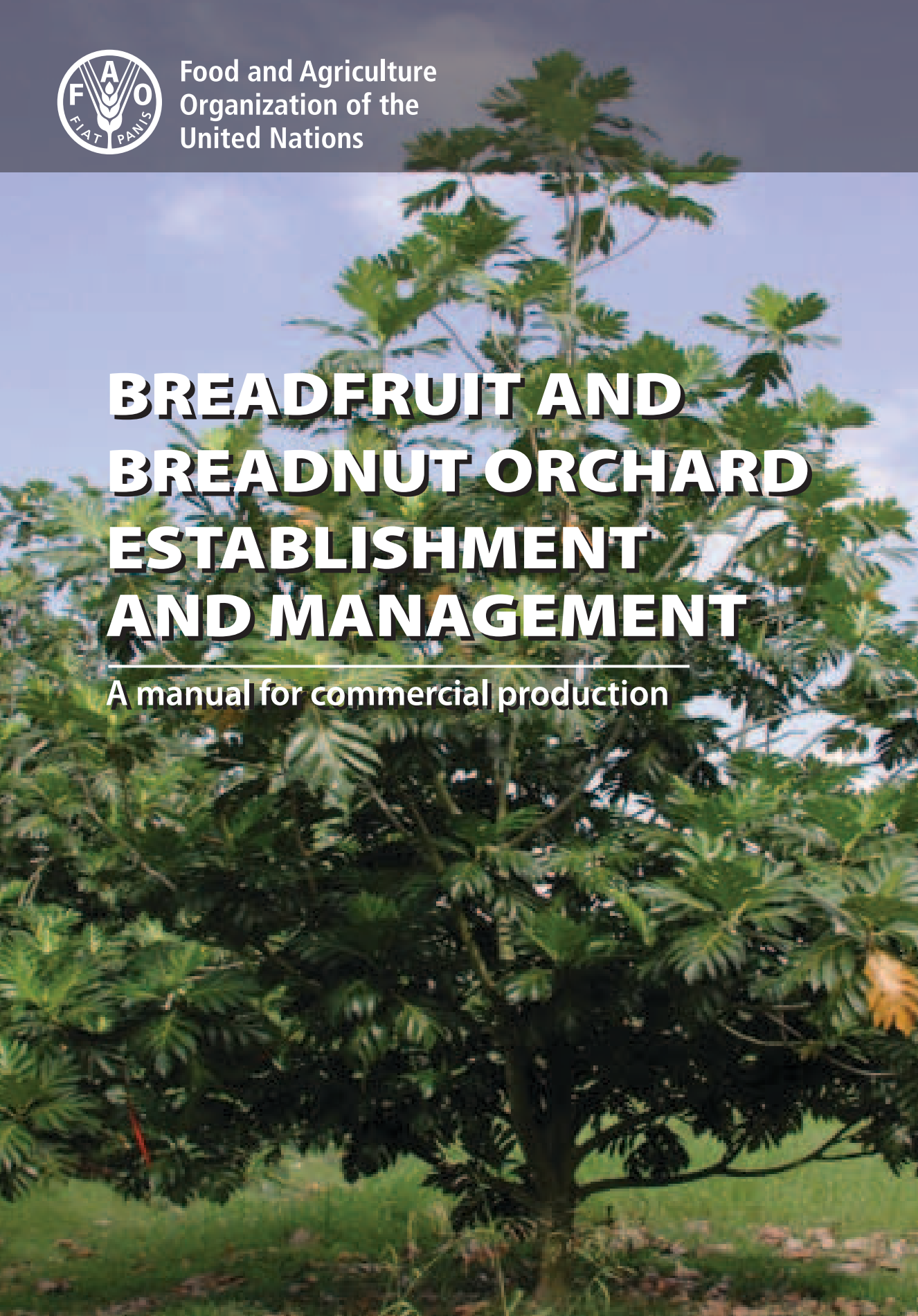
Food and Agriculture
Organization of the
United Nations
BREADFRUIT AND
BREADNUT ORCHARD
ESTABLISHMENT
AND MANAGEMENT
A manual for commercial production

The Manual was produced for St. Kitts/Nevis. However, it is hoped all countries of the Caribbean and beyond will benefit from the information being shared.

Vyjayanthi Lopez
Plant Production and Protection Officer
FAO Sub-Regional Office for the Caribbean (SLC), Barbados

BREADFRUIT AND BREADNUT ORCHARD ESTABLISHMENT AND MANAGEMENT

A manual for commercial production

Prepared by
Laura B. Roberts-Nkrumah

DEPARTMENT OF AGRICULTURE
ST. KITTS AND NEVIS/
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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PREFACE

Breadfruit and breadnut trees grow extensively throughout the Caribbean where their fruits have long been used for food. Although their fruits are sold in local markets, and fresh fruit and processed products are exported from the region, their status as crops of minor economic importance is underscored by production based on a few trees on farms, trees in abandoned areas, and in backyards and by the slow development of commercial orchards.

With the recent emphasis on food and nutrition security in the Federation of St. Kitts and Nevis and in other countries in the region, breadfruit, and breadnut are increasingly being recognised as crops with potential to contribute significantly towards this goal. Breadfruit is an excellent energy source due to its high starch content and breadnut is also high in starch and protein. However, significantly higher levels of consumption by local populations will require increased availability of the these crops in fresh and processed forms, and for the latter especially, trees in the existing production systems cannot supply the required quantity and quality of fruit in a reliable and cost-effective manner. Consequently, FAO has funded a project to support the development of a breadfruit and breadnut industry in St. Kitts and Nevis, with the establishment of commercial orchards as a key element.

The guidelines provided at a training workshop held in St. Kitts and Nevis and in this manual are based on the knowledge gained over the last two decades from research in several areas relevant to breadfruit and breadnut production and a few commercial orchards in the Caribbean. The objective of the manual is to provide continued support for the workshop participants and to share the information with extension officers and prospective producers to encourage increased establishment of commercial orchards for these crops in the region.

ACKNOWLEDGEMENTS

The author wishes to express sincere thanks to the producers and organisations throughout the Caribbean who have shared information on breadfruit and breadnut production. The support of the Department of Food Production, Faculty of Food and Agriculture, The University of the West Indies in research activities, the Department of Agriculture St Kitts in mounting the training workshop and the FAO in funding that activity has also made this manual possible and is gratefully acknowledged. The contribution of the drawings by Gyasi Nkrumah is also appreciated.

GLOSSARY

Adventitious	with reference to roots, this describes roots that do not arise in the usual position as in seedlings but directly on the stem or other locations.
Axil	the angle formed by the upper side of the leaf and the stem to which it is attached.
Backfill	the soil that is removed from the hole and is replaced during planting.
Canopy height	the distance from the soil surface to the point at which branching begins on the tree.
Chilling injury	damage to the cells and tissues of fruits caused by low temperatures.
Cropping system	the pattern of use of an area of land for crop production during the course of a year; it refers both the number of crop species that occupy the land simultaneously or one after the other.
Endocarp	a hard inner tissue in the fruitlet that forms a shell around the breadnut seed.
Heading back cut	a pruning cut that reduces the height of the trunk or a main branch and it is placed just above the node at which a healthy lower branch is emerging.
Inflorescence	a collection of flowers borne on the same stalk (peduncle).
Leader	a main vertical stem which may determine the tree height; it may be the main trunk or a lateral branch.
Maturity index	(plural – indices) – physical or biochemical indicators of the stage of the maturity of the fruit that will determine its quality and shelf life.
Mycorrhizae	the mutually beneficial relationship between the roots of the tree and soil fungi that provides the latter with food while increasing the supply of water and nutrients to the tree.
Rootball	the entire mass of the root system and growing medium e.g. soil, in a container.
Testa	the seed coat or covering over the embryo and cotyledons of the breadnut seed.
Thinning cut	a pruning cut that removes an unwanted branch; it is placed just above the collar where the branch is attached to the trunk, or larger branch.
Tree height	the distance from the soil surface to the highest point on the tree, usually a node or leaf
Windbreak	a row or rows of tall trees and or shrubs used to reduce the wind speed and force by deflecting most of the wind overhead.

