



Chapter 16: Integrated Pest Management



Pests are a constant concern for all farmers. As all farmers know, they can easily destroy entire crops in very little time. Pests tend to prefer specific crops, however. One of the many important benefits of Forest Gardens is that their innate diversity means that a given pest will only affect a one of the many crops that are producing at a given time. So even if you have a pest infestation, you will still have other crops to provide food and income opportunities.

That said, it is in your interest to control any pests as much as possible. Modern, intensive agricultural practices often rely on expensive, synthetic pesticides to kill pests, which often lead to negative environmental affects, not to mention the health threats to those who mishandle the toxic chemicals. Furthermore, pesticides generally kill all insects, including beneficial insects that naturally protect your crops, as well as all the beneficial organisms that live in and around your soils—those that are so critical in maintaining your soil fertility.

In the Forest Garden Approach we encourage natural, organic measures to control pests, using an approach known as Integrated Pest Management (IPM). IPM is an approach that involves managing pest populations instead of controlling or eradicating them. It requires a greater knowledge of the pest, crop, and the environment. Therefore, its strategy focuses on harnessing inherent strengths within ecosystems and directing the pest populations into acceptable bounds rather than eliminating them entirely. It focuses on *pest* management rather than *pesticide* management. This strategy avoids undesirable short term and long term environmental impact and will helps to ensure sustainable productivity of your Forest Garden.

Integrated pest management is a comprehensive long term pest management program based on knowledge of an ecosystem that weighs economic, environmental, and social consequences of interventions. It requires a complex understanding of the crops you are growing, the soils in which you grow them, the pests in your area and their natural enemies, and the interactions between and among all of them. Thus it is impossible to describe IPM approaches applicable to all Forest Gardens. However, we will describe the general philosophy and process for developing an IPM approach in your Forest Garden, a basic overview of many of the common pests farmers are likely to encounter, and recommended approaches for managing them.

The use of pesticides and other approaches that treat the symptoms rather than the root causes are unsustainable and should be the last option rather than the first line of defense. An integrated pest management strategy should always start with the question

'Why is the pest a pest?'. It should also seek to address underlying weaknesses in ecosystems and/or agronomic practice(s) that have allowed organisms to reach pest status.

An integrated process

Integration or compatibility among pest management tactics is central to Integrated Pest Management. Simply mixing different management tactics does not constitute IPM. Mixing the tactics arbitrarily may actually aggravate pest problems or produce other unintended effects.

IPM recognizes there is no "cure-all" in pest control as pests are too diverse to control with any one measure. Reliance on a single tactic will favor pests that are resistant to that practice. In IPM, integrated control seeks to identify the best mix of pest controls for a given insect pest. The determination of the correct cause of pest problem (understanding pest biology) and ecology is essential in manipulating the environment to the crop's advantage and to the detriment of the pest.

Acceptable pest levels

IPM recognizes that eradication of a pest is seldom necessary or even desirable, and generally not possible. The primary objective in pest management is not to eliminate a pest organism but to control all pests to an acceptable level that will have little impact on the productivity of the overall Forest Garden system. The emphasis is on control, not eradication. IPM holds that wiping out an entire pest population is often impossible, and the attempt can be expensive and environmentally risky and unsustainable. An IPM program's initial task is to establish acceptable pest levels, or thresholds, and apply controls where the thresholds are crossed. These thresholds are pest and site specific, meaning that the impact of certain weeds or pests on one site may be negligible, but at another site it may be significant. By allowing a pest population to survive at a reasonable threshold, selection pressure is reduced. This stops the pest gaining resistance to chemicals produced by the plant or applied to the crops. If many of the pests are killed, then any that have resistance to the chemical will form the genetic basis of the future, more resistant, population. By not killing all the pests there will some un-resistant pests left that will likely dilute resistant genes that appear.

IPM process

IPM is applicable to Forest Gardens of all types and species arrangements, and in all climates and agroecological conditions. There are some basic IPM measures, including crop rotation, and soil fertility management and protection, that can go a long way toward preventing pests from populating your Forest Garden. These by no means will control all pests, however. It is extremely important that you carefully monitor the plants in your Forest Garden regularly, identify any issues with pests as early as possible, and determine the best approach to control them. This process includes:

Proper identification of pest damage and responsible pests

Correct pest identification must be the first objective. You must know the pest you are dealing with before you can determine the best approach for controlling it. Cases of mistaken

identity may result in ineffective actions. If plant damage is due to over-watering, for instance, it could be mistaken for fungal infection as many fungal and viral infections arise under moist conditions. This could lead to laborious or costly control methods that would have no effect on the health of the plants you are trying to protect.

