THE GUIDE:

GROWING BREADFRUIT

Module 3 contains an overview of what is needed to maintain a smallholder breadfruit agroforestry orchard, including planting, mulching and irrigation, maintenance (including pruning), nutrient management, pests and diseases, harvesting and risk assessment. This overview provides the details required to help you prepare the data for the financial spreadsheet and calculate the income you can earn for the effort put into your breadfruit agribusiness.

The second part of this section is a link to a spreadsheet for preparing a simple financial analysis of the operation. The output from this spreadsheet is a printable financial projection to be included in your business plan document. It is important to research how much the various inputs will cost. The model will make some assumptions about how your operation will improve over time (over 3-5 years your yields

will increase as the plantation develops and your practices improve), so you can enter increasingly higher-level estimates for revenues.

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About Us

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The PARDI2 Project is funded by the Australian Centre for International Agricultural Research (ACIAR) and facilitated by a consortium of implementation partners, the project 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 PARDI2 project spans 2017-2021, placing a geographical focus on Fiji, Tonga and Vanuatu. For more information, please visit www.pardi.pacificfarmers.com

1.0 Planting, mulching and irrigation

Beds for planting or individual planting sites are laid out after the site is mostly prepared. The soil in these beds or individual holes (±mounding) generally receives additional cultivation to support the establishment of the plants. Soil amendments and compost are added at this stage. The key documents for this module provide guidance on the various options for boosting soil fertility at this stage, for example, the 'Farm and Forestry Production and Marketing Profile for Breadfruit' recommends adding a small amount of slow-release balanced N-P-K fertilizer to the bottom of the planting hole and then covering with soil before planting.

Mulch can be added at this stage or after planting. Mulching is an excellent practice for reducing soil erosion due to rainfall, holding in moisture, keeping the soil cool and reducing weed recruitment. Mulch is most effective if it lies directly in contact with the soil surface, so chopped or chipped organic material is preferable. Uncomposted organic materials should not be mixed into the soil immediately before planting, as the resulting organic activity in the soil [and binding on nitrogen (N)] will suppress plant growth. Planting a groundcover crop removes the need to add mulch. Figure 1 shows the planting of mucuna bean as a ground cover crop with taro. Mucuna improves soil fertility, improves taro yield, reduces weed numbers and improves soil biology.

Figure 1: Mucuna bean that has dried off provides excellent dried mulch ground cover as illustrated here with taro

Where there is large woody matter on the site, this can be dried and biocharred in situ at the sites where the breadfruit plants are to be planted (the biochar is made underground in much the same way as a lovo or umu). This practice gives excellent results in higher-rainfall areas with sticky red clay soils – some of the clay is converted into brick-like pieces which together with the charcoal/biochar greatly improves drainage and growth of young breadfruit trees.

If you are cultivating breadfruit on sloping land, then measures need to be taken to avoid soil erosion. These measures include: (a) planting vetiver grass along the contours using an A-frame to identify the location of the contours; and (b) if the slope is significant, using drop structures to improve drainage and minimise soil loss (Figs. 2a-c). A two-wheeled tractor can be used to improve labour efficiency when establishing your agroforestry orchard (Fig. 3).

Figure 2a: Using an A-frame to determine contours for orchard establishment (Vanuatu)

Figure 2b: Vetiver grass planted along contours

Figure 2c: A drop structure established in the drains at Tui's breadfruit orchard

Figure 3: Two-wheeled tractor for improving overall efficiency

"When is the best time to plant?"

Breadfruit planting stock must be healthy when planted. If you have produced them in a nursery then they must be well 'hardened off' by exposing them to full sun for 2-4 weeks before field planting. Planting materials for all crops need to be ready for planting at about the same time so that the planting area is quickly filled with no gaps for any weeds to establish and take over (which will increase maintenance). Best planting practices need to be observed and these practices are described in the key documents.

Planting early in the wet season and once the soil is saturated can eliminate the need for watering at planting time. If you farm in an area prone to periodic drought then irrigation can be a wise investment. If crops are planted in an area with suitably high rainfall (greater than 2000mm pa) with only short periods of water stress, hand watering or irrigation is less important as the trees becomes established. However, longer duration irrigation may be required if you are growing your breadfruit with vegetables or fruit tree crops such as papaya.

2.0 Maintenance

Weed control is easier with an agroforestry orchard system compared to a monoculture system because the mix of crops used in such a system ought to generally provide dense cover and therefore will shade the ground, inhibiting weed growth. When planning your system you are best to include species that will quickly cover the ground and also some that

will persist for many years. If you plan carefully, removing weeds will be a minor time input and therefore will add little cost.