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INTRODUCTION

Name

Breadfruit (*Artocarpus altilis*) and its close relative, breadnut (*A. camansi*), belong to the botanical family, Moraceae. Within the Caribean, breadfruit is also known as "cow", "panbwa", "pain bois", "frutapan" and "fruta de pan", whereas, breadnut is also referred to as "chataigne". Jackfruit (*A. heterophyllus*) is another member of the Artocarpus genus that is known in the region.

Origin

Breadfruit and breadnut are not native to the Caribbean. The seeded breadnut, which is considered as an ancestor of breadfruit, originated in Papua New Guinea in the Western Pacific region. Thousands of years ago, as early peoples moved eastwards across the Pacific with breadnut, the seedless breadfruit developed and became predominant in in the eastern part of the South Pacific. Most of the breadfruit in the Caribbean came from this region.

Introduction and distribution in the Caribbean

French navigators first introduced breadnut to the Caribbean and later, in 1793, Captain William Bligh, a British navigator, introduced breadfruit and breadnut plants from the Pacific to St. Vincent and Jamaica. While most of the breadfruit and breadnut plants in the Windward and Leeward Islands most likely came from plants sent from the botanic gardens in St. Vincent by the early 1800s, in the Windward Islands especially, some might also have been obtained from the nearby French territories, Martinique and Guadeloupe.

Nutritional value

The most economically important product of the breadfruit tree is the fruit which is a nutritious, high energy food source. A 100 g edible portion of boiled breadfruit flesh provides 114 kcal, mainly from carbohydrates, 4.9 g of dietary fibre, and appreciable amounts of minerals such as calcium, the B vitamins and essential fatty acids. Breadnut seeds are also highly nutritious because they have a high content of both carbohydrate and protein. A 100 g edible portion of dried seed contains 76.2 g carbohydrates and approximately 8 g fat, 17 g protein, 3.2 g dietary fibre and useful amounts of minerals, including potassium and phosphorus.

Utilisation

Breadfruit is consumed after cooking by boiling, steaming, roasting, baking and frying. Breadfruit is a versatile food that it is used to prepare a wide range of dishes and even drinks and it is consumed at any meal. The fruit is processed into commercial products including vacuum-packed, roasted slices, canned slices, and chips, and there is current commercial interest in flour, a traditional product with a wide range of uses. The male inflorescences, described below, can also be candied and used as a snack or as dried fruit for cakes.

Breadnut is consumed both in immature and mature forms. The flesh and seeds of immature fruits are cooked in curry and coconut milk to prepare a highly appreciated dish in some parts of the Caribbean, and the mature seeds are boiled in salted water, roasted or

fried and consumed mainly as a snack. Studies have been conducted on canned peeled seeds in brine, and other processed products have been suggested including roasted nuts, nut butter, nut paste or oil.

The leaves, bark and latex of the breadfruit and breadnut trees are also useful and have commercial potential for medicinal and insecticidal purposes. The wood of old trees has also been used traditionally for construction and furniture-making.

BOTANY AND GROWTH

The breadfruit and breadnut trees are evergreen, perennials with a lifespan of 50 or more years. Under favourable growing conditions, these trees grow continuously and can extend upwards quickly, therefore, they may reach to heights of 20 m or more in less than 20 years. During early growth, breadnut seedlings grow taller than young breadfruit trees. The tree consists of an upright trunk which is usually single, but in breadfruit, there may be two or more main trunks, on which many lateral branches arise in groups, each consisting of 2 to 7 branches, from which smaller branches also arise as the tree grows. The tree has a pyramidal shape because the lower main branches in the canopy are longer and, sometimes are held more horizontally than the upper branches which are usually more erect (Photo 1). Latex is present in all parts of the tree and the wood is quite brittle.

At the ends of the branches are 7 to 15 large, glossy, green leaves, with bright yellow to light green mid-rib and main veins, and short hairs mainly on the lower surface. Breadfruit leaves are commonly about 30 cm long and 25 cm wide, and for most varieties in the Caribbean, the margins are not entire but divided into five or more lobes on either side. The leaves of young breadfruit trees are much larger than in mature trees, sometimes as long as 1 m (3.25 ft), more deeply lobed and fewer on each branch. Breadnut leaves are larger than those of breadfruit at all stages of growth, with more shallow dissection of the leaf blade and they may be a lighter green than those of breadfruit as the trees mature.

L. Roberts-Nkrumah

Photo 1
Breadfruit tree architecture

The root system in breadfruit is **adventitious** because this species is propagated vegetatively. It consists of several lateral roots that branch to produce a network of roots that may extend horizontally for several metres from the tree but only about 0.6 m downward. Breadnut grows from seed and produces a tap root system which is also extensive, but deeper than that of breadfruit. The roots grow with **mycorrhizae** that can beneficial for water and nutrient uptake.

The mature tree bears both male and female **inflorescences** in the **axils** of the leaves. The male inflorescences appear first and are up to 25 cm long generally and light yellow at first, but become light brown as they age (Photo 2 a). Male breadfruit inflorescences produce little to no pollen, therefore, the female flowers are not fertilized and no seeds are produced by the fruits of traditional cultivars grown in the Caribbean. Breadnut male inflorescences produce viable pollen which is disseminated by wind or insects e.g. bees, to fertilise the female flowers and produce a seeded fruit. About 3 to 4 weeks after the male inflorescences appear, round to oval female inflorescences (Photo 2 b) begin to emerge in the leaf axils.

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Photo 2a

Breadfruit and breadnut inflorescences and fruits

Male inflorescence

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Photo 2b

Breadfruit and breadnut inflorescences and fruits

Female inflorescence

These inflorescences consist of hundreds of small female flowers that are fused together and develop into one large compound fruit called a syncarp. In breadfruit, the flowers develop into fruitlets without pollination. These are fused for most of their length, therefore, the fruit has a spongy texture on the inside near to the core and skin of the fruit has a netted appearance. Up to four young fruits may arise in one leaf axil but at least two fall off usually when they are 4 to 6 weeks old. The average length and average diameter of the mature fruits are about 16 cm and 15 cm, respectively (Photo 2 c).

Breadnut fruits are smaller, but similar in basic structure. However, the pulp is thinner and looser than in breadfruit because the flowers are not fused along their entire length. Also at the surface, they are not fused and elongate to form pointed spines that are soft in mature fruit (Photo 2 d). The number of seeds per fruit is highly variable but the average is 56.

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Photo 2c

Breadfruit and breadnut inflorescences and fruits

Fruits

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Photo 2d

Breadfruit and breadnut inflorescences and fruits

Young breadnut fruits and male inflorescence

ENVIRONMENTAL REQUIREMENTS

Temperature

Breadfruit and breadnut are tropical crops that grow best at temperatures between 210 and 320 C; growth is retarded at lower or higher temperatures.

Rainfall

Both crops thrive best in locations where the annual rainfall receipt is 1500 mm to over 3000 mm and well-distributed throughout the year. Breadfruit has a higher water requirement because of its shallower root system and larger canopy. Breadnut can tolerate drier conditions better although breadfruit will grow where rainfall receipt is as low as 1000 mm annually but well distributed.

Light

This is also an important requirement for good growth. Light shade is useful to prevent wilting, stunting and possible death of newly planted trees because the large leaves lose moisture rapidly but the root system is not sufficiently developed to absorb adequate quantities of water. The trees compete strongly for light, by growing quickly to produce a tall, trunk with high branches. Therefore, the trees should be exposed to full sunlight to encourage a lower canopy to develop.

Wind

Sheltered locations are preferable because persistent wind can cause wilting, leaf damage, a lopsided canopy due to more growth on the side that is away from the wind, and stunted growth. Hurricane-strength winds strip off leaves, break branches and may uproot breadfruit trees.

Soil conditions

Breadfruit and breadnut trees can grow on a wide range of soil types but they prefer sufficiently deep, well-drained and moisture retentive soils. Soils that are prone to waterlogging or seriously eroded and shallow should be avoided. The soils should have fairly high organic matter content, adequate nutrient status and a pH of 6 to 6.5.

GUIDELINES FOR SUSTAINABLE BREADFRUIT AND BREADNUT PRODUCTION

SUSTAINABLE PRODUCTION

A sustainable approach to commercial breadfruit and breadnut production is necessary to ensure the availability of a good fruit supply over many years.

