Protected cropping systems training manual

A manual developed for use in the Pacific Islands

FIRST EDITION

Pacific Community
Communauté du Pacifique

Australian Centre for International Agricultural Research
Australian Aid

Protected cropping systems training manual

A manual developed for use in the Pacific Islands

FIRST EDITION

Pacific Community
Communauté du Pacifique

Suva, Fiji, 2022

Original text: English

Pacific Community Cataloguing-in-publication data

Protected cropping systems training manual: a manual developed for use in the Pacific Islands

1. Agricultural systems – Oceania.
2. Crops and climate – Oceania.
3. Agricultural extension workers – Oceania.
4. Cropping systems – Study and teaching – Oceania.
5. Plants, protection of – Oceania.
6. Cropping systems – Oceania – Handbooks, manuals, etc.
7. Plants, protection of – Oceania – Handbooks, manuals, etc.

I. Title
II. Pacific Community

631.580995 AACR2

ISBN: 978-982-00-1349-0

Prepared for publication at SPC's Suva Regional Office,
Private Mail Bag, Suva, Fiji, 2022
www.spc.int | spc@spc.int

Contents

About this training manual

This training manual has been written in collaboration with the research and extension staff of the Fiji Ministry of Agriculture, with expert input from members of the Australian Centre for International Agricultural Research (ACIAR) funded project HORT/2014/080 'Integrating protected cropping systems into high value vegetable value chains in the Pacific and Australia'. It is intended to be used as a resource for government and NGO staff engaged in supporting farmers to adopt and manage protected cropping (greenhouse) production systems.

This manual contains basic guidelines for protected cropping production in Pacific Island countries and territories and documents recommended approaches to be used by extension staff in training farmers who wish to learn about protected cropping systems.

PROJECT CONSULTANT TEAM	NAME
Central Queensland University	Professor Phil Brown
Fiji Ministry of Agriculture	Mr Shalendra Prasad Kasanita Ratu Ilisapeci Batisarisari Ratu Solomoni Naisau Extension Officers Research Officers
Queensland Government	Dr Elio Jovicich
Land Resources Division, Pacific Community	Fereti Atumurirava David Hickes Mani Mua Aloesi Dakuidreketi

This publication has been funded by the Australian Government through ACIAR. The views expressed in this publication are the authors' alone and are not necessarily the views of the Australian Government. The Australian Government neither endorses the views in this publication, nor vouches for the accuracy or completeness of the information contained within it. The Australian Government, its officers, employees and agents, accept no liability for any loss, damage or expense arising out of, or in connection with, any reliance on, or any omissions or inaccuracies, in the material contained in this publication.

How to use this training manual

This manual is designed as both a resource for trainers to gain knowledge about protected cropping production systems and as a source of strategies and materials to be used in delivering training programmes for farmers. Each section in the manual is divided into background reading to provide trainers with the knowledge needed to be confident in delivering training on the topics covered, and recommended training approaches and resources that can be used in delivering training to farmers. This manual is not intended as a comprehensive source of information on protected cropping systems, but rather as a framework that highlights the aspects that are important to consider and encourages further exploration of those areas using other available information sources and first-hand experiences.

Organisations and individuals will find this manual valuable for:

1. equipping a selected group of lead trainers to be able to direct extension and training activities to support the growth of protected cropping in Pacific Island countries and territories (PICTs);

2. supporting research and extension staff to understand all of the important aspects of protected cropping, and to gain the confidence needed to deliver effective training;

3. identifying strategies that can be used effectively to help farmers successfully use protected cropping in PICTs.

Protected cropping approaches vary from low-input, low-cost systems to sophisticated and expensive systems. This manual is focused on the lower input systems that are most applicable to farmers in PICTs but covers a range of systems from very basic structures and crop production practices – suited to those with limited resources and little knowledge of protected cropping – to more advanced systems for those with some experience in growing crops under protective structures. Users of the training manual should engage with farmers to determine the appropriate systems for their situation and use the recommended training approaches for that system.

The manual also includes activities and answers for review of performance. Trainers are encouraged to adapt and create new questions when conducting training to demonstrate their understanding about protected cropping systems and to keep the trainings interesting.

The training manual is intended as a *living document* and trainers are encouraged to add new content and training approaches as they learn more about protected cropping.

SECTION 1

What is protected cropping?

Introduction for trainers

This section is intended to equip trainers with the foundation knowledge needed to understand protected cropping and to explain to farmers what protected cropping systems are and how they work. Trainers should use the information presented and, if desired, the additional resources listed, to learn the basics of crop production in protected cropping systems. The information presented in this section can also be used in presentations to farmers who have no knowledge of protected cropping, as a way of raising their awareness of the production systems. Awareness is the first step on the journey to the successful use of protected cropping, so it is vitally important to establish a strong foundation by explaining the basic knowledge clearly. Farmers who have a strong foundational knowledge are best positioned to make good decisions on whether protected cropping is likely to work for them.

Use this section to develop your understanding of the basic crop production concepts involved in protected cropping, and then use that understanding to help farmers gain awareness of protected cropping.

Understanding protected cropping

Protected cropping is the production of crops within structures that shelter the plants from adverse weather conditions as well as providing growing conditions that better match the ideal requirements of crop plants. Some protected cropping systems can also provide protection from pests and diseases. The key message when explaining protected cropping is that it involves some form of structure that modifies the conditions in which the crop plants grow.

Crops grown in protected cropping systems usually have more reliable production than crops grown in the open field. The protected cropping technology is used to manage and manipulate the growing conditions to reduce uncertainty and optimise crop growth. Different protected cropping structures and production practices have varying capacity to provide optimal conditions, so care must be taken in selecting a structure and production system that suits the location, the resources available and the skills and knowledge of the farmer.

Protected cropping systems were developed in cold climate countries where the use of a glass or clear plastic enclosed structure produces a warmer environment and allows crops to be grown at times of the year when outside temperatures would otherwise prevent most crops from being grown. Since the structure prevents rain from falling on the crops inside, systems for providing the water and nutrient needs of crops were developed as a necessary part of protected cropping. Cold climate protected cropping systems have become quite advanced, with automated heating and cooling systems, precisely regulated irrigation and nutrition programmes, intensive crop training practices, and even the use of artificial lighting to promote crop growth. These high technology systems are amongst the highest yielding crop production systems on earth.

In tropical environments, the use of protected cropping to provide warmer growing conditions is usually not needed. However, protection from the rain during the wet season can allow crops to perform well, so protected cropping systems that are designed to shelter crops from adverse weather conditions are beneficial. Since a plastic covered structure will still warm up inside, the design of the protected cropping structures for tropical conditions is important to prevent temperatures from being too high for the crops being grown.

The capacity to consistently and reliably control or manipulate the growing environment and effectively manage irrigation, nutrition, pests and diseases is the basis of profitable and sustainable production using protected cropping.

What do crops need to thrive?

All plants require four basic inputs to grow. They are:

1. light,
2. water,
3. the gas carbon dioxide, and
4. essential nutrients.

Sunlight is free, so for crops we usually do not need to consider providing light to the plants we grow. Different crops have different light level requirements, so in protected cropping it is important to know the needs of your crop. In protected cropping, the plastic covering on the structure blocks some of the light from the sun from reaching the crop. This can be beneficial as in some situations high light levels can damage plants. For example, sun scald on fruit grown in the field results from exposure to high light levels. If the weather is cloudy for long periods, or if too much light is blocked by the protected cropping cover, this can slow down the rate of growth of the crop and cause other problems in production.

Water also comes for free as rain, but because rainfall is not consistent throughout the year there are times when a crop plant can suffer from a lack of water. Plants consist of around 80%–90% water, so if the supply of water is inadequate, they cannot grow properly. Mild water stress causes reduced crop growth rate and can affect the quality of the crop. Severe water stress results in death of the plant.

Carbon dioxide is a gas in the air, so it is also provided free for crop growth. In humans, when we breathe we take in oxygen gas and through the process of respiration use the oxygen to produce the energy that keeps our cells functioning. When we breathe out, we generate carbon dioxide gas. Plants are able to do the reverse of that: by taking carbon dioxide from the air and using the energy from sunlight in the process of photosynthesis, they manufacture energy-rich carbohydrates and generate oxygen that is released into the air.

All plants require a supply of 17 **essential nutrients** or chemical elements to grow. These include six macronutrients (nitrogen, phosphorus, potassium, sulfur, calcium, magnesium) and 11 micronutrients (sometimes called trace elements). The nutrients perform essential functions in plant cells, including being part of the structure of cells and being involved in biochemical reactions that occur in the plant. All of these nutrients can be found in soils, but sometimes the levels present are not sufficient for normal plant development. In agriculture, it is common to add additional nutrients to the soil either through the addition of manure, compost or chemical fertilizers or through use of good crop rotation containing deep-rooted plants and legume plants.

In addition to the four basic requirements for survival, the growth rate of plants is also influenced by the temperature. The rates of biochemical reactions, including important ones like photosynthesis, are affected by temperature, so all plants have an optimum temperature range in which they will develop most rapidly. If the temperature is too low or too high the growth rate will be reduced, and if plants are exposed to more extreme temperature they can be killed.

The final factor affecting the growth and yield of crops is the impact of weeds, pests and diseases. Weeds growing in a crop can block sunlight from reaching the crop plant as well as taking up some of the water and nutrients from the soil that the crop plants would otherwise have access too. Diseases and pests feed on the carbohydrates that the plant has produced through photosynthesis, so the energy stored that the plant generates is lost to those organisms rather than being used by the plant to grow bigger and produce harvestable products. Damage to plants caused by pests and diseases can also reduce the quality of the part of the plant we harvest, and can also result in rapid deterioration in product quality after it is harvested.

How does protected cropping provide good crop growing conditions?

The protected cropping system requires management of all of the above factors in ways that are often different to field production systems. A well-designed and -managed protected cropping system will allow the farmer to provide a more consistent and generally better environment for plant growth than in the field, but if each of the above factors is not considered in the design and management of the system, then complete crop failure can occur.

The use of a structure places a protective cover over the crop. Selection of the plastic used will influence the light levels inside the structure and having a frame to attach the plastic to also allows the grower to further vary the light levels – through the use of shade cloth to reduce light levels or the use of artificial lighting in high technology structures to increase the light levels.

A plastic-covered structure is like putting an umbrella over the crop – rain will no longer reach the soil where the crop is growing. Since water is critical for crop growth, an irrigation system must be incorporated into all protected cropping structures. A well-designed irrigation system allows the grower to provide the crop with the right amount of water at the right time for maximum plant growth.

In high technology greenhouses, the concentration of carbon dioxide in the air can be increased to promote faster plant growth. This requires specialised structures that don't allow the gas inside the structure to easily move out of the structure. In tropical production systems, manipulation of carbon dioxide concentration in protected cropping is very rarely used.

Crops grown in soil inside a greenhouse have access to nutrients in the same way as field-grown crops, but since the conditions in the structure can be more favourable for plant growth, the nutrient requirements can be higher. Use of organic or chemical fertilizers is needed to promote optimum crop performance. In more advanced protected cropping systems, plants can be grown in peat media or other artificial substrates (not soil) or in a water (hydroponic) system. These systems require all the nutrients to be provided through the irrigation system, which can be beneficial for crop performance as the nutrient inputs can be carefully controlled to ensure the crop receives the right amount of nutrient at the right times.

The design of the protected cropping structure determines the temperature range that will occur inside the structure. All plastic-covered structures will trap heat, so will be warmer inside than outside. In tropical locations this can lead to very high temperatures inside the structure that may be damaging to crops. Designs that promote air movement through the structure (e.g. open sides, roof vents) and that are high (hot air rises, so a high structure has the hottest air furthest away from the crop) are generally used. Orientation of the structure is also important for temperature management. In more advanced systems, cooling can be achieved using reflective covers that can be put in place in very sunny weather, water misting systems in the structure or various mechanical cooling systems attached to the structure.

Pests can sometimes be excluded from protected cropping systems if the structure is covered in insect-proof mesh. Also, since the crop is being grown in what is often a relatively small area and receiving more frequent visits to manage activities such as irrigation, the presence of pests and diseases can be picked up early. A well-managed protected cropping system can lead to better pest and disease management than in the field, but the environment inside the structure is often great for pests and diseases as well as plants, so poor management can lead to significant pest and disease problems.

Recommended training

Trainers who have a good understanding of the foundation knowledge presented in this section can lead training with farmers who have no knowledge of protected cropping. This training is aimed at raising awareness of protected cropping systems. It should be delivered to farmers' groups and communities that have very limited understanding of the concept of protected cropping. For farmers who are interested in taking the first step in adopting protected cropping, the training in the next section of the manual is recommended.

EXERCISE: Introduction	**Why do we do it this way?**
Small group activity: Work with small groups of farmers (divide larger groups up into smaller groups of 4–6). Ask them a series of questions and get them to discuss answers within their group. Answers can be written down or spoken aloud after groups have had a short time for discussion. Examples of questions that can be asked are: 1. Why is it not possible to grow crops all year round in the field? 2. When you think about the best yielding crop you have grown, what things (time of year, weather conditions, crop management practices, soil type) helped get that good yield? 3. When you grow crops in the field, what can you do to stop the crop from being exposed to harsh weather conditions (too much wind or rain, hot and dry weather, cold weather)? 4. If you could control the weather, what would be the perfect weather conditions you would choose to grow one of your crops?	Farmers discussing topics with each other will help them learn from each other's experiences. The questions suggested for this activity are designed to get farmers thinking about what crop plants need in order to grow (you can explain the four key inputs described earlier when discussing their answers), how these things vary in the field, and how difficult it is to control some of these things when growing a crop in the field. If the activity runs successfully, when farmers are aware of the key inputs and how hard it is to control them in the field, then you can introduce protected cropping as a system designed to have better control of inputs and better crop performance as a result.