"How important is pruning?"

Pruning the breadfruit trees is an essential component of maintenance because it increases the efficiency of harvesting, improves fruiting because the fruit is borne on new growth, removes any weak or damaged branches that could break and damage fruit (and possibly injure people), and finally a well-pruned tree will suffer less damage in high winds and therefore recover more quickly after any storm damage.

Figure 4: Pruned trees (left) can be efficiently & cost-effectively harvested. An unpruned tree (right) often requires 2-3 x more time to safely pick without climbing the tree or dropping fruit on the ground making it impractical for commercial purposes.

Pruning starts when the tree is small (< 3 m) so that the branch structure can be managed. Ideally annual pruning is carried out after the end of a fruiting cycle, prior to a new growth flush. There should also be adequate soil moisture so that the trees will regrow quickly. The material from pruning (prunings) can be chopped or chipped to provide mulching material. Around the time of pruning, adding soil amendments, mowing ground cover crops and applying additional mulch may be carried out to ensure favourable conditions for regrowth. Pruning is stressful to trees and results in open wounds that need to heal, therefore any

extra care (e.g. application of grafting mastic to wounds, fertilisation) that can be given to the trees after pruning will help them to recover and grow well. The pictures below (Figs. 5a-5c) from the Breadfruit Production Guide show appropriate pruning for young tree stage Also see the video from Hawaii on pruning of your breadfruit tree https://www.youtube.com/watch?v=AxjYj9Au42w

Figure 5a: For young trees, it is important to control vigorous shoots both from the top and sides. Crown reduction throughout the canopy – rather than only topping – is the best practice.

Figure 5b: The first pruning should be done as needed, usually by Year 3 or 4. Prune back to a strong branch union. Take care to remove aggressive shoots and co-dominant leaders. Prune only branches that need to be pruned to shape the tree to an even domed canopy.

Figure 5c: A pruning height of 4.5-5.5m is recommended. Prune back to the same height each year. You can seek professional advice if you feel it is needed.

Pruning is a skill that requires training or the employment of an experienced arborist at the required times. It is important to prune on the collar using a pruning saw to keep wounds to minimum size and so they quickly grow over. Work safety practices must be adhered to and these will depend on the size of the tree and other factors.

3.0 Nutrient management

Nutrient management is complex, depending on the soil characteristics, environmental effects, the crops being grown together and the overall management. The Breadfruit Production Guide suggests different approaches to nutrient management but these recommendations are based mainly on orchard systems and therefore might not be as appropriate for well-crafted agroforestry-based systems. As discussed in the Breadfruit Agroforestry Guide agroforestry systems are better at retaining plant nutrients and recycling from depth. Best practice is to base nutrient management on regular soil and plant tissue tests for nutrient status supplemented by your regular observations of plant health.

4.0 Pests and diseases

Breadfruit is generally considered to be a relatively pest and disease-free tree, but problems can occur with several fungal diseases and some pests (Figs. 6a-c). Insect pests are whitefly, scale, mealy bug, and fungal diseases include fruit rot (Phytophthora palmivora), brown stem rot (Phellinus noxius) and anthracnose (Colletotrichum gloeosporioides). Breadfruit is also a fruit fly host. This may not be a production problem but it poses a major quarantine/market access issue for fresh breadfruit exports.

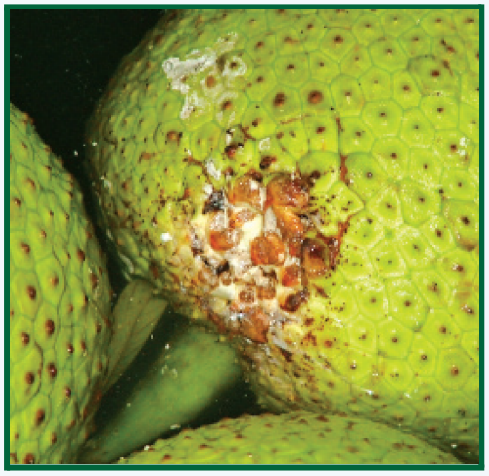

Figure 6a: Fruit Rot

Fruit rot is caused by the same pathogen that causes black pod in cocoa. The main control strategy is good site selection and field sanitation. In Samoa, the harvesting of all mature fruit and the removal of diseased fruit was found to effectively control fruit rot.

