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Monarch Waystation sign and associated illustrations

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Create a Pollinator Garden at Your Nursery: **An Emphasis on Monarch Butterflies**

by Thomas D. Landis, R. Kasten Dumroese, and Matthew E. Horning

We realize that this type of article is a departure for FNN readers but feel that it is important for forest, conservation, and native plant nurseries to be good environmental stewards. In addition, establishing a pollinator garden at your nursery can be good for business, too. Demonstrating the role and beauty of native plants and their pollinators, particulary in a small garden setting, might be a way to improve sales. The plight of pollinators has been in the news a lot lately, and many species of bees, butterflies and other insect pollinators, as well as bats and birds that pollinate, are in serious trouble.

1. The decline of pollinators

The causes behind the decline in pollinators are many, but most can be related either directly or indirectly to human activity. Habitat loss is always near the top of the list—habitat destruction or fragmentation into small, disperse patches threatens all types of insect pollinators (Mader and others 2011). For European honeybees, Colony Collapse Disorder (CCD) has been causing serious problems since 2006. Annual losses have averaged about 33% with a third of these losses attributed to CCD (USDA ARS 2014). A nationwide survey of bumblebees found that several species have declined substantially during the past 2 to 3 decades and are completely missing from entire regions where they had occurred historically (Stokstad 2014). Monarch butterflies (*Danaus plexippus* L.) are an interesting example of pollinator decline because, unlike many other organisms that decline or become extinct because they rely on one specialized habitat, monarchs are generalists that thrived all across North America—that is, until recently.

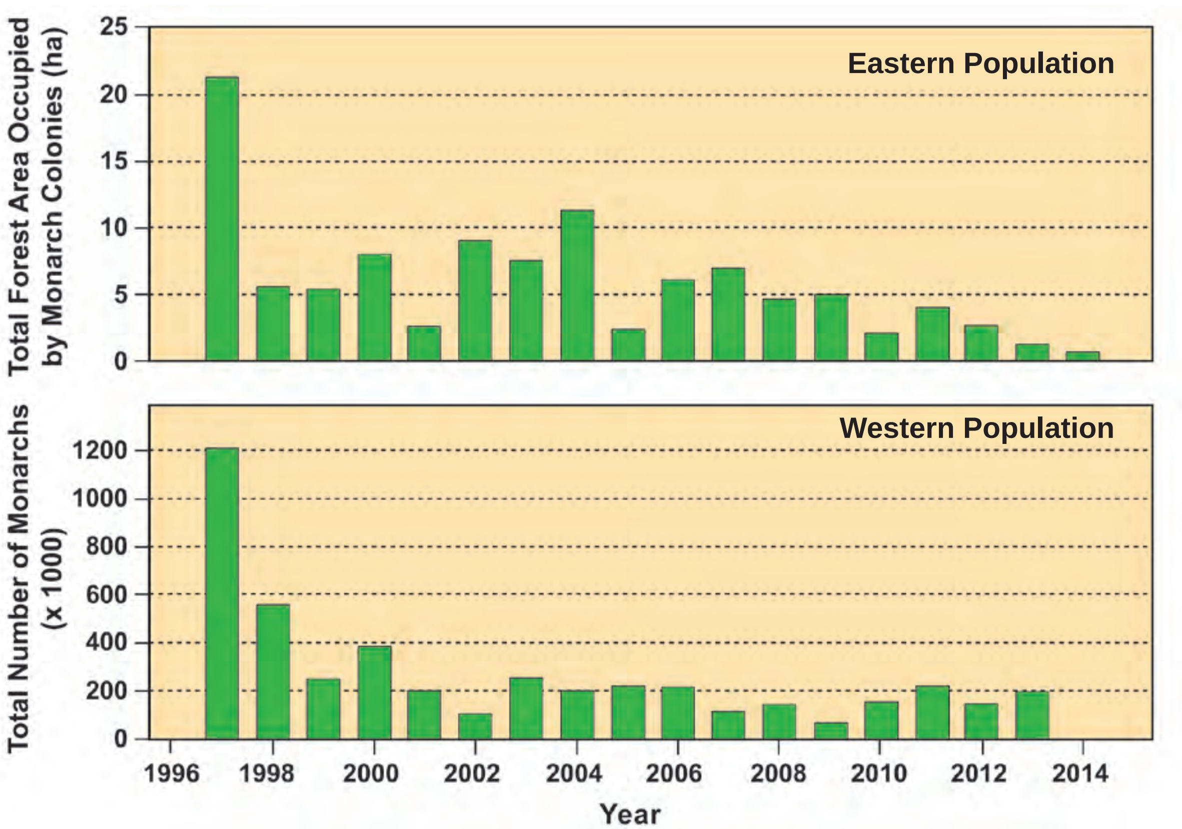


Figure 1 - Although monarchs used to be among the most common butterflies in the United States, overwintering counts of the eastern (upper) and western populations (lower) have declined drastically during the last 2 decades (A, modified from Rendon-Salinas and Tavera-Alonso 2013; B, modified from Jepsen and others 2010).

1.1 The population crash of monarch butterflies

With its large size and striking orange and black coloration, the monarch butterfly has been considered the most well-known butterfly in the world (Commission for Environmental Cooperation 2008). The monarch is a tropical butterfly that has been able to colonize much of temperate North America through annual migrations. Indeed, their long distance migrations to overwintering sites in Mexico and California are among the most unique and spectacular biological phenomena in the world (Luna and Dumroese 2013).

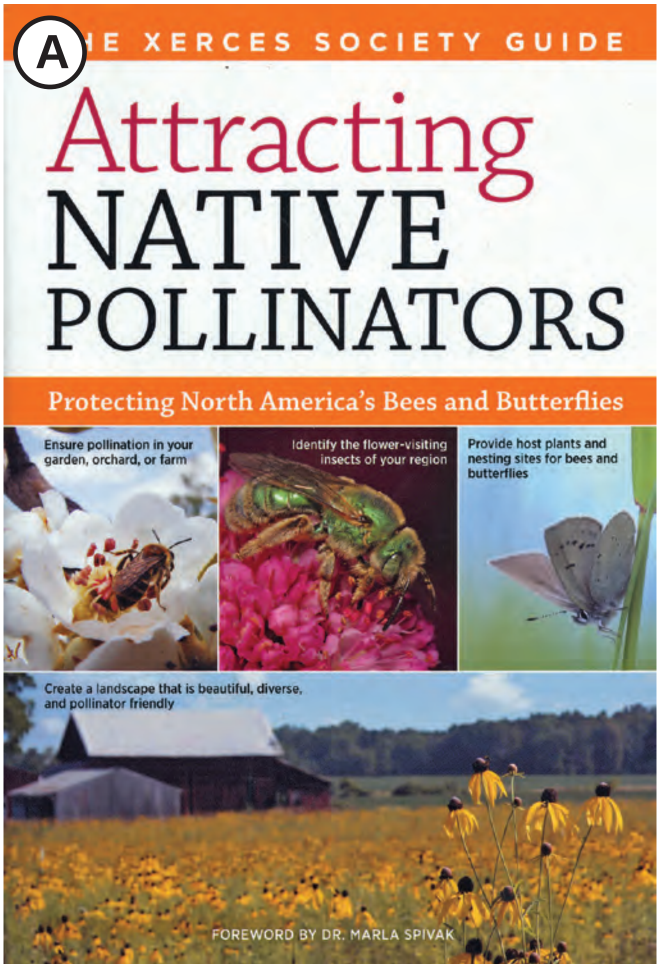
Like many school children, we learned one of our first biology lessons from capturing monarch caterpillars and watching their magical transformation into beautiful butterflies. In fact, in southern Kansas where Tom grew up, monarchs were so common that he remembers wishing he could find some other butterflies to collect for his Boy Scout merit badge. Unfortunately, things have changed. Surveys taken at overwintering sites confirmed our observations that monarch populations had experienced a major collapse in recent years; and, what is more alarming is how quickly this happened. Population levels of the eastern and western groups have crashed in during the past 2 decades (Figure 1). From 1999 through 2010, the eastern monarch group plummeted 81% (Pleasants and Oberhauser 2013). Similarly, annual surveys of the western group overwintering on the California Coast have revealed a nearly 90% percent decline during the last decade (Jepsen and others 2010).