Lead a discussion on the answers to the questions, highlighting how protected cropping can provide a more consistent environment for crops to grow in so they can produce higher yield and better quality.

This training may be done simply to introduce farmers to protected cropping, or combined with the training in the next section if the farmers are interested in adopting protected cropping.

SECTION 2

Introducing farmers to protected cropping

Introduction for trainers

This section is a general introduction to protected cropping systems in the Pacific. It aims to provide a better understanding of the potential benefits and the risks of this type of farming. Trainers should use the information presented in this section to improve their understanding of protected cropping and to use that knowledge to assist farmers to make good decisions on whether protected cropping is the right system for them to consider using.

At the end of this section, trainers should be able to lead activities with farmers that allow them to:

- define protected cropping systems in their own words;
- better understand the benefits and drawbacks of protected cropping;
- relate the potential of the technology to the conditions in their own country;
- be aware of culture and traditional aspects that may influence the promotion and adoption of this farming technology.

In this manual, we define protected cropping as a way of producing crops in structures designed to modify the growing conditions to make them more favourable for crop growth. It is important to note that the protected cropping system does not describe the structure, but rather the set of management practices used to grow the crops within the structure.

Some unfavourable environmental conditions for growing crops include:

- excess rain
- strong winds
- excess heat from the sun
- high humidity
- pests and diseases – including stray animals and chickens/birds.

NOTE: Protected cropping does not necessarily mean protection from natural disasters. The careful management of crops and structures is needed during severe storms to limit damage.

Even though PICTs are spread across vast areas of the Pacific Ocean, the cyclone or hot-wet season is normally from November to April. This is regarded as the off-season period for the growing of many vegetable crops, leaving only about six months or less for the regular vegetable season. Many farmers choose not to plant during the off-season because of the wet soil conditions and frequent pests and diseases associated with high humidity conditions. As a result, locally produced vegetables are mostly short in supply causing prices to fluctuate. In addition, the government and many supply and demand agents have to import most of the vegetables to be able to match local demand. Therefore, protected cropping technology provides a direct solution by helping farmers to produce vegetables out of season, which could minimise imports and settle the price of vegetables so they are affordable to consumers.

During the rainy season, the production quality from farmers is normally quite low because they plant in open fields that are fully exposed. However, growing under protected conditions can guarantee better quality and therefore higher market value. Again, protected cropping also guarantees a better shelf life for longer term storage, which is important in post-harvest handling compared with open field products that may need extra care, which would normally put pressure on the supply value chain.

Stages in protected cropping systems

Growing crops in greenhouses in tropical conditions is very different from growing crops in the open field, so farmers wishing to adopt protected cropping must learn about new technologies and new management practices if they are to be successful. There are many different types of protected cropping structures and scales of production that are available to farmers. Selecting the right structure and the right production practices can be very difficult, particularly for farmers who are new to protected cropping. We recommend that farmers adopt a sequential approach when starting out in protected cropping, beginning with lower cost and less technical structures and systems to gain experience and knowledge in protected cropping before taking further steps to more advanced production systems.

FIGURE 1: A step-based approach to adopting protected cropping systems

The images above are examples of systems that are indicative of the progression from field production to very advanced greenhouse systems. There are thousands of different greenhouse designs and crop management practices that could be used to show the progression, so the above images are used to highlight the concept of progression from low-input, low-technology systems to the most advanced systems. The obvious change as we progress through the steps is in the structures themselves, but many other differences exist that are not so obvious. The costs involved in setting up and operating the systems increase as we go to higher steps. The productivity (amount of production per unit area of land) and often the financial return increases. The equipment and practices used inside the greenhouses to manage irrigation, pests and diseases, and crop growth habit, to harvest and handle the crops produced, and to manipulate the environment around the crop may all change as more complex protected cropping systems are adopted.

When a farmer makes the decision to take another step up the protected cropping development pathway, consideration must be given to all the components that are needed at the new level. The analogy presented below is designed to reinforce the message that a protected cropping system is more than the structure, and that all components need to be addressed to succeed at whatever the step on the sequential adoption process.

The kava bowl analogy

Think of a kava bowl (pictured) – it can hold kava if it is held up by four stable legs.

The bigger the kava bowl, the stronger the legs must be to support it when it is full. In the same way, a protected cropping system can produce good quality vegetables and good profits for the farmer if four aspects of the system are strong enough. These four areas are:

- an appropriate structure, with the right technology inside the structure;
- a suitable programme to manage the growth of the crop;
- a suitable programme to control the weeds, pests and diseases that can affect the crop;
- a market for the product grown in the system that is profitable for that system.

More advanced protected cropping systems are like larger kava bowls – they have a higher capacity (they have higher potential crop yields and bigger financial returns) but that capacity can only be captured if the bowl is supported by legs strong enough to hold its size and weight. If one of the legs is weak, the leg can give way under the weight of the bowl and the kava spills. If one of the legs in the protected cropping system is not strong enough, then in a similar way the system will not be able to achieve the production capacity and financial returns that a system of that size should be able to achieve. And, in the same way that bigger kava bowls have stronger legs, the more sophisticated protected cropping systems require greater attention to detail and generally more management inputs in all four areas.

To support growers to adopt protected cropping systems, information should be available on the potential productivity of the systems at the different steps (the size of the kava bowl), the inputs needed for a system of that size (the cost of the kava bowl), and the technologies and management practices that are most effective at that step (the ways to make the legs strong enough to hold the bowl). Using the kava bowl as an analogy, trainers will be better able to help farmers understand the principles of protected cropping and to support increased adoption of the production system.

Why have farmers not adopted protected cropping?

A survey was conducted in Fiji in 2020 to better understand why most farmers still grow under open field conditions, in other words, why most farmers have yet to adopt the protected cropping technology that has been available in Fiji for over 20 years. The results from the survey noted a high interest in protected cropping. However, technical skills, know-how and the materials needed to operate under protected cropping are major barriers. Awareness of the views and perceptions of farmers is valuable when planning training activities, so the information presented below should be considered when engaging with new groups of farmers.

A total of 44 farmers were surveyed from Rewa, Tailevu and Nadroga provinces in Viti Levu, Fiji. The results indicated that 93% of farmers knew about protected cropping. However, only six farmers (13%) have experienced growing under greenhouse conditions. In fact, almost all farmers surveyed (97%) wanted to have a structure at their farm. The only farmer who did not want a structure strongly believed that there was no need because it was labour intensive and that he could not use his horse indoors. Another farmer noted that he was focused more on root crops like taro and cassava so has no need for a structure, but he would still like to have one. Meanwhile, 89% of the farmers were confident that growing under protected cropping would allow them to earn more money. Most of the farmers (89%) also experienced minor to major damage to their crops during off-season.

FIGURE 2: Farmer awareness on protected cropping in Fiji

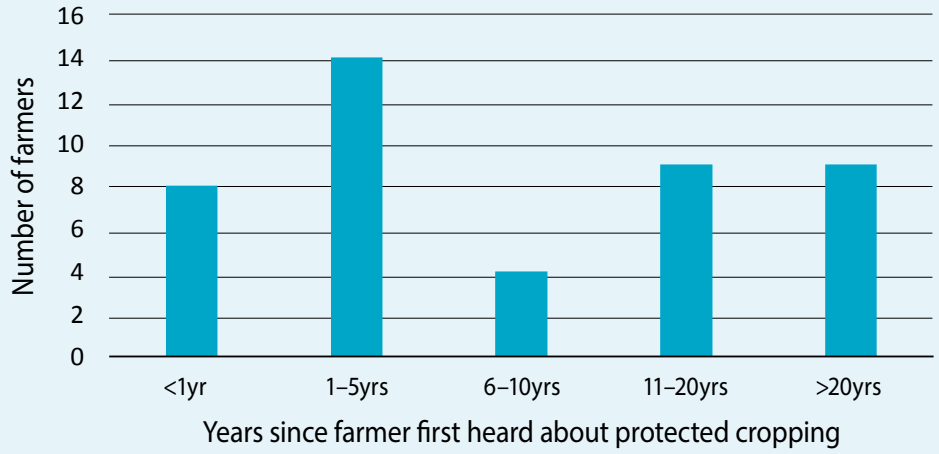


FIGURE 3: Major reasons for farmer delay in acquiring protected cropping structures.

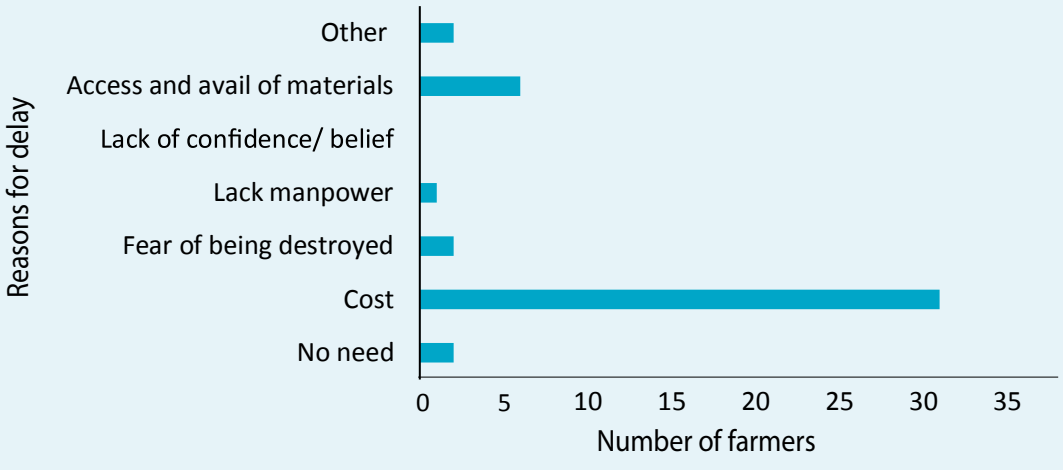


FIGURE 4: Farmer view of potential of protected cropping

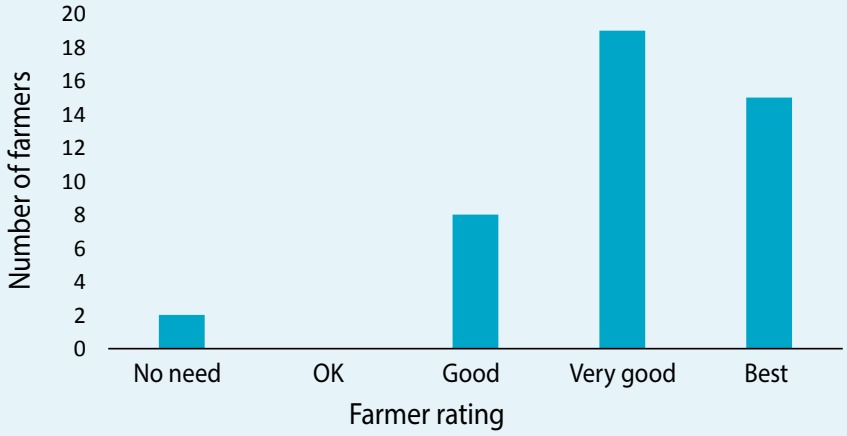
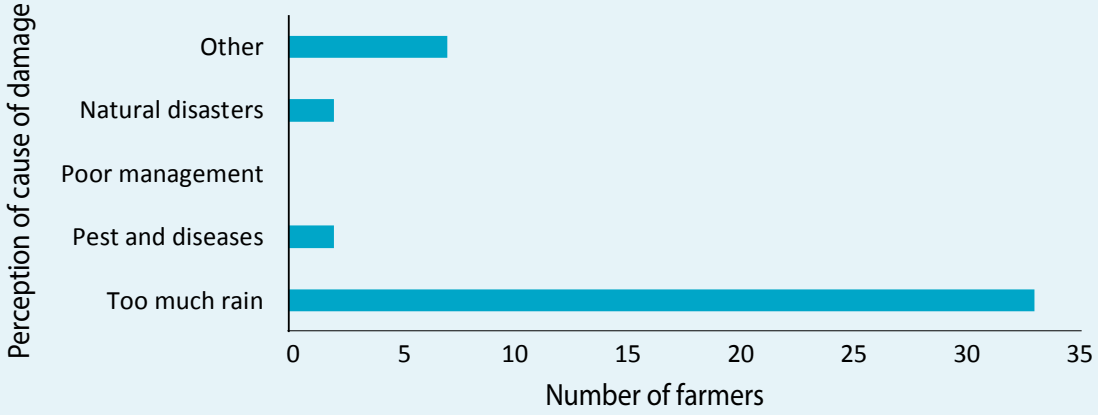


FIGURE 5: Farmer perception of cause of damage in off-season production



In summary, general comments highlighted the need for a transition from open field to protected cropping for more control of supply and quality. In addition, growing under protected cropping was viewed as the best practice these days especially in the wet season and has helped increase income. Climate change was another factor that was considered by farmers; for example, when the weather becomes too hot, too wet, or too dry, and the pests associated with these conditions increase. Farmers also believed that it was much easier to work under structures now to raise seedlings and produce crops, especially on the productivity aspect, with longer hours available to be spent compared with open field conditions (excess heat from sun). Moreover, farmers believe that protected cropping will make farming more interesting and should attract more young people. However, the cost of purchase of protected cropping structures and equipment was a major issue, and many farmers relied heavily on government and donor aid, which was a major barrier to the adoption and diversification of this system. In fact, there were a lot of requests for structures as many have the land and/or labour but not the materials to construct a simple structure. While government and donor aid would continue to support farmers, trainers should consider strategies to help change farmer mindset and attitudes to promote self-reliance.