Pest and host life cycles biology

Understanding crop growth and development is an underlying principle of IPM. We cannot

just focus on the pest. The interactions between crop and pest (as well as the environment) are very important. It is important to carefully monitor your Forest Garden regularly to identify and respond to pests before they become a serious problem. In some cases, however, by the time you see a pest it may be too late to do much about it beyond spraying it with pesticides and having to accept the costs and impact on the greater health of your Forest Garden. Often, however, there is another stage of the life cycle that is susceptible to preventative actions. For example, weeds reproducing from last year's seed can often be prevented with mulches. In other cases, knowing what a pest requires to survive – feeding off of a certain type of plant, for instance – may allow you to remove that element from your Forest Garden.

Evaluate and record results

Evaluation is often one of the most important steps in Integrated Pest Management. It is the process of reviewing an IPM approach and the results it has generated. Asking the following questions is useful: Did the steps you took effectively control the population? Was this method safe enough? Were there any unexpected side effects? What is the next step? Understanding the effectiveness of the IPM approach allows you to make modifications to the IPM plan prior to pests reaching the threshold and requiring action again.

Pest management tactics

There are different pest management tactics to suppress pests. They include host resistance, biological, cultural, mechanical, sanitary, mechanical and, when all else fails, chemical controls. The primary pest management tactic involves maximization of built-in pest reduction features of an ecosystem. Molecular or genetic mechanisms are potentially manifested in a number of these more specific tactics. Each category, discussed below, employs a different set of mechanisms for suppressing populations.

Biological control

This involves the use of other living things that are enemies of a pest to control it. The planting of insectary and nectary plants and aromatic pest confusers, for instance, can

repel pests or attract their natural predators. IPM is mainly aimed at developing systems based on biological and non-chemical methods as much as possible.

Host plant resistance

This involves the use of plant varieties with desirable economic traits, but less attractive for pests or for their reproduction and subsequent development. It also involves withstanding the infestation or infection, or the reduction of pests to a limited level during the plant growth and production period.

Cultural measures

This involves practices that suppress pest problems by minimizing the conditions that favor their existence (water, shelter, and food). Some of these factors are intrinsic to crop production, making the environment less favorable for survival, growth and reproduction of pest species. The appropriate placement of specific crops within your Forest Garden can reduce infestation from insect pests. If followed in an appropriate manner, cultural practices can provide significant relief from pests.

Mechanical control

This is the use of tools to manually control pests. It involves agricultural practices like tilling, manual pest removal, and weeding. The pruning of infested parts of fruit and timber trees, and defoliation in certain crops help reduce pest populations. Chaffing of sorghum and maize stalks and burning of stubbles kills maize borer.

Sanitary control

Preventive practices are important part of an IPM program. These include cleaning field equipment (i.e., tillage equipment, haying equipment, pruning tools, etc.), planting certified seeds where possible, and quarantine or burning of infested crops or vegetation. These are methods used to prevent the introduction or reintroduction of a pest into the field.

Natural control

Natural control involves the enhancement of naturally occurring pest management methods to combat pests like crop rotation, and intercropping of plants that harbor beneficial insects or deter pests.

Chemical control

The therapeutic approach of killing pest organisms with toxic chemicals has been the prevailing pest control strategy for many decades. Safety problems and ecological damage continue to ensue from them, and there are renewed appeals for effective, safe, and economically acceptable alternatives. Synthetic chemical pesticides are the most widely used method of pest control, but they are also generally the most costly, and pose the greatest risk to the sustainability of your Forest Garden system and general environment. The four major problems encountered with conventional pesticides are toxic residues, pest resistance, secondary pests, and pest resurgence. We encourage the

use of natural pesticides—often made from locally available, organic materials—that are more environmentally friendly where possible. We strongly recommend only using synthetic pesticides as a last resort, or only used as required and often only in limited amounts and at specific times in a pest’s life cycle.

Benefits of Integrated Pest Management

The benefits of Integrated Pest Management are immense, directly impacting Forest Gardens and the families who adopt them, and indirectly benefitting society.

- **It protects environment** – through elimination of unnecessary pesticide applications, IPM is an environmentally friendly approach to pest control. In IPM, pesticides are only used when other methods of pest control have failed, and even then in very small doses. IPM measures are used in bringing a pest organism to acceptable bounds with as little ecological disruption as possible.
- **IPM improves profitability** – since IPM approaches aim to apply the most economical pest management tactics, potential profitability is higher for the families who practice IPM.
- **It reduces risk of crop loss by a pest** – applying pest management and monitoring tactics can ensure the reduction of crop loss or damage by effectively controlling pests.
- **It can lead to long term sociological benefits** – long term benefits to society can also emerge from IPM in areas of employment, public health, and well-being of farmers, their families, and surrounding communities.

