 mm in length is cut off and planted directly in potting mix. Put in a nursery shed allowed to grow for 2 - 3 months before being hardened and transplanted.

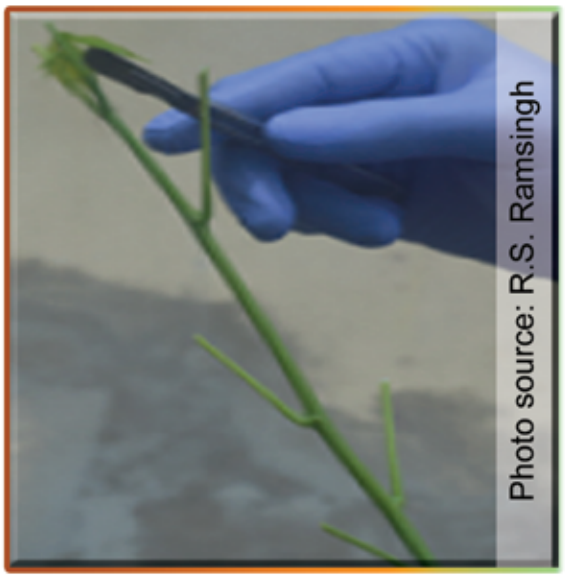
'One leaf - one bud'

ADVANTAGES	DISADVANTAGES
✓ Reduced risk of spreading pests and diseases	✓ Takes about 3 months longer than using a 30 cm sett
✓ Allows more rapid introduction of new varieties to farmers	✓ More resources are need
	✓ Over time there is genetic dilution of the preferred characteristics

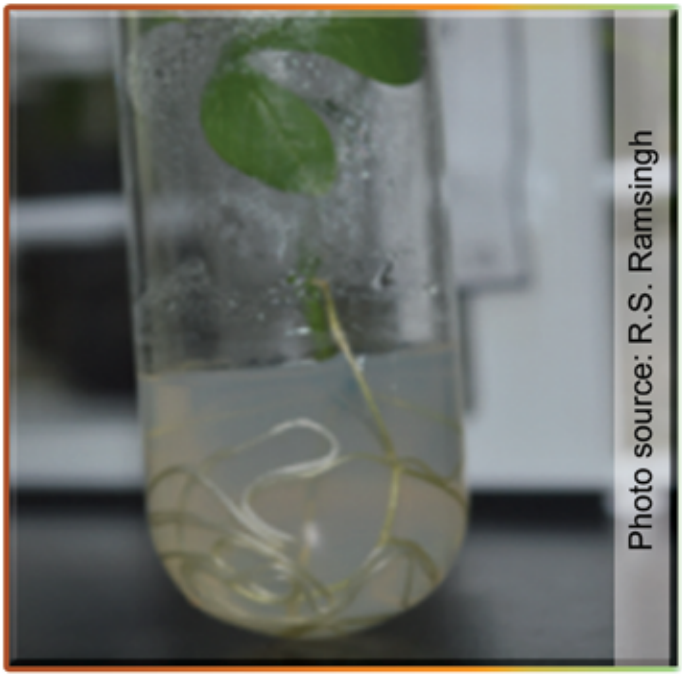
Tissue Culture

This is the most sophisticated method of obtaining planting material. It requires high inputs of materials, equipment, training and skill. However, it is a method that can supply unlimited planting material year round.

Cuttings are selected from plants leaves and the shoots are removed. The cutings are heat treated for a few weeks to destroy pathogens. New shoots will sprout and apical tips are selected and grown in test tubes containing a special medium to produce plantlets.



Removing shoots



Tissue culture

These plantlets are then transferred to a series of new test tubes containing specially formulated media before being hardened and planted in the field.

The time from selection of the cuttings to planting in the field, can be up to five months. This is a very productive bulk multiplication method as each plantlet when grown to a certain size can then be used to produce even more plantlets.

ADVANTAGES	DISADVANTAGES
✓ Pest and disease free	✓ Needs skilled personnel to produce
✓ Genetically identical to parent	✓ Needs specialised equipment and resources
✓ Year round supply of planting material	✓ Takes a long time to produce material that is ready for the field.
	✓ Labour intensive since plantlets have to be very closely monitored especially during the hardening stage.

Market

The cassava farmer needs to consider the market when choosing a variety to plant. Different markets require tubers with specific characteristics (Table 2). Processing of cassava tubers is also undertaken to develop a range of value-added products.

Market vendor weighing cassava for sale

Table 2. Tuber characteristic required for different markets.

Markets	Tuber Characteristics
Municipal	• Slender Tuber • Shelf life of about one week • Good keeping quality in the field since the volume demanded by these markets is not always high
Wholesale	• Slender Tuber • Shelf life of about one week • The keeping quality in the field is not as critical since the wholesale market can accept large volumes
Export	• Excellent shelf life since it may have to last upwards of two weeks before it gets to the consumer. Some initial processing may be needed to achieve this. • Size of tuber desired will vary depending on destination

Food Processing Market

Processing cassava for sale

A cassava farmer may also sell directly to a food processor. The tubers can then be transformed into a variety of products to be re-sold to consumers. Choice of a particular variety of cassava for planting is also influenced by the preferred characteristics of the variety and the intended end product of the processor. Generally, the processor may require large tubers with high protein, sugar or starch content. The range of characteristics seen in locally available varieties of cassava are given in Table 3.

Table 3. Comparative chemical content per kg of some cassava varieties (figures are rounded off).

VARIETY	CARBOHYDRATE g/Kg DB	PROTEIN g/Kg DB	TOTAL SUGAR g/Kg DB	STARCH		
				TOTAL STARCH g/Kg DB	% AMYLOSE	% AMYLOECTIN
CM6119-5	839	31	53	775	31	69
CM 523-7	856	8	30	822	35	65
MCOL 2215	850	29	34	806	35	65
CM 3306-4	850	10	32	804	37	63
CG 1450-4	848	18	13	826	31	69
MBRA 383	848	19	48	798	37	63
CM 2776-5	897	4	10	874	35	65
MPER 183	842	8	14	812	41	59
CM 277203	821	18	57	751	36	64
MCOL 1505	881	6	40	829	42	58
HMC 1	838	22	20	811	38	62
MMEX	868	4	30	831	33	67
CIAT	828	20	11	808	53	47
MCOL 22	876	16	33	835	39	61
YUCA	858	17	18	823	39	61
BLACK STICK	863	14	16	839	67	33

Source: *Research Division, Ministry of Agriculture, Land and Fisheries, GORTT*

Planting

Once the variety has been decided and planting material obtained, it is time to plant the crop.

Cassava is generally planted on ridges that are 100 cm apart.
The plants are established 50 cm – 90 cm apart within the rows.

Plant spacing in the field

The type of planting material determines how the cassava is planted. 30 cm setts are treated with a fungicide and then an insecticide prior to planting. They are planted slanted on the ridges or beds with most of the sett buried and only 2 - 3 nodes exposed.

Setts planted at a slant with 2 nodes exposed

One leaf - one bud planting material would have been established in cups so they would be transplanted into the field. Tissue culture products would also have been established in cups and hardened before being transplanted.

Plants hardening in cups

Mechanical planters usually lay the setts flat and cover the entire piece.