2. Creating and maintaining pollinator gardens

Many organizations and, most notably the Xerces Society, have been advocating for better protection of all types of native pollinators, and how to create beneficial habitat ("pollinator gardens") with native

International Effort to Ensure Conservation of Monarch Butterflies and Other Pollinators

On 19 February 2014 in Toluca, Mexico, President Barack Obama, President Peña Nieto, and Prime Minister Stephen Harper issued a joint statement on behalf of the countries of North America. Of particular interest was this: "*We will continue to collaborate in the protection of our region's biodiversity and to address other environmental challenges...* ***Our governments will establish a working group to ensure the conservation of the Monarch butterfly, a species that symbolizes our association***" (our emphasis). As a follow-up, President Obama issued a Presidential Memorandum on 20 June 2014 to create a federal strategy to promote pollinator health. This memorandum established a Pollinator Health Task Force to be co-chaired by the Department of Agriculture (USDA) and Environmental Protection Agency with representation by many federal agencies, including the Department of the Interior (USDI). This task force has 180 days to produce a Research Action Plan that specifically includes two notable items: 1) *"assessments of the status of native pollinators, including the Monarch butterfly and bees, and modeling of native pollinator populations and habitats" and 2) "strategies for developing affordable seed mixes, including native pollinator-friendly plants, for maintenance of honey bees and other pollinators, and guidelines for and evaluations of the effectiveness of using pollinator-friendly seed mixes for restoration and reclamation projects."* The task force is also preparing a public education plan, recommending methods to develop public-private partnerships, and identifying methods for increasing and improving pollinator habitat. Specifically, the USDA and USDI have just 90 days to *"develop best management practices for executive departments and agencies to enhance pollinator habitat on Federal lands."* Currently, the Forest Service is responding to the memorandum in several ways, including development of *"The Conservation and Management of Monarchs on the Nation's National Forests and Grasslands: A Strategic Framework."* Supporting documentation to the President's memo included this specific language about monarch butterflies: *"Population declines have also been observed for other contributing pollinator species, such as Monarch butterflies, which migrate from Mexico across the United States to Canada each year, returning to overwinter in the same few forests in Mexico. The Monarch butterfly migration, an iconic natural phenomenon that has an estimated economic value in the billions of dollars, sank to the lowest recorded levels this winter, with an imminent risk of failure."* This memorandum from President Obama is extensive and detailed, and looks like it could be a boon for those of us in the native plant business.



plants (Figure 2A). Entire books have been devoted to the need for pollinator habitat and how native plants can be used to support all types of wildlife (Tallamy 2013). Like all animals, monarchs and other pollinators need specific habitats (food, shelter, and water) for breeding and, for migrants like monarchs, during overwintering. Much has been written about the need for protection of monarch overwintering sites and the restoration of these critical habitats (Commission for Environmental Cooperation 2008). Although most of us cannot directly control overwintering habitat, forest, conservation and native plant nurseries can increase breeding habitats for all pollinators by converting their marginal lands and landscapes into pollinator gardens (Figure 2B). Just about every nursery we visit has an ugly, weedy "bone yard" in a back corner that could be used for a pollinator garden. Of course, a garden in a prominent location visible to guests and customers is even better. And, fortunately, pollinator gardens will support a wide variety of pollinators, including monarch butterflies. Pollinator gardens provide these essential characteristics: 1) a balance of sun and shelter; 2) a variety of native plants that

Figure 2 - Pollinator gardens are a popular way to create habitat for bees, butterflies, and other insects (A). Forest, conservation, and native plant nurseries can serve their communities by establishing pollinator gardens, such as this monarch waystation (B) (A, from Mader and others 2011).

serve as food for larvae; 3) pollen and nectar food plants for adults; 4) water; and 5) a pesticide-free zone.

2.1 Sunlight and shelter

Because all insect pollinators are cold-blooded pollinator gardens should be located in a sunny location and receive direct sunlight for at least 6 to 8 hours a day. Monarchs (and most pollinators) are most active above 50 °F (10 °C), and only fly during daylight hours (Oberhaeuser and Solensky 2006; Journey North 2014). Southeast aspects are ideal because they receive morning sun for a quick warm-up but do not get too hot during summer afternoons. Pollinator gardens should also be sheltered from prevailing winds by woody trees and shrubs. Conifers or evergreen hedges are ideal because they provide both wind protection and a place for pollinators to rest overnight. Position woody plants so that they do not shade your pollinator plants, however, as most need full sunlight.

2.2 Native plants as food

Adult butterflies and their caterpillar larvae use plants for food, and it is important to distinguish between native plants (originally found in your local area) and introduced garden plants or cultivars (cultivated varieties). The caterpillars of most butterflies use only one plant genus for food, and these are known as host plants; a few butterflies can utilize several plant genera (Table 1). By contrast, adult butterflies can use a wide variety of native and introduced plants for food. Although backyard pollinator gardens can use native and introduced plants, pollinator gardens at nurseries and elsewhere in the natural environment should only use natives to prevent the possibility of introduced plants escaping and becoming invasive weeds. It is best to plant species in groups or clumps because this makes them more attractive to pollinators. Scatter these clumps randomly rather than planting in rows to make the site appear more natural (Mader and others 2011). Small groups of plants, such as milkweeds, are best because large plantings attract predators and parasites (Taylor, as quoted in Conniff 2013)

2.3 Nectar plants

Pollinators obtain energy from the pollen and nectar of a wide variety of flowering plants. Nectar is high in sugars but also contains other important food components, such as amino acids (Nicolson and others 2007). Lists of good non-native nectar plants can be found on-line (for example, Monarch Watch 2014a) and in books (for example, Mader and others 2011; Holm 2013). It is much more difficult, however, to find information on the best native nectar species for a specific region. The California Horticultural Society has published "California Native Nectar Plants for Butterflies and Day-flying Moths" that lists common insect-plant associations (Caldwell 2014). We realize that some native plant nurseries already have good lists: for example, the Doak Creek Nursery lists "The Top 20" native butterfly host and nectar plants for the Lane County (Oregon) garden (Newhouse 2012).