Disadvantages of Integrated Pest Management

In spite of the numerous benefits of IPM stated, there are also some drawbacks to it:

- **An IPM program requires a higher degree of knowledge and management** – making the decision not to use pesticides on a routine or regular basis requires advanced planning and a higher degree of knowledge and management. This planning includes attention to field histories to anticipate what the pest problems might be, selecting crop varieties which are resistant or tolerant to pest damage, and choosing tillage systems that will suppress anticipated pest damage while giving the crop the greatest yield potential.
- **IPM can be more labor intensive** – consistent, timely and accurate field scouting takes time. However, this information is the corner stone of IPM programs. Without this information you cannot make intelligent management decision.

Pest Prevention Measures

In all cases, it is preferable to prevent pests from attacking your crops rather than trying to control them once they do. The sections below describe the prevention measures you should take to decrease the risk of pests colonizing in your Forest Garden.

Diseases and Pests Common to Agroforestry and Fruit Trees

In this section we will discuss characteristics and controls of certain general categories of pests and diseases which attack tree nurseries and fruit trees. Use the following sections to identify the problem encountered and determine a control method.

Diseases

Disease control starts with prevention. When establishing fruit trees that grow slowly and may be producing for over 50 years, it is important to start preventative measures even before seeding in the nursery. Be especially careful at this stage because preventative measures taken at the time of planting may prevent a disease that could attack an orchard 5 to 10 years in the future. Also, because diseases are not a onetime phenomenon and may take years to develop, preventative measures, especially sanitation, should be practiced routinely, not just applied at one time. There are three types of pathogens that attack plants and cause diseases: fungi, bacteria, and viruses. Fungi are the most abundant. They cannot manufacture their own food and are reliant on the host plants for survival. Fungi travel in the spore stage of their life cycle on animals, wind, water, and insects (vectors or carriers). Fungus diseases can be controlled by fungicides but often come back quickly, necessitating multiple applications.

Diseases caused by bacteria are also very common. Bacteria also travel in a spore state on hosts to infect new plants. Like fungi they also do not manufacture their own food. Bacteria are harder and more expensive to control. Spraying trees with antibiotic is possible but not generally accessible to most farmers in the developing world. Most commonly the infected trees should be destroyed.

Viruses are the most serious type of disease. There is no chemical means for controlling them and infected trees should be destroyed. They are transmitted by sucking insects, especially scales and aphids, and by unclean tools such as knives, machetes, and other pruning tools. Resistant varieties are the only real control method for virus diseases.

Here are a few simple preventative methods that you can use to prevent diseases before they infect your Forest Garden or nursery:

Physical preventative methods

Both fungi and bacteria live and thrive in humid conditions. One of the easiest ways to avoid fungus and bacteria caused diseases are to keep the Forest Garden dry. Build cuvettes (see section on cuvettes) so that the bases of the trunks of your trees remain dry. Pruning can also help. A well-pruned tree with air circulating throughout the branches will be much less likely to be attacked by these diseases. Avoid over-watering! If the trees are planted in clay soils that retain water, water much less than trees in well-drained soils. Try to plant only in well-drained soils.

Resistant varieties

Perhaps most importantly, try to find varieties that are resistant. If disease does attack, take advantage of this and identify trees which are unaffected for future seed sources. Never take seeds or vegetative planting material from diseased sources.

Sanitation

Most disease vectors can be washed off with soap and water. All tools, including baskets for harvesting fruit, should be washed with soap and water before each use. Household bleach or rubbing alcohol should be used on tools to kill viruses. If there is disease in the region you should collect your own fruit and take it to market yourself rather than having collectors from other sites harvest fruit from your own.

If you are examining a disease in another farmer's site, before to wash well before returning to your own or others! Wash yourself, wash your tools, change or wash your clothes. Diseases pass from orchard to orchard very slowly. Fifteen kilometers between two orchards may hold off a disease for years, but you can easily distribute it to your site or to others in one visit.

