Problem Prevention and Holistic Pest Management

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As any experienced grower knows only too well, nursery management is a continuous process of solving problems. One recurring problem is pests. In the past, nursery managers waited for an insect or disease to appear and then sprayed some toxic chemical to wipe out the pest or disease. This approach, however, also wipes out natural predators of the pest, resulting in an expensive and repeating pesticide cycle. Instead of a knee-jerk reaction to a specific problem, "holistic" pest management is a series of interrelating processes that are incorporated into the entire spectrum of nursery culture. Holism is the theory that systems, and each part of a system, should be viewed as a whole and not as isolated parts. "Holistic," then, is an approach that looks at the big picture and considers all parts. Holistic pest management is an integrated and preventative approach that considers the overall health of the plant and the nursery environment to prevent problems and to manage them wisely if they arise. The holistic approach to nursery pest management involves a series of four interrelated practices, which ideally function together (Wescom 1999):

- **Problem Prevention Through Cultural Measures**—through good sanitation, proper scheduling, management of the nursery environment, and promotion of plant health.
- **Problem Detection and Diagnosis**—through monitoring, recordkeeping, and accurate problem identification.
- **Problem Management**—including, if necessary, timely and appropriate pest suppression measures and balance of pest populations with beneficial organisms and pest predators.
- **Ongoing Process Evaluation**—to learn from experience by assessment and improved effectiveness of pest management approaches.

Facing Page: *Beneficial insects are an important part of holistic pest management. The ladybugs (*Hippodamia *species [Coleoptera: Coccinellidae]) in this photo can be seen feeding upon the psyllid pest* Heteropsylla cubana *(Hemiptera: Psyllidae). Photo by J.B. Friday.*

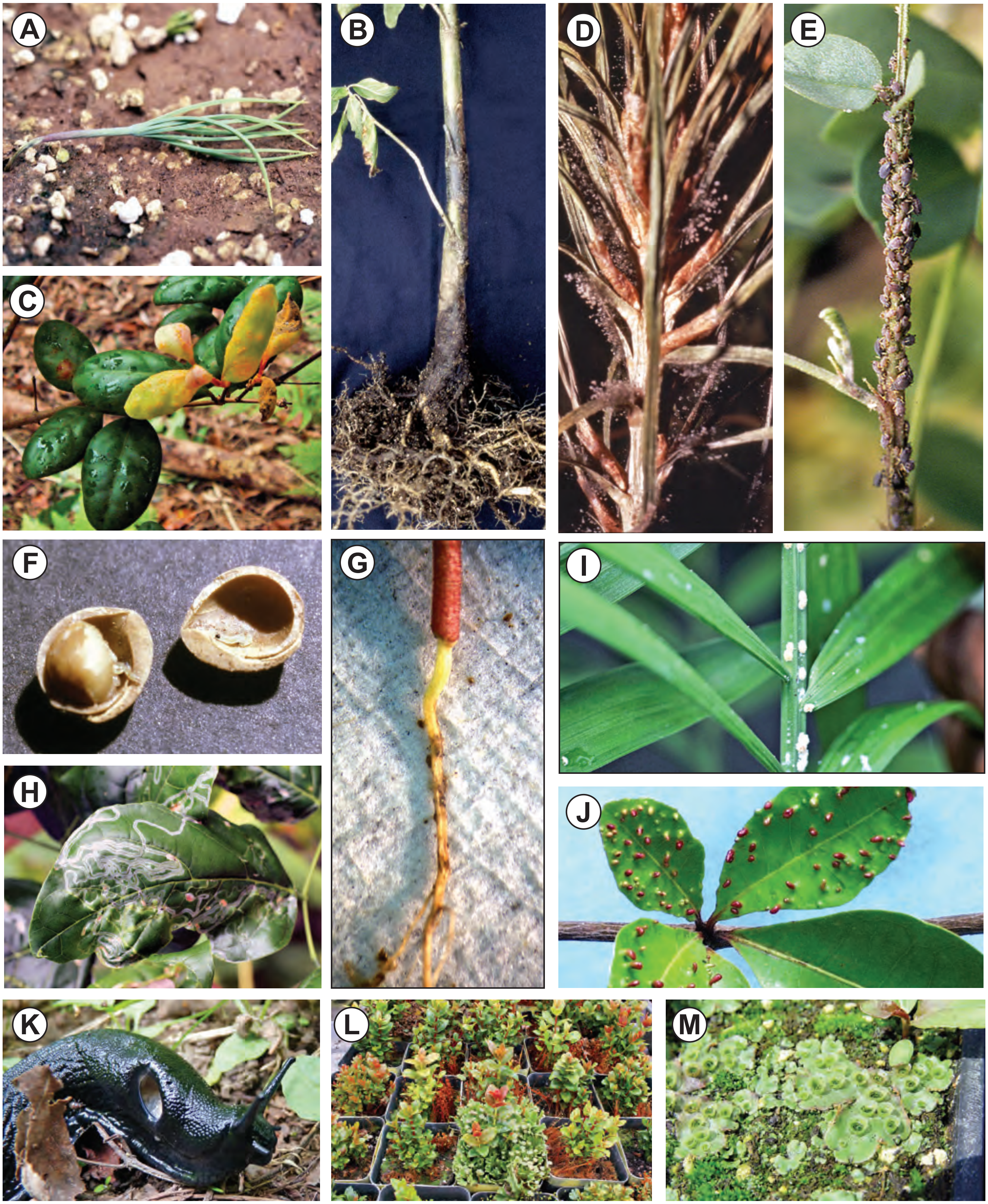

Figure 14.1—A collage of biotic nursery pests. Fungal pests include damping-off (A), Phytophthora root canker (B), fungal rust on ōʻhiʻa leaves (C), and Botrytis blight (D). Insect pests include aphids (E), fungus gnat larvae eating seeds (F) and roots (G), leaf miners (H), mealybugs on palm (I), and mites making leaf galls (J). Snails and slugs (K) can damage nursery plants. Plants such as weeds, liverworts, and algae (L, M) can smother small plants. Photos A through J by Thomas D. Landis, photo K by Brian F. Daley, photo L by R. Kasten Dumroese, and photo M by William Pink.

Nursery Diseases and Pests

Nurseries have many potential pests, including fungi (figures 14.1A–14.1D), insects (figures 14.1E–14.1J), nematodes, snails, slugs (figure 14.1K) and even larger animals such as mice and deer. Other plant species, such as weeds and cryptogams (moss, algae, or liverworts) (figures 14.1L, 14.1M) can become pests when they compete with crop plants for growing space and light.

Plant disease can also be caused by abiotic (environmental) stresses, including heat (figures 14.2A, 14.2B), light (figure 14.2C), and too much or too little water (figures 14.2D, 14.2E). Sometimes, people are pests when they misuse chemicals such as applying too much lime (figure 14.2F) or fertilizer (figure 14.2G).

A useful concept to explain nursery pest problems is the "disease triangle," which illustrates the interrelationships among the pest, host, and environment (figure 14.3). All three factors are necessary to cause biotic disease. For example, a fungus or insect pest is able to survive inside the warm greenhouse environment and attack the host plant. Although many diseases may appear to involve only the host plant and the biological pest, environmental factors are always involved. Environmental stress may weaken the plant and predispose it to attack by the pest, or a particular environment may favor pest populations, enabling them to increase to harmful levels.

Abiotic disease can be visualized as a two-way relationship between the host plant and adverse environmental stress (figure 14.3). Abiotic diseases may develop suddenly as the result of a single injurious climatic incident, such as a heat wave or dust storm, or more gradually as a difficult-to-detect growth loss resulting from below-optimum environmental factors, such as a mineral nutrient deficiency.