Elements of sustainable production

- Concern for human well-being – Beside the food value of fruits, attention must be paid to the selection of technologies and practices that ensure that worker and consumer health and safety are not compromised.
- Environmental stewardship – The production strategies should minimise reduction in the quality and quantity of natural resources at the production site and in the wider environment.
- Financial/economic viability – Orchard management and product marketing should ensure profitability at the farm level and economic viability at the national level.

Requirements for sustainable production

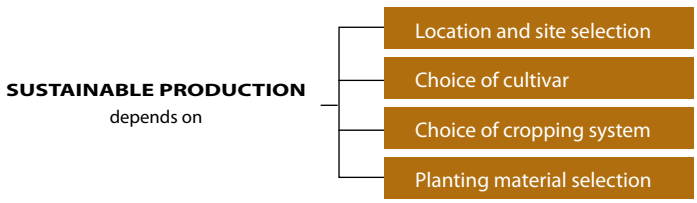
Sustainable production requires planning to ensure consistency among the following

- Market demand for specific products
- Scale of production
- Establishment considerations
- Production systems and management

Information on markets, including demand, quality specifications and prices for fresh and processed breadfruit and breadnut for specific markets, local or export, must be obtained to facilitate decision making and planning. Producers should select the scale of their operations according to the market information and other relevant considerations e.g. the amount of land available; the overall farm objectives, comparative advantages or disadvantages.
The following sections will address establishment and management issues in detail.

ESTABLISHMENT CONSIDERATIONS

Before actual orchard establishment, consideration should be given to and decisions made about the following key technical issues that will ultimately affect sustainable production



Location and site selection

- **Location**
  This is the area of the country in which production will take place. It is often selected firstly on the basis of where land is available to the producer; however, other important considerations should be used to evaluate its suitability. Among these are suitable environmental conditions for production, closeness to market and to sources of inputs, and availability of good access roads for easy transport of inputs to the farm and of fruit to the markets.
- **Site selection**
  The site should provide the environmental requirements for breadfruit / breadnut production. Key among these are rainfall, sunlight and well-drained soil. The ideal site should receive approximately 2500 mm of rain annually which is well-distributed throughout the year and full sunlight throughout the day. The land should be flat to gently sloping (100 slope) to facilitate harvesting, and sheltered from strong or persistent wind which may be experienced on windward sites that are close to the sea.

Where constraints to production exist, additional expenses may have to be incurred for management practices to minimise the problem e.g. irrigation, erosion control on hillsides, drainage and soil amendments. These additional expenses increase the cost of production which may affect competitiveness. Other site requirements which may be necessary to satisfy the Good Agricultural Practices (GAP) requirements for export as organic products or under certain labels e.g. Fair Trade, and their associated costs must be determined.

Choice of cultivar

Market requirements are the major factor influencing choice of cultivar. Both the local and export markets for fresh breadfruit require fruit that are suitable for preparation mainly by roasting or by boiling. Taste and texture of the flesh are important to eating quality. Size and the percentage edible portion are also important especially to local processors, who may also express cultivar preferences based on the nature of the processed product. The size of the market, prices and pattern of demand are also relevant to the choice of cultivar because issues such as productivity and seasonality become important.

No breadnut cultivars have been identified. However, in the Caribbean, there are a few recognised breadfruit cultivars. The most widely known are the 'Yellow' ('Yellow Heart', 'Common') and the 'White' ('White Heart', Yam Pain Blanc). In some countries, there are no given names but cultivars are distinguished mainly by fruit shape – round or long. The following is a brief description of these cultivars:

- **'Yellow'**
  The fruits are round or oval in shape and at maturity, the skin is smooth, greenish brown and usually heavily stained with latex. Fruit weight ranges from 1.5 to 3.5 kg (3 to 8 lb). The flesh of the fruit is light yellow and the colour becomes brighter with age and on cooking. The major bearing period extends from June to September and the minor season is from December to February. This is the

preferred cultivar in the Caribbean on the basis of its pleasant taste and soft, smooth texture. The mature stage of the fruit is considered to be the best for roasting, while the green mature or slightly immature stage is preferred for boiling.

- **'White'**
  This cultivar is similar to the 'Yellow' in shape, size and, to some extent, skin colour, except that there is less brown discolouration and the skin texture may be slightly rougher at maturity. The cultivar can be distinguished from the 'Yellow' mainly by the colour and eating quality of the flesh. The flesh colour is off-white to cream and does not change much as the fruit ages or with cooking. The eating quality is good with a mild taste and a smooth but somewhat firmer texture than the 'Yellow'. 'White' is a very good for boiling and frying, and can be roasted at the full, mature stage.

Both cultivars are suitable for commercial production and for local and export fresh fruit markets and for processing, but seasonality is a major limitation.

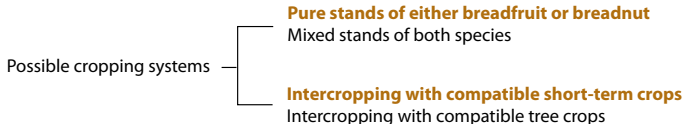
There are at least another four cultivars occurring in St. Vincent and Jamaica, but these are not well known (Table 1). Additional germplasm has been introduced by the University of the West Indies, St. Augustine campus, which is being evaluated with existing Caribbean cultivars to determine their suitability for commercial cultivation and processing. Some of these cultivars may be used to extend the production season by planting a wider range of cultivars.

Table 1
Some other breadfruit cultivars in St. Vincent and Jamaica

St. Vincent	Jamaica
'Kashee'	'Macca'
'England'/'Captain Bligh'	'Cassava'/ 'St.Kitts'
'Waterloo'/ 'Lulu'	'Banbran'/ 'Banjam'
	'Timor'

Choice of cropping system

Two traditional **cropping systems** for breadfruit and breadnut are used on farms in the Caribbean. Border planting of a few trees is common on small farms where short-term, cash crops are the main source of income. These species are also planted in mixed crop systems with other tree crops, especially, on cocoa estates.



In orchard production of breadfruit and breadnut, these species are the major crop. Different cropping systems are suitable for the orchard but the selected system should be based on the farmer's objectives and market conditions. Possible cropping systems include pure stands of either breadfruit or breadnut (Photo 3), mixed stands of both species, intercropping with compatible short-term crops, intercropping with compatible tree crops.

- **Pure stand**
  In this system, the objective is that the mature orchard will consist only of breadfruit and/ or breadnut trees. The trees are grown in rows at closer spacings than in the traditional systems to allow them to occupy the entire growing area at maturity. Pure stands may be more suitable for large plantings with production geared primarily to processors. In this system, the production season and revenue generation might be extended by cultivating several breadfruit cultivars. The availability of more than one cultivar also allows the requirements of different markets to be met by the same orchard, which is also a good risk minimisation strategy. Where more than one cultivar is being planted, they should be established in different rows or in different locations on the farm to optimise the management of each and to reduce the chance of mixing their fruit during harvesting.

  In the first 3 to 4 years, the orchard may be inter-planted with short-term crops for income generation until the trees come into production. These intercrops should not compete with the main crop for light. Root crops should be avoided especially with breadfruit because there is a high risk of damaging the tree roots during harvesting of tubers. With vining intercrops, care must be taken to ensure that the vines do not smoother the young trees.

  This system has the advantage of potentially higher yields, easier management (because only one crop is involved) and even easier replanting. However, consideration must also be given to the higher risks of disease and adverse conditions, for example, hurricanes, which can reduce productivity. Production costs for the crop are also likely to be higher because costs are not shared with other crops.

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Photo 3
A pure stand commercial breadfruit orchard

- **Intercropping systems**
  In this system, mature breadfruit or breadnut trees are grown simultaneously with other crops, which may be short-term crops, or in agroforestry systems with other perennials. In an intercrop system, the population of breadfruit trees is lower than in pure stand because the inter-row spacing is wider to accommodate the intercrops. The precise spacing and arrangement of the trees will depend on the nature of the intercrops and the production management strategies that are chosen. The intercrops should be compatible with breadfruit to minimise competition for growth resources, including light, and for labour inputs.