Sterilizing Soil

When propagating trees in areas where diseases are a problem, it is good practice to first sterilize the potting soil you will use for raising your seedlings and lining planting holes. Soil for nurseries and plantation holes can be sterilized using a simple 50 gallon drum method:

- Remove the top of a metal, 50 gallon drum, and poke numerous holes through it;
- Replace the top inside the drum on supports about 15 cm from the bottom;
- Place the drum on three stones, at a height sufficient to light a small fire underneath;
- Fill the drum with 10 cm of water, and fill your potting soil mix on the top placed inside the drum, to about 3 cm from the top of the drum;
- Bury a potato about 15 cm deep into the potting soil in the drum;
- Spread a thick layer of large leaves or sacks over the soil for insulation;
- Start a wood fire under the drum and keep it stoked;
- When the potato is completely cooked, the soil should be vector free.

Diversify and Rotate!

Monocultures are particularly susceptible to diseases which can quickly spread across an entire field. This is not as much of a threat in a Forest Garden, however it is best practice to diversify the varieties of fruits and other trees you plant in your Forest Garden. If you are planting a lot of mango trees, for example, mix up the varieties and mix up the rootstock seed sources. For citrus however, resistance to diseases comes only from using proper rootstock which is disease resistant, but you can still diversify the varieties grafted on the rootstock. Plant certain varieties in rows with other types of trees between the rows. This way harvesting is still easy yet variation is kept high. One easy thing to do is to put large thick windbreaks with dense trees such as cashews throughout the orchard to segment the field.

If planting short lived fruits (e.g. papayas, bananas, and pineapples) do not plant them in the same spot after removing the previous crop. Instead, rotate in different trees or other crops. It is also a good idea to rotate nurseries. In an area where there was a mango nursery the previous year, this year raise citrus or let it go fallow.

Pest control

As mentioned above, diseases, especially viruses, have no way to move between host plants on their own. As these pathogens spend some of their life cycle in vectors (carriers of the disease), a good way to control diseases is to control the vectors. Scale insects and thrips are perhaps the most infected insects we deal with, but general sucking insects, nematodes, flies, and even the beneficial bees may be carriers of disease.

Keep your trees healthy

Trees have natural defenses against diseases. Weak, sick, or damaged trees may quickly succumb to normally harmless diseases. Lack of water or nutrients, failure to prune dead, damaged, diseased, and disruptive branches, and damage caused by careless pruning, can severely weaken a tree and make it susceptible to diseases. Read the pest sections below to find out how to control these.

Pests

Because pests are such a diverse and unpredictable problem, only so much can be done in advance to prevent infestation. With some pest types, though, preventative measures do exist and should be employed when the pest is known to be in the region:

Sanitation

As in diseases, pests thrive in unclean or unkept areas. Any dead or diseased plants or parts of plants should be removed from the plantation. Dead plant material is a breeding ground for pests and a feeding ground for termites.

When traveling from sites with pest problems, take care not to transport any pests or eggs. Any vegetative matter or soil which is exchanged between sites should be completely cleaned before arriving to another site. Fruit which may contain scales or fly eggs should not be brought to non-infested sites.

When pests are a problem, sterilize soil as described above to destroy all eggs, nematodes, and larvae living there.

Plant resistant species

This is much more difficult with pests than it is with diseases. Some species may be found which are resistant to pests such as nematodes or taste bad to pests such as caterpillars.

Weeding

Keep weeds cleared from in and around your cropping areas and permagarden. Weeds can host pests that will attack your crops.

Termites

Termites are a big problem in the dry tropics. Preventative measures should be taken early on in tree development to control these pests. Despite local rumors, few termite species live off living tissues. They mostly only attack dead wood. The species that do attack living trees, however, are present in some parts of Africa. These species rarely kill adult trees and actually do little harm to healthy trees. When a tree is being attacked and killed by termites it is usually a sign that something else is wrong. Termites can do severe damage, however, and may even kill many seedlings or young trees. A couple of preventative measures can be taken to help alleviate the termite problem:

- **Wood ash** – mix wood ash in with the soil in the nursery and the transplant hole. Wood ash is very abrasive and termites do not like to crawl through it.
- **Neem leaves** – add neem leaves or neem seed cake to soil mixtures in the nursery, and periodically at the outplanting site.
- **Removal of dead wood** – because termites feed mainly on dead matter it is important to keep large amounts of dead wood clear from your Forest Garden and nursery site. After pruning a tree gather up all the cut branches and use them for fuelwood them or take them away, to harbor termites elsewhere. If you have a dead fence to protect your growing living fence or nursery, keep it a suitable distance from the trees and keep the area between the two clean.
- **Mulch** – keep the soil rich in organic matter and covered with mulch. The termites that do remain will feed on this dead plant material and not your trees.
- **Build cuvettes** – Fruit trees love mulch and love periodic additions of manure. Yet these two substances attract termites. By building a cuvette, and adding mulch and manure to the cuvette instead of at the base of the tree - thus keeping the area at the base of the tree clean - the tree trunk will avoid direct exposure to termites.