Protected cropping case studies in Fiji

Farmers may seek information on the experiences of other farmers to help them gain the understanding and confidence needed to take the first step in using protected cropping, and then to keep taking steps into more advanced protected cropping systems. Case studies are a useful training tool to highlight the potential of protected cropping and to assist with providing this information to farmers.

CASE STUDY 1: Tomato crop grown in inexpensive metal hoop structure – Sigatoka Valley

Size:	24 m × 8 m plastic house
Total no. of plants:	380
Irrigation type:	Drip
Commodity:	Tomatoes
Market:	Municipal markets
Price:	FJD 10/kg
Harvesting period:	October 2019 – January 2020
Total income achieved:	FJD 6,670
Benefits:	Enabled to contribute to social activities in the village.
Support:	Able to support grandchildren's school activities.

CASE STUDY 2: Tomato crop grown in galvanised metal hoop structure – Sigatoka Valley

Size:	26 m × 6 m plastic house
Total no. of plants:	350
Irrigation type:	Drip
Commodity:	Tomato (Roma)
Market:	Fijian resorts
Price:	FJD 10/kg grade 01
Harvesting period:	May–August 2019
Total income achieved:	FJD 4,570
Benefits:	Enabled to contribute to social activities in the village.
Support:	Able to support son to attend a prominent school in Fiji (Ratu Kadavulevu School) and grandchildren's school activities. Able to contribute to completion of concrete house.

Recommended training

The recommended training for this section is for use with farmers who already have some knowledge of protected cropping but have not yet tried it. Farmers who have unsuccessfully tried protected cropping may also benefit from the training.

Before commencing training with farmers, trainers should familiarise themselves with the two main concepts presented in this section: the steps (or levels of sophistication) of protected cropping systems, and the four key elements of protected cropping (the four legs of the kava bowl). It is also recommended that trainers review the survey results to understand why farmers have not yet tried protected cropping.

The recommended training activities are designed to provide farmers with an understanding of what is involved in protected cropping (Exercise 1) and to evaluate if protected cropping is likely to work for them (Exercise 2).

EXERCISE 1: Understanding protected cropping	**Why do we do it this way?**
Small group activity: Using the information presented in this section, provide a review of the information from Section 1 and then explain to the farmers the concept of steps or levels of protected cropping and introduce the kava bowl analogy to highlight the four key components of protected cropping systems. Work with small groups of farmers (divide larger groups up into smaller groups of four to six) to help them understand the information presented. Provide butcher paper and markers for each group. Ask them to discuss the steps of protected cropping and the kava bowl analogy, and then write down questions they have on any aspects of the topics that they don't understand. You may need to circulate between groups to prompt discussion on areas they don't fully understand so that they can clearly identify things that they can't explain to each other. Lead a discussion to answer all of the questions.	Farmers discussing topics with each other will help them learn from others' experiences. By discussing the topics, they help each other learn but also will see that there are areas that they need help to understand. No one likes to appear "stupid" by not being able to explain things that they think other people know, so, by allowing farmers to work in small groups with other farmers that they trust, you will be more likely to get them as a group to identify areas that they all don't fully understand. If asking farmers to write down questions doesn't appear to be working well, then an alternative is to ask them to write down areas where they would like more information.

EXERCISE 2: Is protected cropping for me?	Why do we do it this way?
Planning with individual farmers: Work through the following checklist with the farmer (and, if appropriate, with his/her family) to help him/her decide if setting up a protected cropping system is a good decision: • Do you have a suitable site (level land and good soil, not flood prone, not shaded by trees, easy to access)? • Do you have money to buy and run the protected cropping structure, irrigation system and inputs such as seeds? • Do you have access to water for irrigation? • Are you (and your family) prepared to put in the extra time it takes to grow a crop in protected cropping compared to outside? • Are you confident you have the knowledge to grow crops in protected cropping, or access to people such as Ministry of Agriculture staff who can assist with advice? • Have you identified the markets where you will sell your crop, and is the price you are likely to get big enough to cover your costs of production?	There are many examples of farmers who have received protected cropping structures from aid projects or government programmes failing to grow crops successfully in the structures. Working through the checklist with growers will help reinforce the idea that simply having a structure does not lead to success in protected cropping. Each question on the checklist should be used as a prompt for discussion to ensure any farmer choosing to try protected cropping is doing so with full awareness of what is needed to succeed.

SECTION 3

Protected cropping structure design and construction

Introduction for trainers

This section covers one of the "legs of the kava bowl" – the need for an appropriate structure and the right technology inside the structure. Emphasis is placed on structures at steps 1 and 2 in the series of protected cropping steps covered in the previous section. As protected cropping becomes more widely adopted in Pacific Island countries and territories, and growers transition to higher steps, new material should be added to the manual to guide the growers operating in more advanced protected cropping systems.

This section is more technical and should include several practical exercises. The suggested training of technical aspects will help trainees better understand the conditions and especially the reasons why technical decisions are critical. The practical activities will provide more experience for the trainees with the expectation that they will be able to use this training to help think outside the box and be more creative.

At the end of this section, trainees should be able to:

- list factors to consider when designing a structure;
- identify key components of a simple structure;
- identify key components for a simple operating protected cropping system;
- differentiate structure types;
- determine suitable crops for any selected structure and environmental conditions; and
- design their own structure for a target crop range.

Components of protected cropping structure designs

Structure purpose

Farmers occasionally request Category 5 cyclone-proof greenhouses. In other words, many farmers now understand that they only have partial control over their crops in open field systems but more control under rain shelters. So now many wish to have more control, which will lead to the best quality, consistency, and reliability of supply. That farmers are asking for Category 5-proof structures is a major concern, since most people's homes in the Pacific Islands are not Category 5 cyclone-proof. Farmers must therefore be taught to ask more relevant questions such as which structure design they can put up and take down easily with less physical labour, but which is compatible enough to get high returns.

It is clear in the Pacific Islands that no one shoe fits all, and this applies in protected cropping systems. However, the principles are valid, and farmers only need to make some adjustments to adapt to their particular conditions, which can be difficult at times. Protected cropping in the Pacific is mainly a rain shelter. However, it is not only the excess rains that farmers need to protect their crops from. Other major factors include:

- excess heat from the sun
- flooding
- pest and diseases
- natural disasters – particularly drought.

Rain shelter

Rain provides water, which is a basic need in crop production, but excess or insufficient water is not good for several reasons. More moisture than the crops require can cause waterlogging and mineral leaching and promote disease growth. Rain also leads to flower drop on plants, it softens soil and plants can fall over (known as lodging) if not well supported. Of course, insufficient water will lead to unhealthy growth and more problems. Plastic is the best cover for rain, and the type of plastic material makes all the difference in durability and cost.

Excess heat from the sun

Stunted growth and other physical disorders or conditions can develop from excess heat from the sun. If a farmer is more worried about the excess heat than rain, then simply using a shade cloth (with a shade percentage depending on climatic conditions) will be enough. In fact, a plastic sheet can serve two purposes including both rain shelter and shade rather than just the shade provided by shade cloth. Better yet, a combination of plastic and shade cloth is fine if farmers have the means. Used in this way, shade cloth can even secure plastic (especially cheap plastic) from tearing if applied correctly. Therefore, always explore all available options and choose the most cost-effective system for best returns.

NOTE: Light energy (sunlight) is needed by crops for food and development. However, it is the heat that accompanies the light that is troublesome when severe. A plastic cover over a crop in protected cropping can increase the temperature. Some crops have been bred specifically for heat tolerance, allowing those crops to withstand a relatively high temperature. Choosing the right structure that lets in sufficient light and does not make it too hot, as well as choosing the right crop variety, are essential for successful protected cropping.

Flooding

The issue of flooding should be considered at the designing and planning stage. Ensure that the location is not a flood-prone area. Choose an elevated location if possible, as long as it does not compromise other operating measures. Cutting drainage ditches around the outside of the structure can also reduce the risk of water washing through during heavy rain.

Pests and diseases

Pests and diseases will be discussed in Section 5. However, when designing a structure, it is important to consider if there are any stray animals, including birds or chickens, because they can become a big nuisance. In some parts of the Pacific, chickens and stray pigs can be at the top of the economic pest list. Fencing around the outside of the structure should be considered if the risk of animals causing problems is high.

Drought

If the location of the structure is in a drought-prone area, then care must be taken to ensure a safe buffer zone from bush fires and so on. Also ensure that there is a good water source that can be conserved to be used under the structure. The structure itself, if properly oriented and ventilated, can help reduce evaporation and thus, save water during drought conditions.

Factors to consider when designing a structure

There are numerous factors to consider when designing a structure. However, the main areas should include:

1. assets (land, labour, capital – cost of structure);
2. farm plan (seedling nursery, vegetable production, or both);
3. availability and accessibility of inputs (structure, seeds, agronomic tools etc.);
4. site location (water supply, drainage, elevation, orientation, risk of natural disasters etc.);
5. target market and crops.

Assets

Land, labour, and capital are the major three production pillars. Many farmers in the Pacific have the land but lack labour and capital. Some have labour and capital but limited land. Others have only labour but not land and capital and so on. Hence, when designing a structure, any farmer must consider all three (land, labour, and capital). Of course, every farmer would like to have a big structure, but experienced farmers will ask to start small unless they have the expertise and capital needed to hire labour and, importantly, cover the cost of the structure.

Land is important and the area helps determine the operation scale, structure orientation, length and so on. Labour of course is equally important. In the Pacific, advanced technologies like fully automated systems have yet to be promoted and so the need for field labour is still high. Capital, of course, is critical as well. Farmers with more money can increase their land and labour and therefore their output.

Farm plan

Farmers should have a plan before designing a structure. In the end, making profit in addition to their subsistence needs is critical and so farmers must know exactly what they want, for instance, just a nursery, or vegetable production or both. It is important here that experienced farmers share knowledge and lessons learned so that new farmers venturing into the system are not left confused and finding it a huge challenge. At this planning stage, the farmer should already have a fair idea of what type of structure he or she can get or build based on his/her capacity. Many just wait patiently for an opportunity from government or donor aid, which may never come, because there are so many farmers and such aid is usually limited.

Availability and accessibility of materials

Farmers must consider the availability and accessibility of the materials for the structure of choice.

Site

The location of the structure is vitally important. It was noted in a survey that most of the structures built are within 200 m of the household. This means that farmers can visit often and keep it safe. A convenient water supply can be another reason for keeping the structure close to the household. It is also convenient for preparing the structure to limit damage during disaster warnings. The elevation of the location may also dictate the types of crops that are suitable for the conditions. Correct orientation is important to ensure that optimum sunlight is shared by the plants and that the prevailing wind assists in ventilation but does not ruin the plastic cover.

Target market and crops

If farmers are growing for subsistence needs, then the decisions on target market and crops are not so serious, but if for a high value market, then they should consider the type of crops that will be grown. Indeterminate tomato varieties should be staked or trellised and therefore may need a large space to grow in, so therefore the structure needs to be high compared with brassica crops like cabbage.

Once the designing and planning is completed, then comes the purchase of the key materials before construction. Often farmers and promoters of the system around the Pacific fail to execute the designing and planning phase properly so that many structures end up being damaged or destroyed or simply idle for long periods of time.

Designing a simple structure (step 1 of the protected cropping steps)

A simple structure may have a low-cost wooden or PVC material for the main frame. Farmers who have access to bamboo or local timber at no cost should take advantage of that. Gliricidia, African tulip tree, beach hibiscus and others are options for wooden posts that could be used for the frame. Otherwise, cheap PVC pipes may be an option for the main frame. The structure must be strong, with cross-bracing to help keep the poles in place, as the plastic cover placed over the top of the structure acts like a sail on a boat – wind is trapped by the "sail" and it pulls on the points where the cover is attached to the structure, which can result in the cover ripping or the structure itself being bent or broken. Also, during heavy rain the water can pool on the plastic if the cover is not attached very tightly across the structure to allow all of the water to drain off, and the weight of pooled water can also place pressure on the structure causing the plastic to rip or the structure to bend or break. Structures covered only in shade cloth have fewer problems as the wind and rain can move freely through the cloth.

Timber structures will rot over time, so the lifespan of a simple structure can be quite short (two to five years). It is recommended that farmers use step 1 structures (see page 6) to gain experience in protected cropping and, if possible, generate sufficient profit from the production system to allow them to invest in a more permanent step 2 structure. The advantage of a step 1 structure is that the farmer does not need to invest a lot of money to build it, but can still get some of the benefits. If farmers wish to continue operating step 1 structures, they must plan to replace the wooden poles every few years.

