



Breadfruit Compendium: Before You Start

Module 1 gives an insight into the breadfruit tree, the diversity of varieties that exist, and the basics of traditional breadfruit agroforestry. It also highlights issues you will have to consider before embarking on your breadfruit agribusiness – these issues will be looked at in more detail in later modules.

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About Us

Funded by the Australian Centre for International Agricultural Research and facilitated by a consortium of implementation partners, Pacific Agribusiness Research in Development 2 (PARDI2) seeks to promote sustainable livelihood outcomes for Pacific Islands households through research and innovation, catalysing and informing a more vibrant, diverse and viable agribusiness sector.

The project spans 2017-2021, placing a geographical focus on Fiji, Tonga and Vanuatu. For more information, please visit www.pardi.pacificfarmers.com



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1.0 About the Plant

Breadfruit trees can grow to heights of 15-21 metres (m) or more and the trunks may be as large as 2m in diameter at the base but commonly trees reach 12-15m tall. To assist with harvesting, trees can be pruned to a height of 4.5-5.5m. If pruning begins when trees are young (2-3 years old) and continues annually, trees can be kept at a desired size for easy fruit harvesting at the correct maturity for many decades (Fig 1). Commercial breadfruit production in the Pacific is based on small orchards intercropped with other crops (agroforestry orchards) where trees are pruned to a height of around 4.5m to enhance production and assist with harvesting (Fig 2).



Figure 1: Transition from opportunistic “wild” harvest to orchard production with trees pruned to a manageable size and bale kana variety breadfruit being harvested by Sahn Ali from his orchard in Buabau Lautoka Fiji.

Breadfruit has male and female flowers on the same tree. The female flowers fuse together and develop into the skin and fleshy, edible portion of the fruit. Pollination is not required for the fruit to form. Flesh is creamy-white or pale yellow and contains none to many seeds, depending on the variety. Fruits are typically mature and ready to harvest and eaten as a starchy staple in 15–19 weeks from flowering. Breadfruit is high in carbohydrates, and is a good source of minerals and vitamins. Breadfruit has a wide range of adaptability to different ecological conditions, preferring climates with mainly summer rains and/or uniformly distributed rainfall. Breadfruit is propagated from root shoots or root cuttings and by air-layering (marcotting) branches.

“What is the expected productivity from breadfruit?”

Breadfruit can start bearing fruit 2-5 years after planting, depending on the variety, the local growing conditions, the husbandry practices adopted and the type and quality of propagation material. Fruiting can continue for many decades.



The propagation method influences time-to-first fruiting with plants obtained from root suckers fruiting in two years (provided they are planted into a fertile soil), and achieving full production in 4 to 5 years. Plants obtained from aerial layering can start flowering within a year, with some production achieved in the second year and full production in 3 to 4 years.

Under well-managed orchard system conditions, yield estimates range from 16-50 tonnes (t) per hectare (ha) of fruit for a planting density of 100 trees/ha. Annual breadfruit yields per tree vary depending on the variety, tree age, condition, canopy height and diameter, and growing conditions.



Figure 2: Bale kana variety planted as marcot at Tutu Rural Training Centre orchard (Taveuni, Fiji) fruiting within two years

Five-year old trees in the better-managed bale kana breadfruit orchards developed under the Pacific Breadfruit Project (PBP)¹ are now achieving yields of 300 fruit/tree, (375 kg/tree or 37.5 tonnes/100 trees). This is twice the yield that was projected in the original project design. Breadfruit yields will be considerably reduced in regions with lower rainfall (less than about 1800 mm) and/or a pronounced dry season and also be lower where soils are sub-optimal, such as temporarily waterlogged sites, skeletal rocky soils and acidic red clays.

“Is breadfruit a seasonal crop?”