Mechanical planter

Fertilising

There are two fertiliser regimes that can be used to fertilise cassava crops. The first regime uses Calcium Nitrate to supply Nitrogen, Muriate of Potash to supply Potassium and Triple Super Phosphate to supply Phosphorus.

The entire requirement for Phosphorus (25 - 37 kg/ha) can be applied at land preparation stage and ploughed into the soil. This can be done since Phosphorus is immobile in the soil, that is, it does not easily leach out of the soil.

Nitrogen is applied at a rate of 114 - 209 kg/ha and Potassium at 240 - 335 kg/ha. The two can be mixed initially and then a portion can be applied at 6 weeks after planting and the remainder at 16 weeks. If Phosphorus was not applied at land preparation it will also be mixed with the other fertilisers and applied together with them (Figure 2).

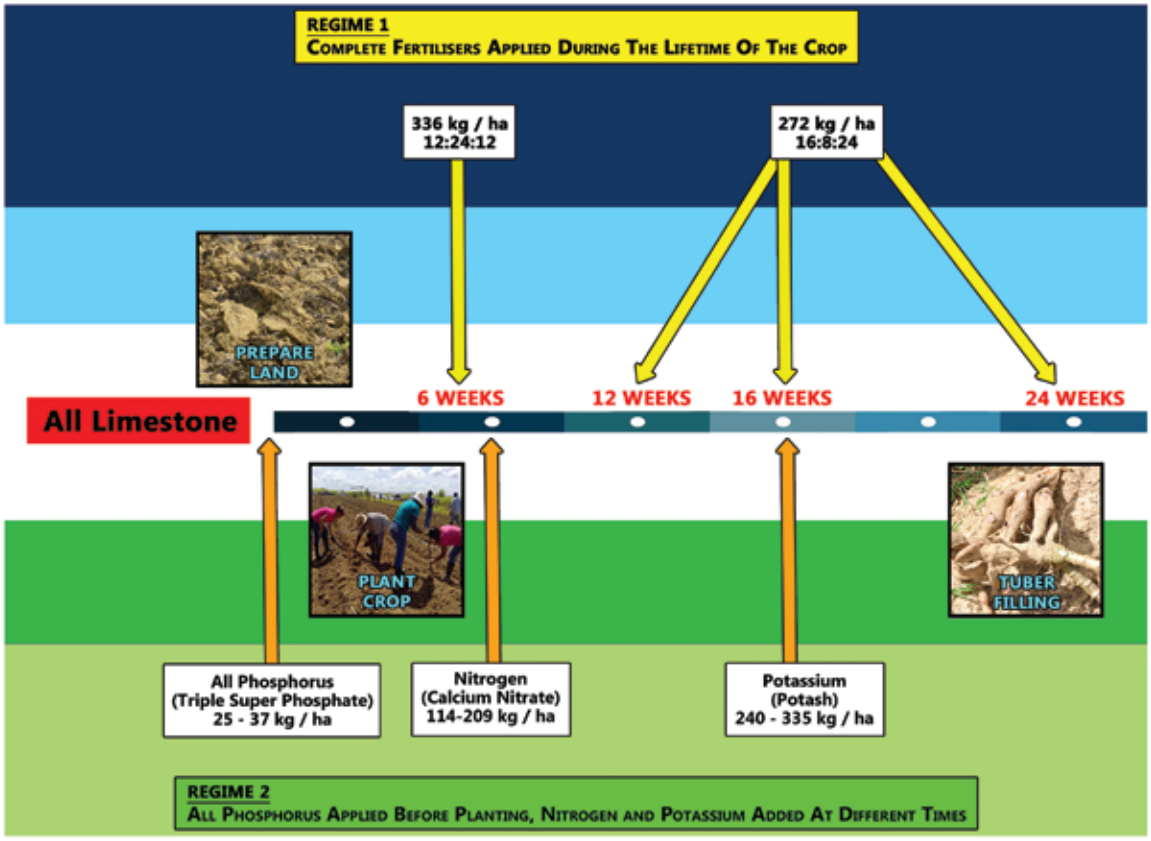


Figure 2. **Diagram showing regime for fertilizer application in the life of the cassava crop.**

The second regime for fertilising cassava recommends the use of two complete fertilisers: 12:24:12 and 16:8:24.

12:24:12 is applied 6 weeks after planting at a rate of 336 kg/ha and at 16 weeks after planting 272 kg/ha of 16:8:24 is applied.

The farmer can split the application of 16:8:24 in two and apply half at 12 weeks after planting and the other half at 24 weeks after planting.

Irrigation

Cassava requires 1000 - 2000 mm of rainfall evenly distributed over the lifetime of the crop. This is the equivalent of 10 million litres - 20 million litres of water per hectare of cassava, for the lifetime of the crop. Generally, for a successful crop the water should be supplied as evenly as possible throughout the entire life of the crop, since erratic watering can cause cracking in the tubers. Despite its need for water, cassava cannot tolerate flooding which causes the tubers to rot. For irrigation, a pond that is 30 m by 30 m by 15 m deep would have the required capacity of 10,000 m^3 for every hectare of cassava that is planted.

Pond used for irrigation of cassava crop.

Cassava can be quite forgiving of drought conditions and will still produce, however, the full potential of the crop will not be reached. The most critical need for water is in the first three months after planting when the majority of root development takes place. If insufficient roots are produced at this stage, then yield will be adversely affected.

Water can be supplied by rain; if it is a rain fed system, timing of planting becomes important. The field should be planted when the crop is sure to receive water for the first three months of life. Rain fed systems are usually planted at the start of the rains in June/July. A further advantage of planting at the start of the rainy season means is that varieties will be ready for harvest in the middle of the dry season when there is little risk of floods destroying the mature tubers.

Cassava can also be irrigated and water can be applied as drip, overhead or fountain tubing. Due to cassava's canopy, drip or fountain tubing are the recommended methods.

Irrigation of cassava fields using fountain tubing (at left) and drip line (at right).

Weed Control

Cassava is most vulnerable to weeds in the first three months after planting when the crop is being established.

Weeds compete with plants for nutrients, increasing the need for fertilisers and sending up the cost of production.

They increase humidity in the field which exacerbates disease symptoms.

Thorny weeds can be a nuisance in the field especially when the farmer has to move through the field, conducting AESAs or applying inputs.

Plant pests like the cassava shoot fly and thrips benefit from weeds in the field as they provide the insects with food and shelter.

Cassava field overgrown by weeds

Weeds can be controlled by weedicides both before and after planting. Physical control by cutlassing or using weed-wackers can be very successful, especially when the cassava plants are tall enough for the operator to move freely underneath.

Stinging weeds

Hand tiller for weed control

Cultivation of the soil around the plants with a hoe or a hand tiller can be a very effective method of weed control however, care must be taken not to damage the developing roots of the cassava plant as this would markedly reduce the useable yield.

Mulching provides several benefits in weed control and pest management. However, local cassava farmers do not have a tradition of mulching their fields.

Not all plants that are growing in the cassava fields are bad and should be destroyed: *Crotalaria sp.* is very useful in cassava fields as it helps manage cassava chinch bugs.

Crotalaria sp.