The cover placed over the top of the structure is a critical part of protected cropping. It is possible to use shade cloth to cover the structure if reducing light levels is the main aim. This is generally only useful for nursery (seedling) production or dry season crop production as the shade cloth allows rainfall to penetrate, so the structure does not protect crops from heavy rainfall, and so they will suffer rainfall damage, flower drop, lodging and increased disease problems. Plastic coverings can be purchased from agricultural supply shops and will protect the crop from rainfall when placed over the structure. Plastic covers of different qualities are available. Cheap plastic covers will not be as strong as expensive covers and can also discolour (turn from clear to white) quickly when exposed to the sun, which makes them much more brittle and likely to rip. Weaker plastic covers are more likely to rip during strong wind or in heavy rain. Discoloration reduces the amount of light reaching the crop in the structure, which can then reduce the yield. Cheap plastic covers are adequate to use on step 1 structures if the farmer has a plan for replacing the cover every few years. In locations where strong winds and heavy rains are frequent, use of more expensive plastic to reduce the risk of ripping and structure damage is recommended.

The height of the structure is an important consideration. Hot air is trapped under the plastic cover at the top of the structure, so if the roof covering is not high, then plants growing in the structure can reach the hot air layer. Low-growing crops such as cabbage are well suited to lower structures, but for crops such as tomato and capsicum that can grow on trellis systems to a height of 2 m or more a high roof structure is needed to avoid heat damage to the crop.

The ability to improvise and be creative is critical in this farming system. It is hoped that once growers grasp the concept of protected cropping, they can use available and accessible cheap materials to start off their structures and then further develop them along the way. Often farmers delay a lot of activities or lack initiative because they do not quite understand the problem and thus rely on materials that may have to be sent from distant sources. Therefore, trainers must ensure that the methods used in the training will help farmers understand the methods. In fact, farmers are very wise and creative from years of experience in farming; they just might need a bit of support to understand all the issues.

Some examples of shade houses and plastic-covered structures are shown below. The shade house structures are suitable for seedling nursery production or for crops requiring lower light conditions during the dry season, but are not suitable for wet season production. Note that the flat roof design in most of the examples is not suitable for a plastic covered structure, because water will not be able to drain off during rainfall.

Shade-cloth structures suitable for seedling nursery and dry season crop production

Low-cost wooden structures with sloping roof suitable for plastic covering

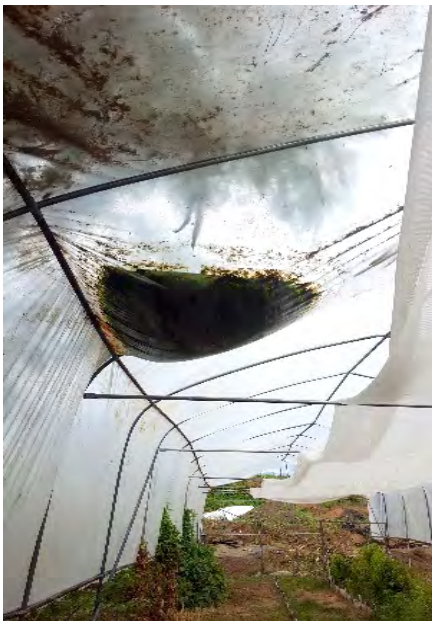
Basic qualities of a good structure

A well-designed and well-constructed structure is a quarter of the work done. Key qualities of a good structure should include:

- a stable structure able to withstand periods of strong wind and heavy rain
- good ventilation (and well-oriented, so factor in prevailing wind and sun motion)
- a good irrigation set-up (and good soil drainage)
- simple to put up or take down
- materials that are accessible, durable, and affordable
- suitability for target crop(s).

Stable structure

The force of the wind blowing on the plastic covering on a structure and the weight of rain that can pool on the plastic mean that the poles and framing timbers of the structure must be strong enough to withstand these forces to avoid collapse. Solid timber poles provide strength and treated pine poles are particularly good as they do not rot as rapidly as untreated timber. Rotting of the base of poles where they are buried in the ground severely reduces the strength of the structure. It is possible to fill the holes where the poles are to be placed with wet cement and then place the poles in the cement to let it set – this stops the water in the soil from contacting the base of the poles and slows down the rotting process. Timber bracing between the poles can also add strength to the structure.



The roof of the structure carries most of the weight and must be strong enough to withstand the forces of wind and rain on the plastic covering. The picture on the right shows how water can be trapped in a pool on the plastic, risking ripping of the plastic or breaking the structure holding the plastic. Bracing of the roof pieces is usually required, both to provide strength and also to reduce the area of plastic where pooling of water can occur. Sharp edges must be avoided on the roof structure as any small puncture or cut on the plastic will be a point of weakness that can lead to large rips in the plastic covering. Also the roof or side-wall structure must have a straight piece of timber or metal to which the plastic can be attached.

Good ventilation

The environment can and may assist in the natural ventilation within, but if a structure is designed for it then that is even better. Good ventilation allows excess heat to escape from the structure especially for a plastic film cover, otherwise the high temperature can influence the micro-climatic conditions which could be harmful to the crops grown.

During the hot wet season (cyclone season) in the Pacific Islands, humidity and temperatures are very high and unsuitable for several crops for a number of reasons. Some crops fail to flower under heat stress while others have flower drop. Flower drop can also be caused by heavy rain and water/nutrient stress.

CASE STUDY 3: Example of poor ventilation

A farmer acquired a brand-new structure, located in the west of Fiji where temperatures are often high. The farmer tried a few times to grow crops and even seedlings, but all died because of the high temperatures that built up inside. In the end, the structure still stands but is of little use to the farmer, who had to build another nursery to house his seedlings using just shade cloth and a wooden frame.

Plastic film cover is extended to ground level, with hot air trapped inside.

The farmer was advised to open the side completely at both ends to allow hot air to escape and roll up both lengths about 2 m and tie at the top supporting frame. This should ensure more cool air circulation inside.

Another farmer faced a similar situation and cut out roof vents to allow the hot air to escape. This compromised the cover and so rain also entered.

Good irrigation system

Irrigation is an essential component of protected cropping systems. The plastic cover over the top of the crop protects it from heavy rain, but also prevents that rain from wetting the soil to provide the water needed by the plant to grow. An irrigation system allows the farmer to supply the water that the crop needs, and because the farmer has control over the timing of the irrigation applications, it is possible to deliver the right amount of water to the crop whenever it needs it. This is one of the reasons protected cropping can deliver higher yields and crops of better quality than field production, because the timing of irrigation can be more reliable than the timing of rainfall. However, the timing depends on the farmer turning the irrigation on and off, which is one of the reasons protected cropping requires the farmer to pay more attention to his/her crop and spend more time managing the crop than for field crops.

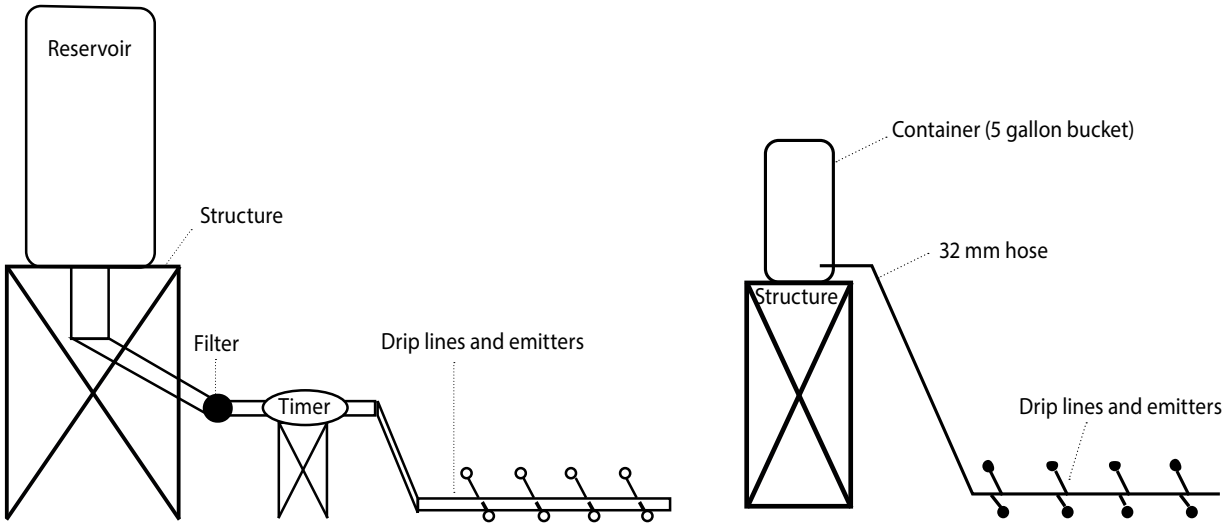
An irrigation system supplies water to the crop. For small, protected cropping structures, it is possible to hand water using a bucket or watering can. This is too time-consuming to be used in larger structures and it is also very difficult to apply the same amount of water to each plant, which results in uneven growth in the crop. Allowing water to flood between the rows of plants in a structure can also be done, but the amount of water applied is hard to control and wetting the soil between rows also encourages weed growth. For this reason, drip irrigation is recommended for protected cropping. These systems can have the water supplied by pumping it directly from a river or other water source, or collecting water into a raised tank from which it can flow through the drip lines in the structure under the force of gravity (referred to as a gravity-fed system).

The gravity-fed irrigation system is a cheap, effective way to provide water for a smaller sized crop area. It is especially cost effective if the climate of the area can provide enough rain to consistently keep a reservoir (water tank) filled using rainwater harvesting techniques. The basic system is very simple, consisting of an elevated reservoir with a pipe coming out the bottom that feeds water into a basic drip irrigation system that is controlled either by hand or with an efficient battery powered timer that controls the rate at which the crop is watered.

The components needed include these items:

1. **A water reservoir**
   a. It must be able to contain at least one day's worth of water.
   b. The greater the capacity of the reservoir the more often it must be refilled.
   c. The complication of having a large container is that you must elevate it above the crop, and refilling a high container is more work.
   d. The reason to elevate the tank is that it adds pressure, which needs to be kept consistent at the point where the drip lines are fed, so that the water is distributed equally.
2. **A structure to support the water reservoir**
   a. It can be constructed of anything that can support the weight of the container when it is filled with water.
   b. It must also be able to withstand outside forces such as the wind.
3. **Piping**
   a. There must be a pipe at the base of the reservoir that lets water flow out, and having a shut-off valve at this connection point is a good idea if the reservoir is larger than one day's worth of water.
   b. The piping, if using the timer method, then feeds the water through a filter.
   c. Different sized piping can be used to change the flow rate. This is done by gradually decreasing the diameter of the lines (pipes) being used, the farther away from the reservoir.
4. **Timer, filter and valves**
   a. A timer can be set up to automatically turn the irrigation system on and off each day, saving the farmer time as he/she doesn't have to be in the crop to turn the irrigation tap on and off. There are many models of battery-powered timers that can be set up and run for a whole season. These timers can control the times at which water is released into the drip lines.
   b. A filter must be installed in the water line before the timer valves. The filter will trap small particles in the water and prevents the smaller lines from becoming clogged.
   c. Shut-off valves can be placed on individual drip lines to allow watering to be directed to only the rows that the farmer wishes to water.
   d. There are many different types of drip irrigation lines. One important feature to look for when setting up the drip irrigation system is how far apart the emitters (holes in the drip line) are placed, since it is best to have the emitters spaced at a similar distance to the spacing between plants in the crop.

FIGURE 6: Diagrams of small- and large-scale drip irrigation system construction



The principle of gravity-fed irrigation systems is that the force of gravity will push water from the reservoir (tank) on the structure above the ground through the pipe attached to the bottom of the tank into the drip lines, from which it is forced out of the emitter holes and into the soil. The higher the reservoir is held above the ground, the higher the water pressure at the drip line and therefore the higher the flow rate of water out of the emitters. This principle is important to understand as it determines how effective the system will be. The longer the length of drip line being used in the crop (the greater the number of emitter points at which water leaks out from the pipe), the higher the water pressure needed to ensure that the flow of water from each emitter is roughly the same. If the reservoir is not high enough for the length of drip line used, the flow of water from the drip emitters closer to the reservoir will be higher than the flow of water from the drip emitters at the end of the line furthest from the reservoir. This is because water pressure drops as the water flows through the pipe.

The same principle applies when pumping water from a river directly into the irrigation system. The water pressure (governed by the power of the pump) determines how evenly the water flows from the emitters along the drip line.

It is important to check the uniformity of dripper water flow along the drip lines when an irrigation system is first set up. If this is not done and the water pressure is not sufficient to ensure uniform irrigation, then it is likely that one end of the crop will receive either too much or too little water through the irrigation system. To modify the system if the uniformity check indicates a problem, the length of the irrigation line can be reduced, or a drip line with wider emitter spacing used (reducing the number of emitters over the length of the line) or the height of the reservoir increased. Periodic checks of the uniformity of the irrigation system as well as looking to see if any of the emitters are blocked should be done in the protected cropping system.

Easy to put up or take down

During cyclone warnings, it is important that the structure cover is taken down and secured to avoid being damaged by strong winds. If a roof cover is permanently fastened to the structure then the farmer will not be able to take it off without damaging the cover itself. Thus, using fastening techniques like the zig-zag wire, groove method or similar is good because it allows the farmer to easily pull the wire out and then release the cover. Clip-on fastenings are also easy to pull off to release the cover, but sometimes if they are too weak then it becomes a problem because it cannot hold the cover firmly.