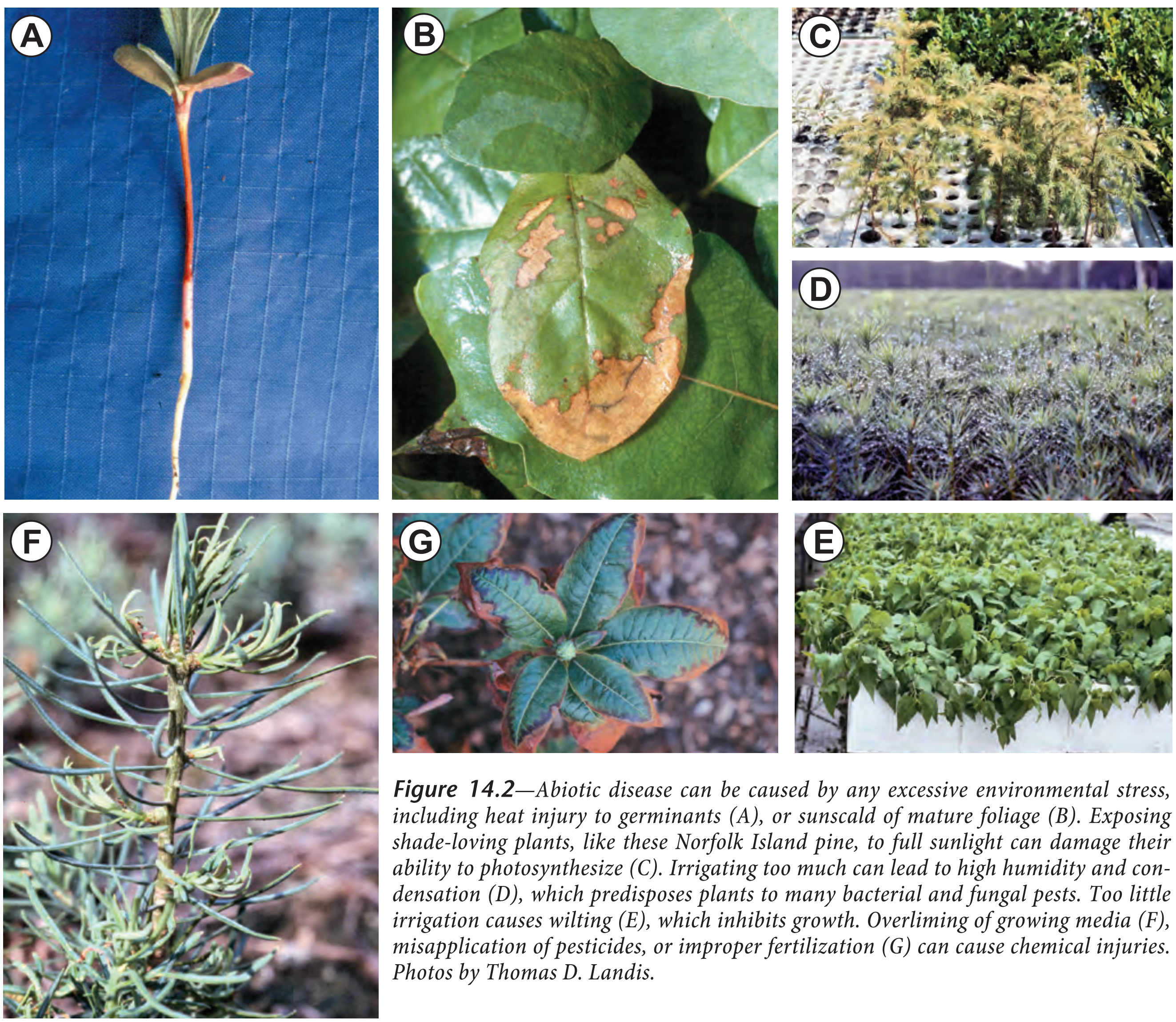

***Figure 14.2**—Abiotic disease can be caused by any excessive environmental stress, including heat injury to germinants (A), or sunscald of mature foliage (B). Exposing shade-loving plants, like these Norfolk Island pine, to full sunlight can damage their ability to photosynthesize (C). Irrigating too much can lead to high humidity and condensation (D), which predisposes plants to many bacterial and fungal pests. Too little irrigation causes wilting (E), which inhibits growth. Overliming of growing media (F), misapplication of pesticides, or improper fertilization (G) can cause chemical injuries. Photos by Thomas D. Landis.*

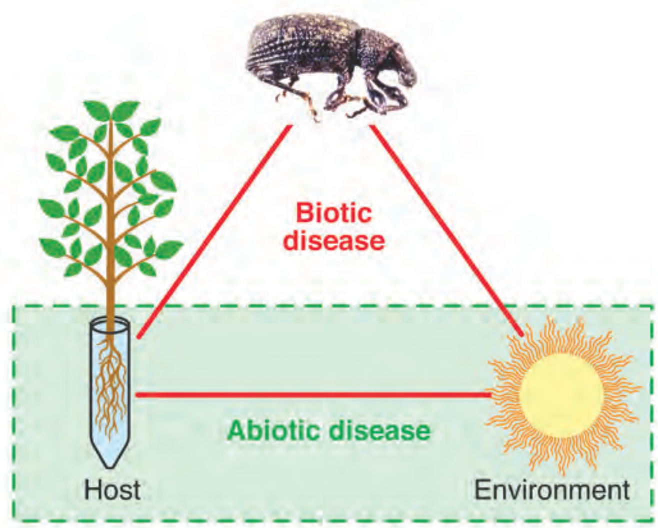

Figure 14.3—The "disease triangle" illustrates the concept that a host, a pest, and a conducive environment are necessary to cause biotic disease. Abiotic disease occurs when environmental factors, like excessive moisture or heat, injure the host plant. Illustration adapted from Dumroese and others (2008).

Problem Prevention Through Cultural Measures

Preventing problems is better than having to deal with them after symptoms occur. Prevention steps include maintaining good sanitation and hygiene in the nursery, proper crop scheduling to avoid diseases and health problems in holdover stock, and promoting plant health through good nursery management.

Good Sanitation

The most logical approach to disease management is to prevent diseases by excluding pests from the growing area. All diseases are much easier to prevent than to cure. Sanitation begins with nursery site selection and preparation.

A source of clean water for irrigation is one of the key considerations in site selection. Some water sources harbor damping-off fungi including *Pythium* and *Phytophthora* (Jaenicke 1999) and need to be avoided if possible. (Treating water may be an option; see Chapter 11, Water Quality and Irrigation.) A weed-free fabric groundcover or concrete floor under nursery benches can also be instrumental in preventing problems. In contrast, having bare soil under plants can allow soil pathogens to splash or blow onto nursery plants and can be a favorable environment for weeds. Weeds near or under benches may provide cover for insect pests including thrips, aphids, whiteflies, and weevils. Weeds can also be a source of pathogenic fungi, such as *Fusarium* (James 2012). Excluding seed-eating rodents and birds with screens or other barriers can prevent these animals from becoming problems and also keeps out any diseases and pests they might bring in on their bodies. Vegetation adjacent to nurseries should be assessed to see how it might positively or negatively affect nursery plant health. For example, a nearby hedge consisting only of mahogany trees infested with the local mahogany shoot borer may increase the likelihood of these pests entering the nursery and affecting a crop of mahogany seedlings. Well-planned adjacent vegetation in hedgerows and windbreaks can provide refuge for beneficial organisms, however, including pollinators and pest predators such as ladybugs, predatory wasps, spiders, amphibians, and birds.

Pests generally enter the nursery growing area through the following modes:

- **Wind**—Airborne fungal spores, seeds, or insects can be introduced on the wind.
- **Water—**Fungus and cryptogam spores and weed seeds can be introduced through irrigation water.
- **Growing Media—**Most growers try to use growing media components that are free from pathogens. However, potentially harmful fungi can sometimes be isolated from some growing media components. When topsoil is used as the growing medium, or as part of a mix, it can carry a variety of insect, fungal, and weed pests to the nursery. See Chapter 6, Growing Media, for more information about the risks associated with using soil as the growing medium.
- **Containers—**Reusable containers may contain residual growing medium or plant roots that harbor potentially pathogenic fungal propagules, moss, or algae.
- **Surfaces in the Growing Area—**Floors, benches, and other surfaces in the growing area may harbor pests.
- **Propagation Materials**—Seeds, transplants, or cuttings are sometimes contaminated before they reach the nursery. Importing plants from other nurseries poses a very high risk of introducing new pests. If the plants have been imported from other islands, this poses a risk not only to the nursery but to the entire island ecosystem as well. Imported nursery stock has been the culprit for introducing several invasive pests and plants into island ecosystems.
- **Transported Pests—**Infested soil or other materials can be carried into the growing area on tools, equipment, or the shoes of workers or visitors.
- **Mobile Pests—**Insects, birds, and rodents can enter the growing area directly.

Checklist for Preventing Diseases and Pests With Good Sanitation

- Start with clean seeds. Seeds can be rinsed with a diluted bleach or hydrogen peroxide solution before stratification or sowing to help prevent seed and seedling diseases (see Chapter 9, Seed Germination and Sowing Options).
- Remove all plant debris from the nursery area before sowing each crop. Also, clean tables, aisles, sidewalls, and floors with a mild bleach or soap solution before sowing.
- Regularly and vigilantly remove all weeds growing under benches and within the crop.
- Use containers that have been cleaned (see Chapter 7, Containers).
- Heat-pasteurize (steam or solarization) any growing media ingredients that may contain pests or diseases. Use soil-free media if possible (see Chapter 6, Growing Media).
- Prevent algae from forming on the floors and benches by ensuring rapid drainage of excess irrigation water and by properly managing irrigation frequency (see Chapter 11, Water Quality and Irrigation). Algae and pools of water provide a breeding ground for fungus gnats and shore flies and the slick surfaces can be a safety hazard to nursery staff.
- Use hooks to keep the hose nozzles off the floor and disinfect planting tools after each use.
- Keep plants off the floor and out of contact with soil if feasible. Elevating plants on benches, with a fabric groundcover or concrete floor underneath, helps to reduce pest problems.
- Test nursery water for problems and treat if necessary.
- Use precaution if importing plant material from other nurseries, especially from other islands. Imported plant materials should be certified pest free. You will ideally use only local, native, or traditional plant materials in your nursery to minimize the risk of spreading insects, diseases, and invasive plants.