  Intercropping has the advantages of spreading risks and costs over more than one crop and a potentially better cash flow if the intercrops are harvested during those periods that breadfruit is out of bearing. It may be a more sustainable system with lower pest and disease incidence if the intercrops increase the genetic diversity within the orchard. Tree crops as intercrops, may also offer better protection against hurricane damage. However, this can be a more difficult system to manage; for example, the nutrition management requirements for different crops can vary and affect the performance of breadfruit. Management of the size and height of breadfruit trees will also be affected by the type of intercrops, especially in agroforestry systems. Also, depending on the population of trees, breadfruit yield may be significantly lower than in pure stand. Therefore, selection of an intercropping system requires serious consideration of the implications.

Planting material selection

Once the number of trees required for the orchard is determined, producers may choose to propagate their own planting materials using either adventitious shoots or air layers for breadfruit and seedlings for breadnut. This is a suitable approach for establishment of small orchards. Producers who have ready access to stock plants and are competent in propagation may also produce their own planting material if they plan to phase orchard expansion in relatively small increments. Alternatively, the plants may be purchased from a reputable commercial nursery, in which case, requests for the required quantities of desired cultivars must be placed well in advance of the proposed planting time. These plants are usually propagated from adventitious shoots, but a few nurseries produce breadfruit plants grafted on breadnut and soon, plants produced by tissue culture may become widely available.

Regardless of the source or type of planting material, keen attention must be given to the quality of the nursery stock. The following selection criteria should be applied

- **Plant size**
  The plants should be approximately 4 to 6 months old and 60 to 70 cm tall. Plants that are too tall or too short for their age should be avoided; this is usually a sign of poor management in the nursery and these plants will require additional attention in the field for proper establishment.

- **Shoot system**
  A single main stem with 6 to 7 well-developed leaves is ideal. Very leafy plants should be avoided, as this may cause the rate of water loss from the plant to exceed the rate of water uptake by the roots in the field and lead to excessive leaf shedding. The stem should be tapered with a greater diameter at the base than at the top, therefore, plants that have very tall stems with slender diameters throughout their length should be avoided. These will require staking and may branch high.
- **Root system**
  The **root ball** should be at least 20 cm (8″) in depth. The roots should fill and hold the root ball together when it is removed from its container, which is typically a black, plastic bag. The main roots, which are typically reddish brown, should not be twisted at the base of the container, encircle the root ball or be growing outside the container. Plants with defective root systems will not establish properly in the field and will show greater tendency to water stress during dry periods and poor anchorage.
- **Plant age**
  Old plants should be avoided; these show most of the shoot and root defects identified above.
- **Plant health**
  Plants must be free of pests, disease or damage on the leaves, stem and roots. Also the plants should not show symptoms of serious nutrient deficiency.
- **Field readiness**
  The plants should be properly hardened or acclimatized in preparation for field establishment. They should be able to retain their leaves at shade levels of 25% or lower without the need for frequent watering, and the leaves should be thick, firm, dark green and glossy. Special attention must be given to plants produced by tissue culture to ensure that they are not severely set back or die in the field because of improper hardening.

GOOD AGRICULTURAL PRACTICES FOR ORCHARD ESTABLISHMENT

LAND CLEARING

This operation is necessary if the orchard is to be established on forested land. Unwanted trees should be removed but a few should be left in place to provide shade while others may be selected to act as windbreaks. If all the trees are removed, they should be quickly replaced by fast-growing trees which will provide these environmental services. It is preferable to use power saws for tree felling instead of heavy machinery such as bulldozers. This is an important consideration for avoiding soil compaction especially on wet or clay soils and soil disturbance that may increase soil erosion. Organic materials should be conserved by cutting up the branches and leaving them in place to rot and to contribute to organic matter content of the soil. Therefore, burning is not recommended. Land clearing should be done at least two years prior to the proposed planting date.

LAND PREPARATION

Land preparation should be undertaken during the dry season. Tall weeds should be removed manually or mechanically, depending on the terrain. The trees will be planted in rows, therefore, it is best to orient rows in an east to west direction to allow for maximum sunlight availability on all sides of the trees during the course of the day.

- **For flat to gently sloping sites**
  Drainage is the key consideration on flat sites and therefore, poorly drained sites should be avoided if possible. If there are no drainage or other soil physical conditions problems, further land preparation may be unnecessary and tillage should be minimal. On flat sites that experience occasional, short periods of water-logging, drainage must be improved. The land may be disc-ploughed, formed into cambered beds and box drains installed, 50 cm wide x 30 – 45 cm deep between the beds. These in-field drains should connect to a main drain at least 1 m deep for rapid water removal. Where hard pans are the cause of impeded drainage and long periods of waterlogging during the rainy season, deep ploughing is recommended to break up the pan before preparing cambered beds and drains.

- **For moderately sloping sites**
  Soil conservation and water management are two key concerns peculiar to upland sites. Breadfruit and breadnut orchards should not be established on slopes greater than 25° (moderately sloping) where there is greater risk of soil erosion and reduced water conservation, and orchard management operations and harvesting are more difficult to conduct.

For such sites, minimum tillage is recommended and only eyebrow terraces are necessary at the planting positions to improve the effectiveness of water and nutrition management for the young trees. Contour drains should be installed to channel water to main drains and grass barriers are recommended to reduce soil erosion and the maintenance requirements of these drains. The main drains should be properly graded to reduce water flow and encourage infiltration and water retention where necessary.

WINDBREAKS

On exposed sites, strong winds can stunt growth of young trees and reduce productivity of mature trees due to desiccation, damage to the leaves and branches, reduced pollination in breadnut and fruit drop. Another undesirable result is lopsided canopy development and leaning of the tree trunk away from the direction of the wind which can affect the stability of tree, especially during fruiting periods. **Windbreaks** of fast-growing species of similar height should be established perpendicular to the path of the prevailing wind at least two years before planting breadfruit or breadnut in order to be effective. Other important aspects of the selection of suitable species and of windbreak establishment and management are:

- the length of the windbreak should extend beyond the length of the production area which is to be protected
- the branch spacing within the canopy of the selected windbreak species should allow wind to filter through at reduced speeds,
- a deep tap root system that provides good anchorage and minimises competition with adjacent breadfruit and breadnut trees for water and nutrients,
- the windbreak trees must be appropriately spaced within their rows to prevent gaps,
- the windbreak canopy must be maintained at a suitable height to deflect the wind over the crop; also, a windbreak is most effective in reducing wind speed over a distance that is ten times the height of the windbreak
- where more than one windbreak is required due to the length of the area to be protected, the windbreaks should be spaced consistent with the configuration of the orchard, to maximise the area under breadfruit or breadnut production, while controlling wind flow within the orchard.

The windbreak species may be fruit trees that can improve cash flow and directly contribute to the profitability of the orchard.

An important function of windbreaks on fire-prone sites is to provide a green belt during the dry season which slows the progress of fires and minimises movement of burning plant material by wind to other parts of the orchard.

SPACING AND PLANT ARRANGEMENT

The selected spacing and arrangement in the orchard must be guided mainly by the expected height and canopy width of the trees at maturity because this will affect light availability and air movement. Tree size is determined by cultivar and environmental conditions. Other important considerations are the cropping system, proposed use of machinery in the field and slope of the site.

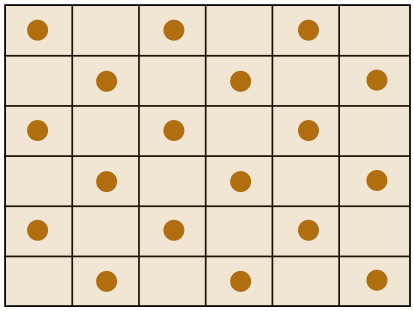


Figure 1
Hexagonal plant spacing

For a pure stand orchard planted with the tradtional breadfruit cultivars or breadnut at a site where the environmental conditions promote rapid growth, for example, high rainfall or high fertility, the mature trees should be maintained at a maximum tree height of 8 m and maximum canopy width of 8 m. The recommended spacing is 10 m x 10 m which would give a plant population of 100 trees/ha (40 trees/acre). However, with narrower canopy width e.g. 6 m, a closer spacing of 8 m x 8 m or 8 m x 10 m may be used to achieve a plant population of 156 trees/ha (59 trees/acre) or 125 trees/ha (47 trees/acre), respectively. At closer spacing, higher yield is possible because the plant population is higher. However, care must be taken to ensure adequate light availability to minimize the tendency to increased tree and canopy height in young trees and to support flowering and fruiting on the entire canopy, and air circulation. Closer spacing is recommended for sites with less favourable environmental conditions for growth because the trees will be smaller, and also for shorter cultivars.