In strong winds, a lone farmer may not be able to put down the plastic cover as the wind force on the cover can make it very difficult to remove safely. Farmers need to be mindful of this and remove the cover in a timely manner rather than waiting until the cyclone is almost upon them.

Suitability of the structure for target crops

Generally, the bigger the height, area and volume of the structure, the better the system, because it allows the farmer to have a wider range of crops to grow inside. Smaller structures, and particularly those that are low and have no air venting, are only suitable for low-growing crops. Smaller structures also allow some rainfall to enter from the sides, so if crops are particularly sensitive to damage from rainfall or are prone to pests and diseases that occur most frequently following rainfall, then they may not be suitable for those structures. Farmers may need to trial different crops and different varieties to determine which ones perform best at different times of the year. Farmers new to protected cropping are advised to talk to more experienced farmers to seek guidance on appropriate crop and variety selection. It is important for trainers to also advise farmers to consider their target markets (the fourth "leg of the kava bowl") when deciding which crops to grow in their structure.

More advanced structure designs

Most farmers receiving training will be attempting to start protected cropping at step 1 (the low cost, basic structure step where they can gain some experience and secure profit to invest in a more advanced structure) but some will be looking to take advantage of opportunities such as aid projects or government support to set up more advanced structures appropriate for steps 2 or 3. These structures are made from steel and should have a much longer lifespan than the simple wooden step 1 structures.

The same key qualities of a good structure can be applied to more advanced structures:

- stable structure able to withstand periods of strong wind and heavy rain
- good ventilation (and well-oriented – need to factor in prevailing wind and sun motion)
- good irrigation set-up (and good soil drainage)
- easy to put up and take down
- materials accessible, durable, and affordable
- suitable for target crop(s).

Step 2 and 3 structures tend to be larger than step 1 structures, so the structural material needs to be stronger to support the greater force that occurs with a bigger area of plastic cover exposed to the wind and rain. Galvanized steel structures are the most common and the quality of the galvanizing and the thickness/strength of the steel are important. Structures that have not been properly galvanized will rust, and this weakens the structure in the same way that rot in timber weakens step 1 structures. Concrete footings for the support poles help provide stability to the structures.

The simplest steel structures are referred to as "hoop houses" as they are made up of a series of hoops with cross bracing. As these structures do not have any roof venting, they can get very hot inside. If using this design, it is important to make the structure as high as is practical and to allow ventilation through the front, back and side sections. Shade cloth can be used to cover these areas to reduce exposure of the outer rows of crops in the structure to heavy rainfall, but shade cloth will reduce ventilation so may need to be removed when the weather is very warm. Hoop houses can be joined together edge-to-edge to produce larger structures. Care needs to be taken when doing this as the larger the area, the hotter it will be in the centre of the structure. Guttering is also needed where the hoop structures join together, or else water will pool in that area, and the systems for attaching the plastic need to be suitable to allow the plastic to be easily removed if a cyclone is expected to arrive.

Some examples of low and high hoop houses are shown below. Note that these structures do not have any roof venting and have side plus front/back sections left open for ventilation or covered with insect-proof mesh to allow some ventilation but keep pests out. Keep in mind that if insect mesh is used, pollinator insects cannot get into the structure so crops such as cucumber that require pollination will not yield very well.

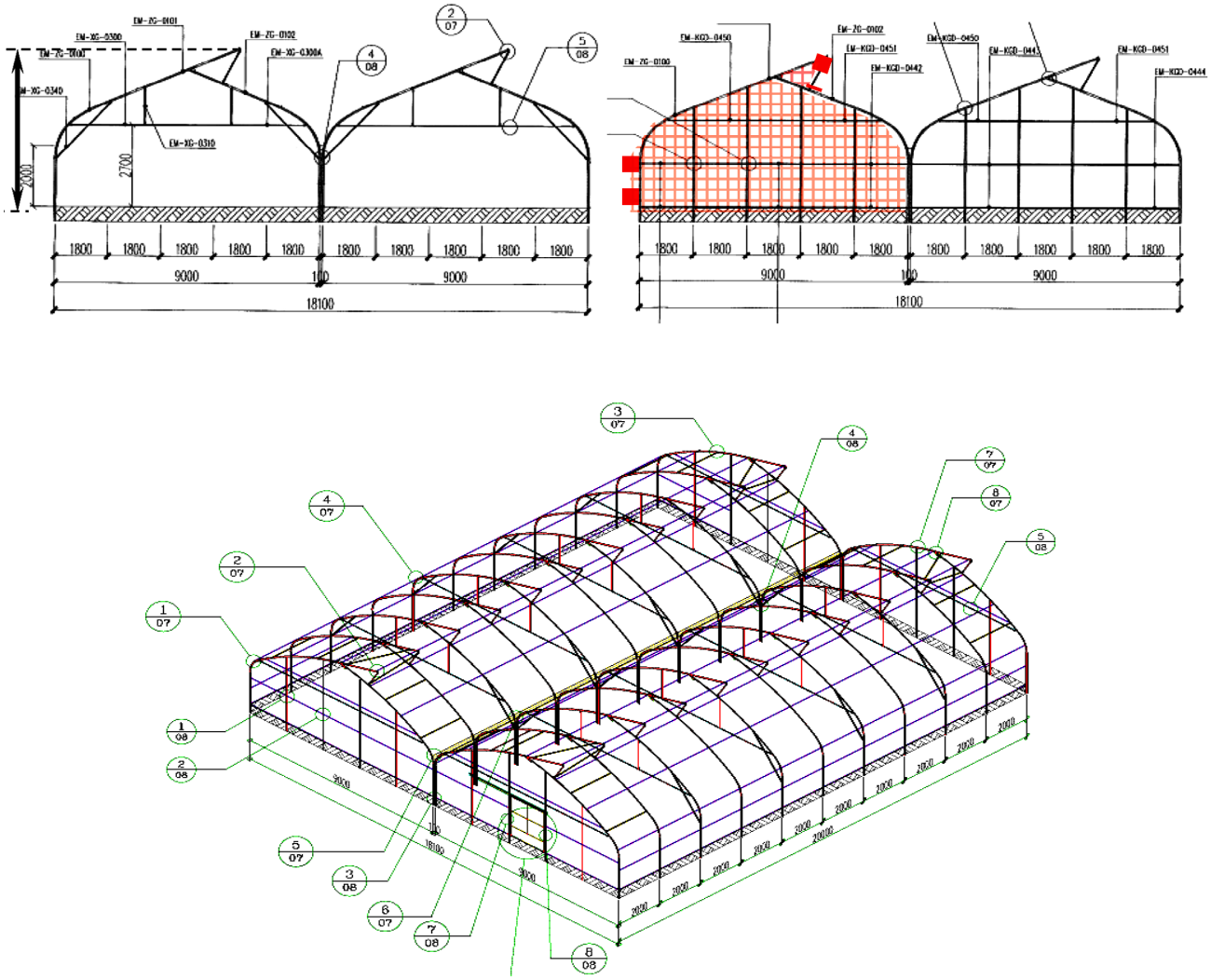
Examples of low and high hoop houses

Structures with roof venting are preferable for Pacific Island conditions. Roof vents allow hot air to escape from the structure and provide more suitable conditions for crop growth, particularly for higher growing crops such as tomato, capsicum and cucumber. When constructing a structure with a roof vent, it is important that it is orientated so that the prevailing wind does not blow into the roof vent space, as this creates high pressure on the plastic and the structure. When wind blows across the top of the greenhouse, it will drag the hot air out of the structure as it moves across.

This picture shows a structure that was oriented with the roof vent facing towards the prevailing wind. The damage caused by strong wind can be seen both from the ripping of the plastic and from bending of some of the steel poles. The design of the structure pushes the wind into the vent if it faces toward the prevailing wind, and because the area of plastic is large, the force of the wind can be sufficient to bend the steel poles.

This picture shows two roof-vented structures erected side-by-side and with roof vents facing away from the prevailing wind. Shade cloth placed over the top of the plastic roof helps keep the inside cooler in hotter weather. The structures have survived several cyclones and have allowed the farmer to produce high-yielding crops over many years. The design for the structure is shown on the following page, and is the recommended design for step 3 structures for Pacific Island conditions. The high roof, good ventilation and attachment system that allows the plastic cover to be easily removed if a cyclone approaches makes it very effective for production of a broad range of crops.

FIGURE 7: Schematic drawings of two roof-vented structures erected side-by-side, with roof vents facing away from the prevailing wind



Recommended training

The training for this section is designed to help farmers select an appropriate structure design for their needs, erect the structure and install an irrigation system suitable for the design.

EXERCISE 1: Field tour to different structures	Why do we do it this way?
Farmers can be taken to visit sites where different structures are being used. Points to discuss with farmers at each structure are: • the type of structure • main frame and cover materials • type of irrigation system (if any) • crops that have been successfully grown in the structure.	Farmers can learn by seeing things first-hand rather than just hearing about them from others. The learning gained by the farmers who own the structures is also valuable.

EXERCISE 2: Irrigation	Why do we do it this way?
Farmers can be shown an irrigation system at an existing protected cropping site, or help to construct an irrigation system at a new site. Each part of the system can be explained to them. Uniformity of irrigation can be tested by placing a measuring container under a dripper at the start and end of a drip line while it is running, and the volume of water captured at each end is then compared.	Farmers can learn by seeing things first-hand rather than just hearing about them from others. Helping to construct an irrigation system gives them confidence to be able to build their own system.

SECTION 4

Crop management

Introduction for trainers

Agronomy is an area that many farmers find difficult to adapt to when making the transition from open field to protected cropping, since many farmers lack experience and training in key areas. Mistakes made in crop management in protected cropping can more quickly lead to big problems in the crop compared to in-field production, so farmers need to learn that more attention to detail is required to successfully manage crops in a protected cropping system. Therefore, it is important that a little more time is spent in this section to ensure that trainees and farmers are well prepared.

At the end of this section, trainees should:

- know the basics to grow a selected or combination of vegetable crops under protected structure;
- know when to apply different agronomic practices in a timely manner:
- understand trellising (types)
- understand mulching
- understand fertilizer
- understand pruning;
- know good spacing for different crops under different structure conditions;
- be able to predetermine time of harvest for target crops for marketing purposes;
- understand the principles and relationship between crop development and relative humidity.

Steps to produce successfully under protected structures

There are numerous methods and factors to consider when growing crops under a structure, but we shall limit our focus to the 10 areas listed below. Postharvest handling is also covered here because it is an important area that is usually left out and only covered under marketing, but not in detail.

- Production plan and land preparation
- Seeds or seedling nursery, land preparation, spacing
- Irrigation system
- Staking/trellising
- Hilling and/or mulching
- Pruning and tying
- Monitoring and timely management
- Fertilizer/manure application
- Integrated pest (including weeds) and disease management (IPDM)
- Harvesting and postharvest handling.

Production plan

All growers must have a production plan prior to sowing of seeds. This production plan will determine the timing of sowing and link with the targeted markets and so on. At this stage, a farmer should have a fair idea of the number of seedlings required for the allocated area in the structure, and the spacing. In fact, it is important that farmers be able to picture the whole production cycle and the next phase, and even to have plans B and C in place.

Farmers have been advised in the past to operate within a safe buffer to guarantee consistent supply. For example, participatory guarantee system (PGS) farmers who have committed to a high-value contract must ensure that they always grow more than needed and build a strong network with other group members and potential growers in surrounding areas to help with their quota whenever needed.

For the crop programme, it is always important that farmers plan to rotate the crops and at the same time have a market; also, that crops like tomato take three months to be ready so farmers must have a plan in place to ensure that income is received throughout the period and there is not a huge gap in their income.

Seeds or seedlings, land preparation, and spacing

Many plants are sown in trays and then transplanted. The example below is for tomato plants.

SOWING BY TRAY METHOD – TOMATO

- Use locally available materials provided that the medium is balanced (fertility, moisture capacity, aeration, texture, and structure) and soil is sterilised to produce healthy seedlings. Seeds must be healthy.
- Sow seed in 50 cc (cm^3), 50-cell trays or similar at 2 seeds per cell and about 1 cm depth.
- Thin seedlings within 7 days after germination and remove any weak or off types to maintain uniformity. Water as and when necessary.
- Hardening of the seedlings can be done within the final week before transplanting. Note that crops grown under structures do not need to be hardened much compared with those for open field conditions.
- Transplant about 4–5 weeks after sowing.
- In times of unforeseen circumstances that may delay transplanting, reduce watering to slow down the development until conditions are ready.

TABLE 1: Suggested sowing preference for crop type

Crop	Direct sowing	Nursery
Tomato	✗	✓
Capsicum	✗	✓
Chinese cabbage	✗	✓
Cucumber	✓	✗
Zucchini	✓	✗
Eggplant	✗	✓
Chilli	✗	✓
Carrot	✓	✗
Long bean	✓	✗

Land preparation is crucial when growing under structures. Farmers are advised to grow on beds that are prepared well. This is because the weather is uncertain, so it is always good to be prepared. Therefore, if growing on soil beds or in pots or even in a hydroponic system, it is important that the growing medium is well balanced for the target crops.