Nematodes

Nematodes, another very common pest problem, can also be controlled or avoided completely by preventative measures listed here:

- **Sanitation** – soil sterilization should be done in nurseries if nematodes have been a problem in the past (see *soil sterilization* section above). Burn any infected plants.
- **Plant resistant varieties** – some varieties have built up natural defenses to nematode attack. Plant resistant varieties wherever possible.
- **Intercrop with marigolds** – marigold roots repel nematodes and can be easily planted at the beginning of the rains with very little effort. Plant them on the bunds surrounding your permagardens and disperse them in beds and other parts of your Forest Garden among plants susceptible to nematode attack. Most marigolds are prolific seeders, so the seeds collected from dead flowers can easily be replanted.
- **Crop rotation** – one of the best ways to avoid continuous nematode infection is rotate crops susceptible to nematodes, never planting them in the same place continuously (see crop rotation in the intercropping section). Bananas and papayas,

which are short lived but especially sensitive to nematodes, should never be planted in the same location after removing, nor in a location where there were other nematode-attracting vegetables or fruit trees.

- **Enrich your soil** – Natural enemies of nematodes are present anywhere nematodes exist. These natural enemies are generally present in health soils enriched with organic matter. Add mulch and manure to cuvettes and keep the soil around trees healthy and full. This will also help the tree stay healthy so that its own defenses can protect it against nematode attack.

Pest Control Measures

Using preventative measures when establishing trees in your Forest Garden, you will avoid many of the common and more serious pest and disease risks. Unfortunately they can still attack your crops even when all precautions are taken, and oftentimes farmers already have some existing trees on the Forest Garden site, some of which may already host some type of pest. It is understandable when problems arise that you may prefer treating these pests with proven chemical treatment rather than experimenting with natural treatments, and we do discuss chemical options for managing pests and disease below. As chemical treatment can diminish the overall integrity and health of your Forest Garden, however, we strongly recommend using chemical treatment only as a last resort.

There has been an emphasis in research on natural and organic pest control methods over the past decade, but unfortunately little has been suggested about organic or biological control of diseases. This is because, as mentioned above, there are few organic methods to destroy disease pathogens other than simply destroying the infected tree. At the same time, even if cures are available, the diseases or pests need to be correctly identified first in order to use the correct treatment, which may not be easy. Figuring out what pathogen, pest, or combination thereof is causing certain symptoms often requires experts that are typically not present or accessible in most places. Although tricky, disease and pest identification is possible to an extent that can be adequate for most cases.

The first step of the IPM process, when an undesired or unnatural symptom exists and is persistent or spreading on or between trees, is to look for and identify a pest. Pests, because of their physical presence, are much easier to diagnose and treat than diseases. Sometimes a pest will be too small to see or will not be present (leaf borers are located inside stems, cut worms only come out at night) so the absence of a visible pest does not immediately mean a disease is present. If the pest is not present ask the following questions about the symptoms of the disease or pest:

- Are the symptoms general all over the plant or localized in one area?
- What parts of the plant are affected? What part of the plant was first infected? Is the disease spreading?

- What are the characteristics of the symptoms? Wilting? Large brown spots? Discoloration? Rotting? Death of part of the plant? Cancers? Perforations? Cuts? Dropping of young fruit? Presence of gum or resin?
- What time of year do the symptoms appear? and
- Is the damage serious enough to require treatment?

After you answer these questions, try to use the following general descriptions to try to identify the problem. If the symptoms do not match up or you still do not feel confident, try to get an expert or extension agent knowledgeable on pests and diseases in your area to help you identify the cause.

Diseases

Although chemical controls may be available, as we have said time and again, we do not encourage their use unless the disease is accurately identified and all other forms of control have been exhausted. Remember that the best way to combat disease is by taking precautions in disease prevention from seed selection to nursery care to outplanting and managing of trees. Keep your trees healthy and control pests which carry disease. However, when symptoms of disease do arise, use this section that describes some of the most common diseases as a reference and foundation from which further investigation can be done.

Fungus Diseases

Fungi can live on the surface or inside the host plant. Powdery mildews and root rots are caused by fungi which live on the surface of a host plant. Fungi can also live inside the host and erupt in the form of downy mildews, leaf spots, blight, rusts, anthracnose, and scabs. Fungi can also remain completely inside the host causing "wilts".