Breadfruit tends to have one large season, followed a few months later by a smaller, secondary season. However, the harvest season varies with the variety. Furthermore a breadfruit variety's seasonality can differ from place to place and year to year. There is recent and widespread anecdotal evidence that breadfruit cropping seasons have expanded, either through several seasons in one year or a longer single season. The timing of rainfall (when it occurs) and temperature variation may also play a significant role in breadfruit seasonality. Seasonality is an important consideration when planning your agribusiness venture because the price of breadfruit can vary significantly depending on

¹ Pacific Breadfruit Project: Australian Centre for International Agriculture Research (ACIAR) funded “Developing commercial breadfruit production systems in the Pacific Islands” 4 year project, which began in early 2011, to assist smallholder farmers in Fiji to move from opportunist “wild” harvest to growing breadfruit as an orchard crop.



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supply/availability and near year-round production is desirable for agribusiness processing ventures.

The main season for the varieties grown in orchards for export in western Viti Levu in Fiji is from November until the end of May. With good orchard management, including irrigation, fruiting can be extended into the dry season.

“Are there alot of different varieties?”

Pacific farmers have selected and cultivated hundreds of named varieties of breadfruit, that show a high degree of morphological diversity, on both volcanic islands and low-lying coral atolls. Morphological descriptors (characteristics) for leaf, fruit, seed and male flowers have been developed and used to distinguish between the different varieties. Selection in the Pacific Islands, especially in Polynesia, has favoured seedless and few-seeded varieties. By planting different varieties you can have fruit of different size, texture, flavour and nutritional attributes to satisfy different markets, products and consumer preferences, as well as provide an extended period of yield and availability. From the financial viewpoint, if fruit are purchased on a per piece basis then the size of fruit is critical to financial viability meaning the selection of variety is pivotal. Larger fruit are unlikely to be suitable for fresh export because they will not meet fruit fly quarantine standards. On the other hand larger-fruited varieties are easier to process with less wastage.

2.0 Breadfruit Cultivation



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2.1 Breadfruit Agroforestry



Figure 3: In this young Samoan agroforestry, crops include noni, cacao, poumuli, and coconut in addition to breadfruit.

Agroforestry is a farming system that integrates trees, shrubs and perennial plants with crops and/or livestock in ways that provide economic, environmental and social benefits. In the Pacific Islands, agroforestry is commonly seen in home gardens where a wide diversity of food crops and often medicinally and culturally significant plants are cultivated. Breadfruit is included in many traditional agroforestry systems, along with coconut palms, native trees, and introduced timber species (Fig 3). As new crops were brought to the Pacific Islands, they were incorporated into agroforestry plantings, along with chickens and pigs.

A modern approach to agroforestry uses principles from the traditional systems, namely:

- A. Short-, medium-, and long-term crops are inter-planted simultaneously after site preparation
- B. Quick coverage of the area with a dense planting of the crops and other desired plants.



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- C. The planting can have multiple vertical layers at all ages from the beginning of the planting

Longer-lived crops replace shorter-lived crops as the latter complete their productive life cycles.

The more traditional system has been adapted along the following lines to establish an agroforestry system that can be more efficiently managed by the farmer's household:

- Plants are arranged in rows with regular, systematic crop spacing for ease of management
- Space between rows provides ease of access and is based upon the desired pruned dimensions of the crop trees.

2.2 Breadfruit Orchards

The Pacific Breadfruit Project (PBP) promoted the development of commercial breadfruit production systems in the Pacific Islands and focussed on Fiji's western Viti Levu area. As a result of the PBP some 40 farming households planted 1,400 breadfruit trees. This has enabled better breadfruit farmers to:

- Adopt the necessary agronomic and horticultural practices such as propagation, pruning and fertilizing that will ensure early- and low-bearing fruit and higher yields.
- Introduce control measures for fruit flies, such as bait spraying, to increase marketable production and to efficiently meet bilateral quarantine requirements for exported fresh fruit.
- Carry out safer and more efficient harvesting of quality fruit at the desired stage of maturity.
- Carry out better and more efficient post-handling of fruit for improved quality.

Orchards can take different forms including (a) traditional block-shaped orchards; and (b) farm perimeter and windbreak orchards, also known as linear orchards (see Figs. 4 and 5).

Orchards can be intercropped with more short-term crops to generate income revenue before the breadfruit is ready for harvesting, such as pineapple, cassava, taro, ginger, turmeric and papaya (see Figs. 6 and 7), thereby adopting an agroforestry approach.