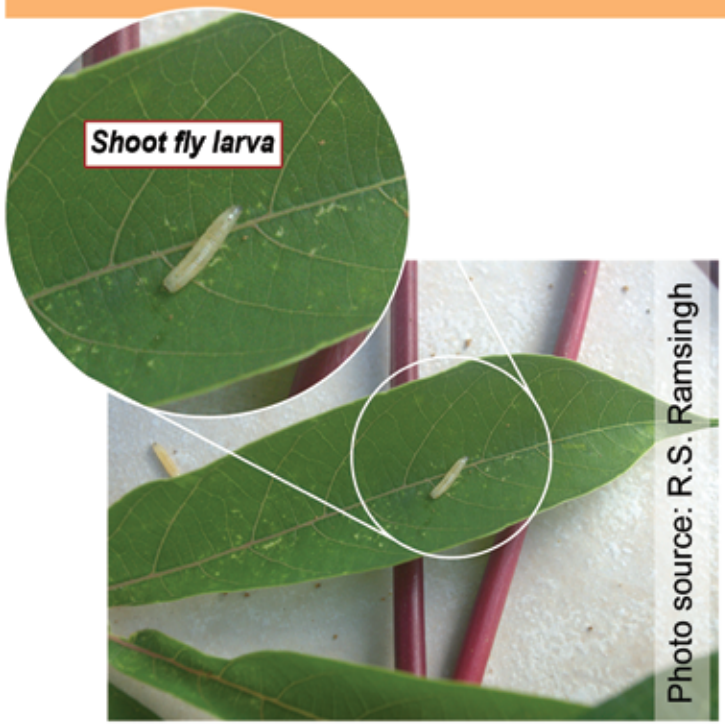
Pest and Disease Mangement of Cassava

Cassava is relatively free of pests and diseases. Few pests attack the crop and even fewer will actually affect the yield. However, there are some pests and diseases that can cause significant losses when present in large numbers.

Shoot Fly

THE PEST *Neosilba pendula & Silba chalybea*

Two flies *Neosilba pendula* and *Silba chalybea* are pests of cassava. They deposit their eggs on the growing points between unexpanded leaves and after hatching, the young larvae tunnel into the stems.



THE DAMAGE

- The newly hatched larvae tunnel into the stem, killing the growing point resulting in a bushy, unwieldy plant.
- Yield is reduced.
- Branches and lateral shoots are thinner and curved.
- Curved stems cannot be used in a mechanical planter.
- Thin stems do not give as vigorous a plant as thicker stems.
- The problem is more prevalent in the dry season.

MANAGEMENT

Cultural

- The adult flies live on weeds so control weeds either chemically, physically or by mulching.

Chemical

- Systemic insecticides control flies.

Thrips Damage

THE PEST *Thysanoptera (Order)*

Thrips are very tiny insects less than 2 mm in length.They possess a pair of fringed wings but are weak fliers, depending mainly on wind currents to move them. Thrips have unique asymmetrical mouthparts and they pupate in the soil.

Photo source: R.S. Ramsingh

THE DAMAGE

- Thrips damage mainly the young leaves.
- They slice open the top cells and suck out the contents causing the characteristic scarring.
- As the damaged leaves grow the scars become more obvious.
- Feeding causes distortion of the leaves.
- Severe infestations can cause leaf drop.

MANAGEMENT

Cultural

- Mulching the soil affects pupation.
- Limit the use of high-nitrogen fertilisers as thrips feed on soft, young growth.
- Yellow and blue sticky traps hung just above the canopy trap the thrips reducing their numbers.

Chemical

- Chemical control of thrips is not recommended.

Chinch Bug

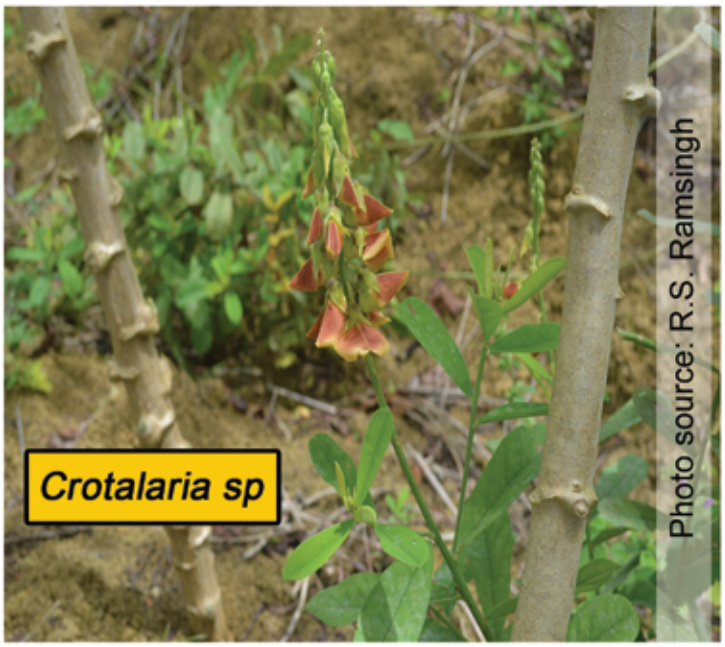
THE PEST *Blissus leucopterus*

This pest is a Hemipteran (true bug), with sucking mouthparts. It is 5 mm long, brown to dark red in colour with white wings and red legs. It lives in the soil but the eggs are laid on the leaves and stems of the cassava.

Damaged tuber

THE DAMAGE

- The adults and nymphs feed on cassava tubers rendering them unmarketable.
- The feeding damage allows the entry of opportunistic pathogens that further degrade the tubers.
- The cassava plant will exhibit symptoms of nutrient deficiency: stunting, yellowing and discoloration.



Crotalaria sp

MANAGEMENT

Cultural

- *Crotalaria sp* is a trap crop for chinch bugs. It can be planted on the perimeter of cassava fields and routinely destroyed to eliminate the chinch bugs.
- Removal of debris from a previous crop reduces sources of infestation.

Chemical

- Soil insecticides can also be used.

Super Elongation Disease

THE CAUSE

Fungus ***Sphaceloma manihoticola***, synonym ***Elsinoë brasilensis.*** This is a very serious disease in cassava.

Photo source: Intechopen

THE DAMAGE

- The first symptom is dark spots on leaves, stems and petioles.
- Spots coalesce, eventually killing leaves, leading to severe defoliation.
- In actively growing plants, there is an exaggerated internode causing weak stems that die back.
- Yield is severely affected.
- If infected planting material is used, subsequent crops will succumb to the disease.

MANAGEMENT

Cultural

- Use disease free planting material.
- Practise field sanitation where the debris from a previous crop is removed.
- Debris can also be burned.

Chemical

- Planting material should be treated with a broad spectrum fungicide.

Brown Leaf Spot (BLS)

THE CAUSE

Fungus ***Mycosphaerella henningsii.***

Photo source: Vikaspedia

THE DAMAGE

- The disease appears as small brown spots with dark borders on the upper leaf surface.
- The brown spots form between leaf veins, so their size and shape are limited by the veins.
- The centre of the brown spots may fall out leaving a hole in the leaf.
- This disease can greatly reduce yields.
- The fungus lives in diseased cassava leaves on the plant or those that have fallen on the ground. It spreads to new leaves and plants by wind or rain splash.

MANAGEMENT

Cultural

- Use planting material that is free of BLS.
- Field sanitation is very important; all infected plants and plant parts must be removed from the field and burnt.

Chemical

- Soak the planting material in a fungicide solution before planting.