When selecting nectar plants for your pollinator garden, choose perennials over annuals and consider small-statured shrubs that can provide nectar as well as shelter. Just because a native flower is blooming, however, does not mean that it is a good nectar producer. An example is the very common California poppy (*Eschscholzia californica*), which produces no nectar (Thorp 2014).

Table 1 - Caterpillars of butterflies are obligate feeders on specific host plants.

Common name	Scientific name	Host plants	Source
Monarch butterfly	*Danaus plexippus*	*Asclepias* spp., milkweed	Neill (2001)
Pale swallowtail butterfly	*Papilio eurymedon*	*Ceanothus* spp., ceanonthus; *Alnus* spp., alders; *Rhamnus* spp., buckthorns	Neill (2001)
Western white butterfly	*Pieris occidentalis*	Brassicaceae, mustard family	Neill (2001)
Mourning cloak butterfly	*Nymphalis antiopa*	*Salix* spp., willows	Neill (2001)
Regal fritillary	*Speyeria idalia*	*Viola* spp., violets	Nyberg and Haley (2014)
Oregon silverspot	*Speyeria zerene hippolyta*	*Viola* spp., violets	Bartow (2014)
Spicebush swallowtail	*Papilio troilus*	*Persea borbonia*, redbay; *Lindera* spp., spicebush	Hughes and Smith (2014)
Painted lady	*Vanessa cardui*	*Cirsium* spp., thistles; *Urtica* spp. nettles	Janz (2005)
Silver-spotted skipper	*Epargyreus clarus*	*Robinia pseudoacacia*, black locust; Fabaceae, legumes	Weiss and others (2003)

Some native host plants, including milkweeds, are also very good nectar producers (Figure 3A&B). The timing of flowering and therefore nectar production is of critical importance, so select a suite of plants that will provide flowers during the entire season when pollinators are active (Table 2). The CalFlora website contains a wealth of information on nectar plants including a handy pie-chart showing when each species is in bloom (Figure 3C&D; CalFlora 2014).

2.4 Water

Like all organisms, insect pollinators need water for hydration but also for a source of dissolved minerals. Some pollinators, such as several species of mason bees (*Osmia* spp.), require water to make mud structures to rear their larvae (Cane and others 2007). Monarchs and other butterflies obtain water by "puddling" so a source of shallow water should be provided. A recent study found a strong correlation between years of drought

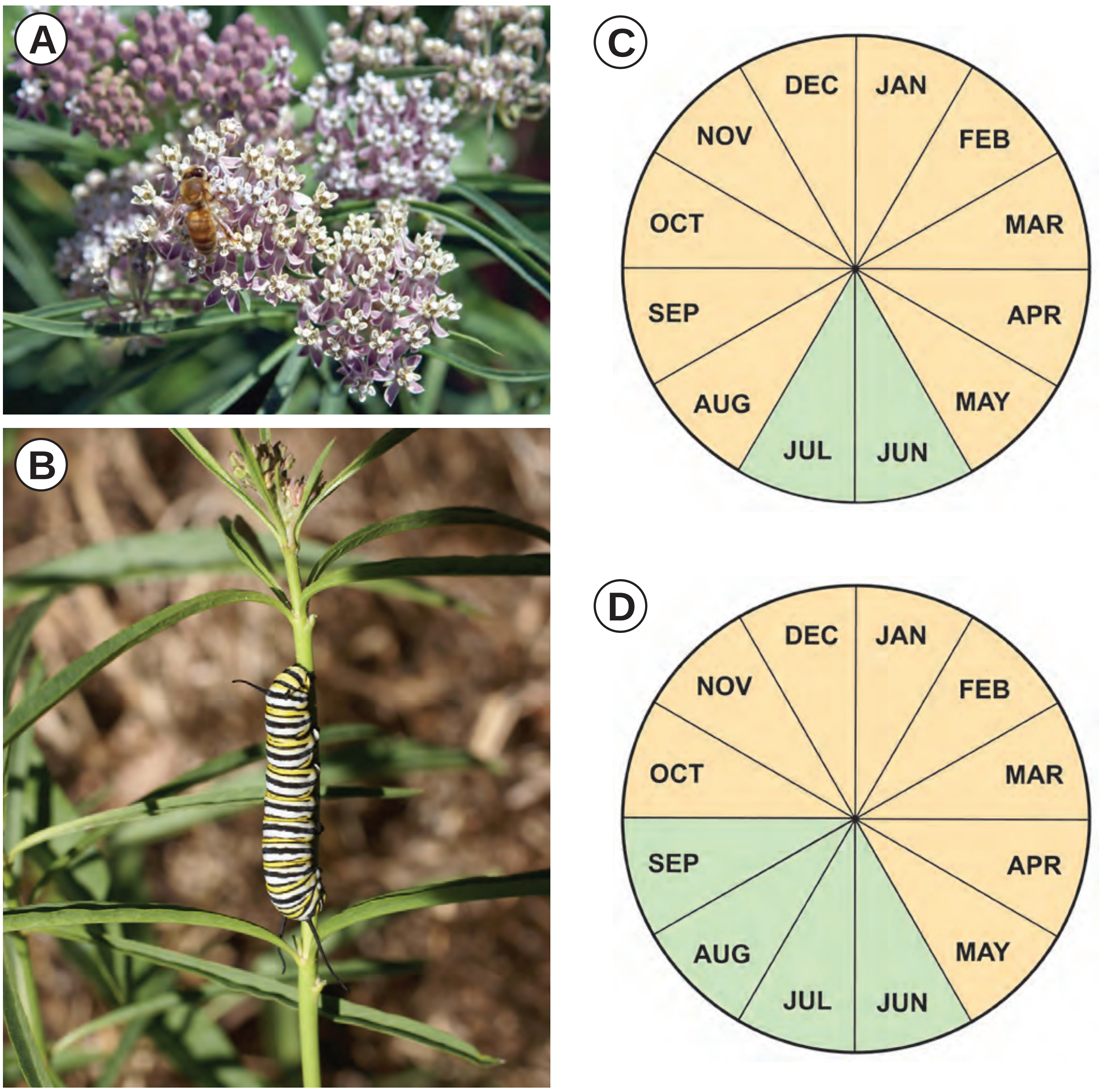


*Figure 3 - Some native plants are both host and nectar plants. The flowers of native milkweeds, such as narrowleaf milkweed (*Asclepias fascicularis*), produce nectar (A) but the leaves also provide food for monarch caterpillars (B). The flowering period for these species varies considerably, however, from 4 to 6 weeks for showy milkweed (*A. speciosa*) (C) to around 4 months for narrowleaf milkweed (D).*

Table 2 – It is important to match the flowering periods of native plants with the activity of pollinators, especially butterflies. Here is an example for the Rogue Valley of south-central Oregon.

Month	Presence of butterflies	Host plants		
		Collinsia grandiflora	*Monardella odoratissima*	*Ericameria nauseosa*
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				

and monarch butterfly population levels in California (Stevens and Frey 2010). Therefore, be sure to provide a water feature in your pollinator garden. Bury a shallow bird bath basin or the saucer of a large pot just below the rim and add some soil and smooth rocks. If you have drip irrigation available, insert a low flow nozzle that will fill the basin until it overflows.

