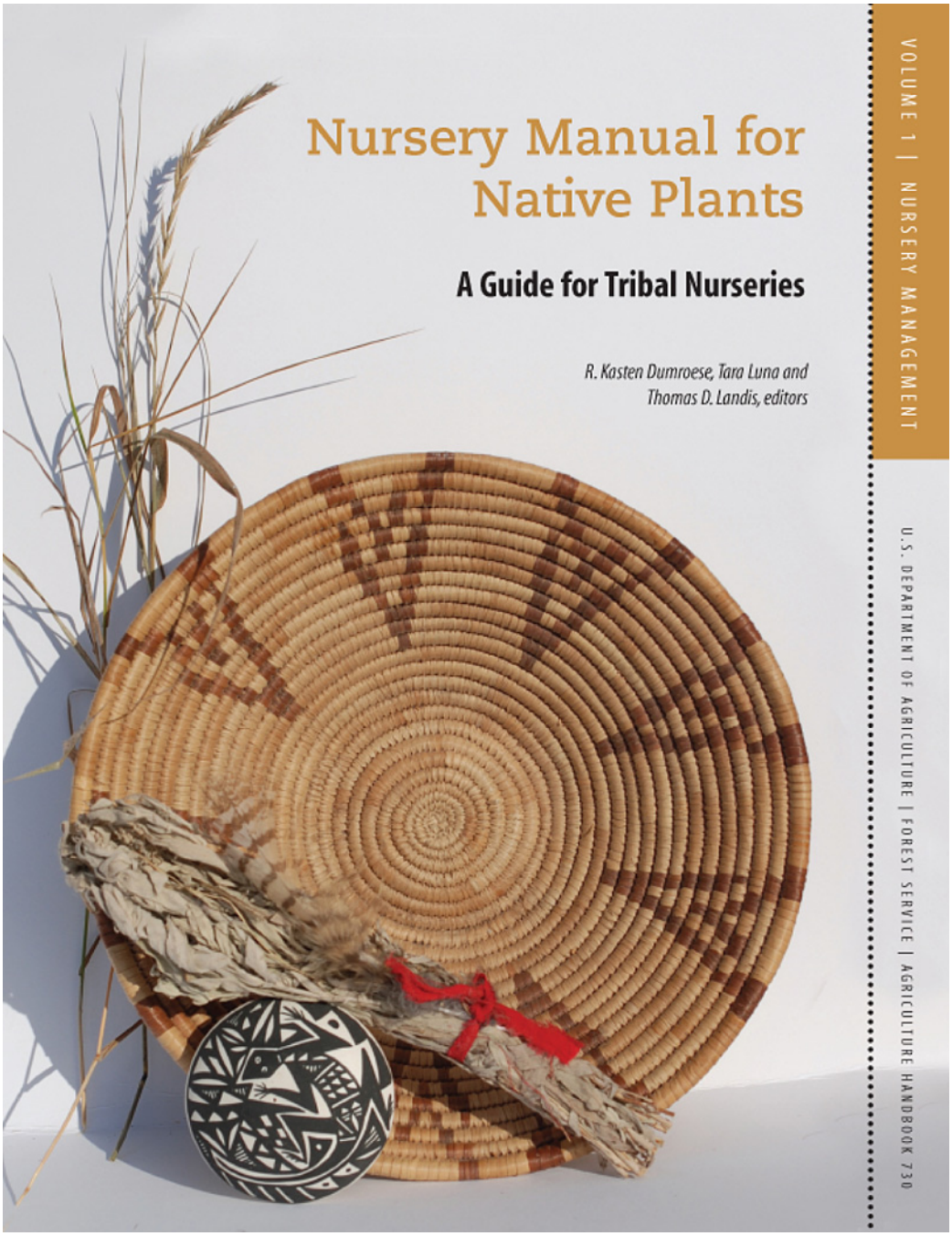

Landis, Thomas D.; Luna, Tara; Dumroese, R. Kasten. 2009. 15: Holistic pest management. In: Dumroese, R. Kasten; Luna, Tara; Landis, Thomas D., editors. Nursery manual for native plants: A guide for tribal nurseries - Volume 1: Nursery management. Agriculture Handbook 730. Washington, D.C.: U.S. Department of Agriculture, Forest Service. p. 263-275.

Holistic Pest Management

Thomas D. Landis, Tara Luna, and R. Kasten Dumroese

15

As any experienced grower knows only too well, nursery management is a continuous process of solving problems. Murphy's Law of "anything that can go wrong, will go wrong" sounds as if it were meant for native plant production.

One recurring problem is pests. Nursery managers have traditionally talked about "controlling" a pest. This approach usually involves waiting for an insect or disease to appear and then spraying some toxic chemical on the already dead or dying plants. Instead of a knee-jerk reaction to a specific problem, pest management should be a series of interrelating processes that are incorporated into the entire spectrum of nursery culture.

WHAT IS "HOLISTIC"?