Figure 4: A linear breadfruit orchard planted along the roads (the "Breadfruit Boulevard") at the Tutu Rural Training Centre on Taveuni, Fiji



Figure 5: A Tutu graduate, following the example of "Breadfruit Boulevard" plants breadfruit along the borders of his farm to prevent wind damage and as a commercial crop



Figure 6: Intercropping breadfruit with pineapples at Tui's orchard opposite Nadi Airport



Figure 7: Intercropping breadfruit with papaya at Prakash's orchard (Johnson Rd, Lautoka)

Commercial breadfruit production can be achieved using the orchard system which adopts the traditional orchard system of planting trees in rows. These rows can be intercropped to varying degrees with a wide range of different crops reflecting the traditional agroforestry system. Increasing the number of crops increases the complexity of the system but at the same time increases income generation and strengthens resilience to external factors such as extreme weather events. The Fiji Breadfruit Manual discusses the Pacific Breadfruit project and the evolution of breadfruit orchards in Fiji in detail.



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Commercial agriculture has focused on monoculture because it makes planting, management, harvesting and marketing activities easier. However, monocultures have serious drawbacks including high susceptibility to pests and diseases, and soil degradation. Monoculture is also more vulnerable to fluctuating market demand for the single commodity being produced. The Breadfruit Agroforestry Guide lists the comparative advantages and disadvantages of commercial agroforestry systems and monoculture (Table 1).

Table 1: Comparative advantages and disadvantages of commercial agroforestry and monoculture

Agroforestry	Tree Crop Monoculture
Advantages	
<ul style="list-style-type: none">• Multiple crops, more options, better risk management• Early returns because of different crops• Higher total productivity• More tolerance of pests and diseases• Crop maintenance rather than weed control• Environmental benefits (improved soil, erosion control, carbon sequestration)	<ul style="list-style-type: none">• Simpler to plan and manage• Labourers require less skill• Easier to mechanize• Maximises production of one crop
Disadvantages	
<ul style="list-style-type: none">• No recipe for implementation• Knowledge intensive depending on a number of different crops• More complex management, including attention to timing of management.• More difficult to mechanize certain operations	<ul style="list-style-type: none">• Reliance on the market for a single crop• More susceptible to pests & diseases• Not using all ecological niches so lower total productivity• Surges and lulls in labour demand• No early yields – all early cash flow is negative• Use of herbicides can result in soil erosion, nutrient losses and degradation• Herbicide can impact breadfruit tree health through uptake by surface roots or root shoots



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“So what are the benefits of the agroforestry approach?”

Economic benefits: the combined yield of all crops growing together in agroforestry/orchard system can exceed that of monocultures by 10-60%. With one crop a grower is at the mercy of supply and demand where excess production and market gluts can result in low prices. A diverse set of crops is less impacted by fluctuations in market prices and can provide a better and more nutritious diet for the farmer’s family. An agroforestry orchard system can also create opportunities to generate an income before the longer-term crops, such as breadfruit, come into production. The annual peak seasons of breadfruit provide opportunities for both local and export markets, including the use of surpluses for value-added, processed products. Finally, multiple crops allows for labour inputs to be better distributed throughout the year.

Environmental benefits: agroforestry orchard systems address soil and water resource concerns through erosion control, soil health improvement, wind shelter and greater resilience to pests and diseases than monocultures. Because of these benefits agroforestry orchard systems are more resilient to climate change, and provide growers with opportunities to incorporate crops/varieties which offer an insurance against crop loss from climate extremes. Breadfruit in itself is relatively tolerant of severe cyclones. Damage on trees, which is usually confined to outer branches, can be mitigated by strategic pruning and trees are seldom uprooted by strong winds.

Social benefits: diversification of crops strengthens food and nutrition security and also supports livelihoods through increasing the opportunities for product development.

But there must be some disadvantages to agroforestry systems?