2.5 No pesticides

All pollinators are especially sensitive to any type of pesticide, so keep your pollinator garden strictly organic. Common household pesticides can be deadly to beneficial insect pollinators. For example, "bio-friendly" pesticides containing *Bacillus thurigiensis* should be avoided as they have been linked to monarch mortality (Hellmich 2001). Monarch mortality can be significant in suburban areas with mosquito abatement programs (Oberhauser and others 2006). Neonicotinoids are relatively new systemic insecticides that were thought to be safe for pollinators, but several recent accidents have caused widespread concern. An estimated 50,000 native bumblebees were killed when a neonicotinoid insecticide was applied to control aphids even though the label warned against use during pollination periods (Darcy 2013).

3. Monarch waystations are specialized pollinator gardens

The monarch waystation concept originated with the Monarch Watch program at the University of Kansas (Monarch Watch 2014b,c). Monarch waystations provide milkweed plants to serve primarily as food plants for caterpillars, nectar plants to sustain adult butterflies and other pollinators. Shelter and water (Figure 4A) also promote monarch butterfly breeding and sustain them through their migrations. As of the end of 2013, almost 7,400 waystations have been established and certified by Monarch Watch. Every state except Alaska has certified waystations, but most are in the eastern US (Figure 4B). With the exception of California, most western states need many more waystations. Monarch Watch has also developed a Facebook page for "Milkweeds for Monarch Waystations," which is a great way to keep track of the latest developments.

3.1 Host and nectar plants

Monarch butterflies require two suites of plants: host plants to feed caterpillars and nectar plants to feed adults. Monarch caterpillars feed exclusively on milkweeds (*Asclepias* spp. [Asclepidaceae]) that are named for their milky sap, whereas the adults are generalists, visiting many types of flowering plants to feed on nectar (Brower and others 2006). Information on about 100 milkweed species that are native to North American can be found on the PLANTS database website (USDA NRCS 2014). All milkweed (and a few other genera in the Asclepiadaceae) are potential food plants for caterpillars although some species are less desirable (Oberhauser and Solensky 2006). For eastern monarchs, the most important northern host plant is common milkweed (*A. syriaca*) whereas in the south, zizotes milkweed (*A. oenotheroides*), green antelopehorn milkweed (*A. viridis*) and spider milkweed

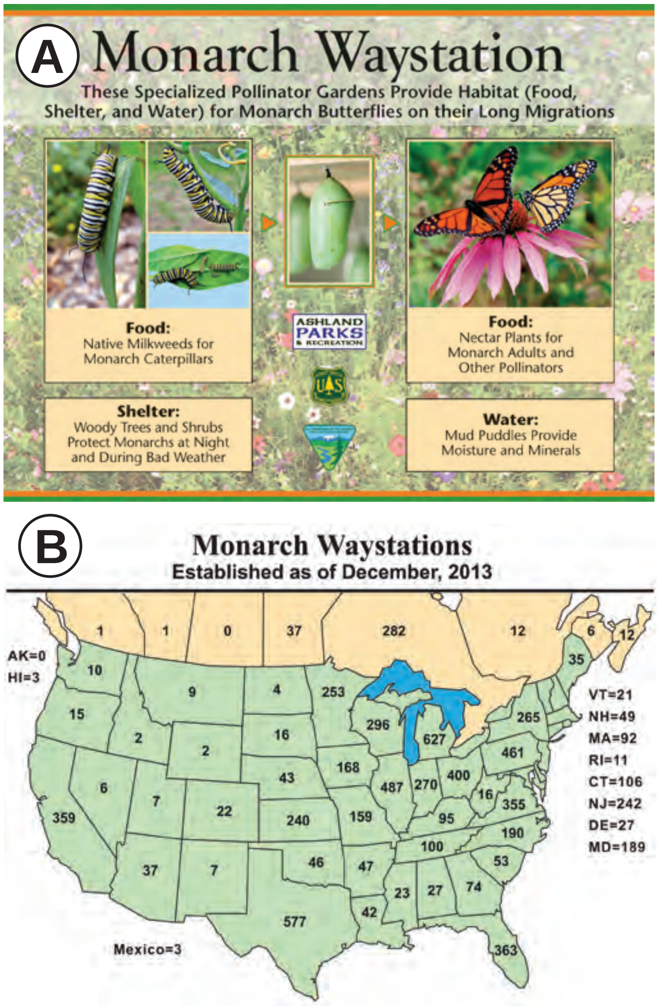


Figure 4 - Monarch waystations are specialized pollinator gardens that provide habitat (food, shelter, and water) for monarch butterflies and other pollinators (A). Monarch Watch originated the Waystation concept and maintains a registry across North America (B). B, from Monarch Watch (2014b).

(*A. asperula*). Western monarch caterpillars are able to feed successfully on showy milkweed and narrowleaf milkweed.

All milkweeds are good nectar producers but their flowering period can vary considerably. Showy milkweed flowers during a relatively short 4 to 6 week period in spring or early summer (Figure 3C), whereas narrowleaf milkweed flowers continually from later spring until early fall (Figure 3D). Nectaring is particularly important during the late summer and fall when the super generation of monarchs begins their long migration south to their overwintering sites. Butterflies convert the sugar to body fat that has to sustain them not only during migration but also at the overwintering sites when most flowering plants are dormant (Alonso-Mejia and others 1997). Joe-pye weed (*Eutrochium maculatum*) is a good choice for much of the US but this genus is not found in Far West or Deep South. Gray rabbitbrush (*Ericameria nauseosa*) is a very common nectar producer that blooms late in the season throughout the western states (Turner 2014). Other important nectar sources during the fall migration include late-flowering genera of the Asteraceae, such as goldenrods (*Solidago* spp.), asters (*Symphyotrichum* and *Eurybia* spp.), gayfeathers (*Liatris* spp.), and coneflowers (*Echinacea* spp.) in the north, and frostweed (*Verbesina virginica*) in Texas (NAMCP 2008).

3.2 Register your waystation

Monarch waystations can provide valuable information for the efforts to restore monarch butterfly populations so please register on the Monarch Watch website (Monarch Watch 2014b). The organization publishes a yearly update on a state-by-state basis, which shows that we have a lot of work to do in some regions, such as the Pacific Northwest (Figure 4B).

4. Propagating nectar plants and milkweeds

Most pollinator plants are grown from seeds, but some can be propagated vegetatively. Some forbs, including milkweeds, can be propagated using "rootstock," which are either fleshy taproots or rhizomes (Dumroese and others 2000). Propagation protocols for many host and nectar plants can be found in the Native Plants Journal and on the Native Plant Network Website (www.nativeplantnetwork.org).

Milkweeds are rhizomatous species and so are particularly well-suited to vegetative propagation; we have discovered that milkweed plants propagated from rhizomes grow much faster and produce larger plants during the first couple of years than those from seeds. This is probably due to the fact that shoots from rhizomes can draw upon moisture and nutrients stored in the rhizome. The details of both seed and vegetative propagation are well documented although some species are much easier to propagate than others (Luna and Dumroese 2013; Landis 2014; Borders and Lee-Mäder 2104). The remainder of this section focuses on milkweed propagation.