Cassava Bacterial Blight (CBB)

Photo source: R.S. Ramsingh

THE CAUSE

Bacteria ***Xanthamonas axonopodis pv manihotis***

THE DAMAGE

- The infection starts off with angular dark spots on leaves, restricted by the leaf veins accompanied by a creamy exudate from the petioles and young stems.
- The leaf spots expand, merge and form large rots.
- The bacteria blocks the stem causing the leaves to wilt.
- The apical meristem also blackens and die leading to the development of a short, bushy plant with the dead, blackened stems thrusting up; this gives the plant a candlestick appearance very characteristic of this disease.

MANAGEMENT

Cultural

- The bacteria is spread by cuttings, so the first and most important practice is to take cuttings from healthy plantations.
- Do not plant new fields next to old, diseased fields since the bacteria can be spread by wind and water.
- If a field comes down with CBB, it should be rotated out of cassava for 1-2 years since the bacteria can remain on the surface of weeds and in insect faeces.
- The bacteria remains on tools so clean with bleach after each use.
- Practise field sanitation: plant debris should be burnt after harvest.
- Use tolerant varieties.

Chemical

- There are no chemicals recommended for the control of cassava bacterial blight.

Anthracnose

THE CAUSE

Fungus
Collectotrichum gloesporides


Photo source: PlantVillage

THE DAMAGE

- The disease starts off as lesions on the stems and leaf petioles.
- Eventually, the affected leaves wilt, droop and die.
- Dead leaves fall off the plants, causing defoliation and a dramatic reduction in food produced.
- Shoots die and other soft parts of the plant are also affected, usually becoming distorted.
- Cankers may develop on the older, lignified stems causing cracking that exposes internal tissues.
- Fungal spores are spread from diseased plants to healthy plants by wind and water.

MANAGEMENT

Cultural

- Use disease free sticks.
- Field sanitation is imperative, as the fungus can survive in the crop debris.
- All of the remains of the previous crop must be removed and burnt.
- *Collectotrichum gloesporides* also infects many other plants such as peppers, bananas and papaya; if rotating cassava with any susceptible crop, care must be taken to remove the crop residues before beginning land preparation for the cassava crop.

Chemical

- A fungicide dip for the setts prior to planting may provide some protection against anthracnose in the crop.

Harvesting of Cassava

Cassava is a highly perishable crop, in fact within four days of harvest, tubers would have deteriorated to the extent that they are no longer fit for human consumption. The inherent short shelf life is further reduced if the tubers are damaged during harvest. There are several factors that affect how easily cassava is harvested.

FACTORS AFFECTING EASE OF HARVEST

SOIL TYPE

- Soil type affects harvesting
- Easier on sands, loams;
- Difficult on clays

LAND PREPARATION

- Properly prepared soil makes harvesting easier
- Plough and rotovate soil
- Form ridges and furrows for manual harvesting

SOIL MOISTURE

- Harvesting can be affected by soil moisture
- Harvesting is easier on sand and loam if they are moist
- Clay soils are hard when dry and sticky when wet making harvesting difficult

METHOD

- The method used affects how easily the crop is harvested
- Manual: 22-51 man hours to harvest a hectare
- Mechanised: 5 hectares harvested in a day

TUBER CONDITION

- Damaged tubers are harder to harvest without breakage
- Tubers damaged by pest and disease
- Tubers cracked due to irregular watering
- Tubers that are weak

Pre-harvest cassava is harvested in one of two ways either manually or mechanically.

Two (2) weeks before the cassava is scheduled to be harvested, the plant should be cut back, leaving only 60 - 90 cm of leafless stem. This practice encourages the conversion of sugars to starch in the tubers, which reduces deterioration of the tubers post-harvest. This is recommended regardless of the method of harvesting.

Manual Harvesting

The soil is loosened around the stem which is used to gently rock the plant back and forth until the tubers can be pulled from the ground. A lever can also be used to enhance the force applied by the farmer.

Loosening tubers

Uprooting the tubers

Mechanical Harvesting

Farmer Modified Tractor

A few innovative farmers have modified their tractors to be used as a planter/harvester. Each modification is unique to the individual farmer.

Mechanical planters/harvesters

These machines are designed to plant and harvest hectares of cassava quickly with minimum damage to the tubers. These machines require flat land and usually cannot handle slopes of greater than 7°. The fields are not prepared with ridges and furrows but usually are flat with drains. The machines are classed based on the number of furrows planted and harvested at a time. There are one furrow, two furrow and four furrow machines. For the Caribbean, the one and two furrow planter/harvester is recommended.

Furrow Harvester

Harvesting Methods

MANUAL

- Slow process; 22-52 man hours to harvest one hectare of cassava.
- Requires physical strength.
- Requires experience; If too much force is applied the tubers can be damaged.
- Allows farmer to harvest only what can be sold.
- Little tuber damage if done properly.

MECHANICAL - COMMERCIAL EQUIPMENT

- Expensive; only justified for large acreages.
- A tractor is needed to power the harvester.
- Designed for flat land.
- Greatly reduced labor requirement.
- Land preparation reduced, there is no need to bank the field as the equipment uses flat land.
- Very fast harvesting.

MECHANICAL - FARMER MODIFIED

- Faster than manual labour.
- Not dependent on limited available labour.
- Modification is expensive, but not as costly as a commercial planter/harvester.

Steps For A Good Shelf Life

Before Harvesting

- 2 weeks before, cut back stems to 60 - 90 cm.
- This will convert sugars in the tubers to starch which protects the harvested tubers from deterioration.

1

Harvest

- Harvest in the early morning.
- Remove tubers carefully by manual or mechanical means.
- Transfer tubers to the shade as soon as possible.

2

Clean and Sort Tubers

- Brush off excess soil from tubers.
- Sort and separate damaged tubers from undamaged ones.
- Wash undamaged tubers in cool water.

3

Store Tubers Appropriately

- Don't damage tubers.
- Pack carefully into crates not bags to prevent damage.
- Do not overfill crates.
- Cover crates with moist material to reduce dehydration.

4

Post-harvest Treatment of Cassava

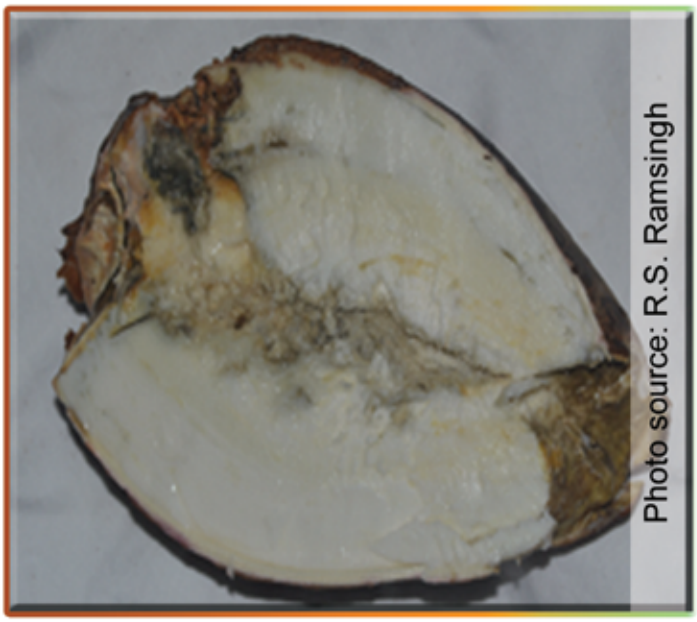
The aim of post-harvest treatment is to get the produce to the consumer in a wholesome condition. This necessitates reducing microbial damage and physiological deterioration of the cassava tubers.