Figure 6b: Brown stem rot

Brown stem rot is a serious breadfruit disease, which in extreme situations can kill the tree. At present, no control measures are available. However, to minimize the risk of the disease spreading, trees should not be planted too closely.

Figure 6c: XXX

Whitefly, scale and mealy bugs are insect pests of concern and biosecurity officers from importing countries can be expected to order fumigation if these pests are detected; fumigation will destroy breadfruit. 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. The practice of some exporters in using a high pressure water hose to remove mealy bugs is not recommended. If ants are observed on and around the tree, then painting a ring of pure neem oil (especially on hot dry days) around the base of the tree can reduce ant access and their role in protecting scale and mealy bugs from natural predators.

"How do I manage pests and diseases?"

Proper care of the trees and good sanitation practices are all essential to reduce the risk of any of the pest and disease problems getting out of control, for example, mealy bug can be a serious problem if trees are stressed by drought and/or poor care. Proper care includes removing diseased fruit, removing dead and dying branches and mulching. Fruits should not be allowed to fully ripen on the tree, fall to the ground and rot. Good air circulation around and under the canopy is also important.

If considering exporting fresh fruit then fruit fly is a pest of specific concern. In Fiji, breadfruit is a host to the fruit fly species, Bactrocera xanthodes. In order to export breadfruit to New Zealand, Pacific Island farmers and exporters must follow an agreed quarantine pathway, which includes bait spraying (Fig. 7), high temperature forced air (HTFA) treatment (Fig. 8) and upper limits to the size of fruit that can be exported.

"What does bait spraying involve?"

Female fruit flies need to ingest protein before they lay their eggs. Protein obtained from the waste yeast left over after the brewing of beer, and to which insecticide has been added, can be sprayed on the underside of leaves. The protein induces rapid bacterial growth, generating an odour which attracts female fruit flies. The flies eat the protein along with the added insecticide and are killed. Because the bait attracts the flies, it is not necessary to spray the entire foliage. This reduces the risk of pesticide residue in the fruit as well as the loss of pollinators and other desirable insects

HTFA treated breadfruit sourced from bait sprayed orchards is permitted for export to New Zealand. It is expected that a similar export pathway will soon be in place for the Australian and USA markets. For fresh export all care must be taken to ensure that bait spray procedures are correctly followed together with the necessary field sanitation measures.

Figure 7: Bait spraying breadfruit prior to HTFA treatment (Sahn Ali orchard Buabua, Lautoka, Fiji

Figure 8: Breadfruit being probed for HTFA quarantine treatment at Nature's Way Cooperative Fiji

5.0 Harvesting, sap management and storage

Breadfruit is edible at any later stage of development but it is essential to understand the different stages of fruit development and maturity, and harvest fruit at the optimal stage for

the desired market or use. Fruit picked too green and still immature will have a longer shelf life than fruit harvested at the full mature stage but greener fruit is undesirable for most dishes and products.

Fruit generally reach full mature size and develop maximum starch levels (creamy texture and full flavour) at 12-16 weeks (or longer in cooler environments) from the time the tiny fruit emerges from the end of the branch. The grower has a window of about 2-4 weeks during which an individual mature fruit can be harvested.

"How can I tell when the breadfruit is ready for harvest?"

The grower must rely upon a combination of visual cues, such as skin colour (deep-green to lighter green or yellow-green), scabbing on and around fruit sections and skin texture changes to determine when the breadfruit is mature. Natural cracks in the skin also begin dripping sap (Fig. 9). The Breadfruit Production and Agroforestry Guides provide a description of fruit development with photos and also fruit maturity indicators for the Ma'afala variety. Nature's Way Manual describes fruit maturity and harvesting in the Fiji situation. Breadfruit at the stage of maturity desired for home consumption cannot be expected to last more than two days in the warm conditions of Fiji. For export, breadfruit has to be harvested at slightly less than full maturity which is described as mature green.

Figure 9: Sap as an indicator of maturity and sufficiently ripe Uto dina fruit being packed ready for export following HTFA quarantine treatment

The fruit must be harvested and handled carefully to avoid damage. Proper handling of the fruit will increase shelf life and fruit quality. The fruit is highly susceptible to bruising, which can cause discoloration of the skin and flesh, release of latex, bringing about ripening and decay. Harvesting, transport and storage are obviously activities where damage can occur. A significant portion of fruit on properly pruned trees can be harvested efficiently and safely from the ground without the use of tools. It is important to take into account safety requirements when harvesting breadfruit. Fallen fruit should not be used commercially because such fruit will have a shorter postharvest life and will be vulnerable to disease (but may be well suited to local food consumption or for livestock if unfit for human consumption).