Holistic is best described through an example. Holistic medicine, for instance, is a relatively recent concept in modern Western culture that emphasizes the need to perceive patients as whole persons, although it has always been a part of the traditional healing practices of Native Americans. It developed as a response to the increasing specialization in medical education that was producing physicians who treated organs rather than the body as a whole. Patients were shuttled from one doctor to another in search of a cure, but each was a specialist in one narrow field. Few could see the "big picture" or provide the patient with a comprehensive diagnosis. A related concern was the increasing dependence on drugs in the treatment of disease. Many patients

RaeAnne Jones of the Sioux Nation by Tara Luna.

felt that doctors were merely prescribing drugs to treat symptoms rather than trying to find out the real cause of the disease. Similarly, holistic pest management means looking at the big picture, not just observing symptoms but considering the overall health of the plant as well as the nursery environment when diagnosing a problem.

WHAT ARE DISEASES AND PESTS?

In native plant nurseries, a disease can be caused by biological stresses that we call pests or environmental stresses. Nurseries have many potential pests, including fungi (figures 15.1A–E), insects (figures 15.1F–J), nematodes, snails, and even larger animals such as mice (figure 15.1K). Other plant species, such as weeds and cryptogams (moss, algae, or liverworts) (figure 15.1L) 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 frosts (figures 15.2A and B), heat (figures 15.2C and D), and chemicals (figures 15.2E and F). Sometimes, people are pests when they apply too much fertilizer, which causes chemical injury known as fertilizer burn (figure 15.2G).

THE "DISEASE TRIANGLE"

A useful concept to explain nursery pest problems is the "disease triangle," which illustrates the interrelationships among the pest, host, and environment (figure 15.3). All three factors are necessary to cause biotic disease. For example, a fungus or insect is able to survive inside the warm environment of a greenhouse 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 15.3). Abiotic diseases may develop suddenly as the result of a single injurious climatic incident, such as a freeze, or more gradually as a difficult-to-detect growth loss resulting from below-optimum environmental factors, such as a mineral nutrient deficiency.

APPLYING THE HOLISTIC APPROACH IN NURSERIES

The Conducive Nursery Environment

One basic tenet of holistic medicine is to recognize how much environment contributes to disease. We just discussed the disease triangle (figure 15.3), which stresses all three factors, but the environment takes an overriding role in native plant nurseries. The principle reason for raising plants in containers in a greenhouse is that all potentially growth-limiting factors can be controlled (table 15.1). Plants are sown at regular spacing in an artificial growing medium formulated for ideal pH and porosity. The atmospheric environment is automated to maintain ideal temperature and relative humidity both day and night. In some greenhouses, even carbon dioxide is supplied to accelerate photosynthesis.

Unfortunately, the ideal nursery environment is also a breeding ground for many pests. Fungus gnats are a good example. The larvae of these small flies can damage seeds or young germinants (figures 15.1G and H) but become a problem only when populations increase in greenhouses with excessively wet conditions. To make matters worse, greenhouses do not contain any natural parasites that normally control fungus gnats (table 15.1).

Recognizing that the nursery environment is well suited for disease problems, high-quality native plants can be best produced by a comprehensive approach using the following steps: (1) prevention through sanitation, (2) good crop scheduling, (3) keeping plants healthy, (4) daily monitoring and good recordkeeping, (5) accurate problem identification, (6) timely and appropriate control measures, and (7) encouraging beneficial organisms.

1. Disease Prevention through Sanitation

Keeping pests out of the nursery in the first place is critical. The container nursery environment is initially pest free, so 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. Any unnecessary vegetation should be removed because it provides cover for seed-eating rodents and birds and can harbor insect pests, including thrips, aphids, weevils, and the European crane fly. In existing nurseries,

Figure 15.1—*A collage of biotic nursery pests. Fungal pests include (A) damping-off fungi, (B) Phytophthora root canker, cedar-apple rust of (C) serviceberry leaves and (D) fruit, and (E) Botrytis blight. Insect pests include (F) aphids, larvae of fungus gnats eating (G) chokecherry seeds and (H) quaking aspen roots, (I) leaf-roller on green ash, and (J) microscopic spider mites on quaking aspen. (K) Mice and other rodents consume seeds. (L) Weeds, liverworts, and algae smother small plants.* Photos A–K by Thomas D. Landis, L by William Pink.

potential pests generally enter the growing area through the following sources:

- **Wind.** Airborne spores, seeds, or insects can be introduced through the ventilation system.
- **Water.** Fungus and cryptogam spores and weed seeds can be introduced through irrigation water.
- **Growing Media.** Most commercial mixes are considered "essentially sterile," but potentially harmful fungi have been isolated from some types of growing media or their components.
- **Containers.** Reusable containers may contain residual growing medium or plant roots that harbor pest propagules, moss, or algae from the previous crop.
- **Surfaces in the Growing Structure.** Floors, benches, and other surfaces in the growing area may harbor pests from the previous crop.
- **Propagation Materials.** Seeds, transplants, or cuttings are sometimes infected before they reach the nursery.
- **Transported Soil and Growing Media.** Infested 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.