4.1 Seed source and seed production areas

Monarch Watch recognizes 73 species of native milkweeds in the United States, but monarchs are only known to use about 30 of these species as host plants. So,

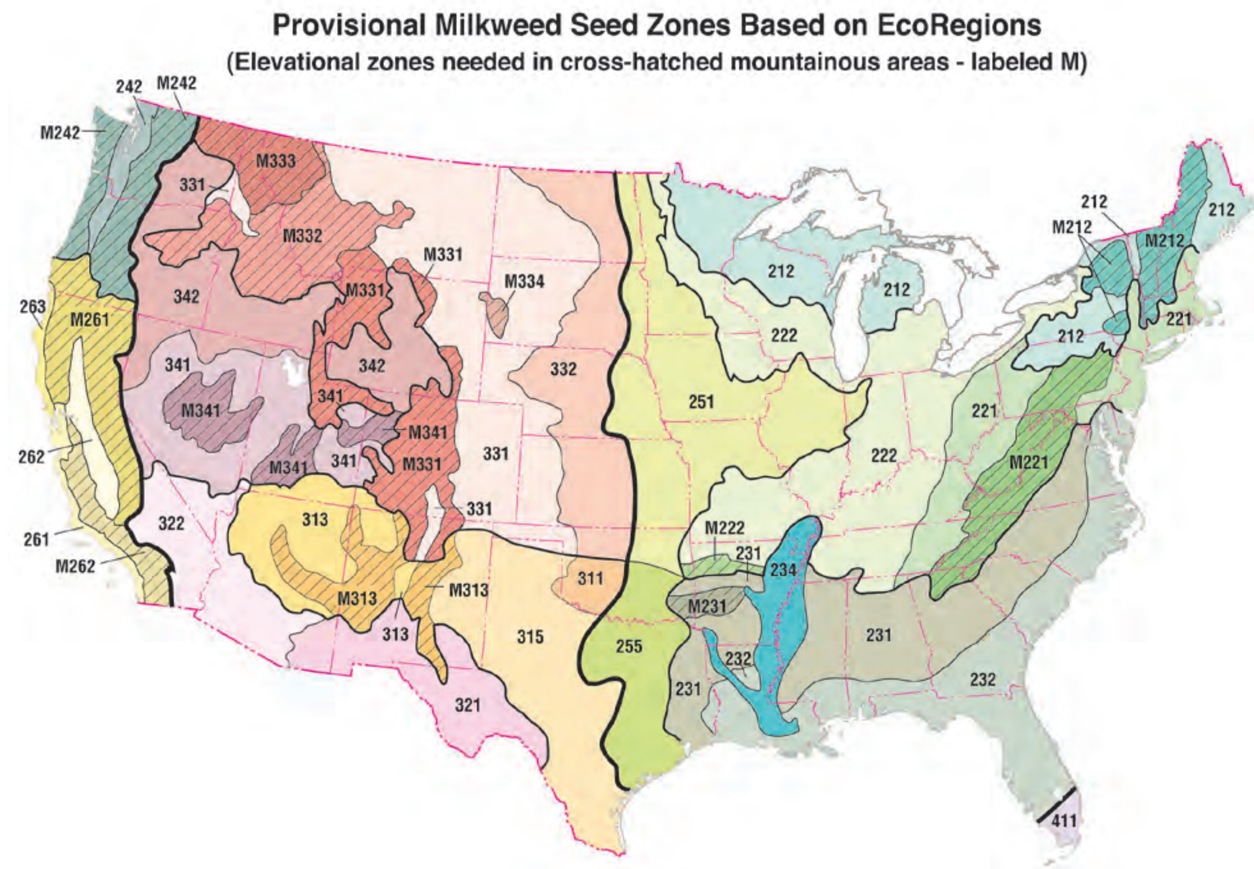


Figure 5 - Provisional milkweed seed zones (Monarch Watch 2014c) based on ecoregions (Bailey 1994).

the first step is to determine which of these milkweed host species occur in your area; helpful state-by-state maps are available on the PLANTS database (http://plants.usda.gov); clicking on the state will take you to the county level. A helpful table with all the milkweed species and the states in which they occur in provided in Appendix 1 of "Milkweeds: A Conservation Practitioner's Guide" (Borders and Lee-Mäder 2014).

Finding source identified, locally adapted milkweed seeds has been a serious obstacle in the past, but efforts are underway to improve this situation. One objective of the Xerces Society's Project Milkweed is to develop local milkweed seed sources (Xerces Society 2013), and they offer a Milkweed Seed Finder feature on their website (http://www.xerces.org/milkweed-seed-finder/). Monarch Watch also has a Milkweed Market that sells seed packets (Table 3) and nursery plants of several species of milkweed (Monarch Watch 2014c). They have developed a milkweed seed zone map for the continental US based (Figure 5), which is based upon ecoregions (Bailey 1994). Milkweed seed sources can also vary with eleva-

*Table 3 - Milkweed (*Asclepias*) species and seed zones currently available from monarch watch (2014c).*

Milkweed species	Seed available for seed zones in Figure 5
Swamp milkweed, *A. incarnata*	221, 222, 231, 315
Common milkweed, *A. syriaca*	222, 231
Butterfly milkweed, *A. tuberosa*	222
Green antelopehorn, *A. viridis*	Western 231, 255
Showy milkweed, *A. speciosa*	331, M331, 342

tion in mountainous areas, which are cross-hatched in Figure 5. For forest trees, elevational seed zones of 500 feet (150 m) are commonly used but nothing is known about the proper elevational zones for milkweeds. For example, along a 30 mile (48 km) transect in southern Oregon, showy milkweed can be found from Gold Hill at an elevation of 1,100 (335 m) feet to Hyatt Lake at 5,100 (1,555 m) feet elevation.

Forest, conservation, and native plant nurseries are well acquainted with the concept of seed zones, and could provide a significant service by establishing seed production areas for local milkweed species on marginal lands around the nursery. By partnering with the Xerces Society and Monarch Watch, this would ensure a long-term supply of source-identified, locally-adapted milkweed seeds. Useful information on establishing and managing milkweed seed production fields can be found in "Milkweeds: A Conservation Practitioner's Guide" (Borders and Lee-Mäder 2014).

4.2 Seed propagation

Although seeds of some milkweed species will germinate without treatment, stratification (cold, moist conditions) improves germination speed and uniformity (Luna and Dumroese 2013). Plants are most commonly grown by direct seeding in containers, although sowing germinants that sprout during stratification would increase seed efficiency and shorten crop cycles (Landis 2014). Propagation protocols for 11 different milkweed species are provided in the Native Plant Network database (for example, Schultz and others 2001). Most nurseries produce milkweeds as container plants, although bareroot beds can yield seeds and rootstock. Direct seeding is best for bareroot production whereas miniplug transplants are an effective way to start bareroot and container stock. Due to their large fleshy rhizomes, milkweed plants do not produce many fibrous roots and will not develop a firm root plug in containers (Figure 6A).