Preventative Measures: Avoid creating humid situations in the nursery and orchard. Build and maintain cuvettes around high-value trees to avoid water-logging roots and trunk. Avoid over-watering. Plant trees only in well-drained soils. Do not water every day in soils which do not drain well. Adhere to spacing requirements to allow aeration between trees. Use resistant varieties when applicable.

Organic control: Prune and burn all infected areas.

Chemical Control: Spray fungicides.

Anthrachnose is probably the most commonly found fungus disease. It plagues the mango although it may also attack citrus, avocado, annona spp, and other species. Generally anthracnose is spread by fungi. The symptoms appear to be very similar for all species. It seems to attack branches, leaves, fruit, and sometimes young roots, and eventually leads to death of the tree. When it attacks mangos the extremities turn brown and the roots may dry up. Leaves

have small, round spots dark brown to black in color or holes which may appear in leaves in place of the spots. Leaves will also fall off the tree. Fruit will have small dark spots, especially young fruit. The disease can also manifest itself as cankers on leaves, roots, and fruit of citrus, annona spp., papaya, and avocado.

Possible Control Measures: For all species, prune and burn all infected branches, leaves, and fruit. Spray infected areas with fungicides.

Damping off occurs in the nursery when fungus disease attacks germinating seeds. This is often a problem with citrus.

Preventative Measures: Avoid excessive watering in the germination bed or after seeding tree sacks. Be sure the germination bed or sacks are well-draining. Treat the seeds with ash before sowing.

Possible Chemical Controls Fungicides.

Cercospora appears as cankers on leaves and spots on fruit. Like anthracnose, its pathogen is usually fungi. The treatment is generally the same as with anthracnose.

Possible Control Measures: For all species, prune and burn all infected branches, leaves, and fruit.

Root rotting caused by *Phytophthora* spp. is common in many places. It attacks many species, although it is most commonly found on citrus, pineapple, papaya, and avocado. Fruit becomes discolored, leaves dry out and fall off tree, and roots are destroyed.

Possible Chemical Controls: Spray with fungicides.

Bacterial Diseases

Bacteria spores are transported by wind, water, animals, insects, and humans. Bacteria can feed off of living or dead tissue. They multiply in the host plant by rapid cell division.

Gummosis is the most common and most serious bacterium spread disease of citrus. It attacks the roots and trunks of trees. Leaves turn yellow, become brittle, and fall off. The most obvious symptom is the gum being excreted from the tree, usually along the lower trunk and roots. It will lead to the eventual death of the tree.

Preventive Measures: Using resistant rootstock, planting in well-drained soils, and making cuvettes are especially important to combating gummosis.

Possible Control Measures: Cut off infected areas and paint with flint coat

Viral Diseases

These diseases cannot be prevented nor controlled by spraying. They are transmitted by sucking insects. By controlling these insects you are indirectly controlling the disease (see “sucking insects” below). Viruses are not visible to the naked eye and can only be seen through an electron microscope, therefore they are known by the symptoms they manifest.

Preventative Measures: For citrus, use resistant rootstocks.

Tristezia is a disease which attacks citrus grafted on non-resistant rootstock. The disease causes “die back” from the twigs inward and results in death of the tree. Early prevention in anticipation is good planning for citrus growers.

Preventative Measures: Grafting onto resistant rootstock and controlling sucking insects are the most important ways to avoid this disease.

Possible Control Measures: The only way to control tristeza is to destroy the infected trees.

Exocortis stunts the growth of the tree by causing slow growth and incompatibility between the budwood and rootstock.

Preventative Measures: Use resistant rootstock.

Possible Control Measures: Destroy infected trees.

Pests

There are basically three types of insects which attack plants: sucking insects, chewing insects, and borers.

Sucking Insects

Sucking insects have modified mouth parts which include a long straw-like appendage that they insert into plants to suck out juices. They can attack the leaves, bark, or fruit of the plant. Large amounts of these insects can weaken a plant or lower a plant's yield. They are also the principal carriers of plant diseases. The first and most obvious symptom of sucking insects are the insects themselves. Sucking insects are usually controlled by contact poisons, which can be made organically from locally available ingredients.