2. Crop Scheduling Is Critical

Crop scheduling is an important component of holistic pest management. A typical native plant nursery will be growing a wide variety of plants with different growth rates. For example, most willows can be grown from seeds to shippable size in as little as 4 months whereas whitebark pine seedlings take 2 to 3 years to be large enough to ship. If you are growing a new species and are unsure of the growth rate, contact other nurseries, check the propagation protocols in volume 2 of this handbook, or check the Native Plant Network (http://www.nativeplantnetwork.org).

Slow-growing plants 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" and rootbound. Plants that have grown too large for their containers are easily stressed and prone to pest problems. Leafy, "leggy" overgrown plants can harbor insects and other pests can infect the rest of the crop.

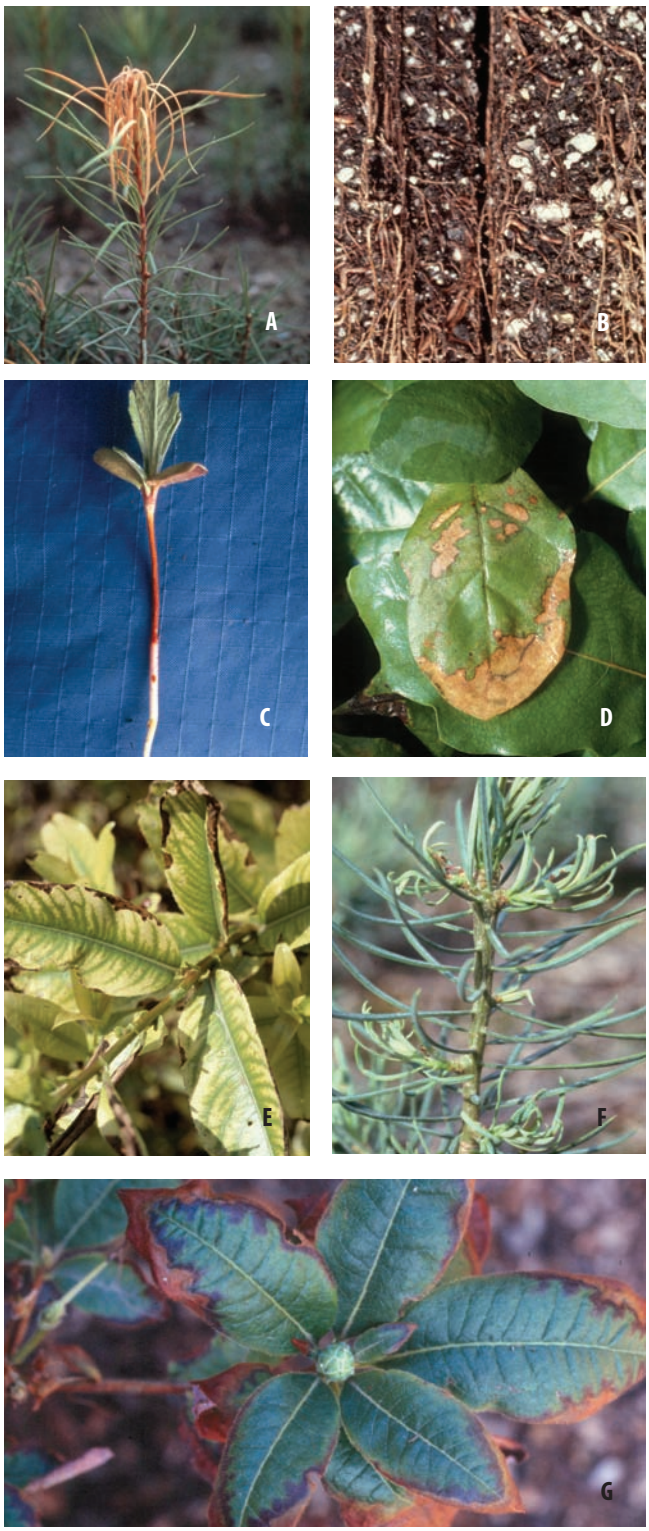

Figure 15.2—*Abiotic disease can be caused by any excessive environmental stress, including (A) frost injury to foliage and (B) especially roots, and (C) heat injury to germinants or (D) mature foliage. Chemical injuries can be caused by (E) the overliming of growing media or (F) the application of pesticides. (G) Fertilizer burn is an abiotic disease caused by improper fertilization.* Photos by Thomas D. Landis.

3. Keep Plants Healthy

A key component of any pest control system is to start with healthy crops; this practice is especially critical for holistic management. Healthy plants are more able to resist infection from 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 and some people believe that healthy plants have chemical defenses as well.