Figure 10: (a) no exposure to sun; (b) 30mins exposure to sun; (c) 60mins exposure to sun; (d) extreme sun burning

Fruit must be kept in the shade as much as possible to avoid adding to field heat and sun burn damage. Harvesting fruit in the early morning hours helps to reduce field heat of harvested fruit. Figures 10a-d illustrate what happens when breadfruit are exposed to the sun for different lengths of time.

Containers for carrying and transporting harvested fruit need to be sturdy and well-ventilated, and allow for one layer of fruit (or two layers of fruit at most). Plastic crates are a good choice for field harvesting and brief storage periods (Fig. 11). Cardboard boxes with good ventilation can also be used. Polypropylene sacks are not acceptable as they do not allow for

ventilation or for protection of the fruit from compaction.

Figure 11 Plastic crate used for transporting breadfruit

"Breadfruit can produce a lot of sap – is that a problem?"

Sap management must also be taken into consideration. Every part of the breadfruit tree, including the fruit, contains a white, sticky sap (also called latex). Sap is concentrated in the skin and around the core of the fruit. The sap that is mainly seen as small globules on various parts of the skin, and which is considered an indicator of fruit maturity, poses little problem (Fig. 12a). Sap may ooze in copious amounts from the stem after the fruit has been picked or from abrasions on the skin causing unsightly discoloration of the fruit which is considered a marketing problem (Fig. 12b). Nature's Way Cooperative Manual describes a relatively simple method for managing the effect of sap on harvested breadfruit.

Figure 12a: Sap as an indicator of maturity; 12b: Unsightly sap oozing from the stem

Figure 12c: Tissue-type paper wrapped around end of fruit stem; 12d: Fruit in crate with paper wad retained.

When the fruit is harvested it is held stem-down to prevent sap from dripping down the stem onto the surface of the fruit. A wad of tissue-type paper is wrapped around the end of the fruit stem to absorb oozed sap (Fig. 12c). Fruit is placed directly into the plastic crate with the paper wad retained or on the ground until sap flow ceases, generally after 10-15 minutes (Fig. 12d).

Good postharvest practices are essential so that the fruit arrives at its destination with minimal quality degradation. Postharvest refers to all practices involved in transport and preparing or storing the fruit for sale, cooking or processing. High quality, unblemished fruit will fetch the best prices. If breadfruit is stored in suboptimal conditions, it will ripen, ruining the fruit for the firm-mature market. Minimizing bruising or other injury must be the overriding aim of any process for handling of fresh or frozen fruit.

"How can I store breadfruit?"

Ideally fruit is harvested, sorted, cleaned, packaged and delivered shortly afterwards to the customer. If this is not possible, then proper storage conditions are essential so that fruit quality, and therefore price, is maintained.

As green mature fruit will usually ripen and soften within 1-3 days, room temperature storage is the least preferred method. Freshly harvested fruit that is fully submerged in cool, clean fresh water can maintain quality for several days or longer (Fig. 13). Refrigeration can also increase shelf life with the optimum temperature range being 12-16°C. At these

temperatures, a shelf life of 10 days is possible and can be extended to 14 days if the fruit is wrapped in plastic. Below 12°C the skin will turn brown.

Figure 13: Breadfruit held in cool water bath to extend shelf life (Mahen's Exports, Sigatoka Valley Fiji)

Keeping the water temperature at about 13°C removes field heat and slows internal respiration. Warm water tends to cause swelling and splitting of fruit and therefore should be avoided. Fruit that is in an advanced state of maturity may take on water through fissures in the skin and develop severe cracks.

6.0 Risk assessment

Cultivation of a long-term tree crop for the export market is not without risks – though obviously planting complementary crops with that tree crop does mitigate risk to a large extent.

6.1 How vulnerable is my orchard to climate extremes?

The most obvious and serious risk factor for any tree crop in the South Pacific Islands is cyclones. The expectation is that cyclones are becoming intense, if not more frequent, due to climate change. Module 1 discussed the resilience of breadfruit to climate change and to extreme climatic events. The expectation is that this tree crop will be more resilient than most other crops to climate change. Management of the tree and the orchard significantly improves the tree's rate of recovery from any cyclone damage. However, it should be assumed that there will be fruit loss due to cyclones and in some of those years the losses

may be substantial. These losses can be simulated in your financial model. Below we show the consequences due to cyclones of: 50% loss of fruit in year 3; a 90% loss in year 5; and a 50% loss in year 8.