Types of Sucking Insects

Scales or mealy bugs will be the most obvious because they do not move or move very slowly. They appear as either black or white spots or bumps on the plant surface. They usually appear on the stems or branches, but are also found on leaves, buds, and fruit. They have either a hard, or cotton-like appearance,

almost resembling tiny oysters or seashells in some cases. Scales live in colonies. Once one is spotted others you can be certain that others are nearby. Sometimes scales live in symbiosis with ants (scales suck the juices out of the plants and the ants feed on undigested sugar excrement from the scales in return for protection from possible carnivores). Scales attack almost all fruit trees commonly planted in Forest Gardens, especially citrus and mango species. Scales are considered the dirtiest pest because they are well known to be carriers of viral diseases. They can weaken plants and lower the quality of the fruit.

Organic Control: Because there may be so many of them, scale insects are difficult to control. Physically removing them is possible but can be laborious. Try using a cotton swab dipped in alcohol to touch each insect. Spot spraying the trees with a mixture of peanut soap and water will also kill scales. Since scales often live closely with ants, a method for controlling scales is to control the ants. The ant species which live with scale insects live on the ground and are forced to use the trunk of the tree as transport to and from the scales. Applications of anti-ant compounds around the trunk can be useful.

Aphids can be too small to see with the naked eye. Aphids reproduce very quickly and live in colonies. Although one of these pests may not be able to do much damage, a colony can severely damage a plant. They often discolor plants at the site of attack. If leaves are turning gray because of many tiny holes on their surface (silvering) aphids may be the cause. They also cause distorted growth like bent or twisted branches and leaves. They can also attack and lower the quality of fruit. As with scales, aphids ants will often be observed alongside aphids. They secrete honey dew which they process from the plant's juices, and the ants eat the honeydew in exchange for protection. Aphids may carry diseases. They usually are active during the plant's growth phase.

Organic Control: Spot spray with a clay/water solution or annona spray. Control the ants (see scales above).

*** Note on scales and aphids - natural enemies can be used to keep these insects under control in your Forest Garden. Often when orchards are treated with insecticides, the enemies are killed rather than the scales and aphids, resulting in a sudden increase in their numbers. For this reason among many others, pesticides should only be used as a last resort and then should be spot sprayed. Another way to control aphids and scales is to control the ants by applying anti-ant compounds at the base of the tree.*

Thrips are the third economically important sucking insect. Thrips are generally too small to see with the naked eye. They may also cause silvering of the leaves and fruit; sometimes infected leaves may roll up. They also are carriers of virus vectors.

Organic Control: Neem oil can be used to spot treat heavily infected areas. Smothering a solution of soap and water on the leaves and stems of heavily infected areas may be enough to dehydrate and kill them.

Chewing Insects

Chewing insects actually eat the plant parts, usually attacking the leaves of the plant. These are usually not a problem for mature plants unless there are a huge number of these insects, as in the case of locust swarms. Chewing insects are a problem in nurseries and germination beds, however. They can completely defoliate seedlings quickly. A seedling that loses all its leaves will be weakened considerably and will take a long time to heal. Often seedlings in fields (cashews, for example) after being attacked by defoliating chewing insects are very susceptible to termites and are destroyed by a combination of these two pests. Most caterpillars and grasshoppers are chewing insects.

Caterpillars are young butterflies or moths. They are easily visible on plants; their primary symptom is leaf damage. Look for the small white eggs often found on the underside of leaves singly or in clusters.

Organic Control: Touch the caterpillars with a rag soaked in kerosene or hand pick them off by looking for damaged plants. Bring a chicken along for a free meal!

Cutworms is a common name given to a group of chewing insects that come out at night. One type of cutworm cuts off seedlings right at the collar, killing the whole seedling. Another type will climb the trees and eat the leaves; they eat irregular holes into the leaves starting with the edge.

Organic Control: Identify the infected plants during the day, then go out at night with your flashlight and hand pick the insects. Try cutting the top and bottom off a large can of tomato paste and putting it around the base of the seedling. You may also dig around the soil of plants showing symptoms to find the cutworm sleeping.

Leaf miners can be identified by clear lines on the leaves of the plant. They are rarely an economically important pest.

Organic Control: Prune and destroy affected leaves or dust the leaves with wood ash.

Boring Insects

Borers are insects that bore inside the plant stem, root, or trunk. Borers can destroy seedlings, plants, and young trees by completely cutting off their stem. If their populations grow uncontrolled they could be a problem for Forest Gardens and permagardens. Symptoms of a borer insect are spot wilting of the infected

branch or plant, and a small hole where the insect entered the stem. Boring insects can cause a lot of damage for annona species.

Control: Prune infected tree branches about 25 cm above the borer's hole. If the branch at the prune site is hollow, prune further up. Destroy the borer.