For orchards on flat to gently sloping areas where machinery may be utilized in some operations, a wider spacing between rows is desirable, so that the spacing may be 10 m x 12 m (83 trees/ha or 33 trees/ac) or 8 m x 12 m (104 trees/ha or 38 trees/ac) depending on canopy width.

Square (e.g. 8 m x 8 m) or rectangular (e.g. 8 m x 10 m) tree arrangements permit easy movement within the field and are suitable for flat areas. A hexagonal arrangement (Figure 1) may be used to increase plant population; at a spacing of 10 m between plants, this arrangement will give 10% more trees/ha than the square arrangement. This arrangement is also preferable on steeper land to minimize the risk of gully formation and soil erosion.

The field should be lined in advance using a tape and stakes to ensure proper measurements within and between rows and all plant positions should be marked with stakes.

HOLE PREPARATION

The stake must be removed and a hole dug in the plant position previously marked by the stake. On heavy soils, the holes should be prepared before planting to allow the soil to dry out and to improve the soil texture. Drying out also reduces the populations of potentially harmful soil organisms. A hole, 45 - 60 cm long x 45 - 60 cm wide x 25 – 30 cm deep, is suitable. The depth of the hole must be just enough to accommodate the root ball of the plant so that the top of the root ball is not lower than the top of the hole. On soils with high clay content, holes with slick sides and bottoms should be avoided because these encourage accumulation of

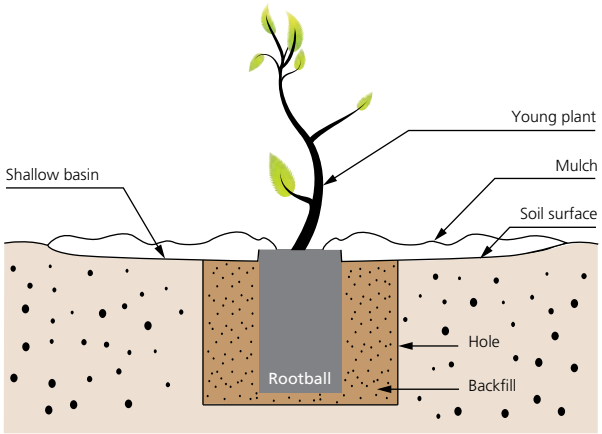
water and retard root penetration into the surrounding soil which causes the plant to become stunted. Therefore, the holes should be prepared when the soil is just moist, not very wet, and the sides should be roughened with the edge of the spade if the soil is not sufficiently friable.

Soil amendments such as lime (for acid soils) and fertilizer may be incorporated into the **backfill**, which is the soil removed from the hole and replaced during planting. A complete fertilizer, with moderate nitrogen (N) and potassium (K), and high phosphorus (P), in a suitable NPK ratio such as 1:2:1 or 1:1:1 should be used if necessary. Slow-release formulations are best for reducing fertiliser loss through leaching. Soils that are very freely draining, prone to drying out or low in organic matter do not have to be prepared very early and about 2 kg of well-rotted organic matter may be incorporated into the backfill before it is replaced in the hole. Alternatively, the holes may be prepared just prior to planting at a depth that is 2.5 to 5 cm (1 to 2") more than the depth of the rootball, if fertilizer is to be added. The fertiliser should be placed at the bottom of the hole and cover with 2.5 to 5 cm (1 to 2") of soil to prevent the roots from being damaged because of direct contact with the fertilizer. Whether or not amendments are used, the finished depth of the hole should also not be deeper than the depth of the rootball.

PLANTING

Breadfruit and breadnut trees may be planted at any time, provided that enough soil moisture or irrigation is available. Otherwise, the beginning of the rainy season is the best time for planting.

The plant is placed in the hole after removing the plastic bag and slightly roughening the sides of the root ball to loosen the roots and to encourage better contact with the soil in the hole. The plant should be turned to orient the foliage to the best position for maximum light interception. Then replace the backfill in the space around the rootball, firstly, by filling half the hole and pressing the soil down firmly, then by completely filling to the top and pressing down the soil again. This procedure helps to remove air pockets so that when the soil



(G. Nkrumah)

Figure 2
Planted young tree

eventually settles, the level of the soil within the hole will not be lower than that of the root ball. It also ensures that the root ball is in proper contact with the soil and that the plant is firmly set in position (Figure 2). However, pressing the soil too firmly may cause soil compaction and should be avoided.

Water the plant thoroughly so that the water penetrates beyond the depth of the hole. On flat areas, a shallow basin, about 1 m wide around the plant is useful to prevent water run-off and encourage infiltration and it may also be mulched under dry conditions. On hillsides, the eyebrow terrace serves the same purpose as the basin.

STAKING

The need to stake newly-planted trees for support or for anchorage should be avoided by using only sturdy plants with well-developed root systems, instead of overgrown, pot-bound or top-heavy plants, by proper planting techniques and by selection of sheltered sites. If, however, staking is required for these purposes, install the stakes either in the hole before it is filled with soil (Photo 4) or outside the hole after planting.

It may also be necessary to install protection staking where livestock or pests, or wild animals such as monkeys have access to the orchard and may damage the young trees.

L. Roberts-Nkrumah

Photo 4

Stake placed in hole with plant before soil replacement

GOOD AGRICULTURAL PRACTICES FOR MAINTENANCE OF YOUNG TREES

The management objective for an orchard with young breadfruit and breadnut trees is that each tree should develop a healthy, extensive root system and a canopy with low, well-spaced, strong branches that is large enough to intercept sunlight but not too tall for management and eventually, harvesting.

LIGHT MANAGEMENT

If the orchard is located on a site that is windy or that experiences periodic dryness, light shade (25%) should be provided. Open-canopied trees or temporary cash crops e.g. banana or plantain, may be used at sufficiently wide spacing because excessive shading will encourage the trees to grow tall with little branching. Three-year-old trees require full sunlight, therefore, all shade should be gradually removed after planting.

WATER MANAGEMENT

The young trees perform best under uniformly moist soil conditions throughout the year. Therefore, for rain-fed orchards in locations with short (less than 6 weeks) dry spells and with soils that retain moisture, the orchard floor should be mulched with the fallen leaves or other well-rotted or composted organic materials to conserve soil moisture. This measure is inadequate where longer dry periods, especially on freely-draining soils, are common and irrigation facilities must be provided in such cases. Irrigation must be immediately at the onset of the dry spell to such soils to avoid low moisture stress symptoms e.g. wilted leaves, premature leaf senescence or yellowing, excessive leaf fall, and ultimately stunted growth. Drip irrigation may be used for young plants but microjet sprinklers are more effective because they encourage growing trees to develop a more extensive root system and they also use water more efficiently than overhead irrigation.

Clear and maintain all drains prior to the onset of the rainy season especially where the soil is prone to waterlogging, because prolonged periods of excessive soil moisture may lead to root death and kill young trees.

NUTRITION MANAGEMENT

Proper nutrition management assists young trees to develop the desired form of root system and canopy described above. Fertiliser application must be based on nutrient analyses of the soil and as the trees develop, analyses of nutrient levels in the leaves should also be used. Under high rainfall conditions, a complete fertilizer should be used to promote vegetative growth, with an adequate concentration of phosphorous (P) especially for root growth. Too much nitrogen (N) will promote undesirable, excessive shoot growth. After 18 to 24 months as the trees approach maturity, potassium (K) should be increased to

Table 2
A nutrition regime for young breadfruit and breadnut trees

Time since establishment (months)	Time of application	Nutrient source	Rate / tree
0	At hole preparation	12-24-12 Organic matter	125 g 2 kg
3		12-24-12	125 g
6	3-4 weeks before end of rainy season	12-24-12 Organic matter	150 g 3 kg
12	Beginning of rainy season	12-24-12	200 g
15		12-24-12	200 g
18	3-4 weeks before end of dry season	12-24-12 Organic matter	200 g 4 kg
24	Beginning of rainy season	13- 13-21	250 g
30	4 weeks before end of dry season	13-13-21 Organic matter	300 g
36	Beginning of rainy season	13-13-21	400 g

Source: Roberts-Nkrumah, 2007

support flowering and fruiting. A recommended fertilizer regime for young breadfruit and breadnut trees is shown in Table 2.