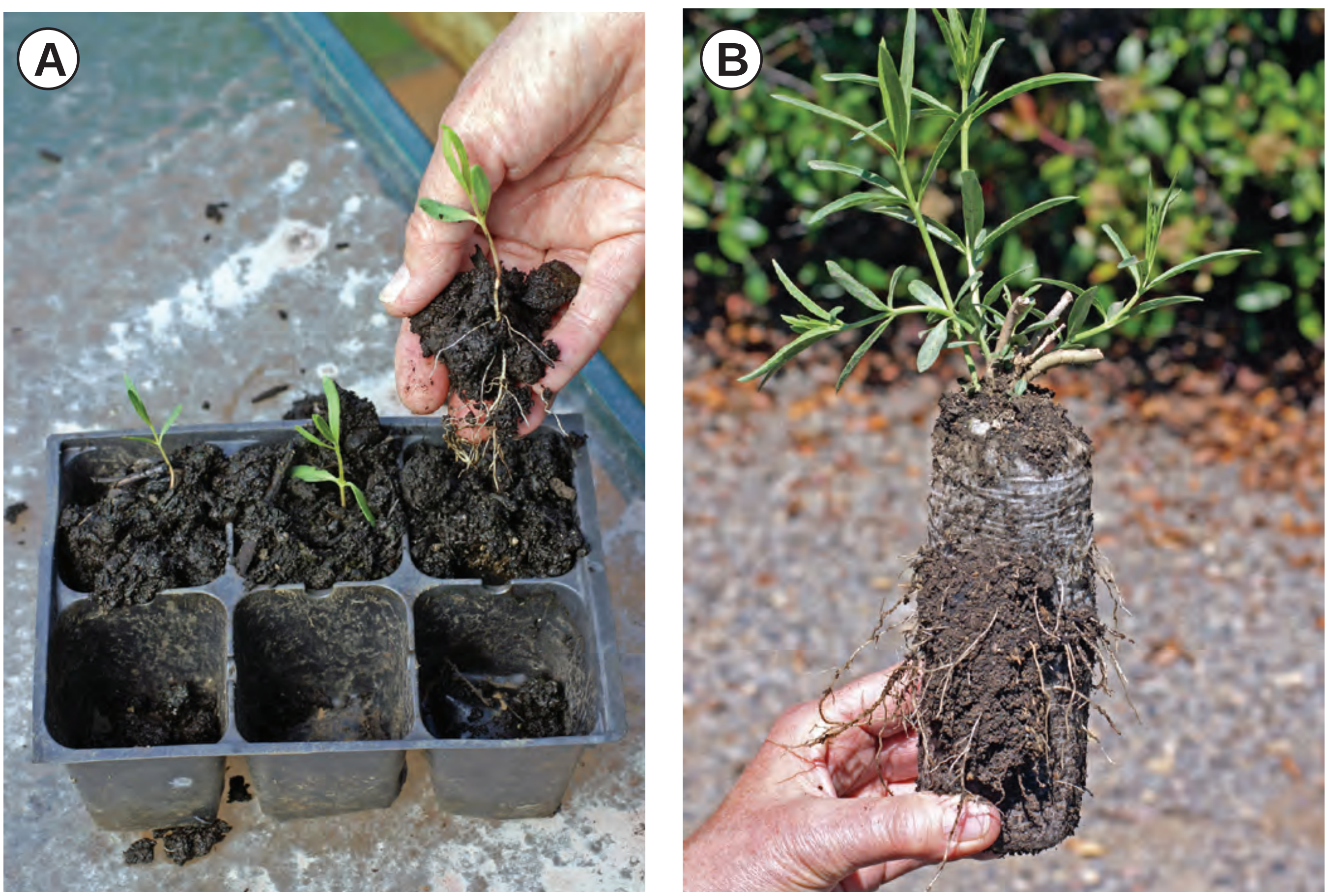


Figure 6 - Due to their rhizomatous nature, milkweeds do not develop many fibrous roots and their root plugs often fall apart during transplanting (A). Therefore, Jiffy® pellets (B) or containers with other types of stabilized growing media are recommended (B).

Sowing seeds into Jiffy® pellets or containers with other types of stabilized growing media is recommended because these products keep the root plug intact regardless of root growth, and allows young plants to be easily transplanted or outplanted (Figure 6B).

4.3 Vegetative propagation

Most milkweed species can be propagated from root cuttings but the process is much more productive for rhizomatous species, such as common and showy milkweed (Luna and Dumroese 2013). Rhizomes have the most stored energy when they are collected during the dormant season but we have had good success propagating from rhizomes during the growing season (Landis 2014). Little has been published about rooting stem cuttings of milkweed but the Live Monarch Foundation reports good success rooting stem cuttings in water with or without rooting hormones. Rooting in Jiffy® pellets also works well with some species (Singer 2014).

5. Summary

Forest, conservation, and native plant nurseries can provide a valuable public service by growing milkweed and other flowering nectar plants that will help create pollinator habitat. Even forest nurseries who primarily grow tree seedlings can convert some marginal land into pollinator gardens. These pollinator gardens could even be expanded to create seed production areas that would provide source-identified, locally adapted seeds for their local communities. Tom has been giving "milkweeds and monarchs" workshops in southern Oregon and the positive public response has been amazing. So, creating monarch waystations and other pollinator garden is a "white hat" activity that can only reflect positively on your nursery, and may create other marketing opportunities. To those of us who care deeply about the environment, it is nice to have a project where we can truly make a difference. So many times, we end up thinking "but, what can one person do?" Growing milkweeds and other native plants and establish pollinator gardens is a simple, but effective way to do something positive for our world.

"I have to believe that we can have an impact if we get the gardeners in this country to help us out by planting milkweed and putting in native plants to stabilize native pollinator communities."

— Chip Taylor as quoted in Conniff (2013) —

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Integrated Pest Management – An Overview and Update

by Thomas D. Landis and R. Kasten Dumroese

Integrated pest management, better known as IPM, is a familiar term for those of us working in forest, conservation, and native plant nurseries. An almost synonymous concept is "holistic pest management" that has been the topic of chapters in recent Agriculture Handbooks that would be useful to growers of native plants (see Landis and others 2009; Landis and others 2014). Let us take a quick look at its history and a more in-depth look at applying the concepts.

1. Brief history and definitions

Pests have been around since humans first domesticated crops, which explains the origin of the "pest" concept—any organism that interferes with society's objectives. The Sumerians, who lived in Mesopotamia around 2,500 B.C., were the first to use pesticides. They applied sulfur dust to control insect pests on their grape crops and, closer to our hearts, the Sumerians were the first people to make beer. Around 300 B.C., the Chinese encouraged natural enemies to control crop pests and by 1,100 A.D. they were using soaps as insecticides (Frazier 2014).

Moving ahead to the 1930s, a revolution in pest control occurred when dichloro-diphenyl-trichloroethane, better known as DDT, became the first synthetically produced pesticide. Due to its successful use during World War II to control malaria and typhus among troops its discoverer, Swiss chemist Paul Hermann Müllerg, was awarded the Nobel Prize in Medicine in 1948 (Encyclopedia Britannica 2014). After the war, DDT was widely used as an agricultural and domestic insecticide; it was so effective against mosquitoes that it was routinely sprayed with fogging equipment along municipal streets in the 1950s. It was not long, however, until people began to notice some unforeseen drawbacks to the use of DDT. In 1962, Rachel Carson wrote her environmental classic Silent Spring, which chronicled the adverse impacts of DDT spraying and suggested that the indiscriminate use of DDT was responsible for the death of many birds as well as a possible cause of cancer. This expose resulted in her receiving death threats from chemical companies but generated such a public outcry that DDT was eventually banned from agricultural use in the United States (Frazier 2014).