An important aspect of keeping plants healthy is to maintain conditions that are conducive for plant growth but do not favor pests or have damaging environmental extremes. For example, root diseases are common in all types of nurseries and are often brought on by environmental stresses. As an example, 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* does little harm to healthy seedlings but typically invades dead or dying roots. The fungus then uses these sites as a base for further invasion of healthy roots (Unestam and others 1989). On a practical basis, therefore, opportunistic pathogens such as *Fusarium* do not cause disease unless plants are under environmental stress (figure 15.4).

Marginal growing conditions for native plants 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 greenhouse benches, where water can puddle and excess fertilizer promotes their growth. This problem is particularly common where floors of greenhouses are covered by a weed barrier or gravel. Switching to concrete floors alone can often cure a fungus gnat problem (figure 15.5) because concrete dries faster and is easier to keep clean.

4. Daily Monitoring and Good 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 horticultural problems that are conducive to pests while they are still minor and can be easily corrected. In small nurseries, the

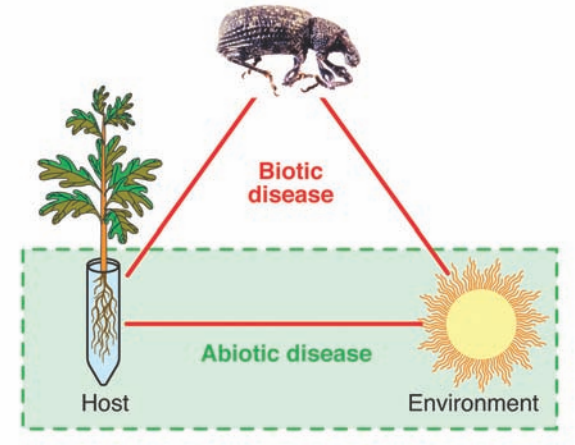

Figure 15.3—*The "disease triangle" illustrates the concept that a host, a pest, and a conducive environment are necessary to cause biotic disease. Abiotic disease occurs when environmental factors, such as frost, injure the host plant.* Illustration by Jim Marin.

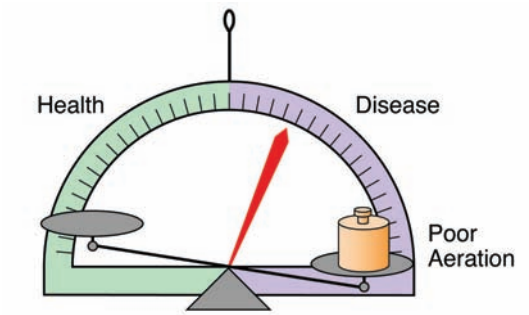

Figure 15.4—*Many nursery diseases are caused by environmental stresses, such as poor aeration, which predispose plants to attack by opportunistic pests.* Illustration by Jim Marin.

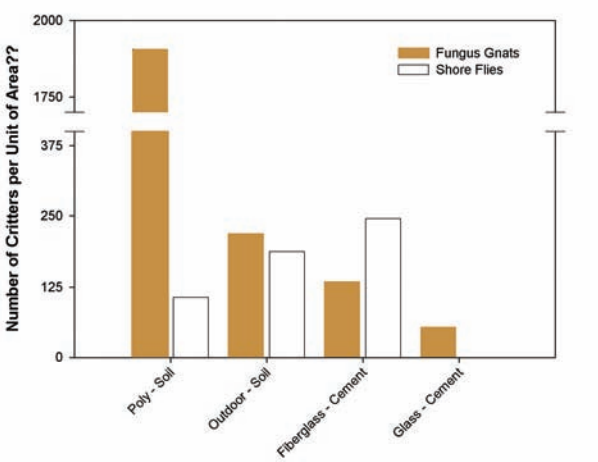

Figure 15.5—*Many nursery pests, such as fungus gnats, thrive in nurseries with soil floors where they reproduce rapidly on algae, mosses, and liverworts to the point at which populations can cause significant damage to crops.* Illustration by Jim Marin.

Table 15.1—The ideal propagation environment of a greenhouse consists of edaphic (pertaining to the soil) and atmospheric (pertaining to the air) factors that have advantages and disadvantages

	Advantages	Disadvantages	
	No Growth-limiting Factors in Physical Environment	Ideal Conditions for Some Pests	No Beneficial Organisms
Edaphic	Water Mineral nutrients	Fungus gnats, *Bradysia* spp.	Mycorrhizal fungi
Atmospheric	Light Humidity Carbon dioxide Temperature	Botryis blight, *Botrytis cinerea*	Insect parasites

grower or nursery manager should do the inspections, but, in larger facilities, one person should be designated as crop monitor and 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 (figure 15.6). The person should also be inquisitive and have good observation skills. Often, irrigators serve as crop monitors because they are regularly in the nursery, checking whether plants need watering.