The fertilizer should be applied in a ring in a shallow furrow around the tree, outside the drip line of the canopy, and covered with soil to prevent loss through rainfall run-off. Alternatively, fertilizer should be applied during irrigation. On upland sites, apply the fertilizer in the eye-brow terrace around the young trees as described previously. For older trees on hillsides, the fertilizer is applied in a semi-circular furrow on the uphill side of the tree, outside the drip circle and covered.

Organic matter, as compost or well-rotted farm yard manure, is beneficial to soils with low, organic matter, and shortly before the beginning of the dry season. The material should be placed at least 20 cm away from the base of the tree trunk to avoid collar rot problems. Some typical rates are presented in Table 2.

TRAINING

Young breadfruit and breadnut trees must be trained to develop a low-branching canopy and that is short enough to facilitate harvesting. Prune 1 to 1.2 m tall trees that have not branched by using a **heading-back cut** to remove the top 15 - 20 cm from the main stem, to encourage branching at less than 1 m. A slanting cut is made just above a node with a sharp, clean secateur. If the tree has already produced branches, it should be head-backed to the first group of branches before it reaches 2 m in height, by removing the main stem at the internode just above the uppermost branch in the group (Plate 5). The lateral branches that grow out from the main stem eventually will also begin to grow vertically; these should also be head-backed at 1 to 1.5 m to limit their height and to encourage branching.

L. Roberts-Nkrumah

Figure 5
Breadfruit training

Remove any branch that is causing overcrowding to encourage an open canopy in which the branches are spaced evenly. Use a **thinning cut** for branch removal. Use a lopper or a sharp pruning saw to make a slanting cut just above the collar of the branch, and not flush with the stem, to ensure proper healing.

Cuts on young trees are relatively small and should heal easily. It is not necessary to apply paint or any sealant to the cut as this can encourage rotting of the stem if moisture is trapped below the sealant. Young trees can be pruned at any time of the year during dry weather. The fruits are borne towards the ends of the branches, therefore, training should be completed by the time the trees are 30 months old to allow them to develop sturdy branches with enough foliage for the mature phase.

CROP PROTECTION

A string trimmer should be used to remove weeds within and between rows, but immediately around the trees, weeds should be removed manually to avoid damaging the stems. Vines should be removed entirely. Weeds in the inter-row spaces may also be brush cut or controlled with a non-selective, systemic herbicide, especially weeds in the drains. If herbicides are used, drift should be avoided by using a shield and by spraying under calm or low wind conditions. Soil-acting and systemic herbicides that can damage the trees should be avoided and the decision to use herbicides should be carefully considered if they may pollute drainage water that flows through other cropped areas on- or off-farm. Intercropping and mulching suppress weeds effectively and reduce the need for herbicides. Also placement of irrigation water and fertilizer where they are easily absorbed by the roots can limit weed growth in areas where the tree roots have not yet extended.

Diseases are not common on young trees in well-drained sites with proper air flow within the orchard. Pests are also not usually prevalent, but the pink hibiscus mealy bug (*Maconellicoccus hirsutus*) can cause serious leaf distortion and stunting of the plants. An integrated pest management approach should be used for control including biological control and removal of all host plants, such as sorrel (*Hibiscus sabdariffa*) and broom weed (*Sida* sp.) from the field. If the field is known to have nematodes, while the orchard canopy is still relatively open,

their population can be reduced by solarisation. For this procedure, moist soil is covered with plastic, preferably black, which is sealed at the edges to retain heat for a period of about 6 weeks under dry, high sunlight conditions. Wasps and ants can hinder manual operations, and termites can eventually destroy trees, therefore, their nests should be destroyed.

GOOD AGRICULTURAL PRACTICES FOR MAINTENANCE OF MATURE TREES

The main objective of maintenance operations on mature trees is that the trees should produce good, regular yields while maintaining proper vegetative growth.

WATER MANAGEMENT

The same procedures used for the young trees should be followed. If the orchard is irrigated, enough water should be applied weekly before the trees begin to show symptoms of low moisture stress and maintained throughout the dry period. A commonly recommended rate in the Caribbean is 2.5 cm (1″) water/week. Adequate soil moisture is required to maintain growth and to retain leaves, flowers and fruit. High fruit fall due to low soil moisture early in the bearing season may be followed by flowering and fruiting again which can produce a later and possibly smaller crop. If the drought is late in the season, loss of larger fruits close to maturity may occur with no new flowering in that bearing season. Mulching should be done during in the dry season by distributing fallen leaves over the orchard floor to a depth of at least 7.5 to 10 cm (3″ to 4″) but a 45-60 cm (18-24″) wide band should be left clear, immediately around the trunk.

In the wet season, all drains must remain clear so that proper drainage is maintained in the field. This is critical to the health of the root system.

NUTRITION MANAGEMENT

The nutrition programme for the orchard should be guided by soil and leaf tissue analyses. Inorganic fertilizers should always be applied when the soil is moist, therefore, for a crop that is rain-fed entirely, all fertilizers must be applied during the rainy season. To minimize loss, the fertilizer should be applied in two to three dosages where the dry season is distinct, whereas under conditions with well-distributed, high rainfall, or where supplemental irrigation is available, it is better to divide the annual fertilizer requirement into four smaller applications. The crop will benefit from an additional application of P to promote root growth during the wet season and of N to support leaf growth during the dry season. The fertilizer should be applied by broadcasting evenly on the beds. Table 3 presents an example of a nutrition programme for mature trees.

TREE SIZE CONTROL

Like most breadfruit cultivars, ‘Yellow’ and ‘White’ are not naturally short-statured, therefore, the size of mature trees has to be managed. In conjunction with light, water and nutrition management, physical approaches can also be used to maintain the trees at a desirable height and with a suitable branch arrangement.

Table 3
A nutrition programme for rain-fed mature breadfruit trees in a wet and dry climate

Tree age (years)	Time of application	Nutrient source	Rate (kg) /plant/yr
3 - 5	Early rainy season and late rainy season (split applications)	13-13-21	0.8 – 1.4
	Early rainy season	Triple superphosphate	0.25
	Late rainy season	Urea	0.5
6 - 10	Early rainy season and late rainy season (split applications)	13-13- 21	1. 6 – 2.0
	Early rainy season	Triple superphosphate	0.25
	Late rainy season	Urea	0.5
>10	Early rainy season and late rainy season (split applications)	13-13-21	2.0
	Early rainy season	Triple superphosphate	0.25
	Late rainy season	Urea	0.5

Source: Roberts-Nkrumah, 2007.

Heading back the main stem or trunk, as described under the section on 'Training', will result in several lateral branches that grow upwards as **leaders**. These branches should be pruned to control their growth (Photo 6). Excessive leaders and additional shoots that crowd the interior of the canopy should be removed because heavily shaded branches may die and those that survive will produce fewer and smaller fruit (Photo 7). The remaining main branches should be cut back so that the tree remains at the desired height. On sites with high rainfall receipt, pruning may have to be conducted annually to control regrowth.

Photo 6
Pruned (heading back) leaders

Photo 7
Shoot emergence after pruning causing crowding of inner canopy

L. Roberts-Nkrumah

Branch thinning (removal) (Photo 8) and selection of new leaders is best undertaken during the period of vegetative growth between the major and minor fruiting seasons when the new shoots are still small. The leaders should be pruned by heading back at the commencement of the dry season before flowering begins for the major season, because regrowth is usually slower in this period and the environmental conditions are better for wound healing.

If pruning is done on time, hand pruners or loppers and pruning saws with well-sharpened blades for clean cuts are usually satisfactory for these operations. Removal of larger branches is more costly because it may require trained personnel using power saws, it also creates larger wounds that heal more slowly, and it causes greater stress on the plant which may sometimes become unthrifty and die eventually.

L. Roberts-Nkrumah

Photo 8

Thinning cut to remove unwanted branch

CROP PROTECTION

Weeds

Weed control practices as described for the young trees should be continued. As the canopy closes in and with mulching, most weeds will be suppressed and weed control will be needed mainly for the drains.