About that same time at the University of California, a team of entomologists developed the concept of "Integrated Control," which advocated a combination of chemical and biological controls. Integrated control also stressed regular monitoring and introduced the economic threshold for determining when any control is warranted (Warnert 2009). In the years that followed, integrated control was applied to all types of pests and included other tactics such as cultural controls. This more comprehensive concept became known as integrated pest management (IPM). In 1972, President Nixon signed a law that made IPM a national policy and the US Department of Agriculture created IPM programs at state Land Grant universities. Nixon also established the US Environmental Protection Agency that is responsible for reviewing Environmental Impact Statements of other federal agencies (US EPA 2014).

2. Working definition of IPM

IPM is one of those concepts that can mean many things to different people, and much has been written about procedures that just are not practical. An operational IPM program is based on an awareness of potential pests and regular monitoring (scouting). Controls are only applied when damage reaches an intolerable level (economic threshold), and a combination of cultural, biological, and chemical tactics are employed (Alston 2011a; Figure 1). The least toxic chemical that will control the pest is applied only as a last resort (Olkowski and others 1991). IPM programs can target a single species, for example, Fusarium root disease (James and others 1990) and lygus bug (*Lygus lineolaris*) (Bryan 1989), or an entire nursery program (for example, Dumroese and Wenny 1992).

2.1 Based on prevention

One of the first conceptual breakthroughs to using IPM is that the emphasis is on prevention, rather than eradication. For nursery pests such as grey mold, which is caused by the fungus *Botrytis cinerea*, the spores are

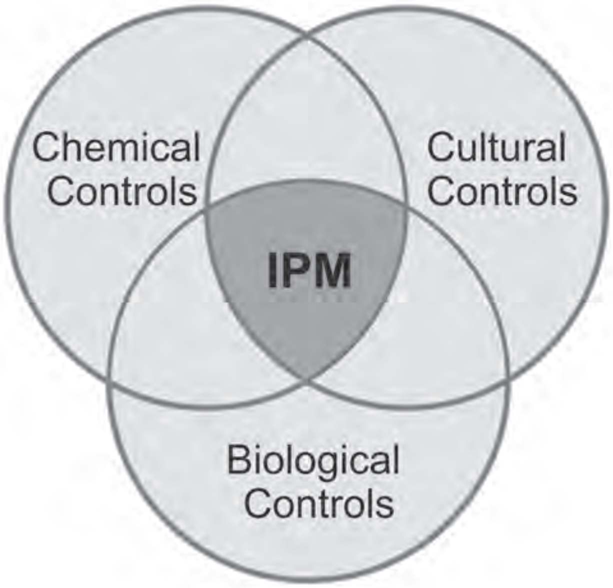


Figure 1 - Integrated pest management uses a combination of cultural, biological, and chemical controls.

always present because this fungus grows on many common weeds. Because it is an excellent saprophyte, grey mold typically gets established on the senescent foliage that develops in dense nursery crops as larger and younger foliage shades out the older cotyledons and primary foliage (Landis and others 1990). Because it also rapidly invades any damaged or stressed tissue, it is impossible to completely eliminate grey mold from your nursery.

2.2 Use least toxic chemicals as a last resort

Damping-off is another fungal disease that has always been common nursery pest (Landis 2013a). Before IPM, controlling a disease like damping-off typically meant spraying chemicals on seedlings that are probably already infected. Many pesticides are labeled for damping-off fungi but they only function as preventative chemicals and cannot cure infected seedlings. Many nurseries just routinely apply pesticides to prevent damping-off because they consider these chemical treatments as cheap insurance. However, the only true way to find out if these protective pesticide applications are effective is to not apply them to part of a crop as a control treatment (Figure 2). You might just find that they are unnecessary. During a 5-year period at the University of Idaho Center for Forest Nursery and Seedling Research, the percentage of container seedlings acceptable for shipment remained constant or even increased slightly when protective pesticide applications were reduced (Dumroese and others 1990). During this same period, the nursery also increased the total number of seedlings produced by 60%, showing that IPM can be scaled up as nurseries expand.

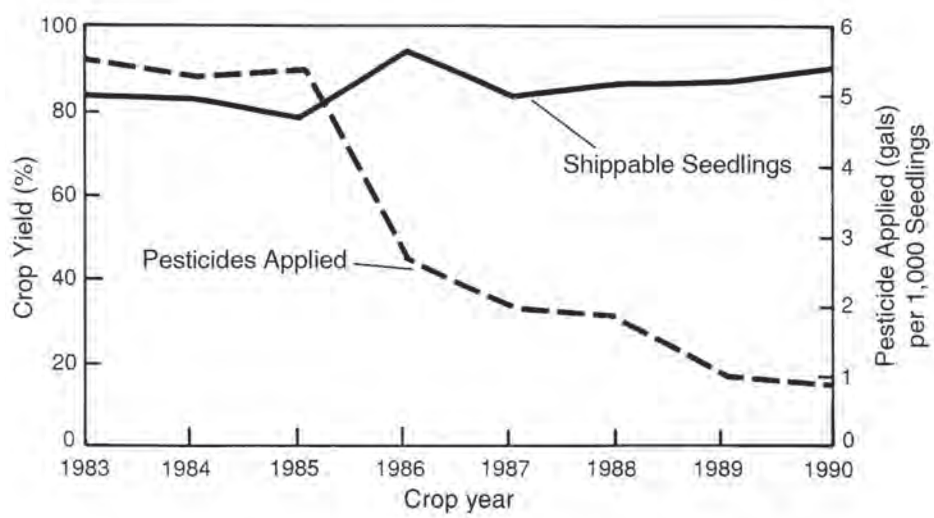


Figure 2 - The true test of whether protective pesticide applications are effective is to stop applying them for a period of time (modified from Dumroese and others 1990).

3. IPM is a systems approach, rather than an incident approach

For an IPM program to be effective, it should be applied as a systems approach rather than a "knee-jerk" response. A comprehensive discussion of a systems approach to managing ornamental nursery pests based on a hazard analysis of critical control points is presented by Parke and Grünwald (2012). A simple but effective systems approach to IPM consists of 6 sequential steps.

3.1 Be vigilant—assign scouting responsibilities

Because an effective IPM program is based on early detection and control, the entire nursery workforce should receive regular pest training so that they are constantly looking for problems. Although all workers must be alert for pests, the best procedure is to designate scouts whose primary responsibility is to monitor for any growth abnormalities. A good disease scout should have the following characteristics:

Experience. Scouts should have extensive experience is all phases of the nursery system, and be knowledgeable of the growth phases of all the crops so that they can quickly spot when something is out of the ordinary. Experienced nursery workers, such as irrigators or inventory personnel that are regularly out in the crop, make the best scouts. After several seasons of working with crops, scouts will further refine what is normal and what is not. Scouts should have access to current and past growth records so that they can make comparisons and detect when things just are not looking right.