Microbial Damage

Microbial damage reduces the shelf life and market appeal of cassava tubers.

Microbes that live in the soil can enter tubers that are damaged during harvest. Washing the tubers after harvest reduces this risk. Of course, damage by pests such as chinch bugs will also allow microbes to enter and rot the tubers.

Clean tubers can be dipped in a chlorine solution of 100 ppm for 10 minutes. They can also be treated with a fungicide dip, both of which will reduce the risk of microbial deterioration.



Microbial spoilage

Washing tubers

To reduce the loss of harvest due to microbes:

- manage pests while the crop is growing
- do not damage tubers during harvest
- wash tubers as soon as possible after harvest
- treat tubers with chlorine solution
- treat tubers with a fungicide

Physiological Deterioration

The main symptom of physiological deterioration in cassava is vascular streaking.

This is the oxidation of the water and food carrying tissues and occurs when the respiration rate is high, which occurs if the tubers are hot, if the tubers are immature and if the tubers are injured.

When the temperature is high, respiration rate goes up. Unfortunately, the by-products of respiration are carbon dioxide and heat which further increase the respiration rate.

Oxidation of tuber

Immature tubers naturally respire at a higher rate than mature tubers due to the increased permeability of young skin. When tubers are injured, they produce ethylene which also causes vascular streaking, as well as increasing the respiration rate.

Another physiological effect of high respiration is the reduction of starch and hence weight of the tuber. During respiration, starch is converted to sugar which is metabolized to carbon dioxide, water and heat.

To avoid physiological deterioration of the tubers

- harvest them when they are mature,
- keep them cool:
  - harvest in the early morning before field heat builds up
  - put harvested tubers in the shade as soon as possible after harvest
  - wash with cool water
- keep them uninjured:
  - harvest carefully
  - use crates not bags for storage

Crates

Moisture Loss

To keep cassava tubers as long as possible, protect them from moisture loss. Waxing is a common technique used to prevent loss of moisture. After treatment with a fungicide, the cassava is coated in paraffin wax and the wax is allowed to dry. Waxed cassava has a shelf life of 2 months.

Another method is to seal the washed, fungicide treated tubers in a polythene bag within 3 hours of harvest. This creates a modified humid environment which extends the shelf life up to 21 days.

Refrigeration

Cassava is susceptible to chilling injury when stored at low temperatures, which causes a breakdown of tissues and changes in cooking quality and flavor. However cassava responds quite well to storage at 3° C.

Steps to ensure a good shelf life

Post-harvest treatment begins at harvest and continues until the customers buy the tubers.

These are the steps to ensure the best possible shelf life for cassava.

1. **Harvest when tubers are mature.**
2. **Do not damage tubers during harvest.**
3. **Harvest early to avoid field heat.**
4. **Use crates to harvest.**
5. **Shade the tubers from the sun.**
6. **Wash tubers in cool water.**
7. **Soak in a chlorine solution of 100 ppm.**
8. **Treat with a fungicide.**
9. **Coat with wax.**
10. **Put in a modified atmosphere.**

Value-added Cassava Products

Farine

Process:
- grated
- juiced
- rubbed to a fine texture
- salted
- sun dried
- cooked

Uses: porridge, soups, breads

Flour

Process:
- grated
- juiced
- dried
- ground

Uses: pasta, bread, cakes, cookies

Starch

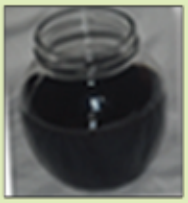
Process:
- blended
- washed repeatedly
- water collected
- water left to settle
- settled starch removed
- dried

Uses: food, laundry

Cassareep

Process:
- grated
- juiced
- cooked
- caramelised

Uses: pepper pot, sauces



Wine

Process:
- grated
- juiced
- cooked
- fermented

Uses:
- drink
- vinegar

Value - added Cassava Products

Cassava lends itself to a multitude of processing techniques leading to a plethora of value-added products. The tubers have a high starch content and homogenous flesh, making them suitable to be frozen, fried, dried, caramelised, baked, ground into flour and fermented.

Fries and Logs

Cassava tubers can be peeled, washed, cut into logs or fries, and frozen. This is perhaps the simplest and one of the most popular ways of adding value to cassava. Several entrepreneurs package and sell cassava logs and cassava fries to groceries and restaurants.

Cassava logs

Chips

Cassava chips

Peeled and washed tubers can be sliced thinly and fried at high temperatures to make cassava chips.

There are several manufacturers and cottage processors in Trinidad and Tobago who make, package and sell cassava chips. The snack is gaining popularity locally.

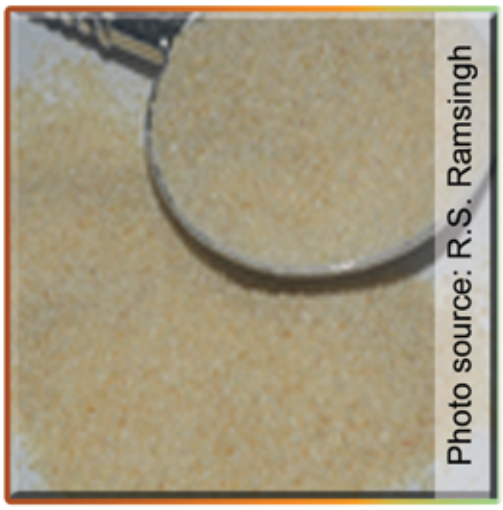
Cassava can be grated and then squeezed to extract the liquid; both the liquid and the meal can be further processed to produce several value-added products.

Farine

The pressed meal is dried in the sun while being frequently turned and rubbed to create a very fine texture. Salt is added during the drying process. When fully dried, it is then parched in a hot, dry pot. Farine is mainly used to make porridge and can be stored for a long time in an air tight container. Produced mainly by cottage level processors.

Farine

Flour



Cassava flour

Cassava bread

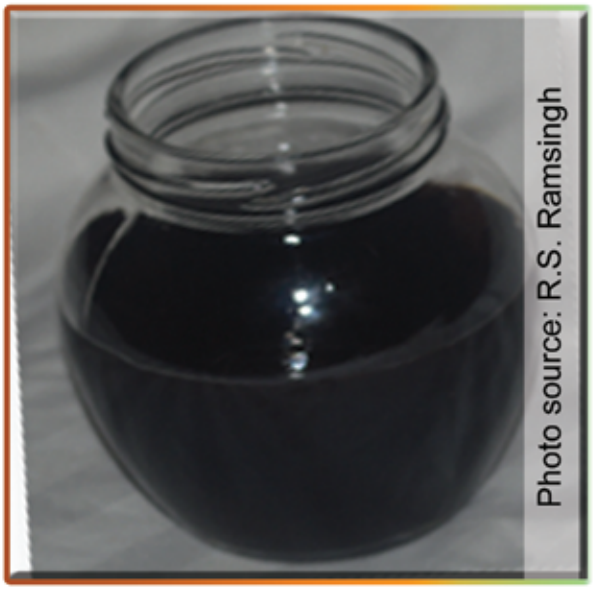
To make cassava flour, the pressed meal is baked at a very low temperature for a few hours and then ground into flour.
Several cottage processors do produce small amounts of local cassava flour for sale in supermarkets, but the market is far from saturated.