Proper Scheduling

Crop scheduling is an important component of holistic pest management. A typical tropical plant nursery will be growing a wide variety of plant sizes and species with different growth rates. For example, in Hawai‘i, koa can be grown from seeds to shippable size in as little as 3.5 months, whereas native Hawaiian sandalwood seedlings take 1 year or longer to be large enough to ship. Slow-growing plant species should be started first so they have maximum time to grow. Species that grow very quickly should be scheduled later in the season so that they do not become “top heavy” (figure 14.4A) or rootbound (figure 14.4B). Plants that have grown too large for their containers are easily stressed and

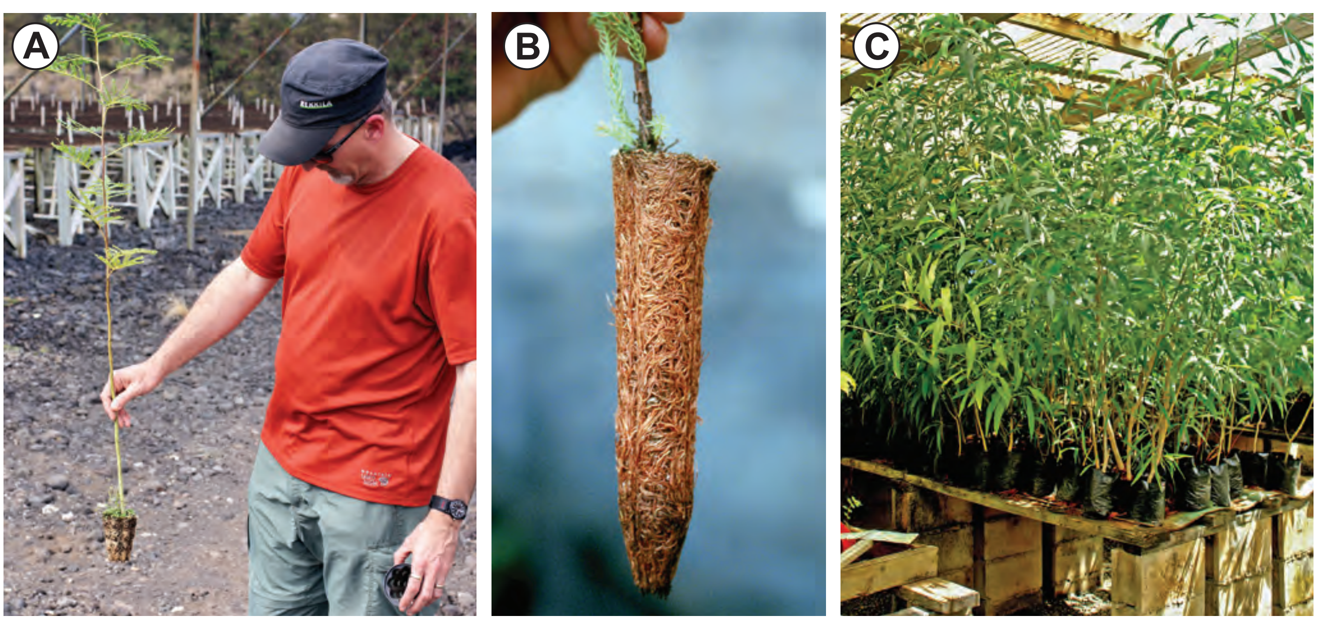

Figure 14.4*—Keeping nursery stock at the ideal size for their containers is a challenge with rapidly growing species, such as this* Acacia koa, *which quickly become “top heavy” (A). Although it is harder to detect, roots may grow so fast that they become “rootbound” (B) and stressed, which leaves them susceptible to fungal root diseases. Tropical plants cannot be held over for too long without becoming unbalanced, so crop scheduling is critical (C). Photos by Thomas D. Landis.*

can harbor insects and other pests that can infect the rest of the crop. One of the most common problems in tropical nurseries is that most plants never stop growing and so it is challenging to keep crops from becoming too large for their containers (figure 14.4C). See Chapter 4, Crop Planning: Propagation Protocols, Schedules, and Records, for more information on crop scheduling.

If you are growing a new species and are unsure of the growth rate, contact other nurseries, and check the propagation protocols in the Native Plant Network (http://www.nativeplantnetwork.org).

Managing the Nursery Environment

An important aspect of preventing disease is to maintain environmental conditions (such as moisture, light, and ventilation) that are conducive for plant growth but that do not favor pests or have damaging environmental extremes. For example, root diseases are common in all types of nurseries worldwide, and are often brought on by environmental stresses. Swedish researchers studied the fungal pathogen *Cylindrocarpon destructans* in relation to root rot problems of pine seedlings in container nurseries. Suspected predisposing stress factors included excessive moisture, low light, and exposure to fungicides. They found that *C. destructans* typically invades dead or dying roots and then uses these sites as a base for invasion into healthy roots (Unestam and others 1989). Opportunistic pathogens, such as Fusarium, are more likely to cause disease when plants are under environmental stress (figure 14.5).

Marginal environmental conditions often favor insect pests. For example, fungus gnats become a problem only under wet conditions and especially in locations where algae, moss, and liverworts have been allowed to develop. Often, these conditions exist under nursery benches, where water can puddle and excess fertilizer promotes their growth. This problem is particularly common where nursery floors are covered by a weed barrier or gravel. Switching to concrete floors can often cure a fungus gnat problem because concrete dries faster and is easier to keep clean.

Water Can Be Harmful to Plant Health

Too much water on plants (figure 14.2D) encourages damping-off, root disease, fungus gnats, moss and liverwort growth, excessive leaching of mineral nutrients, potential groundwater contamination, and foliar diseases such as Botrytis blight (figure 14.1D), powdery mildew, and Rhizoctonia. Over-irrigation may cause plants to grow rapidly and spindly making them more susceptible to environmental stresses such as excessive heat, wind, or cold. Too little water on plants may cause damage to root systems through salt accumulation or desiccation, allowing entry points for root disease pests. Plants under severe moisture stress have lower resistance to pests and stresses associated with heat, humidity, and wind.

Proper irrigation management is one of the best ways to limit pest problems.

Checklist for Preventing Diseases and Pests by Managing the Nursery Environment

- During sowing and the establishment phase of the crop, keep humidity levels and condensation problems low by venting the nursery area well. Do not overwater germinating seeds and seedlings. During the active growth stage, reduce humidity within the leaf canopy to prevent the development of many foliar diseases. Reducing humidity can be accomplished by improving air circulation by increasing distance between plants, increasing the frequency of ventilation, and pruning shoots as necessary.

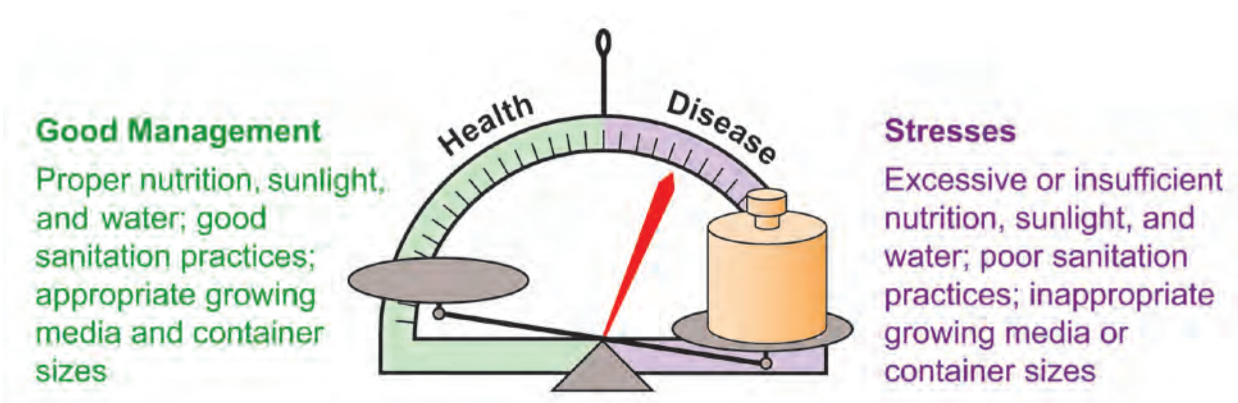

***Figure 14.5**—Many nursery diseases are caused by stresses, which predispose plants to attack by opportunistic pests. Illustration adapted from Dumroese and others (2008).*

- Water only in the morning, never later in the day. Favorable environmental conditions for several fungal diseases include a film of moisture for 8 to 12 hours, high relative humidity, and warm temperatures. By watering early, rising daytime temperatures will cause water to evaporate from the leaf surfaces and reduce favorable conditions. (As an exception, Botrytis problems often occur when conditions are humid but temperatures are cool [James 2012].)
- To optimize healthy environmental conditions for different crops, use separate propagation structures for growing plants with different environmental and cultural requirements, or, if you have a single growing area, group plants with similar growing requirements together and take advantage of microenvironments within the nursery area. For example, north of the equator, the south side of the nursery is usually warmer and drier than the north or east section of the nursery. Plants requiring drier conditions will benefit from being grouped on the south and west sides of the nursery. Plants requiring cooler temperatures (such as high-elevation species) or those requiring more frequent irrigation can be grouped together on the north and east sides.
- Improve air circulation and reduce humidity and condensation with spacing between plants, using fans, and orienting to prevailing breezes to produce horizontal airflow.