	1	2	3	4	5	6	7	8	9	10
Returns per day of household labour	- 18	22	16	142	9	223	267	120	268	269
Average annual gross margin per acre	**$ 7,576**									
Average annual gross margin per tree	**$ 152**									
Average annual return per day of household labour	**$ 144**									

As the result of these fruit losses the average annual gross margin per acre falls from FJD 8,419 to FJD 7,579; and the average annual return per day of household labour falls from FJD 185 to FJD 144. Under such circumstances, breadfruit would remain significantly more remunerative than alternative land uses such as sugar cane (which are often more adversely impacted by cyclonic winds and flood damage).

A prolonged drought during the breadfruit trees first 18 months of growth also poses a major risk. Once the tree is fully established, the impact of drought is considerably reduced – although an extended severe drought in dry/intermediate rainfall zones will impact on productivity. Thus, you may need to consider the installation of appropriate irrigation systems – particularly if you want to intercrop with vegetables and depending on your site.

For further information on breadfruit and climate change, including cyclones see:

- McGregor A, Taylor M, Bourke RM, and Lebot V, 2016 Vulnerability of staple food crops to climate change In: Vulnerability of Pacific Island agriculture and forestry to climate change, Taylor M, McGregor A, Dawson B, Eds. Pacific Community, Noumea, New Caledonia http://www.spc.int/DigitalLibrary/Doc/LRD/Agriculture/Vulnerability_Pacific_agriculture_climate_change.pdf
- McGregor AM, Tora LD, and Lebot V, 2016. Planting breadfruit orchards as a climate change adaptation strategy for the Pacific islands. Acta Hortic. 1128, 55-66 https://doi.org/10.17660/ActaHortic.2016.1128.8

6.2 Market access issues with fresh horticultural exports

If you are considering exporting breadfruit then fruit fly control must be taken seriously because of the potential impacts flowing from an importing country detecting any fruit fly eggs or larvae. Fruit fly eggs or larvae may be present on some fruit if growers do not follow the correct procedures. HTFA treatment will kill the eggs and larvae. However, if New

Zealand Quarantine authorities discover just one egg, “dead or alive” verification, which takes three days, will be required. Fiji had been exporting HTFA treated fresh breadfruit to New Zealand since 1997, with no quarantine issues encountered until May 2019, when breadfruit exports were suspended after fruit fly larvae was discovered in an oversized fruit. This was the consequence of a rogue exporter sourcing fruit that was significantly larger than the specified size limit from farmers who were not registered under the bilateral quarantine agreement. The offending exporter has his licence cancelled and stricter requirements relating to breadfruit variety and size and field sanitation are being drafted. The expectation is that the suspension will soon be lifted – however, in the meantime fresh breadfruit exports have been stopped - to the detriment of farmers and other exporters. Farmers have no market if exporters decide to suspend breadfruit shipments therefore diligence is required on the part of farmers and exporters to ensure that fruit fly procedures are strictly adhered to.

Fortunately, other markets remain for the breadfruit orchards. The fruit can either be sold for freezing prior to export or to the local fresh breadfruit market. It is expected that these market access risks will be further ameliorated as the breadfruit processing industry develops. You will need to consider what you might be able to do to reduce the impact of any potential future market loss. Appropriate intercropping is one such strategy. It was demonstrated in Fiji that by incorporating cassava as an intercrop in a breadfruit orchard, it was estimated that the farm can earn an average of FJD 1,545 per annum over the first 5-years.

The transition from firm to soft breadfruit happens quickly (sometimes in a matter of hours). If softening happens when breadfruit is still with the wholesaler or retailer, claims for compensation can be expected against the exporters and future orders may be curtailed. To minimize the risk of fruit softening in the market, growers and exporters need to closely follow the recommended guidelines for breadfruit production and export. These guidelines are presented in the Fiji Breadfruit Quality Guidelines (Fig. 14) produced by Nature’s Way Cooperative, who operates Fiji’s HTFA.