Spacing is very important in a protected cropping system. Spacing can dictate several aspects of care including the need for pruning, density and therefore productivity. Optimum spacings vary between crops and varieties but the basics are the same. If drip irrigation is used, then plant spacing must be predetermined to ensure the correct dripping space is applied.

In an open field there is plenty of sunlight. However, under a structure, and depending on the percentage of shade, a crop can either thrive or be affected. For instance, the round purple cabbage needs enough sunlight to develop the proper purple colour, which is sometimes not well established when grown under a bit too much shade. Some crops tolerate shade more than others. Spacing is therefore an important part of the whole system

NOTE: Open field spacing does not always work for indoor planting. When light is limited, sometimes increasing the spacing for enough sunlight to reach all plants is good, otherwise plants start growing thin in search of the sun rather than being productive.

Land preparation is critical. Ensure that soil is well manured and prepared to achieve good structure and texture with the right pH to support a wide range of crops.

Irrigation system

Irrigation is a crucial factor in all crop production. Farmers normally say, "no water, no crops!" However, too little, or too much, water is also not good for growing crops. Just right is always the target, which is not always met. With irrigation, the best situation would be the one that provides for the needs of the plant while minimising waste and promotion of weed growth as well as high humidity.

In protected cropping, the drip irrigation system is highly promoted as one of the best. The figures below show a drip irrigation set-up.

There are many ways to control moisture to ensure farmers do not overwater. A traditional method would be to press a stick on an irrigated spot and the depth to which the stick penetrates is how far the moisture has reached and then the farmer can refer to the crop stage information to estimate the root system and reach (crop water needs). Another indicator for enough water intake is to observe the crop at the hottest time of the day. A crop that is well irrigated will still look happy and healthy while a crop that is not irrigated enough will start to wilt.

Irrigation system set-up. Drip lines in place.

Farmers trained on how a drip irrigation system works.

Notice how the water just wets around the plants only rather than the whole area.

There are now also tools (such as electronic moisture meters, shown below) to accurately check moisture levels. These are not essential for step 1 protected cropping systems but can be useful to assist farmers to learn how much water needs to be applied per irrigation to achieve good crop results.

Electronic moisture meters.

Staking or trellising

Staking and trellising is important in protected cropping systems for crops like cucumber, tomato, capsicum, zucchini. Brassica crops and most herbs do not necessarily need staking.

Staking is crucial for a number of reasons. It improves ventilation, ensures good hygiene, reduces disease pressure, improves quality of fruits, extends production period and so much more.

Common types of trellising

Net trellising of cucumber.

Vertical string trellising of cucumber.

Coiling of tomato from initial vertical string trellising method.

Cucumber – vertical trellis with a coiling vine to allow for easy handling. This method is good, but care must be taken when handling the crop.

Vertical string trellising of cucumber and A-staking of tomato. This method can be improved but is good for semi-determinate varieties like Melrose.

Horizontal trellis with a net support – cucumber crop.

Hilling and mulching

Hilling and mulching are important aspects of agronomy. Hilling helps to support the plants and strengthen the root system, while mulching, depending on the type of mulching, can reduce weed pressure while supplying plants with nutrients.

Pruning and tying

Pruning is critical but depends on the crop or variety that is grown. Pruning helps to keep the crops manageable and maintain quality of fruits. It also minimises disease build-up and improves ventilation. Tying is critical when staking to support the crop.

TABLE 2: Crops and their required pruning

Crop	Variety/habit	Stage	Part pruned
Tomato	Determinate	Growing, flowering, fruiting, harvest	Lower leaves, old and diseased
	Semi-determinate, indeterminate	Growing, flowering, fruiting, harvesting	Lower and older leaves, lateral shoots (depending on how many main vines to manage)
Cucumber	Genuine, Monjavo, Barbary, etc.	Flowering, fruiting, harvesting	Lower older and or diseased leaves, side shoots, early flowers
Capsicum	Golden Bell, BlueStar, Yolo Wonder	Flowering, fruiting, harvesting	Lower old and diseased leaves, inside shoots, flowers of first three nodes
Chinese Cabbage	Pak choi	Growing stage	Old and diseased leaves
Zucchini	Summer squash	Growing stage, flowering, fruiting, harvesting	Old and diseased leaves, those touching the soil, prune upwards following the fruiting
Long bean	Yard long	Flowering, fruiting, harvesting	Old and diseased leaves

Monitoring and timely management

Monitoring is key in any production system. It is a general concept as much as it can be specific. There are so many areas that can be monitored in this system alone. Monitoring here will be more towards timely management of technical applications as well as for adverse conditions.

A well-developed monitoring system can save a farmer so much money, time, and effort and in return achieve the best returns possible. For instance, staking is good but when done at the wrong time because of lack of monitoring and decision-making then it becomes pointless. A farmer who visits his/her farm daily will have a better understanding of his/her crop (because the monitoring is done daily) than a farmer who visits once a week. Monitoring will allow the farmer to determine when to add fertilizer, and when to weed or control pests and so forth.

Fertilizer and manure application

The application of fertilizer is important. However, a timely application to meet the needs of the plant to produce its best without inviting pests, leaching, or becoming toxic to the environment is the aim. For generations, farmers have been applying fertilizer by feel (trial and error) and with little knowledge gained from experience and from agriculture officers. It is important to promote organic methods and/or at least a sustainable approach to maintain good soil health.

Pest and disease management

Pests and diseases will always be a risk unless operating an advanced hydroponic system with a higher level of control on crop health and security. This will be elaborated on in Section 5.

Harvest and postharvest handling

The harvesting stage of a crop is important and the market demand plays a key role here. Crops like capsicum can be harvested at horticulture maturity and physical maturity. However, others like cucumber are best harvested at horticulture maturity or earlier for best quality unless grown for seed production.

High quality capsicum grown under protected cropping in Fiji.

Cucumber varieties grown under protected cropping in Fiji.

Recommended training

The recommended training for this section is for use with farmers who already have some knowledge of protected cropping but have not yet tried it. Farmers who have unsuccessfully tried protected cropping may also benefit from the training.

Before commencing training with farmers, trainers should familiarise themselves with the two main concepts presented in this section: the steps (or levels of sophistication) of protected cropping systems, and the four key elements of protected cropping (the four legs of the kava bowl). It is also recommended that trainers review the survey results done to understand why farmers have not yet tried protected cropping.

The recommended training activities are designed to provide farmers with an understanding of what is involved in protected cropping (Exercise 1) and to evaluate if protected cropping is likely to work for them (Exercise 2).

Exercise 1: Pruning and training	**Why do we do it this way?**
Demonstrate pruning and training methods in a crop of tomato, capsicum and/or cucumber, and allow the farmers to have a go at the pruning and training themselves.	Hands-on experience, guided by a trainer who can explain what needs to be done and why it should be done, is the best way for farmers to learn pruning and training as well as other crop management strategies.

Exercise 2: Irrigation	**Why do we do it this way?**
Using a drip irrigation system, let the system run and after 10 minutes cut into the soil below a dripper with a spade and see how far the water has spread into the soil. Repeat after 20 minutes and 30 minutes. The same exercise can be done by pouring a cup of water slowly onto the soil and then checking to see how deep it has spread, then adding a second cup and so forth. This shows how much water (or how long the system needs to be run for) to ensure the soil is wet to the bottom of the root zone (usually 30–40 cm depth).	Hands-on experience, guided by a trainer who can explain what needs to be done and why it should be done, is the best way for farmers to learn irrigation management as well as other crop management strategies.

SECTION 5

Integrated pest and disease management under protected cropping systems

Introduction for trainers

Pests and diseases are an important part of the protected cropping system and supply chain. They are major factors that can upset a crop and plan at any point in time – from seed source to consumer kitchen.

In this section we focus on pests and diseases but mainly on those associated with protected cropping. The four pillars of the kava bowl are interrelated so that if a weakness occurs in any one leg, the whole system collapses.

At the end of this section, trainees should be able to:

- differentiate between biotic (living organism) and abiotic (non-living or environmental) stress factors;
- identify major pests and disease symptoms;
- understand the integrated pest and disease management (IPDM) strategy;
- determine relevant immediate cultural practices for any given situation;
- prevent a pest and disease situation by managing other aspects of the system; and
- identify and promote the presence of natural enemies.

The warm, humid conditions and abundant food under protected conditions provide an excellent, stable environment for pest and disease development. Biotic and abiotic plant stress under a protected cropping system is very much like in the open field but there are a few pests that thrive mostly under protected cropping systems, such as root-knot nematodes and broad mites.

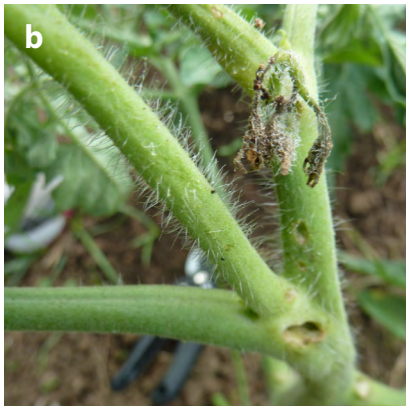
Some common pests and diseases under protected cropping systems

A. Biotic causes

Pests

Tomato fruit borer

- Young larvae feed on tender foliage and stem *(a and b)*.
- Mature larvae thrusts only a part of its body into fruits and eats the inner content, boring holes in them in the process *(c)*.
- Attacked fruit ripens early *(d)*.



Green peach aphids

- Green peach aphids are common pests in greenhouses and most crops are susceptible to attack.
- They can cause economic damage by their feeding activities.
- They suck plant sap causing wilting of leaves

A. Biotic causes

Pests

Broad mite

- Broad mites attack a wide range of vegetables.
- Their hosts include peppers, tomatoes and cucumbers.
- Mites usually feed on the lower leaf surface causing leaf edges to roll under resulting in distortion and stunted growth *(a)*.
- Russet-coloured, rough skin fruit is a key symptom of a high mite infestation, causing loss of yields and quality *(b)*.

Whitefly

- Whiteflies are found on the underside of leaves where they suck the sap, resulting in pale, wilting leaves.
- They also excrete 'honeydew', accumulating sooty mould on the leaf surface.

Root-knot nematode

- Root-knot nematodes are minute, worm-like animals that are very common in the soil.
- They are very common in tomatoes and capsicums.
- The first visible symptoms are usually seen on the foliage of plants which consist of wilting of the youngest leaves and the ends of the branches during the hottest part of the day *(a)*.
- Below ground symptoms are quite distinctive with galls/lumps developing all over the roots *(b)*.

A. Biotic causes

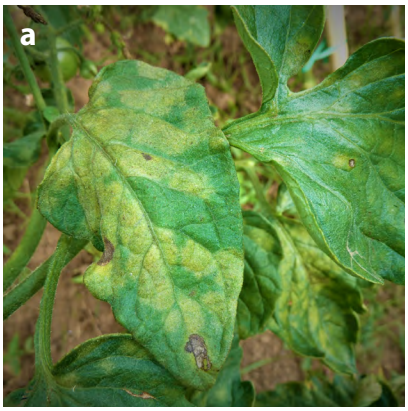
Some common diseases

Early blight

- Rough circular brown spots appear on leaves *(a)* and stems *(b)*.
- As spots enlarge, concentric rings appear giving it a target-like appearance.
- Very common in tomatoes.

Tomato leaf mould

- Tomato leaf mould is a fungal disease of tomato.
- Yellow patches on upper leaf surface *(a)* with grey-brown mould growth on corresponding under surface *(b)*.



Powdery mildew

- Powdery mildew is a common fungal disease that affects a wide variety of plants.
- Symptoms appear as light grey or white powdery spots on infected leaves or fruits e.g. cucumber.

A. Biotic causes		
Some common diseases		
Frogeye spot on capsicum • *Cercospora* leaf spot symptoms are primarily circular lesions with a white centre. • Leaf lesions are distinctive as spots are circular to oval with a light grey centre.		
Bacterial wilt • Bacterial wilt is a complex disease that occurs in plants such as *cucurbits* and *solanaceae*. • It is caused by a soil-borne bacterium. • Common symptoms are leaf wilting and often mortality with severely infected plants.		

B. Abiotic/ physiological stresses

Blossom end rot

- Blossom end rot is not a disease but a physiological disorder that begins with tan, watery soaked areas at or near the blossom end of fruit which usually enlarge and turn black and leathery.
- This condition is linked to a lack of calcium (Ca) absorption by the roots which may be induced by insufficient irrigation.

Catface

- Catface tomatoes have irregular deformed fruits, sometimes with protrusions with corky scars of varying sizes at the end of the fruit.
- It is related to poor flower formation which may be due to weather conditions at flowering time.

Recommended training

EXERCISE 1: Pest and disease identification	Why do we do it this way?
Visit a crop where pests and/or diseases are present and ask the farmers to identify which plants are affected as well as the pest or disease causing the problem.	First-hand experience in identification helps the farmer remember the symptoms of different pests and diseases.

EXERCISE 2: Pest and disease control	Why do we do it this way?
Small group discussion Allow farmers to discuss the pests/diseases they have observed in their crops and identify the crop management practices that they have used to control those pests/diseases when they have been present in their crops.	Farmers will learn strategies for effective pest and disease control from each other. The trainer can then guide discussion to add new strategies that the farmers may not have identified.