Promotion of Plant Health

Healthy plants are more able to resist infection from pathogenic fungi and attack from insects and other pests and can also tolerate environmental stresses better. Much of this resistance can be attributed to physical characteristics such as a thick, waxy cuticle on the foliage, balanced shoot and root, and optimum mineral nutrient contents. Some healthy plants also produce chemicals such as tannins, which deter pests. Management of the nursery environment to ensure plants receive proper sunlight and water as described previously, as well as the steps of good sanitation and proper scheduling, is important for plant health. Appropriate nutrition, growing medium, and container size and type; use of beneficial microorganisms and other practices described in this manual are important for promoting plant health on all levels.

Plants must have a proper growing medium to be healthy. Good growing media provides physical support and aeration to the roots, and holds water and nutrients for the plant, as described in Chapter 6, Growing Media. Appropriate container selection is described in Chapter 7, Containers. Different species will require different containers types and sizes based on their growth characteristics and target specifications. Fertilization at the appropriate level to help plants grow in a healthy and balanced way is discussed in Chapter 12, Plant Nutrition and Fertilization. Excessive fertilization can make plants more susceptible to problems, including sucking insects and diseases. Consider eliminating nitrogen fertilization during germination because it encourages damping-off fungi (James 2012).

If plants do become sick or unhealthy, it is rarely, if ever, practical to try and "save" them. Remove dead and dying plants; dispose of them away from the nursery to prevent reinfection. Remove any plant debris in the containers or on the floor on a regular basis.

Problem Detection and Diagnosis

Even with good sanitation, crop planning, plant health, and management of the nursery environment, problems may appear. A holistic approach emphasizes detecting problems early through regular monitoring and recordkeeping so they can be addressed quickly and with minimal cost and effort. If a problem is detected, the time is taken to diagnose it accurately and determine its true source. With an accurate diagnosis, the problem can then be treated accordingly.

Monitoring and Recordkeeping

Regular monitoring or "scouting" is a critical part of the holistic approach. A daily walk-through of the nursery will reveal developing pest outbreaks or environmental problems that are conducive to pests while problems are still minor and easily corrected. In small nurseries, the grower or nursery manager should do the inspections, but, in larger facilities, one person should be designated as the pest scout. This person should have nursery experience and be familiar with all the plant species at all growth stages. It is essential to know what a healthy plant looks like before you can notice any problem. It is also essential to know what beneficial organisms look like (such as natural enemies of pests, mycorrhizal fungi growing on the roots, and so on). The person should also be inquisitive and have good observation skills. Often, irrigators serve as pest scouts because they are regularly in the nursery, checking whether plants need watering.

Crop monitors (figures 14.6A, 14.6B) need to carefully inspect each species being grown, record the environmental conditions in the growing area, and make other observations. It is important to establish a monitoring and recordkeeping system for all areas of the nursery, including any structures, rooting chambers, and outdoor

Figure 14.6—Regular pest monitoring or "scouting" is critical to identifying problems early (A). Pest scouts inspect the seedlings and the nursery environment (B). Pest scouts should carry a hand lens, notebook or recording device, and camera to identify and document problems (C). All potential problems need to be noted in the daily log (D) and reported to the nursery manager. Photo A by Tara Luna, photo B by Diane L. Haase, photo C by Thomas D. Landis, and photo D by Kim M. Wilkinson.

growing areas. These records are invaluable for avoiding future pest problems when planning the next crop. In addition to looking at crop plants, pest scouts should check all nursery equipment and should carry a 10X to 20X hand lens for close examination and a notebook or voice recorder to record observations. When a problem is noted, a camera with a closeup lens is an excellent way to document the problem (figure 14.6C). All observations should be recorded in a daily log (figure 14.6D), and any suspicious problems need to be immediately reported to the nursery manager. Inspections need to occur on a daily basis after sowing the crop and during the establishment phase, when plants are most susceptible to diseases such as damping-off. When problems are detected early, plants can be treated or isolated from the rest of the nursery or greenhouse crop.

Use yellow sticky cards (figure 14.7) to detect white flies, aphids, fungus gnats, and shore flies. Place one to four cards every 1,000 ft^2 (90 m^2) and space them evenly in a grid pattern, with extra cards placed near vents and doorways. Inspect these cards weekly to detect and monitor these pests. Record the information and replace the cards as needed. Use blue sticky cards, which are more attractive to thrips, around plants susceptible to this pest. Observing and recording pest predators can also be valuable: insect-eating birds, amphibians, spiders, predatory wasps, and other creatures that may be residing in or near the nursery.

Accurate Problem Identification

Nursery managers and pest scouts must be able to identify problems quickly and accurately before the problems can cause significant damage. Although biological pests such as fungi and insects are always present, abiotic stresses typically cause more problems. Disease diagnosis requires a certain degree of experience and training, and nursery workers need to be trained to quickly spot

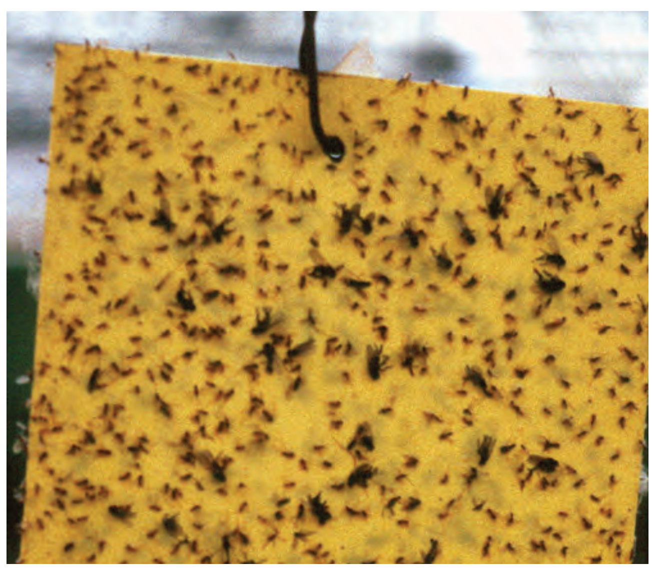

Figure 14.7—Yellow sticky cards are essential for monitoring the types and population levels of insects pests. Photo by Thomas D. Landis.

new problems and incidents of abiotic injury. Workers who are in the growing area daily have the best chance of detecting potential problems so they can be accurately identified and treated before they can intensify or spread.

A general characteristic of abiotic diseases is that the symptoms tend to show up very quickly (see textbox example). Problems caused by biotic agents generally take longer to develop, with decline occurring over time (James 2012). If abiotic damage has been eliminated as the cause of the problem, then a pest or disease must be diagnosed. Landis and others (1990) features identification keys (figure 14.8), and color photographs of many diseases, insect pests, and horticultural problems of conifer crops, but no single reference is available about diseases and pests of tropical plant species. Although pest scouts can make a tentative diagnosis of disease and pest problems, they need to confirm their conclusions with the nursery manager and a trained nursery pest specialist. Plants with undiagnosed symptoms may be sent whole to the nearby extension office or land-grant university for diagnosis and suggested followup.

Many diseases and insect pests damage a wide variety of host plants. For example, damping-off fungi (figure 14.1A) affect all species during germination and emergence and Phytophthora root rot (figure 14.1B) can infect larger plants. Other pests are host specific, however, and pest scouts must understand their basic biology and life cycle for accurate diagnosis. In tropical nurseries, it is very important for nursery growers to be aware of newly introduced diseases and the range of species that are affected by them. For example, ʻōhiʻa rust is caused by a fungus (*Puccinia psidii*), which also infects guava, eucalyptus, and a range of native species in the Myrtle family. In Hawaiʻi, it has been found on introduced timber and ornamental species and native and endangered species of nīoi. It affects leaves and meristems, inhibiting growth and development and is especially severe on seedlings, cuttings, and saplings. The first symptoms are chlorotic specks, which after a few days become pustules containing uredia producing yellow masses of spores (figure 14.1C). Pustules can coalesce and parts of the plant can be completely covered with them. After about 2 to 3 weeks, pustules dry and become necrotic. The disease can cause deformation of leaves, heavy defoliation, dieback, stunted growth and eventual death. On fruits of guava, and other hosts in the Myrtle family, the lesions occur mostly on buds and young fruits that eventually rot as the rust matures. Understanding the life cycle of the pest is essential for accurate diagnosis and management. Some of the more common tropical plant pests and ways to monitor, diagnose, prevent, and, if necessary, treat them, are included in table 14.1.