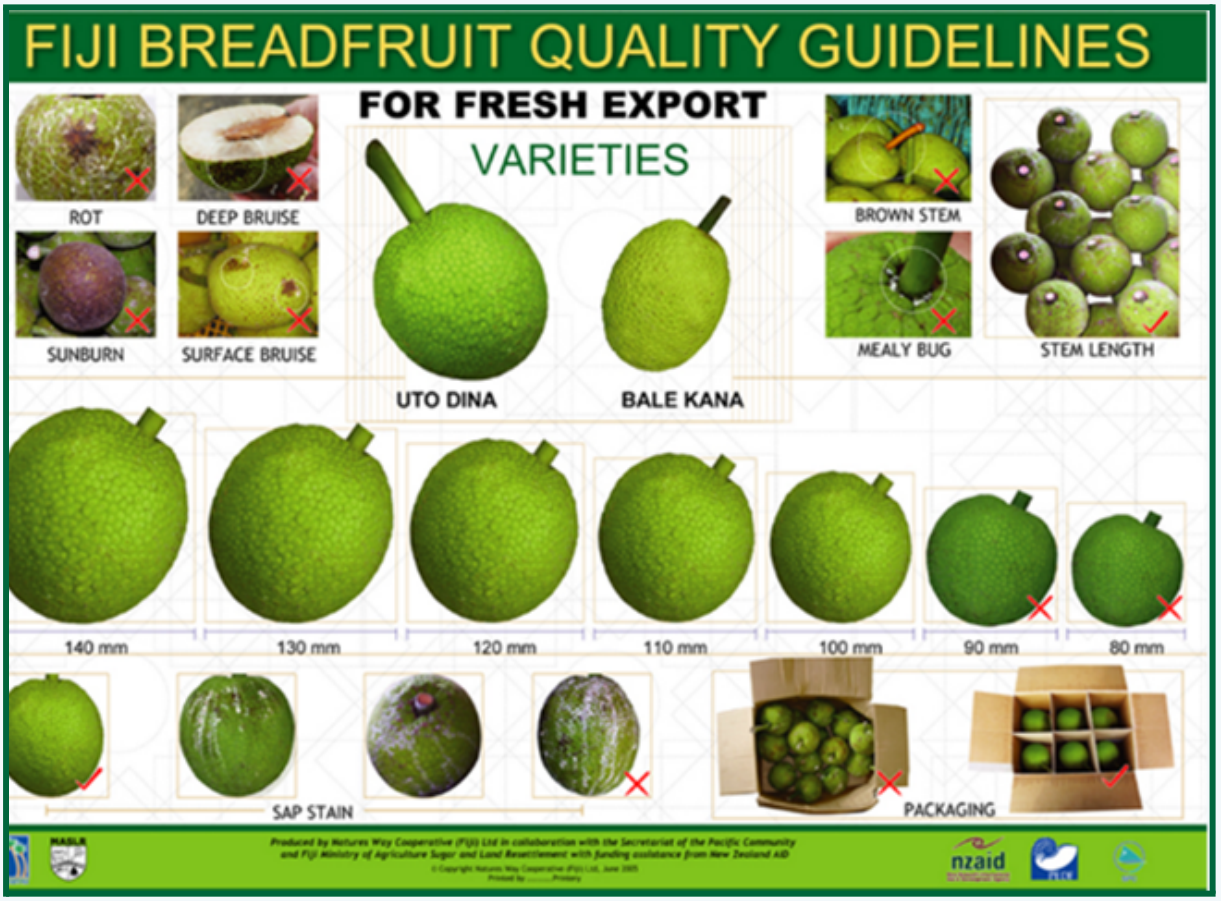

Figure 14: Fiji breadfruit quality guidelines

6.3 Pest and diseases

Breadfruit grown as a traditional crop is known to have minimal incidence of pests and diseases. The susceptibility to fruit fly in most Pacific Island countries is an important exception, (although this is more a quarantine risk rather than a production issue). However, the susceptibility to pests and diseases could be expected to increase when the breadfruit is grown as an orchard crop. This risk can be ameliorated if appropriate agroforestry measures such as alley cropping and field sanitation (removing overripe fruit) are adopted.

The following questions take into account what has been presented in this module. You should consider them carefully as the answers will provide the information you need for the business plan.

Questions	Answers
Will you need to add soil amendments to your planting area and also what nutrient management practices on a yearly basis do you envisage?	Y / N
Do you have a plan for mulching?	Y / N
Will you have to install irrigation?	Y / N
What will be the labour input for planting, weeding, pruning, bait spray application (if relevant), harvesting, sap control and field packing?	Y / N
What harvesting and pruning equipment will be required – stick picker, pruning saw, pruning lopper, ladder, plastic field bins?	Y / N
Do you envisage any storage requirements – if yes, what will these be?	Y / N
What transport will be required for all activities outlined in this module?	Y / N
What is planned for damaged or second grade fruit to optimise economic and other returns –composted; part processed into chips or flour; or stock feed for chickens and pigs?	Y / N