Crop monitors should carefully inspect each species being grown, record the temperature and environmental controls of the greenhouse, and make other observations. It is important to establish a monitoring and recordkeeping system for all areas of the nursery, including the greenhouse, rooting chambers, and outdoor nursery. These records are invaluable for avoiding future pest problems when planning the next crop. In addition to looking at crop plants, scouts should check all greenhouse equipment and monitor the growing environment. Pest scouts should carry a 10X to 20X hand lens for close inspection and a notebook or tape recorder to record observations. When a problem is noted, a camera with a closeup lens is an excellent way to document the problem (figure 15.7). All observations should be recorded in a daily log (figure 15.7), and any suspicious problems should be immediately reported to the nursery manager. Inspections should 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 15.8) to detect white flies, aphids, fungus gnats, and shore flies. Place one to four cards every 1,000 square ft (90 square m) and space them evenly in a grid pattern, with extra cards placed near the vents and doorways. Inspect these cards each week to detect and monitor these pests. Record the information and replace the cards as needed to keep track of population trends. Use the blue sticky cards, which are more attractive to thrips, around plants susceptible to this pest.

5. Accurate Problem Identification

Nursery managers and disease scouts must be able to identify problems quickly and accurately before the problems can inflict 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 should be trained to quickly spot new problems as well as incidents of abiotic injury. Workers who are in the growing area daily have the best chance to spot potential problems before they can intensify or spread.

Unfortunately, no single reference is available for the diseases and pests of native plant species. Some common nursery pests and causes of abiotic injury were provided in a previous section. Volume 5 of the *Container Tree Nursery Manual* (Landis and others 1989) series features identification keys and color photographs of many diseases, insect pests, and horticultural problems of conifer crops (figure 15.9). Although pest scouts should make a tentative diagnosis of disease and pest problems, they should confirm their conclusions with the nursery manager and a trained nursery pest specialist.

Many diseases and insect pests damage a wide variety of host plants. For example, damping-off fungi (see

figure 15.1A) affect all species during germination and emergence and Phytophthora root rot (figure 15.1B) can attack many species of larger plants. Other pests are host specific, however, and disease scouts must understand their basic biology and life cycle for accurate diagnosis. Rust fungi are very specialized pests and attack only one group of plants, but some rusts alternate between host plants. Cedar-apple rust is caused by a fungus (*Gymnosporangium juniperi-virginianae*) and needs two hosts to complete its life cycle: junipers and certain plants of the rose family (Rosaceae) such as serviceberry or hawthorn. On junipers, the disease appears as woody, spherical galls. In the spring (early May), brown, horn-like projections called "telia" grow out of the woody galls (see figure 15.1D). During wet weather, the telia absorb water, become orange and gelatinous, and emit spores that infect the rose family plants. On this second host, the fungus infects leaves to cause bright-orange spots (see figure 15.1C), which eventually produce their "aecia" on fruit and the underside of leaves. In late summer, the aecia produce spores that reinfect junipers. The disease must pass from junipers to rose family plants to junipers again; it cannot spread between rose family plants. You can see that understanding the life cycle of the pest is essential for accurate diagnosis and management.

Some of the more common pests on native plants, ways to monitor them, and their diagnostic symptoms are included in table 15.2.

6. Timely and Appropriate Control Measures

One key concept of holistic pest management is the minimal use of chemicals. Chemical pesticides should be used only after all other environmental and horticultural controls have been considered. For example, you can reduce the use of pesticides by excluding pests via screens or barriers that can exclude small pests, such as insects, to big pests, such as mice and deer (figure 15.10). Most native plants can be grown with few fungicides and insecticides, but, because the nursery environment is so favorable for many pests, chemicals are sometimes needed. The important thing is to choose a pesticide that is targeted for the specific pest and is safest to use.

Many people believe that any natural or organic pesticide is always safe to use, but this belief is incorrect. A number of registered botanical insecticides can be toxic to applicators or the environment. The relative

WHAT IS THE MOST DANGEROUS CHEMICAL APPLIED IN THE NURSERY?

By far, the chemical used most frequently in the nursery that causes the most damage is water. Too much water on plants encourages damping-off, root disease, fungus gnats, moss and liverwort growth, excessive leaching of mineral nutrients and potential groundwater contamination, and foliar diseases such as Botrytis blight and 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 damage or desiccation, allowing entry points for root disease pests. Plants under severe moisture stress have lower resistance to stresses associated with heat, cold, and wind.

One of the best ways to limit pest problems is to irrigate plants properly.

Figure 15.6—*Disease scouts must be familiar with all crop species at all stages of development. The burl on the stem is normal for this redwood seedling but could be a problem for other plants.* Photo by Thomas D. Landis.