Abiotic Factors as "The Usual Suspects"

I was growing a new crop of a mahogany species. The plants were fairly young with only four to six leaves each. They were growing slower than past crops, and some of the oldest leaves had brown leaf margins that I attributed to uneven watering. Otherwise the seedlings seemed fine. Because they were growing slowly, I thought I would help them along by applying a fertilizer. But a day or two after that, the seedlings were all wilting and the brown leaf margins were spreading into the leaves. With the leaf margin burning and the plants wilting and dying, I suspected root rot. I immediately sent some affected plants to the local land grant university extension service, with an urgent message. While I waited for the reply, I researched options for treating root rot, most of which involved safety gear and unattractive pesticides. The extension agent contacted me sooner than I had hoped, saying he had not completed his diagnosis but so far had detected dangerously high levels of salts in the growing medium; the plants were exhibiting signs of salt toxicity. As we talked, I remembered that I had used a batch of untested coir as one of my growing medium components for this crop. I had heard that coir can sometimes contain high levels of salts because of processing, but I had not taken the time to test this batch before planting. The seedlings had been struggling along in somewhat salty conditions (which explained the slower growth and burned leaf margins) and my fertilizer application added even more salts, pushing them over the edge into salt toxicity. With that, they could not take in enough water with their roots because of salts in the medium, and the chloride they were taking up was scorching their leaves. The extension agent suggested I flush out the salts from the growing medium. As soon as I got off the phone, I drenched the seedlings with clean water until water dripped out the bottom of the containers, and repeated again a few hours later. Almost overnight, the seedlings perked up. Some of the smallest had died and were a loss, but the remaining trees quickly grew new leaves and within a few weeks were in full health. I learned from this scare that abiotic factors need to be the first suspects when diagnosing plant problems. A quick check from an EC meter would have revealed the problem inexpensively in only a few minutes. I also learned that taking the time to ensure the basics, such as growing medium quality, are okay can save a lot of stress—for me and for the plants. — Kim Wilkinson

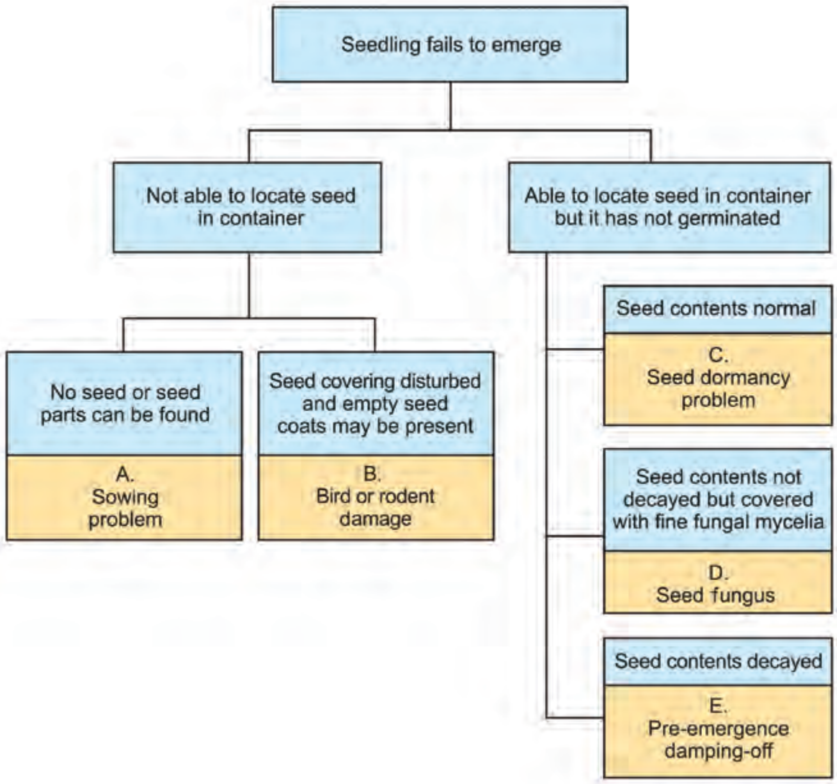

Figure 14.8*—Pest identification keys are very useful in helping make the correct diagnosis of nursery pests. Illustration from Dumroese and others (2008).*

Check with local regulations before ordering and introducing biological control organisms.

Problem Management

After a problem is accurately diagnosed, it must be evaluated to determine what, if any, management action is necessary. The first line of defense is always to assess and, if possible, improve pest prevention practices including good sanitation, physically excluding pests, proper crop scheduling, and promotion of optimal plant health through appropriate fertilization, irrigation, ventilation, and other care. If the problem persists, the holistic approach calls for assessing the effects of the pest or disease. In some cases, simply doing nothing may be the most cost-effective solution; plants can tolerate some damage and nature can be allowed to take its course (Mizell and Short 2009).

If action is taken, the goal is usually to reduce crop losses to acceptable levels, rather than to eradicate pests. A spectrum of management options is available, with treatments including—

- Modifying and managing the nursery environment.
- Culling affected seedlings.
- Mechanically removing pests (picking off, swatting, trapping—ensure staff are trained to know the difference between beneficial pest predators and actual pests).
- Using biological controls such as beneficial microorganisms and pest predators, diseases, or parasites (table 14.1).
- Using the least toxic pesticides available as a last resort to lower pest populations to a tolerable level (Wescom 1999).

Timely and Appropriate Pest Suppression Measures

Synthetic or natural pesticides should be considered only as a last resort after other environmental and horticultural control measures have been considered. Practicing good hygiene and sanitation, including using pathogen-free seeds, growing media, and containers, is critical. You can often reduce or even eliminate the use of pesticides by physically excluding pests with screens or barriers that can keep out pests large and small, from insects to rats to pigs (figure 14.9). If seedlings are affected by fungi, you can reduce the seedling's susceptibility by spacing out the plants and increasing air movement through the nursery area, and by watering appropriately and lowering the humidity around the plants (Wescom 1999).

Table 14.1*—Common pests of tropical plants and their symptoms, prevention, and treatment. Although a variety of pesticides are available for these diseases, only biological and organic control options are provided. Ideally, nursery staff will monitor daily for signs of these diseases.*

Type of pest	Signs and symptoms	Monitoring	Prevention	Biological control options
Fungi				
Botrytis blight *(Botrytis cinerea)*	Plants have leaf blights, stem cankers, gray mold. Mold is most noticeable on older foliage. Affected seedlings are usually in groups.	Concentrate monitoring where crop is closely spaced and air circulation is poor and at the base of plants. Look for dieback, stem cankers, and powdery gray mold on foliage.	Increase spacing between containers as crops grows larger. Water only in the morning or use subirrigation. Keep humidity low by increasing air flow. Surface sterilize greenhouse floors, walls, and benches between seedling crops.	Apply products containing *Trichoderma harzianum* or *Streptomyces griseoviridis* to foliage. When discovered, remove symptomatic seedlings from growing area.
Fusarium wilt (Example: *Fusarium oxysporum*)	Leaves cup downward or stems bend in a crook. In later stages, brown or red streaks can be seen on the leaves. Orange spores (sporodochia) may be on stem.	Look for downward bending leaves or "cupping" of leaf margins. Can be confused with water stress or root rot. Send sample to laboratory to confirm.	Use mesh benches to encourage airflow. Do not overwater crop. Keep humidity low. Sterilize re-used containers between seedling crops. Use pathogen-free seeds and growing media.	Apply products containing *Trichoderma harzianum* or *Streptomyces griseoviridis* as a soil drench. Remove and isolate infected plants as soon as problem is detected.
Crown rots (Example: *Fusarium* species)	Plants are stunted, wilted, and off-color. Roots are discolored and turn brown or black. Main stem becomes weak and water soaked in appearance. Some affected seedlings may have orange-yellow spore structures [sporodochia] on main stem just above the ground line.	Monitor weekly for wilted, off-colored plants with discolored root systems. Pay attention to media that stays wet. Affected seedlings are usually concentrated in groups. Send samples to diagnostic laboratory to confirm pathogen identity.	Do not overwater crop. Increase spacing between containers as crop grows larger. Keep humidity low.	Apply products containing *Trichoderma harzianum*, *Trichoderma virens*, or *Streptomyces griseoviridis* as a drench.When discovered, remove symptomatic seedlings from growing area.
Root rots (Examples: species of *Fusarium*, *Pythium*, *Rhizoctonia*, *Phytophthora*, and *Cylindrocarpon*)	Seedlings are stunted, wilted, chlorotic, or necrotic and often occur in groups. Roots are discolored (dark brown or black) and decayed (epidermal tissues may be easily sloughed off). Main stems become weakened and water soaked. Some affected seedlings may have orange-yellow spore structures [sporodochia] on the main stem just above the ground line.	Monitor weekly for wilted, chlorotic, and necrotic seedlings with discolored and decayed roots. Problems can be especially severe in containers with prolonged wet growing media (poorly drained). Affected seedlings are usually concentrated in groups. Send samples to diagnostic laboratory to confirm pathogen identity.	Do not overwater crop. Increase spacing between containers as the crop grows larger. Keep humidity low. Sterilize re-used containers between seedling crops. Use pathogen-free seeds and growing media.	Apply *Trichoderma harzianum*, *Trichoderma virens*, or *Streptomyces griseoviridis* as a drench.
Damping-off (Examples: species of *Fusarium* and *Pythium*)	Seeds do not germinate or seedlings collapse at soil line just after emergence. Dark decayed spots appear on stems at soil line of emerged seedlings. Surviving plants may later develop crown or root rot.	Monitor new sowing daily during germination and establishment phases. Excavate seeds and cut to check for decay and discard infected containers immediately.	Cleanse seeds and growing area. Use sterile media and containers. Avoid over-sowing, crowding of seedlings, or planting seeds too deeply. Keep greenhouse and media temperatures warm during germination and establishment. Keep humidity low. Do not fertilize with nitrogen during seedling establishment phase.	Treat seed with running-water rinses for a minimum of 48 hours prior to sowing, or surface sterilize with bleach or hydrogen peroxide solutions (1:10). Apply products containing *Trichoderma harzianum* or *Trichoderma virens* as a drench at time of sowing.
Powdery mildew (Examples: species of *Blumeria*, *Podosphaera*, *Microsphaera*, and *Erysiphe*)	Plants may have white powdery fungal growth on upper or lower leaf surfaces. If severe, a white coating can be seen on foliage.	Monitor weekly. Inspect susceptible species. Look in areas near vents and greenhouse entrances or any location with a sharp change between day and night temperatures. Use a hand lens to see white, powdery threads and spores.	Place susceptible species where drastic changes in temperatures do not occur. Water only in the morning or use subirrigation. Keep humidity low. Increase spacing between containers as crop grows larger.	Remove infected leaves as soon as detected. Move infected plants to structure with more constant temperatures. Treat with Neem oil or horticultural oil. Try test tray first. Can also use sulfur powder as an organic preventative fungicide. Some plants are sensitive to sulfur injury so use lowest rate recommended. Do not apply within 2 weeks of an oil spray treatment.