The main disadvantage centres on more complex management, especially if you are going to incorporate many different crops. Further, as each site is different, there is no ‘recipe’ or plan for implementation – no ‘one size fits all’. The first stage of selecting crops requires a lot of thought – crops have to grow well together and have a local use and/or market (or purpose such as soil improvement). Because of the diversity within the system management activities are generally more complex and time-sensitive, and of course, because there are several different crops being grown together, wider knowledge and experience is needed compared to when a single crop is being cultivated.



3.0 Establishing your breadfruit agroforestry orchard

Good planning is important for reducing costs and at the same time optimizing outcomes and income potential. Planning is more complex than planning for a monoculture system because of the number of crops that can be involved and the need to source appropriate planting materials ahead of plantation establishment. Compatible crop selection, spacing, and maintenance are all planning issues that require consideration before starting on establishment. Planning consists of collecting site and market information, evaluating the different crop options and complementarities and then developing an implementation plan. Table 2 has been extracted from the Breadfruit Agroforestry Guide to give you an idea of what a plan for implementing an agroforestry approach to breadfruit production would look like.

Table 2: Implementing an agroforestry approach to breadfruit production

Time relative to planting the site	Activity
24 weeks before planting (recommended)	Planning, site assessment, project design, and begin sourcing and assembling appropriate plant materials.
8 to 16 weeks before planting	Ensure nursery stock will be field ready according to your schedule. Make decisions on any soil adjustments needed based on soil tests
1 week before planting	Pruning of any trees and shrubs that will be integrated into the new planting
Planting time (can be multiple days)	Site preparation at onset of rainy season with planting immediately after site is prepared
0-4 weeks after planting	Intensive maintenance, watering (if needed)
5+ weeks after planting	Regular maintenance, replanting where needed, harvest, additions of organic matter.

3.1 Site evaluation and preparation

Site evaluation will help you make decisions about soil and water resources, drainage and irrigation etc. On sloping land you will need to identify the contours and install drains and



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drop structures or protective vegetation, such as pineapple or vetiver grass belts, along the contours to minimise soil erosion.

If you are already cultivating breadfruit and the trees are productive and healthy, then your site is suited for breadfruit production. If you are starting from scratch then you will have to ensure that your site provides the conditions favourable for breadfruit cultivation and productivity.

Breadfruit generally prefers the hot, humid tropical lowlands with an ideal daytime temperature of 21-32°C although they can be productive at both higher temperatures (40°C) and at lower temperatures (15°C). Outside of the ideal temperature range, trees will grow but fruit yield and quality will be affected if night temperatures are consistently below 10°C. Between 1500 and 3000 mm rainfall per year is desirable, preferably of fairly equal distribution or with a summer maximum. Short dry periods are tolerated but there is evidence that prolonged dry weather inhibits flowering and therefore decreases production. A site with uniformly distributed and consistent rainfall could avoid this problem.

Breadfruit prefers deep, fertile, well-drained soils with a neutral pH between 6.1 and 7.4, but grows well in a fairly broad range of conditions. In Fiji a breadfruit trial (bale kana and uto dina varieties) was carried out on marginal talasiga soil in the Sabeto Valley, with the assumption that trees would be productive if they were fertilized and well-managed. The performance of the trees was compared with trees cultivated on fertile, well-drained soils (Legalega, Nadi). After two years the stem girth of the trees on the Sabeto site only doubled compared to a five-fold increase in the stem girth at the Legalega site. After three years over 50% of the Sabeto trees had died, compared with zero losses at Legalega. In marginal environments, breadfruit cultivation is best limited to the lower slope with deeper soils and better water relations.

Any crops selected to grow with breadfruit must be adapted to the same conditions.

3.2 Machinery and equipment

Basic requirements include a rotavator for site preparation, spade for planting holes, knapsack sprayer for bait spraying, cane knife for weed control (brush cutters are problematic because of the damage to the basal part of the trunk), good pruning tools (long handled or extendable pruning saw), and a pole with hook for harvesting fruits.



3.3 Labour needs

An individual farmer with family support can generally look after a modest scale agroforestry orchard system. Keeping trees pruned enables all members of the family to be involved in fruit collection, rather than a system with tall trees from which fruit collection requires tree climbing skills and is therefore hazardous without the right climbing safety equipment and training. Data collected from productive breadfruit orchards in Fiji showed that over a ten-year period a 50-tree breadfruit orchard required 41 days average annual input of family labour from planting. For fresh export the main requirement for labour is in harvesting, sap control and packing.