Pests

There are few serious pests on mature trees. One problem that sometimes occurs is that dark-brown, hard, sunken areas develop on some fruits which make them unsaleable because of their disfigured appearance and the bitter taste of the affected areas when the fruit is cooked. Some farmers attribute this problem to damage caused by bees to the fruit and refer to it as 'Bee sting'. This is most likely the anthracnose disease that is described in the next section. While steps may be taken to discourage the presence of insects that are associated with this problem, it is necessary to consider first whether they are playing any beneficial roles before deciding on the use of pesticides. Pink hibiscus mealy bugs should be controlled as already described. Cutting ants or bachacs (*Atta* sp) can be controlled by use of baits on the orchard floor. Bumble bees (*Xylocarpa* sp.) may bore into damaged branches and can be controlled by minimizing damage to the trees, especially during pruning, by making small cuts. Wasps, ants and termites should be controlled by destroying their nests.

Diseases

- **Fruit rot**

Rots are the major fruit disease problem in breadfruit, but it is much less prevalent in breadnut. It has been attributed mainly to two fungal pathogens, *Glomerella cingulata* (the immature form is *Colletotrichum gloeosporioides*) and *Phytophthora palmivora*. *Glomerela cingulata* causes anthracnose which first appears as round, brown spots on the surface of immature fruits and may be spread by insects such as bees, and by wind. The spots expand to form larger lesions that are grey at the centre and dark brown at the margins. The spores also infect mature fruits which may fall off the tree. On the other hand, *P. palmivora* infection appears first as small, water-soaked lesions on the surface of mature green fruit that spread and develop light brown centres, with fungal growth and spores at the margins. With both pathogens, the lesions may coalesce to form large, discoloured areas on the peel (Plate 9). The entire fruit may become mummified on the tree and if not removed early can also infect branches and cause dieback. Both diseases are spread by rain and water, and are more prevalent under the high temperature and high relative humidity conditions of the rainy season.

These diseases can be controlled by ensuring that the orchard is well drained and that the tree canopies are pruned for proper air circulation. Field sanitation is also important, therefore, infected branches should be pruned and, with diseased fruits from the trees and orchard floor, should be removed from the field and burned in order to reduce the inoculum load. Applications of copper fungicides with or without metalaxyl (or phosponic acid for *Phytophthora*) with a mistblower at the onset of the rainy season and during fruit development can reduce the incidence of the disease but the withdrawal period for use of these chemicals prior to fruit harvest must be observed.

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Photo 9
Fruit rot on breadfruit

- **Tree Dieback or Decline**
  Tree decline occurs in some parts of the Caribbean. The first symptoms are excessive leaf yellowing and leaf fall, followed by the dieback of the younger branches. This dieback eventually extends to larger branches and the trunk and can kill the entire tree (Photo 10). Both breadfruit and breadnut are affected, but tree death is much more common in breadfruit.

L. Roberts-Nkrumah

Photo 10
Tree dieback on breadfruit

The disease occurs mainly in mature trees and death can occur in as short a period as 6 months or the tree can decline gradually over a 2 year period. Diseased trees may be detected first in the wet season because they show symptoms typical of water stress and later, during the dry season, deterioration is very rapid. Several non-aggressive fungi, bacteria and high populations of certain nematodes species have been found in association with diseased trees. *Phythophtora* sp. is known to cause a similar disease in avocado (*Persea americana*) and nutmeg (*Myristica fragrans*). Certain environmental conditions such as waterlogging, soil salinity and wind stress due to hurricanes may precipitate the disease.

Tree decline does not occur everywhere, therefore, its control starts with site selection. It is necessary to ensure that the orchard is well-drained and tree health is maintained, with especial attention to the root system, and field sanitation. Solarisation has also been found to reduce nematode populations and may aid recovery of individual trees. This disease is still being investigated to identify the causative factors.

- **Root rot**
  This disease, which also affects avocado, is caused by a fungus, *Rosellinia* sp. The disease spreads rapidly, and trees do not usually survive. Recommended control measures are isolation of affected trees with ditches, application of lime to the soil and use of copper fungicides.

- ***Abiotic factors***
  Sunburn gives affected fruits a scorched appearance that renders them unmarketable. Fruits that are exposed to strong sunlight, especially at the top

of the tree, are more susceptible to this problem than those in the lower canopy where there is more shade. As the orchard matures and more self-shading occurs, the incidence of sunburn should be lower.

Cracking occurs mainly around the shoulders and sometimes along the sides of mature fruit. These fruit ripen quickly and are unmarketable. Uneven water supply during fruit development and growth causes cracking. When fruits that begin their development in the dry season are subjected to rapid water uptake at the onset of the rainy season or when they are close to maturity, the skin splits in the areas of the fruit with most water uptake and rapid cell enlargement. Timely irrigation during dry periods and harvesting of mature fruit alleviates this problem.

YIELD, HARVESTING AND POSTHARVEST HANDLING

YIELD

Breadfruit trees begin bearing in less than three years after field establishment, especially 'Yellow', while breadnut may take three years where the environmental conditions and management of the crop are very good. Trees come into bearing later under less favourable conditions. Both 'Yellow' and 'White' cultivars tend to have two production seasons, with harvesting extending from June to September, the major season, and from January to March, the minor season. The actual commencement of the season and its duration depends on several factors including the prevailing weather conditions, and crop factors e.g. cultivar. The first fruits to mature come are at the top of the canopy where flowering and fruiting begins first because of better light receipt than in the lower canopy. At full maturity, a tree may produce more than 100 to 250 fruit depending on cultivar, age and management. Early fruit fall, approximately 6 to 8 weeks after bearing begins, may be as high as 25%. The other fruits reach maturity in 14 to 16 weeks by which time the majority attain a weight of 1.5 to 2 kg. Table 4 shows average yields for the 'Yellow' and 'White' cultivars at different ages.

Table 4
Annual yields (fruit number* and weight/tree) of the 'Yellow' and 'White' breadfruit cultivars

Tree age (years)	'Yellow' cultivar		'White' cultivar	
3 -4	50 – 100	(100 – 200 kg)	30 - 60	(60 – 120 kg)
5 - 8	150 – 200	(225 – 300 kg)	100 - 200	(150 – 300 kg)
9 - 10	200 – 250	(300 – 375 kg)	200 -250	(300 – 375 kg)
>10	250	(375 kg)	250	(375 kg)

**Source:* Roberts-Nkrumah, 2007.

Breadnut trees begin bearing in three years. The mature trees will produce approximately 100 fruits each weighing an average of 1 kg. Fruit number is lower than in breadfruit because the trees have fewer branches.

Table 5
Annual yield/tree of breadnut

Tree age (years)	Fruit no. (and weight) / tree		Seed yield (kg)
3	40	(40 kg)	18.4
4	60	(60 kg)	27.6
5	90	(90 kg)	41.4
≥10	100	(100 kg)	46

It should be noted that tall, unpruned trees at wider spacing can give higher yields/tree but a high percentage of the fruit may not be harvestable and many fruit may be damaged during harvesting. However, well-managed smaller trees, at higher plant populations should give similar or higher yields/ha.

HARVESTING

Breadfruit and breadnut fruits should be harvested at the stage of maturity that is required for the method of preparation for consumption. This requires some knowledge of the **maturity indices** for different stages of fruit development. Fruit size, skin colour, skin texture and the absence or presence of latex on the skin are the main indicators of the stage of fruit maturity for these species.

MATURITY INDICES FOR BREADFRUIT

Breadfruit is harvested at the following stages of fruit maturity:

Immature

Fruits are usually less than 12 weeks old, bright green in colour, very firm and still fairly undersized. The cut fruit exudes copious quantities of latex and the flesh, which is initially almost white, quick discolours. The flesh also has higher water content and the taste is very bland compared with more mature fruit. A small percentage of fruits is harvested at this stage for use mainly as an ingredient in soups e.g. "Mannish Water" or for pickling as in "Souse".

Green mature

At this stage the fruit has completed its development (typically by 14 weeks) and has reached the dimensions of a mature fruit but has not begun to ripen and is still very firm. The peel may be greenish brown with some latex stains, especially in 'Yellow' which has a smoother peel than 'White'. The cut flesh shows little or no discolouration and less latex flow than in immature fruit. The flesh is very starchy and not sweet to the taste. A large percentage of fruit is harvested at this stage in countries where the fruits are consumed mainly by boiling or steaming. Fruits that are to be exported are also harvested at this stage to prevent premature ripening.