Table 14.1—Continued

Type of pest	Signs and symptoms	Monitoring	Prevention	Biological control options
Rhizoctonia web blight (Example: *Rhizoctonia solani*)	Stems and leaves may collapse and turn to mush with fine, web-like fungal strands on the plant tissue and at soil line.	Monitor leafy herbaceous plants, especially where they are closely spaced. Look for cobweb-like growth that mats leaves. Send samples to diagnostic laboratory to confirm pathogen identity.	Sterilize containers between seedling crops. Use mesh benches to encourage airflow. Place susceptible crops near vents and fans. Increase spacing between containers as crop grows larger. Keep humidity low.	Apply products containing *Trichoderma harzianum* as a preventative.
Fungal rusts (Examples: species of *Gymnosporangium*, *Cronartium*, *Peridermium*, and *Melampsora*)	Rust brown spots or stripes may be seen on lower and upper leaf surface.	Monitor regularly and be sure to check undersides of foliage.	Group susceptible species where temperature and humidity can be easily controlled. Increase spacing between containers as the crop grows larger. Keep humidity low. May have to eliminate rust-alternate hosts if present in the vicinity of the nursery.	Isolate plants immediately.
Fungal leaf spots (Examples: species of *Alternaria*, *Septoria*, *Botryosphaeria*, *Taphrina*, *Rhytisma*, and *Phyllosticta*)	Alternaria leaf spots are usually brown or black with a yellow border. Septoria leaf spots are small gray to brown with a dark brown edge.	Monitor weekly for leaf spots. With a hand lens, look for small fungal fruiting bodies. Send samples to diagnostic laboratory to confirm pathogen identity.	Use mesh benches to encourage airflow. Keep nursery floor clean and free of pooled water. Water only in the morning or use subirrigation. Do not overwater crop. Keep humidity low. Increase spacing between containers as crop grows larger.	Periodically remove affected seedlings from growing areas. Apply products containing *Trichoderma harzianum* as a preventative. Remove infected leaves as soon as problem is detected. Isolate infected trays of plants from the rest of the crop.
Insects				
Sucking insects (Example: Aphids)	Plants have distorted new growth, sticky honeydew, and/or sooty mold.	Monitor twice weekly. Look on underside of leaves and on tips of new stems.	Don't overfertilize. Shoot prune vigorous tender growth as needed. Watch for outbreaks.	Use aphid midges, aphid parasites, or lady bugs. Apply insecticidal soap every 6 days. Pyrethrin-based products can also be effective as a contact insecticide.
Fungus gnats (Example: *Bradysia* species)	Seeds that do not germinate or plants with weak or stunted growth and root damage.	Monitor every other day, especially during germination and establishment phases. Look for tiny winged flies near growing media surface. Use yellow sticky cards to detect adults.	Keep nursery floor clean and free of pooled water and algae. Do not overwater crop. Use a good seed mulch.	Use yellow sticky cards to reduce adult population levels. Apply products containing *Bacillus thuringiensis* ssp. *israeliensis* every 7 days as a drench. Formulations of entomopathogenic or insecticidal nematodes in the genera *Steinemema* and *Heterorhabditis* are also effective.
Mealybugs	Plants may have white cottony residue. Sticky honeydew on leaves and sooty mold may develop.	Look for small, oval, soft-bodied insects covered with a white, wax-like layer on the underside of leaves.	Keep nursery environment clean. Increase spacing among plants. Practice good sanitation. Keep temperatures cool. Remove infected plants.	Apply *Cryptolaemus montrouzieri*. Use predatory beetles or parasitic wasps; pyrethrin insecticides are effective but must contact the pests. Spray with insecticidal soap or oil, or swab bugs with rubbing alcohol (limit alcohol contact with foliage).
Soft scales	Honeydew and sooty mold develop if scales are present.	Look for yellow brown to dark brown scale insects along veins and stems.	Provide plants with good growing conditions and proper care, especially irrigation, so they are more resistant to scale damage.	Use parasitic wasps, insecticidal soap, or pyrethrins. Prune infested branches or cull entire plant.
Spider mites	Plants may have light-yellow flecking of leaves, discolored foliage. Leaf drop and webbing occur during outbreaks and severe infestation.	Look on undersides of leaves, especially along veins. Use a hand lens to look for webbing, egg clusters, and red adult mites. Look in areas of that are hot and dry, near the heaters and vents.	Lower nursery temperatures and raise humidity levels, especially in the south and west edges of the nursery and near vents and furnaces.	Use predatory mites or predatory midges. Apply insecticidal soap every 6 days.

Table 14.1—Continued

Type of pest	Signs and symptoms	Monitoring	Prevention	Biological control options
Thrips	Plants may have distortion of new leaves, buds, and shoot tips. White scars on expanded leaves.	Use blue or yellow sticky cards placed just above canopy foliage for detection.	Increase container spacing on leafy crops as needed to detect problems early.	Use predatory mites, pirate bugs, lacewings, insecticidal soap, and pyrethrins.
White flies	Plants may have distorted new shoot and leaf growth.	Use yellow sticky cards to detect adults. Look for adults on the uppermost tender leaves. Immature larvae are found on the underside of leaves.	Inspect new plants coming into the greenhouse and reject infested plants. Create a "host-free" period in the growing area for 2 weeks to starve the flies. Practice good weed control in and around the nursery.	Use predatory beetles or whitefly parasites. Apply insecticidal soap every 7 days. Pyrethrin-based products can also be effective as a contact insecticide.
Stem or twig borers (Example: species of mahogany shoot borer, twig borers [*Xylosandrus compactus* and *Xyloborus* species])	Affected seedlings usually have main stem cankers that may cause stem breakage at point of insect activity. Cankered tissues are usually black and insect frass may be present.	Look for main stem cankers often associated with blackened tissues and frass from insect activity. Damage can be randomly spread throughout seedling growing areas.	Don't allow infested stands of tree hosts near nursery area. Avoid holding susceptible seedlings past readiness date.	Remove damaged seedlings when they are found.
Caterpillars	Foliage with chewing damage; moths may be visible around plants.	Inspect plants regularly. Look for fecal droppings, bites taken out of leaves, and webbing (tent caterpillars). Check in evening or at night; some species hide during day.	Install screens around greenhouse to keep moths out.	Apply products with *Bacillus thuringiensis* ssp. *kurstaki,* as needed. Pyrethrin-based products can also be effective as a contact insecticide.
Other biotic pests				
Bacterial diseases (Examples: species of *Pseudomonas*, *Xanthomonas*, and *Agrobacterium*)	Plants are stunted with swollen or misshapen leaves. Look for water-soaked leaf spots or angular lesions on the stems. May have gall-like growths on main stem at or just below the ground line.	Inspect new plants coming into nursery. Look for water-soaked, dark brown to black leaf spots on leaves and wilted stem tips. Confirm diagnosis with a laboratory.	Increase spacing between containers as crop grows larger. Water only in the morning or use subirrigation. Keep humidity low.	Remove infected leaves as soon as problem is detected. Isolate infected trays of plants from the rest of the crop.
Nematodes (Examples: species of *Xiphinema*, *Meloidogyne*, *Pratylenchus*, and *Radopholus similes*)	Affected seedlings will be stunted, with chlorotic or necrotic foliage; roots will be damaged with evidence of feeding [lesions] or galls.	Look for chlorotic and necrotic seedlings, often concentrated within groups. Roots will appear damaged or have galls.	Use soil-free media. Keep plants at least 3 feet off the ground on benches, with a groundcover or concrete floor underneath.	Prevent soil from entering nursery. Formulations of entomopathogenic or insecticidal nematodes in the genera *Steinemema* and *Heterorhabditis* are available as biological control agents.
Slugs	Plants may have chewed holes on leaves with smooth edges and slime that dries into silvery trails on foliage.	Look for chewed holes on leaves and trails of slime. Slugs hide under dense foliage and under containers and benches.	Keep plants on raised benches or pallets. Space containers as needed so that slugs can be detected easily.	Pick slugs off plants. Keep containers on benches. Use saucers filled with beer to attract slugs away from plants. Put down a piece of plywood or wet cardboard at night; slugs will gather underneath. Ducks will eats slugs.
Viruses	Look for mosaic patterns on foliage, leaf crinkle or distortion, streaking, chlorotic spots, and distinct yellowing of veins and stunted plants.	Monitor weekly. Inspect all incoming plants. Send samples to laboratory to confirm.	Usually not a problem with native plants; can be a problem on cultivated varieties, ornamentals, plants grown by tissue culture.	None. Remove and discard all infected plants immediately. Thoroughly clean area of nursery where infected plants were growing.