Cassava flour does not contain gluten so it can be used by those who suffer from gluten, intolerance. The flour can be used to make a variety of popular products like muffins, roti, bread, pastelles and pasta.

It must be noted that cassava flour cannot usually be simply substituted for wheat flour since their chemical profiles are different, despite a superficial physical resemblance. An entirely new series of recipes will have to be developed and promoted if cassava flour is to replace imported wheat flour in any significant quantity.

Cassareep

Cassareep is a thick, dark-coloured liquid that is used to make Guyanese Pepper pot. It is made by cooking the extracted liquid from the cassava tubers on a low heat until it caramelizes. It is not very common in Trinidad and Tobago, but there is great potential to produce it, especially as a by-product of the production of flour and farine.



Cassareep

Cassava Wine

Cassava wine

The extracted liquid from cassava tubers is cooked until it thickens. Water, sugar and yeast are added to the liquid and it is allowed to ferment until an alcohol content of at least 12.5% is reached. The wine can then be bottled and aged.

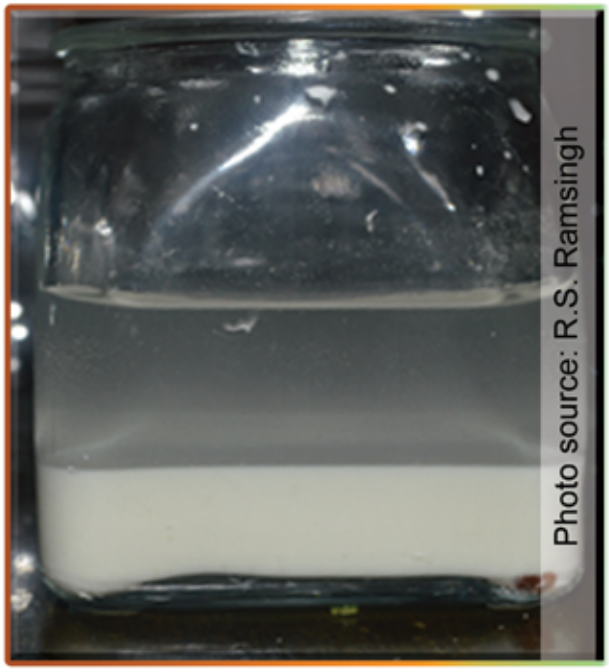
There is a rapidly growing niche market for local wines produced by cottage processors; cassava wine has great potential to fit into this niche.

Cassava wine can be further fermented to produce vinegar which is a completely unexploited product that no one is currently producing and selling.

Cassava (Tapioca) Starch

Most of the value-added commodities are edible or potable, however cassava can also be used to make starch which can be used in the food, textile and manufacturing sectors.

The peeled tubers are blended with water to a fine consistency. It is allowed to settle, water is decanted and the starch dried for further use.



Cassava starch (tapioca)

Varieties of Cassava

Some varieties of cassava are more suitable for particular types of processing than others, due to their chemical composition. Table 4 provides an outline of the attributes of eleven varieties of cassava and the types of end products that can be developed from the respective raw material.

Table 4. A comparison of chemical component levels in eleven varieties of cassava and the value-added products that are best suited for production.

	CM 6119-5	CM 523-7	MCOL 2215	CM 3306-4	CG 1450-4	MBRA 383	CM 2766-5	MPER 183	CM 2772-03	MCOL 1505	HMC 1
											
	Clone	Clone	Clone	Clone	Clone	Clone	Clone	Clone	Clone	Clone	Clone
CARBOHYDRATE g/Kg DB	839	856	850	850	848	848	897	842	821	881	838
PROTEIN g/Kg DB	31	8	29	10	18	19	4	8	18	6	22
TOTAL SUGAR g/Kg DB	53	30	34	32	13	48	10	14	57	40	20
TOTAL STARCH g/Kg DB	775	822	806	804	826	798	874	812	751	829	811
AMYLOSE %	31	35	35	37	31	37	35	41	36	42	38
AMYLOPECTIN %	69	65	65	63	69	63	65	59	64	58	62
MONTHS TO HARVEST	10	8	8	8	8	11	9	11	11	9	10
EFFECTIVE YIELD t/ha	25.56	51.87	37.55	56.25	20.53	39.49	36.35	30.83	25.12	40.14	26.67
DRY MATTER CONTENT %	36	34	36	36	37	35	31	33	30	33	34
PULP COLOUR	Cream	White	White	White	White	White	White	White	Yellow	White	White
NO TUBER	8	7	6	8	9	8	6	4	10	10	7
RECOMMENDATIONS	Highest protein flour	Good for flour	Matures rapidly	Matures rapidly	Best for chips		Best for starch		Best for syrup	Good for flour	
	Good for freezing	Good for freezing	Good for freezing	Highest yield	Best for flour		Best for freezing		Good for wine	Good for farine	
	Good for syrup	Good for farine								High yield	
	Good for wine	High yield									

Varieties of Cassava

Different varieties have different attributes that will make them more suited for one use compared to another. No one variety would have all the desired characteristics, so the producer has to prioritise and choose the ones with the best traits for a particular purpose. The desirable traits are determined by the market for which the cassava is being produced.

a) Selling To The Fresh Market

When selling to the fresh market, the two main considerations are yield and months to harvest.

Fresh market

Yield

Producers who are selling to the fresh markets would consider the yield to be the most important characteristic. There is no value added when sold on the fresh market and the mark up for cassava is quite small, so the producer has to rely on quantity to increase profitability.

Recommended Varieties:

From trials conducted by the Research Division MALF, high yielding varieties were:

- **CM 3306-4 yields of 56 tons per hectare.**
- **CM 523-7 yields of 52 tons per hectare.**

In comparison the popular MMEX yields approximately 33 tons per hectare.

Months to Harvest

In addition to how much the variety yields, consideration must be given to how quickly a harvest can be reaped, since profitability is increased with turnover.

Recommended Varieties:

There are four varieties that mature within 8 months:

- CM 523-7
- MCOL 2215
- CM 3306-4
- CG 1450-4

Interestingly, the two highest yielders are among the fastest to mature.

Field with cassava varieties

b) Selling To A Processor

The choice of a variety for selling to a processor is dependent upon the processor's intended cassava product development.

Frozen Cassava

The most important attributes that make a cassava variety suitable for freezing are high starch content, low percentage amylase and high percentage amylopectin.

Amylase causes grittiness in frozen cassava which is unacceptable.

Recommended Varieties:

- CM 2776-5 - highest in starch content
  - second highest amylopectin content
  - second lowest in amylase content
- CG 1450-4 - high starch content
  - highest in amylopectin content
  - lowest in amylase content

Frozen cassava

Production of Cassareep, Wine and Vinegar

Cassareep is made when the sugar in the liquid pressed from the grated flesh are cooked until they caramelise. The starting material for these products is the liquid extracted from the grated flesh of the cassava tubers

Cassareep is made when the sugars in the liquid are cooked until they caramelize. Wine is made by adding yeast to ferment the sugar, changing it to alcohol and carbon dioxide. In making cassava wine, the fermenting liquid is usually fortified with additional sugar. Lastly, vinegar is made when bacteria ferment the alcohol to produce acetic acid.