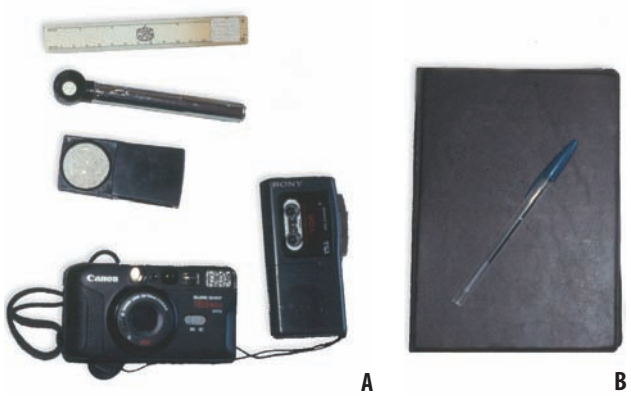

Figure 15.7—*(A) Crop monitors and disease scouts should carry a hand lens, notebook or tape recorder, and camera to identify and document problems. (B) All potential problems should be noted in the daily log and reported to the nursery manager.* Photos by Thomas D. Landis.

Figure 15.8—*Yellow sticky cards are essential for monitoring the types and population levels of insects pests.* Photo by Thomas D. Landis.

Figure 15.9—*Pest identification keys are very useful in helping disease scouts follow a logical and critical procedure and make the correct diagnosis.* Illustration by Jim Marin.

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 15.3, insecticides from natural sources can be just as hazardous as or even more hazardous than chemical pesticides.

Still, we recommend that you always consider natural pesticides first because they degrade faster than synthetics. Faster degradation reduces their impact on nontarget organisms; they are generally less toxic to humans, mammals, and beneficial insects such as bees. Most natural pesticides are less harmful to host plants when applied according to label directions.

The drawbacks of natural pesticides are that they must be applied more frequently because of their rapid degradation, they are often more expensive, may be more difficult to obtain, and little data exist on their effectiveness and long-term toxicity.

7. Encourage Beneficial Organisms

Holistic management involves using beneficial fungi, insects, and other organisms to help prevent pest impacts on crop plants. (table 15.2). Most people working in a nursery have heard about mycorrhizal fungi and realize that they have many benefits to the host plant including protection against root pathogens. The fungi that form mycorrhizae are often very host specific but there is little published information for many native plants (see Chapter 14, *Beneficial Microorganisms*).

SUMMARY

Your efforts to provide optimum growing conditions for the plants that you grow will go a long way toward preventing disease and insect problems. This practice, in conjunction with maintaining sanitation in the greenhouse, is the most useful and least expensive tool for preventing diseases and pests. Incorporate a holistic approach to diagnosing and treating problems by giving as much attention to the environment as to the pest. Many problems are triggered by environmental stresses that can be easily avoided or corrected by good horticultural practices. Pest control measures may not be needed if everyone at the nursery makes a concerted effort to prevent problems. By having regular, frequent monitoring of the crop and by keeping records, your nursery will be able to detect problems early and develop measures to prevent problems with future crops.

Table 15.2—Common diseases and pests, symptoms, prevention, and treatment measures for native plants

Pest	How To Monitor	Prevention	Signs and Symptoms	Biological and Organic Control Options
Aphids	Monitor 2 times weekly. Look on underside of leaves and on tips of new stems.	Shoot prune vigorous tender growth as needed. Watch for outbreaks in early summer months.	Plants have distorted new growth, sticky honeydew, and sooty mold.	Use aphid midges, aphid parasites, lady bugs, Safer soap applied every 6 days, pyrethrins.
Bacterial diseases	Inspect new plants coming into greenhouse. 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 (see appendix 15.A).	Plants are stunted with swollen or misshapen leaves. Look for water-soaked leaf spots or angular lesions on the stems.	Remove infected leaves as soon as problem is detected. Isolate infected trays of plants from the rest of the crop.
Botrytis blight	Concentrate monitoring where crop is closely spaced and air circulation is poor, and on tender leafy species. Look for dieback, stem cankers, and powdery gray mold on leaves.	Increase spacing between containers as crops grows larger. Water only in the morning or use sub-irrigation. Keep humidity low (see appendix 15.A).	Plants have leaf blights, stem cankers, gray mold.	Apply *Trichoderma harzianum* (PlantShield), *Streptomyces griseoviridis* (Mycostop).
Caterpillars	If moths are seen in the greenhouse, look for caterpillars. Look for fecal droppings, bites taken out of leaves and webbing (tent caterpillars).	Screening.	If damage is seen, look for caterpillars under containers or in growing media. Many caterpillars feed at night and hide during the day.	Apply BT *Bacillus thuringiensis* ssp. *kurstaki* (Pro DF) as needed, pyrethrins.
Crown and root rots	Monitor weekly for wilted, off-colored plants with discolored root systems. Pay attention to media that stays wet. Check soluble salt levels.	Do not overwater crop. Increasing spacing between containers as crop grows larger. Keep humidity low. (see appendix 15.A).	Plants are stunted, wilted, and off-color. Roots are discolored and turn brown or black. Main stem becomes weak and water soaked in appearance.	Apply *Trichoderma harzianum* (PlantShield, RootShield), *Trichoderma virens* (Soil Guard), *Streptomyces griseoviridis* (Mycostop).
Damping-off disease	Monitor daily during germination and establishment phases. Look for seeds that do not germinate and seedlings that collapse at soil line just after emergence. 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 green-house and media temperatures warm during germination and establishment. Keep humidity low (see appendix 15.A).	Seeds do not germinate; seedlings collapse at soil line just after emergence. Dark dead spots appear on stems at soil line of emerged seedlings. Infected plants may later develop crown and root rot.	Use *Trichoderma harzianum* (PlantShield, RootShield), *Trichoderma virens* (Soil Guard).