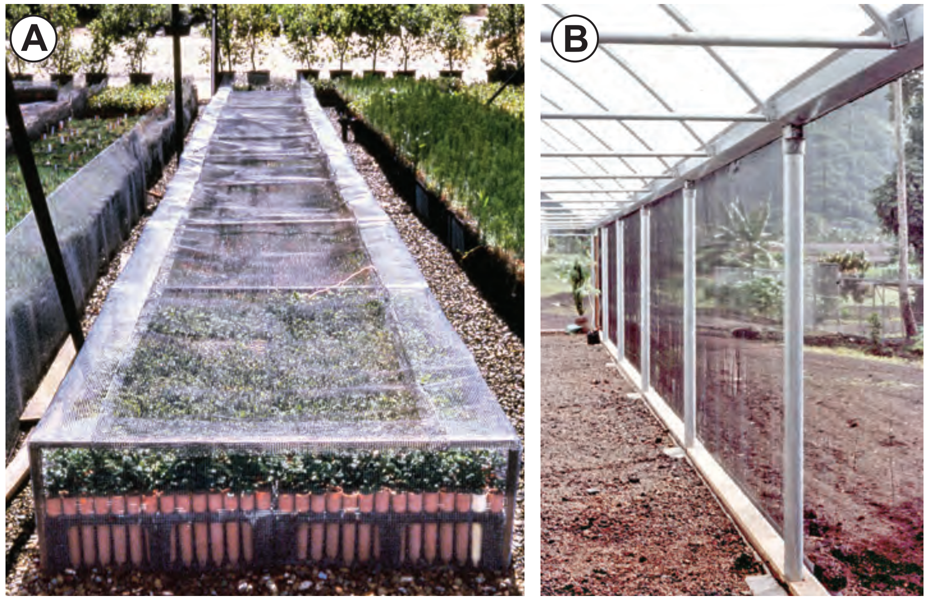

Figure 14.9—Large-seeded species can be especially vulnerable to pests such as mice and birds after they are sown in containers. Measures such as caging newly seeded containers and young seedlings (A) or adding mesh or screen walls (B) can be used to exclude a variety of pests from insects to mammals. Photo A by Tara Luna, and photo B by Thomas D. Landis.

In contrast, using a pesticide even once can put you on a treadmill of escalating use and collateral damage that can be difficult to escape. For example, if you have a rat problem, you can easily and cheaply poison the rats with a rat poison (rodenticide). The rats that ingest this poison will die over the next few days. The poison, however, may move through the food web to natural enemies of rats, including wild raptors and owls, and to domestic or feral cats and dogs. The few rats that survive the poisoning can reproduce much more quickly than their slower reproducing natural predators can. In other words, a time lag will occur between when the rat population recovers and when their predator populations recover. During this time lag, another infestation of rats can emerge, with numbers now unchecked by scarcer, slower recovering predator populations. A reinfestation may compel you to poison the rats again, setting the struggling predator population back even further, if not eliminating them locally. This cycle could be avoided by considering alternate measures, such as finding ways to prevent the rats from entering the nursery area in the first place. If full exclusion is not feasible, trapping the rats and killing them yourself can bring their population down to a tolerable level without poison, or you can adopt a skillful cat or two to do the rat-trapping and killing for you. These options are more labor-intensive in the short term, but can pay dividends in the long term by keeping natural checks and balances healthy. This example uses large animals such as rats, owls, and cats to illustrate a concept, but the same population dynamics apply with many insects. For example, aphids multiply more rapidly than the ladybug predators that can help keep aphid populations in check, as long as the ladybugs are not indirectly poisoned by the nursery manager's attempts to control the aphids (Hemenway 2009).

Most tropical plants can be grown without fungicides and insecticides. Because the nursery environment is so favorable for many pests, however, chemicals are sometimes used. If choosing to use chemicals, the important thing is to choose a pesticide that is least toxic, safest to use, targeted for the specific pest, short-lived in the environment, and will not contaminate the environment or reduce populations of pest predators (Mizell and Short 2009). The chemical must be registered for the pest and crop plant being treated and used as the label directs.

Many people believe that any natural or organic pesticide is always safe to use, but a number of registered botanical insecticides can be toxic to applicators or the environment. The relative toxicity rating for any chemical is known as the LD_{50}, which indicates the lethal dose that is required to kill 50 percent of a population of test animals. As can be seen in table 14.2, insecticides from natural sources can be as hazardous as chemical pesticides.

Still, if considering pesticides, we recommend that you always consider natural pesticides first because they tend to degrade faster than synthetic pesticides, which reduces their effect on nontarget organisms. Most natural pesticides are more likely to meet the holistic criteria of lower toxicity, pest-specific, short-lived, and least collateral damage compared with synthetic pesticides. The drawbacks of natural pesticides are that they must be applied more frequently because of their rapid degradation, commercial ones are often more expensive and may be more difficult to obtain, homemade ones may vary in efficacy and safety, and little data exist on their effectiveness and long-term toxicity.

Table 14.2*—Comparative safety of common botanical and synthetic insecticides. Adapted from Cloyd (2004).*

Insecticide	Class	Toxicity rating (oral LD_{50} in mg/kg)	Label warning (danger is most toxic and caution is the least)
Nicotine	Botanical	50 to 60	Danger
Sevin	Synthetic	850	Warning or caution
Malathion	Synthetic	885 to 2,800	Caution
Pyrethrin	Botanical	1,200 to 1,500	Caution
Neem	Botanical	13,000	Caution

LD_{50} = lethal dose to 50% of subjects.

Balancing Pest Populations With Beneficial Organisms and Pest Predators

Holistic management involves using beneficial fungi, insects, and other organisms to help prevent pest effects on crop plants (table 14.1). When these methods are used, it is important to maintain a healthy biological balance in the nursery.

Microsymbionts

As described in Chapter 13, Beneficial Microorganisms, microsymbionts such as mycorrhizal fungi, rhizobia, and *Frankia* have many benefits to the host plant, including protection against root pathogens. For example, rhizobia bacteria in nitrogen-fixing plants can help reduce or eliminate nitrogen fertilizer use for those crops, reducing risks of attracting sucking insects with overfertilized succulent foliage. A study of tropical hardwood nurseries in Haiti reported that "trees inoculated with the proper microsymbiont are more vigorous and have far fewer diseases or nutrient deficiency problems" (Josiah and Allen-Reid 1991: 56). Inoculants included manufactured rhizobia for nitrogen-fixing legumes, crude *Frankia* inoculants made from nodules for ironwood (*Casuarina* species), and locally gathered ectomycorrhizae for pines (Josiah and Allen-Reid 1991).

Biological Disease Control

Biological disease control uses beneficial or benign organisms to help protect nursery plants from diseases. Biological controls must also be registered for the crop, pathogen, and location where they will be used. Biologicals are generally designed for a particular plant pathosystem and may not have efficacy for others, although these products are sometimes advertised or applied as broad-spectrum use (James 2012). For example, biological fungicides are made of beneficial or nonharmful organisms applied to the growing medium to protect roots from certain pathogens (Francis 2009). Different types of biological fungicides have different ingredients and modes of action, some preventing pathogen infestations in crops by competing with or excluding pathogens, and others by producing antagonist, antifungal, or antibiotic substances to inhibit pathogens. Some of these products are certified for organic production, while others are patented, hybrid organisms with specific modes of action. Growers in tropical areas may wish to explore the concept of biological disease controls and see if locally appropriate, naturally occurring options for disease control are feasible to make or purchase. Introduction of new microorganisms is usually not appropriate or legal for island ecosystems. Also, effects on pathogens are generally much more subtle than chemical pesticides. A few examples of biological fungicides are included in table 14.1.