Cassava by-products

Recommended Varieties:

- CM 2772-03 has a sugar content of 57 g per kg
- CM 6119-5 has a sugar content of 53 g per kg

Production of Flour and Farine

Both flour and farine are produced from cassava tubers that have been grated and the liquid squeezed out, leaving the meal to be further processed.

The important characteristic is dry matter content; the less water the tubers have, the highest yield of flour and farine will be obtained from them.

To make farine, the meal is salted and sundried. While being dried, it is frequently turned and rubbed to create a fine texture. Finally, it is roasted in a hot pot before being packaged.

To make flour, the meal is baked at a low temperature for several hours before being ground into flour.

Cassava flour

Recommended Varieties:

- CG 1450-4,
- CM 6119-5,
- CM 523-7

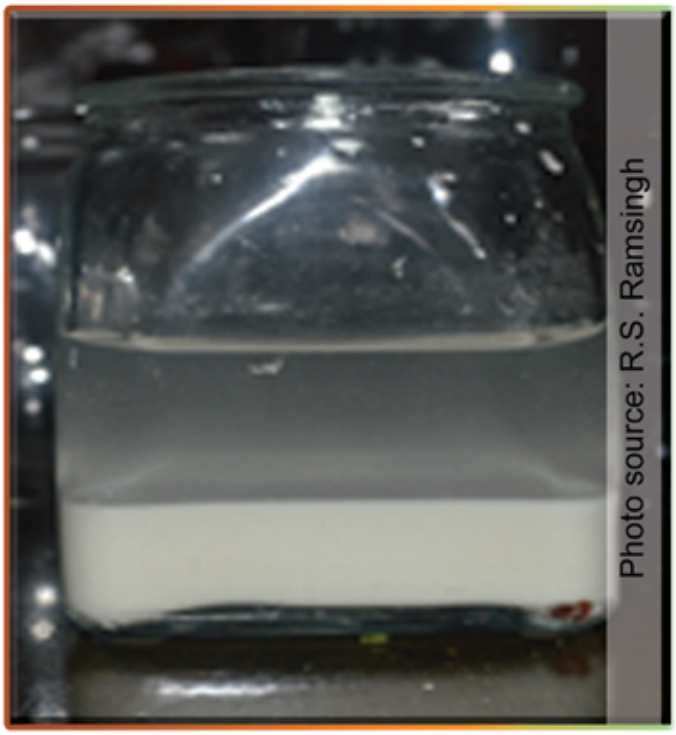
Production of Starch

The variety of cassava selected for starch production must have a high starch content. Unlike freezing however, the percentage amylopectin and amylase are not significant.

Starch is made by blending water and tubers until the tubers are very finely ground. This mixture is allowed to settle, water is decanted and the starch dried and packaged.

Recommended Varieties:

- CM2766-5



Starch

Cassava Value Chain

The cassava industry in Trinidad and Tobago receives financial and non-financial support from both the public and private sectors. These interventions are meaningful to different degrees yet there are still significant gaps that have to be closed (see Table 5). If the needs of the components in the chain are not met consistently, the development of the cassava industry will be hampered. The diagram below shows the various components of the value chain and their roles and relationships (Figure 3).

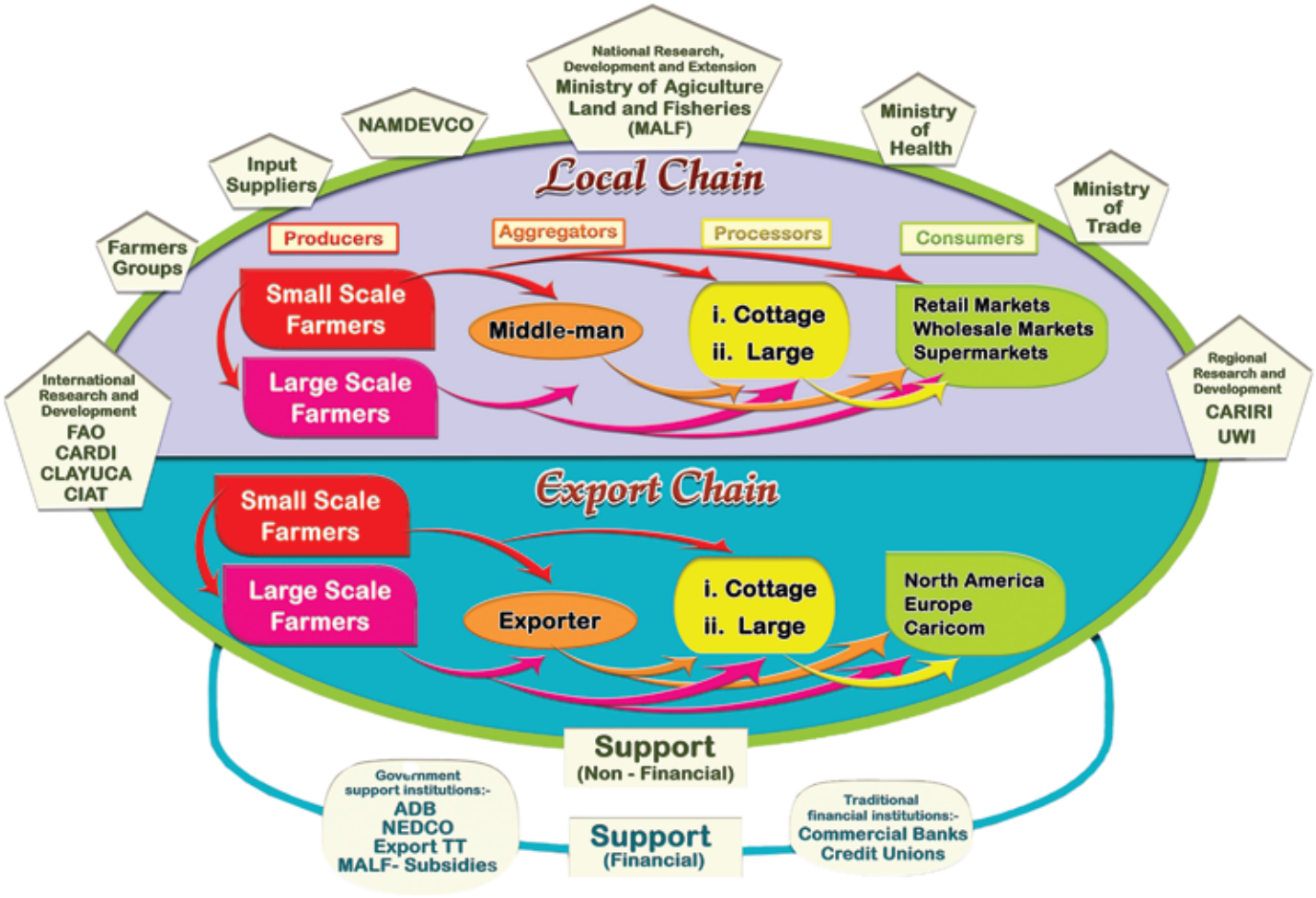


Figure 3. A graphical representation of the cassava value chain components and their roles and relationships.

Table 5. The components of the cassava value chain, their needs and the supporting bodies.