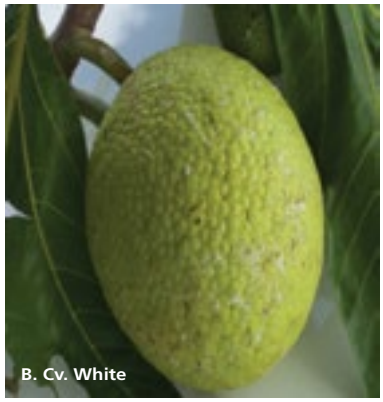
Fully mature

The fruit at this stage may be 15-16 weeks old. The skin of 'Yellow' fruit changes to brownish yellow-green, the peel becomes very smooth and latex staining may be prolific (Photo 11 a), while the skin of 'White' fruit becomes light green and the peel is smoother with more latex stain than in less mature fruit of that cultivar, but it is less stained than 'Yellow' fruits (Photo 11 b). The cut flesh is light yellow and white to cream in 'Yellow' and 'White', respectively, and shows no discolouration or latex exudation. The flesh is firm and may be slightly sweet on cooking. A high percentage of fruit is harvested at this stage for local markets where roasting is the preferred method of preparation.

Ripe

At this stage, the fruit is less firm than in earlier stages, in 'Yellow' the flesh colour is brighter yellow, and the cut fruit may exude a slightly fruity aroma. The cooked fruit is softer and distinctly sweet in taste. Breadfruit is not commonly consumed at this stage in the Caribbean, however, ripe

fruit may be used for some recipes e.g. fritters, cakes, punch or for any dish in which the breadfruit taste is desired. Note that cultivars may differ in time to maturity and in the maturity indices for different stages of maturity. Location differences may also affect time to maturity.



L. Roberts-Nkrumah

Figure 11
Mature breadfruit of the 'Yellow' and 'White' cultivars

MATURITY INDICES FOR BREADNUT

Maturity indices for breadnut are less well-developed because this species is not as widely consumed as breadfruit in the Caribbean or elsewhere. The following description of stages of fruit maturity is based on fruit age (and size), skin texture and spacing of the spines, skin colour, flesh colour and firmness, seed characteristics and eating quality:

Immature

The fruit is 6 to 8 weeks old, less than the mature size, with bright green skin, and closely arranged spines on the skin. The fruit is very firm, and the cut flesh is white and exudes much latex. The seeds are immature and the **endocarp** is white to tan coloured and fairly soft. A significant percentage of fruits are harvested at this stage for consumption of both the flesh and the seeds after cooking.

Mature

The fruit is 8 to 10 weeks old, at mature size that is quite variable, and with brownish green skin and more widely spaced spines. The fruit is firm, the cut flesh light yellow with little latex exudation, and the seeds are mature and surrounded outside by a distinctly brown, thick, hard endocarp, and an inner thin, brown **testa**. The seeds have the best eating quality at this stage and a high percentage of mature fruit is harvested for seed consumption.

Ripe

Usually ripe fruit are not harvested but seeds are collected from freshly fallen fruit. These fruit are quite soft, with brown skins and bright yellow flesh. Some seeds may begin to germinate. Eating quality declines if the seeds are not consumed quickly after the fruit falls or as germination progresses.

HARVESTING PROCEDURES

Harvesting should be done early in the morning when air temperature and field-heat in the fruit are still low. A harvesting method that minimises damage to the fruits should be used because any damage will reduce their marketability. A single person may harvest fruits by hand on shorter and younger trees, but as the trees grow taller, a harvesting aid (fruit picker) can be used. This consists of a bag attached to a long pole (Photo 12). A hook or blade may be attached to the end of the pole, or an area on the ring to which the bag is attached may be sharpened to serve as a knife to detach the fruit. The individual fruit is positioned in the bag before it is detached with the harvesting aid, which is lowered to the ground and the fruit removed from the bag. The fruit is harvested with the peduncle attached. The latex is allowed to drain from the peduncle before the fruit is placed in a container for removal from the field. For fruits that cannot be reached from the ground, a picking team of two persons is used; one person climbs the tree, harvests the fruit using the fruit picker and lowers it to the second person, on the ground, who removes the fruit from the bag. Fruits should never be thrown from hand to hand or allowed to fall to the ground.

L. Roberts-Nkrumah

Photo 12

Harvesting breadfruit with a fruit picker

Marketable, harvested fruits are placed in field crates (Plate 13) for transport to the packing house in covered well-ventilated vehicles. Fruits may also be transported in larger containers with cold water or in trucks equipped with chilling facilities to remove field heat. It is critical to avoid damage due to bouncing and bruising during transport, as this will encourage infection, shorten shelf-life and reduce marketability. Therefore, fruits should not be transported in bags. During the entire harvesting process, fruit of different cultivars should be kept separate.

L. Roberts-Nkrumah

Photo 13

Harvested fruit place in plastic crated for transport from field

POSTHARVEST HANDLING

The crates are off-loaded at a packaging facility that is covered and well-ventilated. The fruits should be washed to remove dirt and field debris in cool water containing 150 ppm sodium hypochlorite and with pH 6.5 to prevent post-harvest disease infection, then air-dried on a flat surface. All fruits must be examined to ensure that they meet market specifications – cultivar, stage of maturity, size, freedom from blemishes damage, disease. Fruit for export should be graded for size, with fruit of different sizes being placed in separate cartons. Well-ventilated cartons should be used and fruits packed in a single layer and separated from adjacent fruits by separators to prevent bruising during transport. Fruit for the local market should also be graded and packed in sturdy crates for delivery.

If fruit must be stored before delivery, a storage temperature of 12.5 to 13°C must be maintained. Lower temperatures will cause **chilling injury**, while at higher temperatures the fruit will ripen more quickly. The ideal relative humidity is 90-95% to prevent water and weight loss and shrivelling.

The storage time between packing and delivery to the market should be as short as possible to ensure that the fruit still has a reasonable shelf life when it reaches the consumer.

CONCLUSION

Successful commercial breadfruit and breadnut production can be accomplished by adopting good agricultural practices used for other tropical tree crops. The key to successful production is careful planning, particularly site selection, choice of cultivar and tree spacing and arrangement, consistent and proper execution of all cultural operations, harvesting and postharvest handling. Well-maintained breadfruit and breadnut orchards with good canopy cover can benefit the environment by minimising soil erosion, increasing water infiltration and recycling nutrients. It has also been established that pure stands of both crops can generate a positive cash flow as soon as production begins and if well-chosen short-term crops are intercropped, this could be achieved from the first year of orchard establishment. Therefore, commercial breadfruit and breadnut production can be sustainable because it can be financially viable for producers, environmentally friendly and can contribute to food and nutrition security for the country.

"Breadfruit and breadnut have excellent potential for contributing to food and nutrition security, viable livelihoods, sustainable environments and adaptation to climate change which are all key elements of the Agricultural Development Strategy of the Ministry of Agriculture of the Federation St. Kitts and Nevis. As significant sources of carbohydrate and protein, respectively, breadfruit and breadnut can partially replace imported sources of these nutrients and thereby contribute to the reduction of the high food import bill, while playing a significant role in the management of prevalent non-communicable, lifestyle diseases through their nutritional content. Both crops can be processed into a range of products that will increase availability as well as improve the ease of preparation and of diversifying the methods of consumption.

Under the project TCP-STK-3401, a workshop titled '*Breadfruit Orchard Establishment and Management*' was conducted over two days, 10 and 11 December 2013, with the key objectives being (1) To provide participants with up-to-date knowledge on the establishment and management of breadfruit and breadnut orchards and (2) To provide participants with competencies in the key areas of cultivar identification, planting material selection, lining an orchard, hole preparation, planting and harvesting using a harvesting aid. The 30 participants consisted of farmers, processors, and staff of the Departments of Agriculture in St. Kitts and in Nevis, especially those with responsibility for plant propagation activities. The first session covered the establishment of commercial orchards, an overview of the botany, growth and development, and environmental requirements for breadfruit and breadnut production and an outline of sustainable production. The training on orchard establishment comprised two practical exercises, one on site selection for orchard establishment based on environmental conditions, mainly rainfall, and the other on cultivar selection using fresh samples of breadfruit and breadnut leaves, male inflorescences and fruit.

The Manual was produced for St. Kitts/Nevis. However, it is hoped all countries of the Caribbean and beyond will benefit from the information being shared".

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