Sap on the skin of breadfruit is inevitable. Two kinds of sap exist: (a) small globules on various parts of the skin which are seen as an indicator of fruit maturity (Fig 8); and (b) white, sticky sap which oozes from the stem after the fruit has been picked or from abrasions on the skin (Fig 9). The former poses little problem, the latter causes unsightly discolouration of the fruit and is considered a marketing problem. All current breadfruit exporters carry out various procedures aimed at removing the bulk of unsightly sap.



Figure 8: Sap as an indicator of maturity

General agribusiness skills: Ideally if you are embarking on an agribusiness enterprise you should also have, or seek to strengthen the following skills/experience: (a) knowledge of the value chain and an understanding of the importance of quality throughout the entire production and marketing system; (b) accurate record-keeping and strict financial management; and (c) an understanding of pest and disease management.



4.0 Pests and diseases to be aware of

Breadfruit trees are generally considered to be a relatively pest and disease-free tree but trees can be affected by several fungal diseases. However, such problems can be minimised by starting with vigorous and healthy trees and paying attention to good practices, such as:

- Pre-planting removal of all tree stumps (including burning out stumps to make biochar and eliminate sources of brown butt rot fungus);
- Mounding of planted stock in areas which experience temporary waterlogging;
- Removing fallen fruit quickly from the site; and
- Ensuring that good air circulation is maintained around and under the tree canopy.

Practices to improve soil microbial biodiversity, such as mulching and growing appropriate ground cover crops can also help mitigate the impact of disease organisms.

Fruit fly is a production pest for breadfruit in Pacific Island countries as well as a quarantine problem for export markets – with certified quarantine treatment (high temperature forced air – HTFA) required. Farmers and exporters must follow an agreed quarantine pathway and adhere to strict field sanitation. Other insect pests of concern are whitefly, scale and mealy bug. These pests are usually found around the fruit stalk. Care must be taken in removing these pests as breadfruit skin is very sensitive – any rough abrasion will lead to more sap release, bruising, blackening and reduced shelf life. Bands of neem oil or petroleum jelly around the base of the tree can be used to reduce access of ants to the canopy and allow the natural predators of these insect pests to control them.

5.0 Harvesting, products and commercial markets

Breadfruit is most commonly harvested and consumed when near mature/mature. Determining the optimal stage of maturity to harvest fruit is important. Maturity indicators vary with the variety and in some cases location. Visual signs include skin colour, scabbing on and around fruit sections and skin texture changes.



Figure 10: Immersion of breadfruit in water to slow ripening



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The Fiji Breadfruit Quality Guide for Fresh Export provides pictures which illustrate the development stages of the fruit (Fig 11). Breadfruit has a limited shelf life, quickly going from the mature to soft, ripe stage in one to several days (or a few hours) once harvested. Proper handling will increase shelf life and fruit quality and reduce losses. Fruits can be kept immersed in tanks of fresh water to slow ripening (Fig 10).



Figure 11: Breadfruit Quality Guidelines for fresh export

Breadfruit for local consumption is harvested at full maturity, which is achieved at about 12-16 weeks after flowering in Fiji. Breadfruit at this stage of maturity cannot be expected to last more than two days in the warm conditions, which is insufficient time to allow for fresh export. If exporting breadfruit, harvesting has to take place at slightly less than full maturity, to achieve the necessary balance between shelf-life and acceptable eating quality. Such fruit is best described as mature green.



Is there scope for processing and value-adding?

Mature and ripe fruit can be processed into a wide range of products, including chips. Steamed or roasted mature fruit can be minimally processed – sliced, vacuum packed, and frozen – and sold in local markets as well as being exported. Alternatively such fruit can be mashed into dough, vacuum packed and frozen for further use which can include the base for flat breads, pizza etc. Figs 12-16 show examples of processing and value-adding of breadfruit. Module 4 deals specifically with processing and the opportunities that are available.