Flies

There are some species of flies that lay eggs in fruit, thus destroying the fruit, and some that have maggots that eat plant tissue. Fruit flies are the most economically important as they may be able to attack fruiting trees in your Forest Garden in great numbers and destroy that fruit's harvest. Small yellow stains with a black spot in the middle on a fruit is a sign eggs were laid. Later the fruit will have localized rotting, cavities where the maggot eats on the inside, and may drop off early.

Organic Control: Make poisonous bait traps to catch the flies. Mix two teaspoons full of household ammonia and 1/4 teaspoon of soap powder in a quart of water. Fill a jar with the mixture and put the jar right next to the sunny side of the plant. This bait should be changed once a week. Also destroy any affected fruit.

Physical Control: Collection and disposal of fallen infested fruits and the infested soil should be removed. Undersized fruits left on the tree should be picked and destroyed. If the trees are few in number, bagging the fruit with cloth or paper bags can be resorted.

Ants

Ants may use the plants in your Forest Garden as homes (the red ant on mangos and oranges, for example), or cause indirect harm to the plant by protecting other insects such as scales or aphids. Red ants may not cause any direct damage to the tree except for damage to the leaves at the nest site but can cause discomfort when the tree is worked on or harvested. These need to be controlled because if left unchecked the ant will reproduce until the trees are completely overtaken. Control is simply finding, cutting down, and burning the nests.

Non-insect pests

Mites are tiny animals, often invisible to the eye, which suck the juices from plants much like aphids and scales do. Mites are related to spiders and thus are not technically insects. They cause silvering of the leaves and fruit by the millions of tiny "bites" they leave. They can weaken trees and lower the quality of the fruit. One species, which attacks citrus, appears as tiny red dots on the underside of leaves. Look for leaves on citrus which have small light spots on the top; turn the leaf over and look for the mites.

Organic Control: Try spot spraying with a soap and water solution.

Nematodes are microscopic worm-like parasites that stick their heads into roots and suck out plant juices or live entirely inside plant roots. They can cause general tree wilting, small production of fruit, small sized fruit, and stunted growth. To confirm the presence of nematodes dig up the roots of the infected plant and look for the “nodes” (small bumpy swellings).

Organic Control: Crop rotation. Sterilize the soil. See *Nematodes* section under *Pest Prevention Measures* above

Snails can be a problem during the rainy season in nurseries. They eat the leaves of young plants and can completely destroy them.

Organic Control: Use sunken bowls filled with beer as traps. Trenches a few centimeters deep made around the nursery and filled with wood ash will prevent snails from entering. Adding salt in trenches, or put directly on the snails will kill them.

Diseases and Pests Common to Permagardening Crops

This section lists some common pests that you may encounter in your permagardens, along with some recommended control measures.

White Fly

- Indication of Presence: fly around when disturbed, make honey dew
- Plants Affected: beans, brassicas, cucurbits, okra, , Solanaceae
- Habit: underside of leaves
- Damage: Sap-feeding weakens plants, transmits viruses
- Controls: remove infested plants/leaves, sticky traps, insecticidal soaps, neem oil, hillbilly breath

Mealy Bugs

- Indication of Presence: Mealy bug colonies
- Plants Affected: Sweet potato, water spinach, papaya
- Damage: Deformation of new growth, reduced yield, death of plant
- Habit: Underside of leaves, new growth
- Controls: Good cultural practices for plant vigor, beneficial insects, physical removal

Leaf Miners

- Indication of Presence: White tracks in leaves
- Plants Affected: Cucurbits, okra, , Solanaceae
- Damage: Reduced photosynthesis, reduced yield
- Controls: Remove infested parts

Fruit Flies

- Indication of Presence: Holes in exterior fruits, maggots in interior, deformation or rotting around the portion of the fruit infected
- Plants Affected: Cucurbits Solanacea, beans, Papaya
- Habit: Vegetable Fruits
- Controls. Remove dead fruit, Hillbilly breath

Pepper Maggots

- Indication of Presence: Peppers begin to form translucent brown patches
- Plants Affected: Hot pepper, green pepper
- Habitat: Maggots – peppers, Flies - leaves
- Controls: Destroy fallen fruit, crop rotation, Hillbilly breath

CHAPTER 16: REFERENCES

1. The information found in this chapter is largely taken from C.O. Ehi_Eromosele, O.C. Nwinyi and O.O. Ajani. INTECH. Chapter 5: Integrated Pest Management. 2013.
<http://cdn.intechopen.com/pdfs-wm/42758.pdf>