Ecosystem Balance

Only a few species of insects, bacteria, and fungi are harmful to plants. Most are harmless or beneficial, acting as pollinators, nutrient recyclers, food for birds and mammals, and pest predators (figure 14.10). The use of broad-spectrum chemical pesticides can be deadly to many harmless and beneficial organisms and to some of the wildlife that eat them. Furthermore, widespread herbicide use has enabled people to annihilate supposedly "useless" vegetation in hedges, gulches, edges, and fallow areas—destroying much of the food and shelter needed for diverse life forms. With the loss of ecological balance caused by these indiscriminant practices (Hemenway 2009), crop losses have been increasing. Reversing the loss of biodiversity and ecological balance on a local level is beneficial for nurseries and for the environment.

Practicing holistic pest management avoids harming beneficials with indiscriminant pesticide use. It is important that everyone who works in the nursery recognizes and protects benign and beneficial critters. Uninformed people may see a harmless spider and react by squishing it unless they understand how that spider might be helpful. Insect pest predators can include spiders, beetles, lacewings, wasps, Syrphid flies, pirate bugs, snakes, birds, toads, lizards, and more (Josiah and Allen-Reid 1991). In addition, parasitic insects exist, such as parasitic wasps and tachinid flies, that kill pests by laying eggs inside them (Hemenway 2009).

*Figure 14.10—Sometimes called "the gardener's best friend," anoles (*Anolis *species) eat many pest insects including moths, locusts, and cockroaches. Photo by Brian F. Daley.*

Nurseries may also protect and create habitat for beneficials and foster biodiversity, from soil organisms to insects, birds and, where appropriate, larger mammals. These "refuges" can include a simple patch of native flowers planted around the nursery's entrance sign, a border planting at the edge of the groundcover, a fallow area, windbreaks, hedgerows, or dedicated reforestation areas. For example, windbreaks have been found to harbor beneficial insects and birds that help to balance out populations of crop pests, reducing needs for pesticides (Stace 1995). Windbreaks on farmlands have been shown to harbor not only native wildlife, but also to foster native tree seedlings and ecosystem regeneration processes within the windbreak (Harvey 1999).

A key to planning refuge areas near the nursery is to consider what sorts of life forms you want to attract. Then, consider what they need for food and forage, safe travel corridors, reproductive habitat and nesting sites, and shelter from weather and predators. For example, native bees are important pollinators for native plants in many parts of the world, and their populations have been in decline. Different bees have different needs, but most native bees require a year-round supply of pollen and nectar from a diversity of native flowering plants. For shelter, native bees need a safe place to nest, usually in undisturbed ground, in hollow stems, or holes in trees (Vaughan and Black 2008).

The tips below can help to attract a diversity of benign and beneficial insects, animals, and other organisms to available areas including borders, hedges, windbreaks, and other refuge spots around the nursery (adapted from Wilkinson and Elevitch 2000):

- Learn about the intended species' needs for food, habitat, and other necessities. Plant the known food sources for target species. Native plant species are most likely to support native life, from soil fauna to birds. Some native wildlife may also have become accustomed to exotic species for food or habitat as well, however, and some naturalized exotic species may be important predators for exotic pests.
- Do not practice "clean culture." As long as it does not pose a safety problem, leave leaf litter and mulch, uncultivated soil, dead logs, and snags, which are important to many kinds of life from native bees to birds.
- Plant and protect a variety of species. Complex, multistoried plantings are more attractive to diverse animals than plantings of only a few species.
- Create a variety of habitats within the area. Tall trees, smaller shrubs, herbaceous plants, and standing dead snags provide important niches where different creatures can find their preferred shelter, food, and so forth.
- If possible, try to create corridors—connected areas where birds and insects can live or travel through safely. Ideally, the corridors will be contiguous, without large gaps. If the nursery is near a larger forest, park, or riparian area, creating a corridor between this area and the new planting may help species colonize the refuge area. Cooperation with neighbors may also help create larger and wider corridors.

Another recommendation is to ensure alternate hosts for certain pests are not grown near the nursery. For example, not all rust fungi have alternate hosts but those that do can be controlled by removal of these alternate hosts.

Diversity

Nursery areas can sometimes be devoted to a single plant species grown closely together—a potential buffet for the pests of that species. Studies in silviculture, agroforestry, and sustainable agriculture illustrate the benefits of mixed plantings for reducing pest problems. For example, in Southern Florida and the Caribbean, the mahogany shoot borer (*Hypsipyla grandella* [Lepidoptera: Pyralidae]) has a major effect on the survival and health of native West Indies mahogany seedlings and trees (figure 14.11). To reduce the likelihood of attack by mahogany shoot borers, researchers and growers are moving away from mahogany monocultures and into diversified plantings, with some success (Howard and Merida 2010). Reasons for the effec-

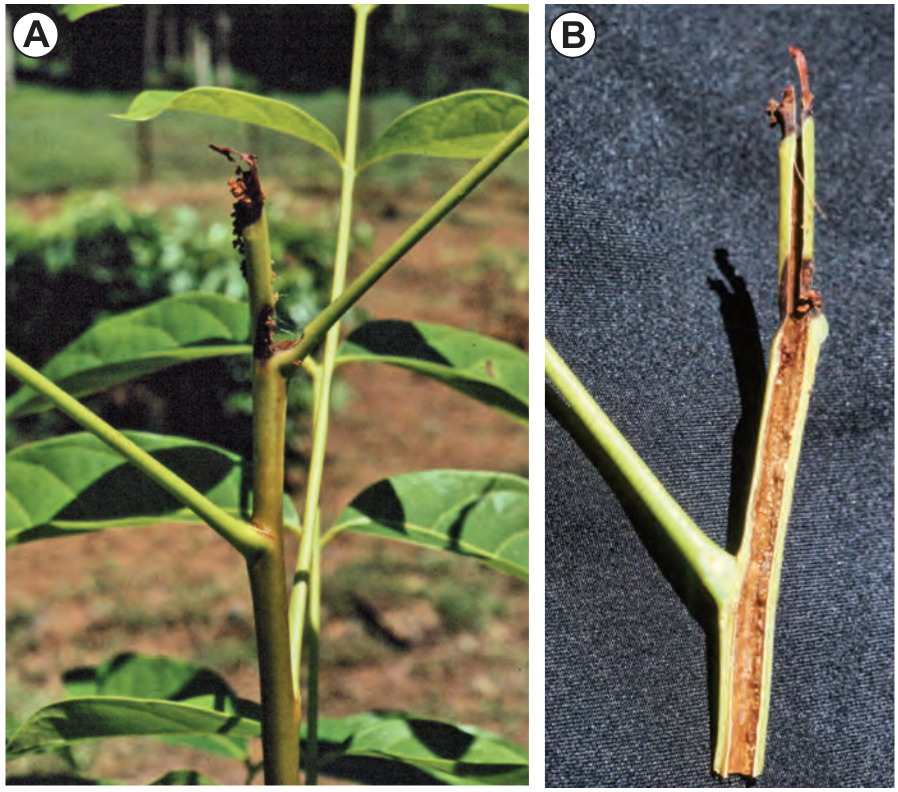

***Figure 14.11**—The mahogany shoot borer (*Hypsipyla grandella*) has a major effect on the survival and health of native West Indies mahogany seedlings. Photos by Thomas D. Landis.*

tiveness of diversification range from not attracting large numbers of pests to providing habitat for greater biodiversity to balance out pest populations. Nursery growers who wish to diversify can mix plants of different species throughout the nursery instead of growing all the same species in one section (see story about "hiding" seedlings from rust in Chapter 20, Discovering Ways to Improve Nursery Practices and Plant Quality), although they will still want to group mixtures of species according to their growth stage and culturing needs. They can also diversify areas around the nursery as described in the previous section. Clients may also be interested in outplanting in diverse patterns instead of large monocultures.

Ongoing Process Evaluation

Assessment and Improved Effectiveness of Pest Management Approaches.

Take time to assess and learn from problem prevention and holistic pest management practices in your nursery. Evaluate the nursery's daily log seasonally and annually to assess the effectiveness of current practices. What is working well? Where is there room for improvement? How effective are the sanitation practices? Are any pest trends noticeable, such as a decrease in one type of pest but an increase in another over time? Are any crops being grown that are so susceptible to pests that it may not be cost-effective to produce them anymore? Do any instances exist where some seedlings are unaffected by a pest while others are hit hard? If so, what is the difference? Has the presence of beneficial organisms and natural pest predators been documented? How can new staff be trained to help scout for pests, recognize beneficials, and diagnose problems in the nursery? Do any management practices exist that might warrant a small experiment in the nursery (see Chapter 20, Discovering Ways To Improve Nursery Practices and Plant Quality)? What lessons did you learn that you can share with other growers?

Taking time to observe and reflect on pest patterns and holistic management processes can make it easier year after year to prevent problems and manage them effectively if they arise.

Acknowledgment

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