Table 15.2—(continued) Common diseases and pests, symptoms, prevention, and treatment measures for native plants

Pest	How To Monitor	Prevention	Signs and Symptoms	Biological and Organic Control Options
Fungal leaf spots	Monitor weekly for leaf spots. With a hand lens, look for small fungal fruiting bodies. Confirm problem with a laboratory.	Use mesh benches to encourage airflow. irrigation. Keep greenhouse floor clean and free of pooled water. Water only in the morning or use subirrigation. Do not overwater crop. Keep humidity low (see appendix 15.A). Increase spacing between containers as crop grows larger.	*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.	Apply *Trichoderma harzianum* (Plant Shield). Remove infected leaves as soon as problem is detected. Isolate infected trays of plants from the rest of the crop.
Fungus gnats	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 greenhouse floor clean and free of pooled water and algae, do not overwater crop. Use yellow sticky cards and a good seed mulch.	Plants have weak or stunted growth, seeds that do not germinate, root damage on seedlings.	Apply BT *Bacillus thuringiensis* ssp. *israeliensis* (Gnatrol) applied every 7 days as a drench, mite predators, parasitic nematodes.
Fusarium wilt	Look for downward bending leaves or "cupping" of leaf margins. Can be confused with water stress, root rot. Send sample to laboratory to confirm.	Use mesh benches to encourage airflow. Do not overwater crop. Keep humidity low (see appendix 15.A).	Leaves cup downward or stems bend in a crook. In later stages, brown streaks can be seen on the leaves. Orange spores may be on stem.	Apply *Trichoderma harzianum* (Plant Shield, Root Shield), *Streptomyces griseoviridis* (Mycostop) as a soil drench. Remove and isolate infected plants as soon as problem is detected.
Mealybugs	Look for small, oval, soft-bodied insects covered with a white, wax-like layer on the underside of leaves.		Plants may have white cottony residue. Sticky honeydew on leaves and sooty mold may develop.	Use predatory beetles, parasitic wasps; pyrethrins.
Powdery mildew	Monitor weekly. Inspect susceptible species. Look in areas near vents 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 (see appendix 15.A). Increase spacing between containers as crop grows larger.	Plants may have white powdery fungal growth on upper or lower leaf surfaces. If severe, white coating can be seen on foliage.	Remove infected leaves as soon as detected. Move infected plants to structure with more constant temperatures. Treat with Neem oil, horticultural oil, Safer soap. Try test tray first. Can also use sulfur fungicide as an organic fungicide. Some plants are sensitive to sulfur injury so use lowest rate recommended. Do not apply within 2 weeks of an oil spray treatment.

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Table 15.2.—(continued) Common diseases and pests, symptoms, prevention, and treatment measures for native plants

Pest	How To Monitor	Prevention	Signs and Symptoms	Biological and Organic Control Options
Rhizoctonia web blight	Monitor leafy herbaceous plants, especially where they are closely spaced. Look for cob-webby growth that mats leaves together.	Use mesh benches to encourage airflow. Place susceptible crops near vents and fans. Increase spacing between containers as crop grows larger. Keep humidity low (see appendix 15.A).	Stems and leaves may collapse and turn to mush with fine, web like fungal strands on the plant tissue and at soil line.	Use *Trichoderma harzianum* (Plant Shield, Root Shield).
Rusts	Look for yellow and rusty orange spots on the upper and lower leaf surface.	Group susceptible species where temperature and humidity can be easily controlled. Increase spacing between containers as crop grows larger. Keep humidity low (see appendix 15.A).	Rust brown spots or stripes may be seen on lower and upper leaf surface.	Isolate plants immediately.
Slugs	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.	Plants may have chewed holes on leaves with smooth edges and slime that dries into silvery trails on foliage.	Pick slugs off plants. Keep containers on benches. Use saucers filled with beer to attract slugs away from plants.
Soft scales	Look for yellow brown to dark brown scale insects along veins and stems.		Honeydew and sooty mold develop if scales are present.	Use parasitic wasps, Safer soap, pyrethrins.
Spider mites	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 greenhouse temperatures and raise humidity levels, especially in the south and west edges of the greenhouse and near vents and furnaces.	Plants may have light-yellow flecking of leaves, discolored foliage. Leaf drop and webbing occur during outbreaks and severe infestation.	Use predatory mites, predatory midges. Apply Safer soap every 6 days.
Thrips	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.	Plants may have distortion of new leaves, buds, and shoot tips. White scars on expanded leaves.	Use predatory mites, pirate bugs, lacewings, Safer soap, and pyrethrins.