EXERCISE 3: Pest and disease prevention	Why do we do it this way?
Small group discussion Allow farmers to discuss the pests/diseases they have observed in their crops and identify the crop management practices that they have used to prevent those pests/diseases from affecting their crops. Encourage discussion of practices that prevent the pest/disease from appearing rather than practices used to control the pest/disease after it is present.	Farmers will learn strategies for effective pest and disease prevention from each other. The trainer can then guide discussion to add new strategies that the farmers may not have identified.

SECTION 6

Managing marketing

Introduction for trainers

In the past there has been a failure of consistent supply to high-value markets and also to the local municipal markets. The participatory guarantee system ensures there is agreement between the supplier and the buyer at a premium price. This manual introduces some fundamental principles of marketing to assist local growers and protected cropping farmers.

Marketing of produce is an important element of any farming enterprise, and in the case of protected cropping it is just as important as getting the crop management practices right. In addition, protected cropping systems can generate produce out of season and at a higher quality than field production, which opens opportunities for farmers to access new and higher value markets. This market access does not happen automatically, so farmers adopting protected cropping will require support to help them understand financial aspects of their new production system and to build skills and knowledge needed to access different markets.

The objective of this section is to allow the trainer to assist farmers to:

- understand key factors that contribute to managing the market;
- develop a marketing plan;
- identify the key activities in designing a basic production plan;

Understanding marketing

What is marketing?

Marketing includes the following processes:

- determining the needs and wants of consumers and being able to satisfy those needs and wants
- all of the activities necessary to move a product from the producer to the consumer. The steps involved in this path are referred to as the supply chain.

Before we proceed further to learn about marketing, we need to understand the actors involved in the supply chain. The interaction of different actors along the supply chain is important to ensure the grower and all other chain members receive what they expect.

Understanding the key factors that contribute to managing the market

Valuing customers/buyers

Valuing your customers is a vital strategy to assist you to attract customers.

Communication

Communicating the characteristics of your products to your customers is vital. If they currently purchase similar products elsewhere, you need to communicate what makes your products different from and better than the others.

Understanding your target market

Set a sales target for every market to maximise sales.

Determine the best period to sell your product to maximise your customer satisfaction: off-season period would be the best period when there are only a few producers to compete with.

Understand the quality of the commodities that are to be matched or imported by high-value markets or resorts.

Marketing plan

A marketing plan answers the questions of how, where, and to whom to sell products and at what price. Examples of parts of a plan for markets in Fiji are given below.

Market analysis includes finding out which market has the best demand and how it will develop. Is there/will there be competition? What potential exists for adding value – e.g. packaging, drying? And can the protected cropping farmer sell directly to supermarkets in Sigatoka or Suva?

It is known that Grade 1 (perfect) tomatoes can be sold direct to the resort, hotels and hospitality outlets. It is well known too that the price improves considerably out of season in the months of November to February. Thus producing tomatoes and sell them in these months is expected to bring in more revenue.

We also plan to make use of cold stores to provide a buffer stock should there be a problem with one smallholder farmer not being able to produce enough to meet production commitments due to social obligations such as weddings or funerals.

Market arrangements: how will we make the arrangements needed with the resorts for the sale of the product regarding, amount, price and time for delivery? This may require weekly tenders, and we will need to ease into this system. There will be strict conditions that the vegetables must be delivered without damage, and must be packed in plastic crates, and be of even grade, without blemishes.

Product: what is it, in what form and how is it packaged?

Place: where is the product sold at present and in the future? What are the transport costs to get there? Is there a need for salespeople?

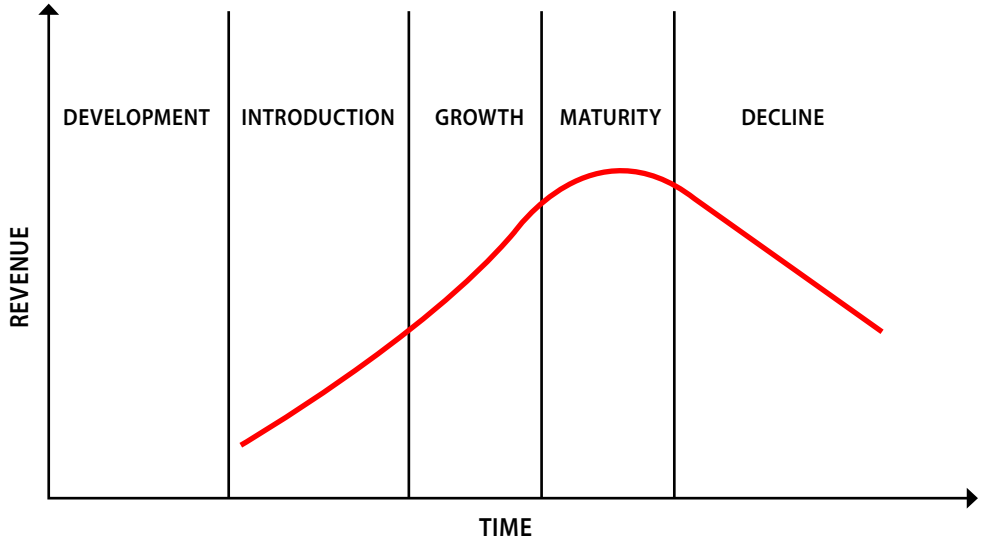
Price: what are the expected highest and lowest prices? We expect to achieve a price that is higher than market prices on average, though at times, and particularly when we start and until we become recognised for high quality, we may have to accept lower prices, but the higher volume will mean good returns.

Promotion: how will we advertise, if needed?

Production life cycle

This is a management concept and used by marketing professionals as a factor in deciding when it is appropriate to increase sales/production, reduce prices, expand to new markets.

FIGURE 8: The production life cycle



The four stages that the cycle follows, after development, are: introduction, growth, maturity, and decline.

- **Introduction**: At the introduction stage of the product life cycle, the product or service is introduced to the market.
- **Growth**: After a product is introduced in the market, consumers become interested in it. Sales are increasing and competitors are emerging as well.
- **Maturity**: The market has reached saturation. Some producers at the late maturity stage of the product life cycle begin to leave the market due to a poor profit margin.
- **Decline**: Continuous decline in sales is the sign that we have entered this phase of the product life cycle.

Key activities in designing a basic production plan

In off-season there is a shift in demand and supply of tomatoes due to there being very few producers, which causes the increase in price. Protected cropping farmers are encouraged to make use of the off-season period to take advantage of the higher prices available.

FIGURE 9: A basic production plan for tomatoes

Activities	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Land clearing												
Land preparation and raising seedlings												
Erect structure												
Transplant												
Management												
Pruning												
Harvesting												

Seasonal calendars

Seasonal calendars are important tools to know the best time to produce to maximise revenue for individual farmers. The graph below illustrates that from January–April off-season period the price is high. From May to September, the seasonal price (on-season) is when the price of the commodity is low due to excess supply in the market. Later, from October to December is off-season period when the price increases due to an increase in demand and low supply.

FIGURE 10: Seasonal price during wet and dry seasons

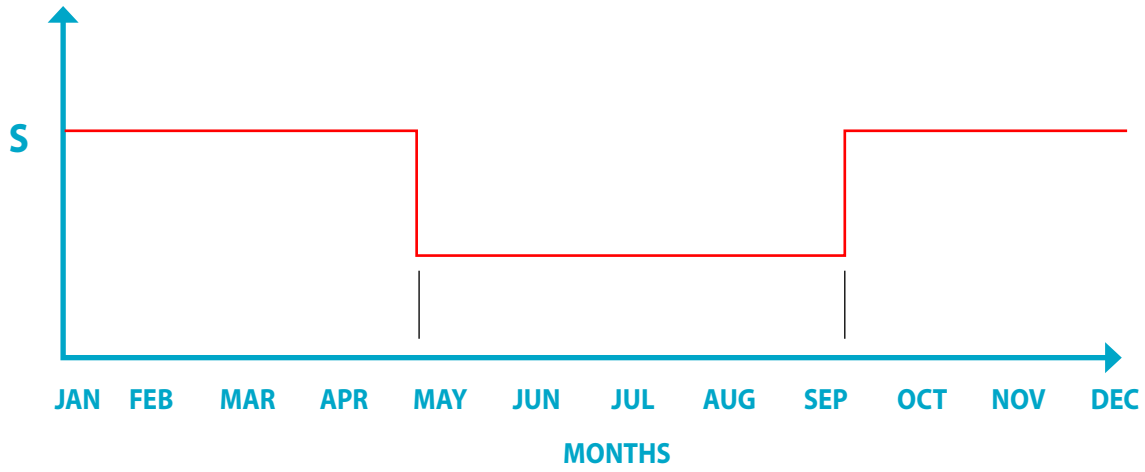
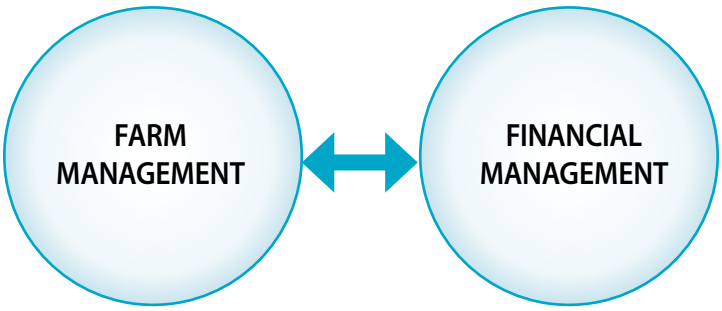


FIGURE 12: Relationship between farm management and financial management



Understanding the supply chain

A supply chain is a network between a business and its suppliers to produce and distribute a specific product to the final buyer.

Below are specific activities at each stage of the supply chain, from land preparation to the final stage buyer. Every actor along the supply chain plays a vital role.

FIGURE 11: The supply chain

SECTION 7

Basic financial management

Introduction for trainers

Many farmers prefer to concentrate on production rather than planning, recordkeeping, marketing and financial management. However, the escalation in input costs, the ability to access capital, and greater volatility in commodity markets make financial and risk management skills highly important.

The focus of this section will assist the grower to make appropriate financial decisions to elevate from subsistence to at least semi-commercial farming. Financial tools will assist in making good financial decisions.

Why basic financial management?

- Assist in planning
- Ensure to manage costs effectively and efficiently
- With proper financial reports, sound decisions and plans for the next financial period can be made
- Ability to measure growth

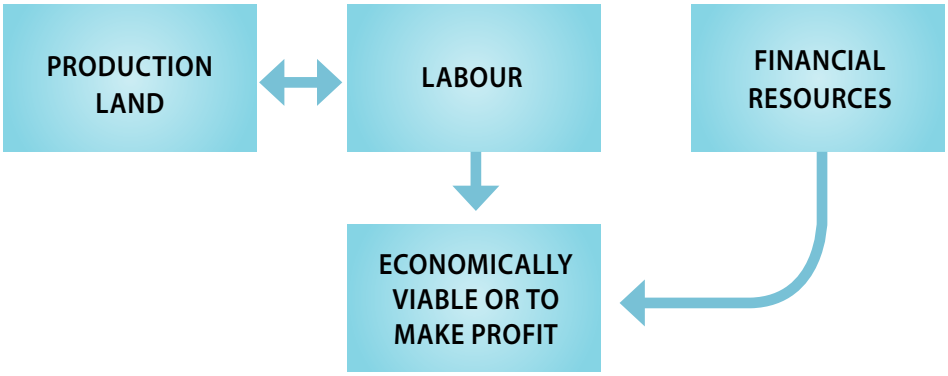
The objective of this section is to allow the trainer to assist farmers to be able to:

- understand the business goals.
- understand the significance of good recordkeeping.
- know on how to control your costs.
- determine efficiency/productivity of assets (protective structure)
- calculate the profitability of the business.
- gain better profit from the breakeven point with the best quality output.

Understanding farm management

Farm management involves making and implementing decisions involved in organising and operating a farm for maximum production and profit. It is in farmers' interest to know about farm management: how to organise, manage and plan the farm in the best possible way. This involves a series of management decisions, related to what to produce, how, and to whom to sell; how to compete in the local and export market; how to finance and how much to invest in product differentiation; how to organise the productive farm enterprises and how to become part of a farmers' cooperative. The illustration below shows how this works together.

FIGURE 13: Farm management processes and decision-making



Effective financial management

Effective financial management is vital for business survival and growth. It involves planning, organising, controlling and monitoring your financial resources in order to achieve your business objectives.

How financial management and farm management are related

Financial management is key to farm management as it provides relevant financial tools, such as a comparison budget and actual; return on assets (ROA); gross profit margin and break even sales for decision making.

Business goals

Business goals are a predetermined target that a business or individual plans to achieve in a set period of time. These goals are often split into short-term goals and long-term goals.

In small business, there is usually a close connection between each of these. The following categories are business goals using four broad perspectives.

Profits: relate to the balance between sales and costs, net earnings and provide for family.

Service: relates to customer service /relationship

Social: relates to giving back to your family, your community/society; and charitable giving

Growth: relates to business expansion through new products, business lines, stores, etc.

SMART principles

S **Specific**: goals should be focused and well defined

M **Measurable**: what does success look like?

A **Achievable**: goals should be realistic

R **Responsible**: who is accountable for delivery of the business goal?

T **Time-bound**: a timeframe should be set when the goal is to be completed.