Figure 12: Samoan breadfruit chips sold domestically



Figure 13: Samoan breadfruit flour sold in local supermarket



Figure 14: Samoan breadfruit flour sold in New Zealand



Figure 15: Dried breadfruit being sliced ready to manufacture into chips or flour at the Tutu Rural Training Centre



Figure 16: Breadfruit buns and breadfruit made for participants at the Tutu Rural Training Centre

Breadfruit flour and flour-based value-added products have been gaining market interest in recent years because of their nutritional attributes (these are discussed in some detail in Module 5 – Markets and Marketing). A recent marketing study identified substantial and immediate market opportunities to expand fresh and frozen breadfruit export markets. These findings are summarised in Module 5 and presented briefly below.



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For the future, major breadfruit market opportunities exist in supplying processed breadfruit products to export markets. Peeled frozen breadfruit (a ready-to-cook) product is being exported by Samoan and Tongan enterprises to Australia and New Zealand and has been shown to be viable for reasonably small-scale enterprises. However, overall the realisation of this export market is dependent on overcoming raw material supply constraints and a substantial increase in capital investment and private sector involvement.

“What about the local market?”

More immediate market opportunities exist for processed breadfruit products sold into local markets (Figs 12-16). Breadfruit provides a healthy substitute as it is a complex carbohydrate, rich in fibre, low in fat, high in the essential amino acid lysine (which is low in most plant foods), free of cholesterol and gluten. Further, it has a moderate glycaemic index (blood sugar shock) compared to that of white potato, white rice, white bread, and cassava. All of these attributes combine to produce a staple that would help to alleviate the increasing and alarming rise in non-communicable diseases (NCDs), and it is concerns over NCDs that is expected to drive the large domestic market. The likely negative impact of climate change on global rice production and the knock-on effect on the cost of imported rice is also likely to give processed breadfruit products a comparative advantage.

6.0 What income you can expect to make and the capital you need

The Pacific Breadfruit Project’s Technical Officer, Mr Kaitu Erasito, conducted a financial analysis in April 2019 for a 50-tree breadfruit orchard established in 2012. This orchard followed the recommended package of practices and relied only on household labour. The initial establishment cost (excluding labour) of the orchard was FJD 506. The orchard came into production in year 2 (25 kg of marketable fruit/tree) and full production in year 7 (320 kg of marketable fruit/tree). The breadfruit is sold at the farm gate to local fresh market traders, and to a local processor, with an average selling price of FJD 0.45/kg. The following financial returns were estimated:

- Average annual gross margin over a 10 year period (revenue – non labour costs) FJD 4,321;
- Average annual gross margin of FJD 85 per tree; and most importantly,
- Return per day of family labour effort FJD 104

The full financial model for the small orchard is presented Module 6 (the Business Plan) – along with appropriate simulations.



7.0 The Basics

Now you should have a reasonably good understanding of breadfruit as a crop and what is required to grow breadfruit commercially. If you are interested in learning more and developing a business plan then you can proceed to the next modules. It is recommended you think carefully about and answer the following questions:

Questions	Answers
Do you have access to farmland, either your own or that you can lease for at least 10 years?	Y / N
Does your land or proposed land provide conditions well suited for cultivating breadfruit? Your land must not be subject to flooding, including saltwater inundation from king tides (on atolls)	Y / N
Is there easy access to water for irrigation if necessary – that is, in areas with a strong dry season and/or less than 2000mm annual rainfall?	Y / N
Have you carried out any preliminary discussions regarding marketing breadfruit, for example, a small scale processor, local market vendors, exporters etc?	Y / N
Do you have access to planting material of the preferred variety or a range of suitable varieties which will provide fruit over an extended period during the year?	Y / N
Do you have the labour available to establish and maintain a breadfruit agroforestry orchard?	Y / N

If you have answered 'yes' to the questions above then you can now proceed to the next module. If there are some questions to which you have not answered 'yes' or where you are unsure and/or unclear, then it would be best to talk to your Agriculture extension officer (or any other person with the relevant detailed knowledge of breadfruit, its production and marketing).