Table 15.2—(continued) Common diseases and pests, symptoms, prevention, and treatment measures for native plants

Pest	How To Monitor	Prevention	Signs and Symptoms	Biological and Organic Control Options
Viruses	Monitor weekly. Inspect all incoming plants. Send sample to laboratory to confirm.	Usually not a problem with native plants; can be a problem on cultivated varieties, ornamentals, plants grown by tissue culture.	Look for mosaic patterns on foliage, leaf crinkle or distortion, streaking, chlorotic spots and distinct yellowing of veins and stunted plants.	None. Remove and discard all infected plants immediately. Thoroughly clean area of greenhouse where infected plants were growing.
White flies	Use yellow sticky cards to detect adults. Look for adults on the uppermost tender leaves. Immature larvae are found on the underside of leaves.		Plants may have distorted new shootand leaf growth.	Use predatory beetles, whitefly parasites, Safer soap applied every 7 days; pyrethrins.

Figure 15.10—*Native oaks can be especially vulnerable to pests such as mice and deer after they are sown in containers. Simple measures such as caging newly seeded containers and young seedlings can be used to exclude a variety of pests from insects to mice and deer.* Photo by Tara Luna.

Table 15.3—Comparative safety of common botanical and synthetic insecticides.

Insecticide	Class	Toxicity Rating (Oral LD_{50} in mg/kg)	Label Warning*
Nicotine	Botanical	50 to 60	Danger
Sevin	Synthetic	850	Warning/Caution
Malathion	Synthetic	885 to 2,800	Caution
Pyrethrin	Botanical	1,200 to 1,500	Caution
Neem	Botanical	13,000	Caution

Modified from Cloyd (2004); * danger is most toxic, caution is least toxic

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APPENDIX 15.A. CHECKLIST FOR PREVENTING DISEASES AND PESTS

1. Start with clean seeds. Seeds can be treated with a very mild diluted bleach or hydrogen peroxide solution before stratification or sowing to help prevent seed and seedling diseases.
2. Remove all plant debris before sowing the crop. Also, clean tables, aisles, side walls, and floors with a mild bleach or soap solution before sowing.
3. Vigilantly remove all weeds growing under benches and in the crop.
4. Use containers that have been cleaned (see Chapter 6, *Containers*).
5. Use a heat-pasteurized growing medium.
6. Prevent algae from forming on the floors and benches by ensuring proper and rapid drainage of excess irrigation water and by properly managing irrigation frequency. Algae and pools of water provide a breeding ground for fungus gnats and shore flies.
7. Use hooks to keep the hose nozzles off the floor and disinfect planting tools; dirty hose nozzles and planting tools can infect growing media with pathogens.
8. During sowing and the establishment phase of the crop, carefully manage the greenhouse environment to keep humidity levels and condensation problems low by venting the greenhouse frequently; avoid cool temperatures that delay germination. Do not overwater germinating seeds and seedlings. Remove dead and dying plants; make sure they are disposed of away from the nursery to prevent reinfection.
9. 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 in the greenhouse, and pruning shoots as necessary. Remove any plant debris on the floor on a regular basis. Remove dead and dying plants; make sure they are disposed of away from the nursery to prevent reinfection.
10. 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 temperatures between 55 to 65° F (13 to 18°C). By watering early, rising daytime temperatures will cause water to evaporate from the leaf surfaces and reduce favorable conditions.
11. Use separate propagation structures for growing plants with very different environmental and horticultural requirements, or, if you have a single growing structure, group plants with similar growing requirements together and take advantage of microenvironments within the greenhouse. For example, the south side of the greenhouse is usually warmer and drier than the north or east section of the greenhouse. Plants requiring cool temperatures or those requiring more frequent irrigation should be grouped together on the north and east sides, while plants requiring drier conditions should be grouped on the south and west sides of the greenhouse.
12. Reduce humidity; high relative humidity encourages the development of many foliar diseases, including *Botrytis*, powdery mildew, and *Rhizoctonia*. Improve air circulation and reduce humidity and condensation with fans that produce horizontal air flow. Relative humidity and condensation can also be reduced by heating and venting moist greenhouse air; heat and vent two to three times per hour in the early evening after the sun sets and again during early morning. Many growers use oversized vent fans and louvers to increase air flow in the greenhouse.

APPENDIX 15.B. PLANTS MENTIONED IN THIS CHAPTER

chokecherry, *Prunus virginiana*
green ash, *Fraxinus pennsylvanica*
hawthorn, *Crataegus* species
juniper, *Juniperus* species
oaks, *Quercus* species
quaking aspen, *Populous tremuloides*
redwood, *Sequoia sempervirens*
serviceberry, *Amelanchier alnifolia*
whitebark pine, *Pinus albicaulis*
willows, *Salix* species