Goals that do not meet the above principles lack the teeth to focus an entrepreneur on outputs to meet outcomes that will result in tangible business gains and therefore success.

Attributes of recordkeeping

An effective record keeping system is one which:

- ✓ is as simple as possible
- ✓ enables required information to be quickly found
- ✓ contains accurate data
- ✓ links individual records and follows a path that enables cross-checking
- ✓ separates business and private finances.

The following are basic guidelines for record keeping:

- ✓ Open a bank account in the business name.
- ✓ Put all business receipts and payments through the business account.
- ✓ Use a duplicate deposit book.
- ✓ Record sufficient details on the cheque butt.
- ✓ Establish a petty cash system.
- ✓ Avoid making personal withdrawals from your business account.
- ✓ File all documents, such as rental agreements, lease agreements.

When filing documents use a simple system so you can find them as needed and keep an index. A simple alphanumeric system is sufficient.

Source documents

Below are good examples of important source documents that can assist in preparing financial performance statements:

SALES RECORD						
Date	**Sales**	**Quantity**	**Market outlet**	**Unit price ($)**	**Total income ($)**	**Remarks**
28.03.22	Cassava	40 bags	Sigatoka Market	$40/bag	$1,600	Cash sales
30.03.22	Capsicum	20 bags	MH Supermarket	$15/kg	$300	Cash sales

EXPENSES RECORD					
Date	**Operation**	**Quantity**	**Unit cost ($)**	**Total costs ($)**	**Comments**
26.03.22	Purchase of NPK	10 x 40 bags	$79/bag	$790	Fertilizer bought from Agchem

AREA STATEMENT OF THE MONTH OF _____ , 20____					
Name of Farmer:				**Date:**	
Crops	**Unit**	**Opening**	**New plant**	**Harvest**	**Closing**
Cassava					
Mature	acre				
Immature	acre				
Dalo					
Mature	number				
Immature	number				
Vegetables					
Capsicum	acre				
Cucumber	acre				
Eggplant	acre				
TOTAL					

PLANTING RECORD						
Date	Field No.	Crop	Area planted/Total number of plants	Expected harvesting time	Expected yield (kg)	Remarks

FERTILIZER RECORD								
Date	Field No.	Crop	Area planted/ Total number of plants	Age of crops	Types of fertilizer	Recommended application rate (g/plant)	Total quantity applied	Remarks

PESTICIDES RECORD									
Date	Field No.	Crop	Area planted/ Total number of plants	Age of crops	Types of diseases or insects	Level of infection (%)	Name of pesticides	Recommended application rate	Total quantity applied

LABOUR RECORD				
Date	Details of activity	Total number of labourers involved	Total number of hours	Total labour costs

HARVESTING RECORD						
Date	Field No.	Crop	Area harvested or number of plants harvested	Production (kg)	Amount rejected	Remarks

Source documents are the foundation of the financial recording system as they:

- Provide evidence of a financial transaction
- Are normally issued at the time of the transaction or include the date in the document
- Can be external or internal to the business
- Are issued by the business or to the business.

It is important not just to identify the documents required, but to have a clear understanding of their purposes as follows. In the event of a dispute, a primary source document is evidence that the transaction occurred.

Financial tools

There are four financial tools to assist farmers to make appropriate financial decisions. Using the right tools for analysis helps businesses obtain accurate information, a thorough and clearer picture of financial positioning strengths and weaknesses, and allows farmers to make educated decisions.

1. Financial statements (Comparison)

We use this tool to compare what is planned for and against the actual as shown below. The variance or difference will assist you to make better financial decisions and also able to compare the planned gross margin and actuals. Financial statement analysis is the process of analysing a company's financial statements for decision-making purposes.

Item	Budgeted	Actual	Variance
Income:			
Tomatoes	xx	xx	xx
Variable costs:			
……	xx	xx	xx
……	xx	xx	xx
Less total variable costs	xx	xx	xx
Gross margin	xx	xx	xx
Fixed costs:			
……..	xx	xx	xx
……..	xx	xx	xx
Total costs			
Total operating costs			
Profit (Income less operating costs)			

2. Return on assets (ROA)

The term return on assets (ROA) refers to a financial ratio that indicates how profitable a business is in relation to its total assets. The ROA figure gives investors an idea of how effective the business is in converting the money it invests into net income. The higher the ROA number, the better, because the company is able to earn more money with a smaller investment. Put simply, a higher ROA means more asset efficiency. The ROA should be equal to or greater than 0.5. This indicates the profitability of assets. A figure lower than 0.5 indicates poor profitability.

Return on assets can be calculated as follows:

Efficiency of assets = Sales/total assets

Example:

Sales = $5000

Total assets = $13,500

$5000/$13,500 = 0.37:1

In this example, total assets are not as productive or efficient as it can be since 0.37 is less than 0.5.

3. Gross profit margin (gross profit/sales)

Gross profit margin is a system of measurement that assesses how efficiently the business generates profit from sales of products or services. Gross profit margin can help a business compare performance against other farming businesses or peers, and also assess their own performance over time.

4. Breakeven point

The main purpose of breakeven analysis is to determine the minimum output that must be exceeded for a business to make profit.

Example 1: **Sales = $100; Fixed costs = $30 and Variable costs = $70**

Therefore, $100 = $70+30; this indicates the business not making any profit i.e. zero profit.

Benefits:

(i) Better judgement: set the quantity (kg) to achieve better profit

(ii) Better position to compete in the market in terms of price

(kg) = Fixed cost

Contribution Margin (CM = Selling price less Variable costs)

Example 2: **Selling price per kg $3**

Variable cost per kg = $1.10

Therefore, contribution margin (CM) = $1.90 ($3.00 - $1.10)

BEP (kg) = Fixed costs/CM

$30.00/$1.90

= 15.78 kg

This indicates if the farmer produces output of 15.78 kg with a selling price of $3, the farmer will achieve zero profit. However, if the farmer sells more than 15.78kg a profit will be made.

5. Cost per crop

Selling anything for less than it costs to produce makes no business sense, so knowing your cost of production per crop can greatly improve decisions about what to sell, when and how much.

Determining the cost per crop:

Total costs (Variable plus Fixed costs) divided by the total number of plants in a protected structure.

Example: **Total costs = $4500**

Total number of plants in the structure = 500

Therefore, cost per crop = $4500/500

$9.00 per crop

Therefore, if the farmer wishes to make a profit the farmer has to achieve sales/income above the cost of $9 per crop.

6. Preparation of a simple budget

A budget is:

- a plan, forecast or a forward-looking income and spending plan
- for a period of time, usually up to 12 months
- a standard for control purposes.

The following steps are a guide to preparing a budget:

1. **Calculate your Gross sales:** Income generated from the sale of commodities.
2. **Calculate Variable costs:** A variable cost is a corporate expense that changes in proportion to how much a company produces or sells. Variable costs increase or decrease depending on a company's production or sales volume—they rise as production increases and fall as production decreases.
3. **Calculate Gross margin:** The *gross margin of an option is the gross income produced from the option less the variable costs from implementing it.*
4. **Calculate Fixed costs:** The term fixed cost refers to a cost that does not change with an increase or decrease in the number of goods or services produced or sold.
5. **Calculate Operating costs:** Variable costs + Fixed costs.
6. **Calculate Net profit:** Income less Operating costs (Total costs).

7. Preparation of financial performance statements

The basis of good quality financial performance statements is the proper recording of financial transactions and filing of source documents. The financial performance of a farm business can be summarised in the key areas in the financial statements. Information from these statements can be used:

- to make important financing and investment decisions;
- to provide evidence to support credit applications;
- to derive performance measures for analysing the farm business; and,
- to develop budgets for planning purposes.

Glossary

Purchase	payment
Sales	receipt
Variable costs	costs that change as the quantity of the good or service that a business produces changes
Fixed assets	Assets that are purchased for long-term use and are not likely to be converted quickly into cash, such as land, buildings and equipment
Transactions	Business-related events that took place

Recommended training

EXERCISE 1: Marketing	Why do we do it this way?
Work with small groups of farmers (divide larger groups up into smaller groups of 4–6). Get them to discuss answers within their groups and then present their findings on a flip chart or butcher paper after the groups have had a short time for discussion. 1. Choose a product/commodity (for example, tomato/capsicum/watermelon, etc.). 2. How will you communicate your commodity to the buyer? Include: • quality of product • why your product is different from the others.	It helps farmers to think about what the buyers of their products may desire and expect. The trainer can then guide discussion to add new points that the farmers may not have identified.

EXERCISE 2: Supply chains	Why do we do it this way?
https://www.youtube.com/watch?v=zBtnKPEo1mM&t=21s Draw a supply chain of your farm produce on flip-chart paper.	Assists farmers to understand the supply chain and identify steps in their supply chain.

EXERCISE 3: Supply chains	Why do we do it this way?
As an individual or organisation: 1. List the factors that may cause a broken chain.  2. List the factors that may cause a perfect chain 	Improves understanding of the cost for each stage. Assists smallholders to draw up a simple budget/financial plans. Helps farmers to become aware of the cause of weak and perfect links. Assists growers to mitigate the risk. Helps farmers identify possible weak links.

EXERCISE 4: Supply chains – Group discussion	Why do we do it this way?
What would be your decision be when there is a change in consumer demand?	To understand well the consumers' demand. The group discussion allows participants to share experiences.

EXERCISE 5: Business goals	Why do we do it this way?
A. On a white board or sheet of butcher's paper, draw horizontal and vertical lines to form a cross that divides the board/paper into four quadrants. Head each quadrant as follows: • **Profit** • **Service** • **Social** • **Growth** Give each table a bundle of Post-it notes. Participants are to list one goal per Post-it note and place each in the relevant quadrant. **NOTE FOR TRAINER:** The emphasis of this module is: • specifying business goals in a meaningful way; • introducing business documents; • the content of business documents not the format; • participant and group activities; • active participant discussion. **B.** Identify some of your own short-, medium- and long-term goals and write them down using the **SMART** method. **Short term** Exactly what do you want to achieve? **Medium term** How will you know when you have achieved it? **Long term** Is it something that you can do?	To give /allow the farmer to have a clear and achievable goal

EXERCISE 6: Prepare a simple budget	Why do we do it this way?
SALES: Tomatoes: 500 kg @ $3/kg **VARIABLE COSTS:** Seeds: 2kg; price: $2/kg Land preparation: 5 hours at $10/hr Labour: 2 persons per day @ $20 each/day Transport: 4 trips – $100 per trip NPK: 10kg; $2/kg **FIXED COSTS:** Land rent: $300; payment for plastic house: $200	Planning helps the farmer to achieve what is planned for or to make a profit.

EXERCISE 7: Financial performance (Actual)	Why do we do it this way?
INCOME: Tomatoes: 500 kg @ $3/kg **VARIABLE COSTS:** Seeds: 3kg; price: $2/kg Land preparation: 4 hours at $10/hr Labour: 6 persons per day @ $20 each/day Transport: 5 trips –$100 per trip NPK: 9kg; $2/kg **FIXED COSTS:** Land rent: $300; payment for protected cropping structure: $150	Measuring actual financial performance helps the farmer to match against what is planned/ budgeted.

Exercise 8: Calculate the difference (Variance)	Why do we do it this way?
Budgeted less the Actual	It assists with comparison: which item from the Variable/fixed costs is overspent? Monitoring and controlling your expenses

ITEM	Budgeted	Actual	Variance
INCOME	**FJD**	**FJD**	**FJD**
Tomatoes	1500	1500	0
Variable costs:			
Seeds	4	6	-2
Land preparation	50	40	10
Labour	80	240	-160
Transport	400	500	-100
NPK	20	18	2
Less total Variable costs			
Gross margin	946	696	**250**
Fixed costs:			
Land rent	300	300	0
Payment – PC structure	200	150	50
Total costs	**500**	**450**	
Total operating costs	1054	1254	
Profit (Income less operating costs)	**446**	**246**	

EXERCISE 9: Comments	Why do we do it this way?
1. Gross margin in percentage **2. Differences (Variance)**	To understand the profitability of the business

EXERCISE 10: Return on assets (ROA) – Comments	Why do we do it this way?
Return on assets (ROA): **Sales/Total assets**	To understand when/what to supply

EXERCISE 11: Breakeven point (BEP) – Comments	Why do we do it this way?
Refer to the exercise, Calculate the BEP **SOLUTIONS:** Selling price per kg = $3 Variable costs per kg: Total variable costs = $554 Total kg = 500kg 554/500 = $1.11 Therefore, Contribution Margin (CM) = $3 – $1.11 = $1.89 BEP = Fixed costs/CM = $500/1.89 265 units (kg) 265 units(kg) x 3 = $795 265 units (kg) x 1.11 = 295 =$500 Less Fixed costs ($500) = 0 (zero profit) **DISCUSS:** 1. $795 Income/sale 2. BEP (Units) = 265 units 3. What if the farmer increased the level of output/quantity *Increase* – How it affects the profit *Decrease* – How it affects the profit	• Better judgement: set the quantity (kg) to achieve profit or Revenue greater than Costs (R>C). • Confidence to compete with price in the market.

Produced by the Pacific Community (SPC)
Suva Regional Office
Private Mail Bag, Suva, Fiji

Telephone: + 679 337 0733
Email: spc@spc.int
Website: www.spc.int

ISBN 978-982-00-1349-0