ROLE	NEED	FACILITATING BODY
Producer		
	Consistent supply of high quality planting material of each variety	MALF, Nurseries, Farmers Groups
	Reliable supply of good quality water throughout the cropping cycle	MALF, WASA
	Access Roads	MALF
	Up-to-date information on agronomy, pest and diseases, post-harvest treatment	MALF, UWI, International and Regional Research and Development Institutes
	Protection from Praedial larceny	MALF (Praedial Larceny Squad), Ministry of National Security
	Rapid Soil Testing Facilities	MALF, UWI, CARIRI, Private Labs
	Finances	ADB, Commercial Banks, Credit Unions, MALF (Subsidies)
	Access to markets	MALF, NAMDEVCO
	Labour	Private Sector, Ministry of Labour, Farmers Groups
	Chemical Inputs	Private Sector, Ministry of Health (Pesticide and Toxic Chemicals Board)
	Technological Aids; Apps for Record keeping, Pest and Disease Identification etc	UWI, International and Regional Research and Development Institutes
	Hedge against Natural Disasters	ADB, MALF (Flood Damage payments etc.)
Aggregators		
	Access to producers	MALF, Private Sector
	Access to markets	MALF, NAMDEVCO, NEDCO, Private Sector, Ministry of Trade
	Storage Facilities	MALF, NAMDEVCO, Private Sector
Processors		
	Clearly stated steps to get value added products approved for sale	Ministry of Health (Chemistry Food and Drugs)
	Support in entering new and foreign markets	Ministry of Trade, ExportTT, NEDCO
	Pool of Skilled Labour	MALF, UWI

SUMMARY

1. Decide on Market:-

a. Fresh
   i. Wholesale ii. Retail
b. Processor
c. Export

2. Select Variety

a. Suited to Market

3. Prepare Land

a. Soil Test
b. Clear vegetation
   i. Trees
      1. Cut trees
      2. Dig out roots
   ii. Grass and Shrubs
      1. Spray
      2. Cut
      3. Plough in

c. Plough
d. Rotovate
e. Add Amendments (Limestone) and Fertiliser (optional)
f. Manual Planting/Harvesting
   i. Bank ii. Ridges and Furrow
g. Mechanical
   i. Flat bed ii. Drains

4. Plant

a. Manual
   i. Setts slanted 2 nodes exposed
   ii. Bulk multiplication: All transplanted
      1. Two, four or six node
      2. One leaf - one bud
      3. Apical tips
      4. Tissue Culture

b. Mechanical
   i. Machine plants setts flat

5. Manage Crop

a. Irrigate 1000 mm - 2000 mm (10 - 20 million litres) water for the lifetime of the crop
b. Fertilise
   i. Phosphorus 25 - 37 kg/ha
   ii. Nitrogen 114 - 208 kg/ha
   iii. Potassium 240 - 335 kg/ha
c. Control Weeds
   i. Cultural
   ii. Physical
   iii. Chemical
d. Manage Pests and Diseases

6. Harvest

a. At maturity
b. Cut back plant 2 weeks before harvest
c. Do not damage tubers
d. Early in the day to avoid field heat
e. Manually or Mechanically

7. Post - harvest Management

a. Wash tubers
b. Soak in Chlorine solution 100 ppm
c. Treat with fungicide
d. Wax
e. Seal in plastic to create Modified atmosphere packaging
f. Store at 3° C

8. Develop Value - Added Products

a. Frozen Logs and Fries
b. Farine
c. Flour
d. Starch
e. Cassareep
f. Wine

PHOTO	PAGE	CREDITS
Pest and Disease Mangement in Cassava Chapter		
Chich Bug pest	Pg 22	BugGuide.net
Super Elongation Disease	Pg 23	Intechopen
Black Leaf Spot Disease	Pg 24	Vikaspedia
Anthracnose Disease	Pg 26	PlantVillage
Value Added Cassava Chapter		
Fries and Logs	Pg 36	Google photos
Cassava Chips	Pg 36	Google images
Casava bread	Pg 37	Google photos
Varieties of Cassava Chapter		
Frozen cassava	Pg 37	Google photos

References

1. Anderson, N.P., Hart, J.M., Sullivan, D. M., Christensen, N.W., Horneck, D.A. and Pirelli, G.J. 2013. Applying lime to raise soil pH for crop production (Western Oregon) EM 9057. Oregon State University Extension Service. 21 pgs. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9057.pdf

2. Caribbean Agricultural Research and Development Institute (CARDI). 2011. Commercial cassava production. CARDI Technical Bulletin: Issue 5. 16 pgs. http://www.cardi.org/wp-content/uloads/2011/02 Commercial-Cassava-Production-Technical_Bulletin Final.pdf

3. Food and Agriculture Organization (FAO). 1988. Storage and processing of roots and tubers in the tropics. http://www.fao.org/3/X5415E/x5415e02, htm#:~:text=Yams%2C%cassava%20and%20sweet%20potatoes,on%20a%20time%2Ftemperature%20interaction.

4. Food and Agriculture Organization (FAO). 2013. Save and grow: Cassava. A guide to sustainable production intensification. 145pp. http://www.fao.org/ag/save-and-grow/cassava/en/4/inde.html

5. Li, S., Liu, Y., Wang, J., Yang, L, Zhang, S., Xu, C., & Ding, W. 2017. Soil acidification aggravates the occurrence of bacterial wilt in South China. Frontiers in microbiology, 8, 703. https://doi.org/10.3389/fmicb.2017.00703

6. Ospina Patino, B., Cadavid, L F., Garcia, M. and Alcalde, C. 2012. Mechanized systems for planting and harvesting cassava (Manihot esculenta Crantz) In: Ospina, B. and Ceballos, H. eds. Cassava in the third millennium: Modern production, processing, use and marketing systems. Pp. 374-394. CIAT, CTA.

7. Roy, A. K., Sharma, A., Talukder, G. and Talukder K. 1988. Some aspects of aluminum toxicity in plants. Botanical Reviews 54, No. 2, 145-78.

8. Salcedo A., and Siritunga D., 2011. Insights into the physiological, biochemical and molecular basis of post-harvest deterioration in cassava (Manihot esculenta) roots. http://www.cardi.org/wp-content/uloads/2011/02 Commercial-Cassava-Production-Technical_Bulletin Final.pdf

9. Science Direct. 2021. In: Science Direct. https://www/sciencedirect.com/topics/food-science/starcj-retrogradation

10. Seesahai, A., Ramlal-Ousman, M. and Lalchan, M. 2008. A guide to growing cassava successfully. Root Crop Bulletin #1. Research Division, Ministry of Agriculture, Land and Marine Resources, Trinidad. 4 pgs.

11. Shadrack K. A., Ahmad A. and Byju G. 2018. Review of various harvesting options for cassava. In: Vidurenga W. ed. Cassava. InTechOpen, DOI: 10.5772/intechopen.71350. Available from: https://www.intechopen.com/books/cassava/review-of-various-harvesting-options-for-cassava.

12. Singh, R.P. and Anderson, B.A. 2004. The major types of food spoilage: An overview. In: R. Steele, Ed., Understanding and measuring the shelf-life of food. CRC Press, Boca Raton, pgs. 3-23. Doi:10.1533/9781855739024.1.3

13. Wickham L., 1990. Tropical root crops - Post-harvest quality and handling systems for quality maintenance. In: Proceedings of A workshop on post-harvest handling of horticultural commodities for export. Pages 37-46 Trinidad and Tobago.

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