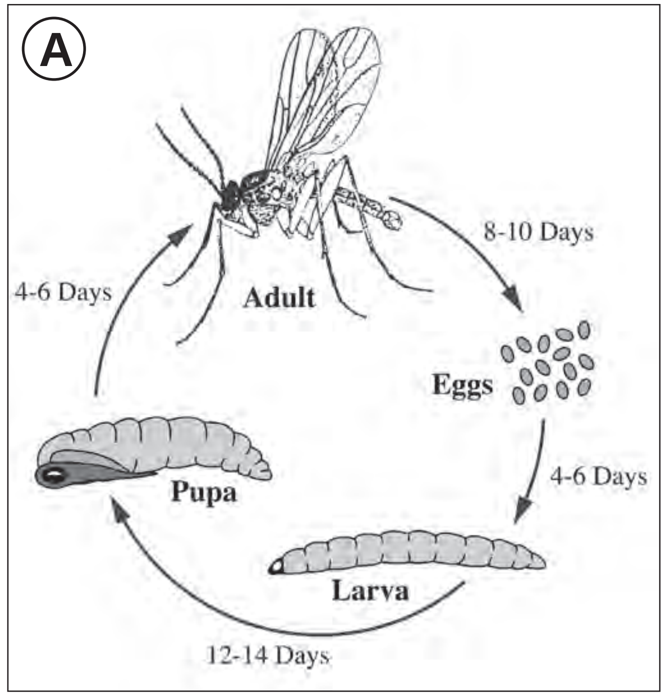
Observant. Scouts must be patient and take the time to look at each crop, and be inquisitive enough to check into any growth abnormalities. Allow scouts to have a flexible work schedule so that they can come into the nursery before and after normal working hours, and occasionally on weekends. Being away from the pressure of nursery work projects eliminates distractions and allows time for patient observation.

Well-trained. Scouts should be trained in disease diagnosis and identification, and be allowed to attend training sessions. Scheduling visits to other nurseries and talking to other nursery workers is a great way to learn and share experiences.

3.2 Identify pests promptly and accurately

"Know Your Enemy" is one of the major precepts in the classic book *The Art of War* that was written by Sun Tzu, an ancient Chinese military strategist. The analogy works for nursery pests too. All nursery workers should be given regular training on what pests could occur and the type of damage to look for. Understanding the life cycles of nursery pests is critical to good IPM. For example, fungus gnats (*Bradysia* spp.) are a common greenhouse pests that can affect many different greenhouse crops. Scouts must realize that the adult fungus gnat may be a nuisance but the larvae are what cause damage (Figure 3A) by eating seeds and fine roots of seedlings (Landis and others 1990). Scouts must be able to distinguish between adult fungus gnats and harmless shore flies (*Scatella* spp.) (Figure 3B), and realize that damaging populations of fungus gnats are usually an indication of excessive, and wasteful, irrigation.

Many nursery problems can be diagnosed by unique signs and symptoms but this is not the case with the newest and most serious nursery disease, *Phytophthora ramorum*. Signs and symptoms of this fungus-like pest are can vary considerably among hosts and are impossible to distinguish from other plant pathogens (including other *Phytophthora* species), insect damage, or abiotic injury (Kliejunas 2010). The presence of the pathogen can only be confirmed by experts using sophisticated and specialized techniques (Landis 2013b). This stresses the fact that good nursery scouts must know when to ask for expert advice.



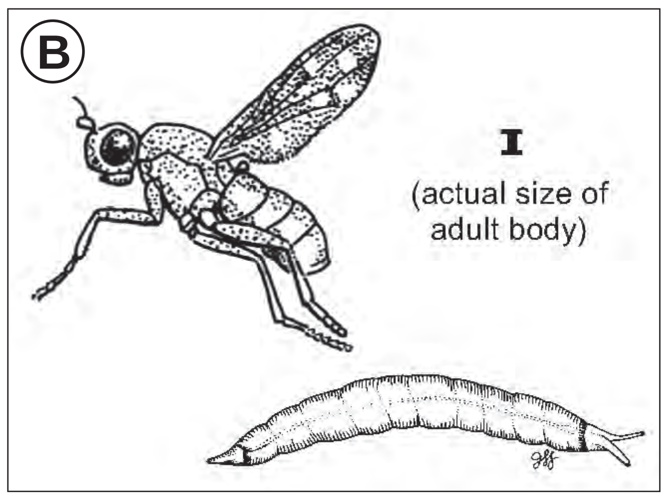


Figure 3 - Fungus gnats are common nursery pests, but understanding the life cycle (A) is critical to good IPM. A Y-shaped wing vein distinguishes common fungus gnats from other common small greenhouse flies (B) that may be a nuisance but don't damage seedlings (modified from Bethke and Dreistadt 2001).

3.3 Monitor your crops and keep good records

Monitoring your crop by using history plots can serve many purposes in the nursery, but one of their best uses is to detect and diagnose problems. These plots can be established in portions of bareroot seedbeds or container tables and can help identify when losses occur (for example, during specific growth phases) and focus observations to find the cause (see Landis 1997 for establishing history plots). Sometimes, history plots will reveal the cause of poor seedling growth may not be a pest. Often, for example, the first symptom that something is wrong is that plants don't grow or develop at a normal rate. This hidden stunting is not diagnostic in that it cannot identify the specific problem, but it is an early "heads-up". The only way that this stunting can be diagnosed is by taking good growth measurements from history plots, charting them manually or by computer, and then comparing current growth rates with those from previous crops. As an example, when a crop of blue spruce (*Picea pungens*) container seedlings showed early stunting compared to past crops, switching to a high nitrogen fertilizer at week 8 solved the problem (Figure 4). Note, however, that crops response was not immediate but the additional fertilizer took another 4 weeks to increase the shoot growth rate.

Another example is lygus bug, where critical observations recorded for consecutive years on pest occurrence and seedling damage identified the specific interval in the pine crop cycle when damage was likely to occur. Then, pesticide applications could be applied during the most opportune time to prevent damage, which was subsequently reduced from 17 to 6% (Bryan 1989).

3.4 Prevent pests through strict sanitation

The old adage "prevention is the best cure" certainly applies to nursery pest problems. The simplest approach to pest prevention is to make a list of your most significant nursery pests, and do some research into how they occur. Then, you can develop techniques to keep them from entering or spreading in your nursery. A wealth of good information has been published about nursery pests. For example, Forest Nursery Pests (Cram and others 2012) contains excellent information on the most common pest problems that you might encounter in your nursery, and well as other useful information on diagnosis and integrated pest management.

A more systematic approach to pest prevention is to develop a hazard analysis of critical control points (HACCP). A control point is any step in a production system that can be measured, monitored, controlled, and corrected, and a critical control point is the best step at which significant hazards can be prevented or reduced. The HACCP system consists of a series of logical steps to identify, evaluate, and correct sources of hazards (USFDA 2012). The HAACP approach has been developed to prevent the spread of pests and diseases in ornamental nurseries in Oregon (Parke and Grunwald 2012), and the same concepts can be applied in forest, conservation, and native plant nurseries.

A good bareroot nursery example of how the HAACP process can be applied is the transplanting operation. The introduction of transplants has been shown to be a significant risk for introducing pests, especially root rot

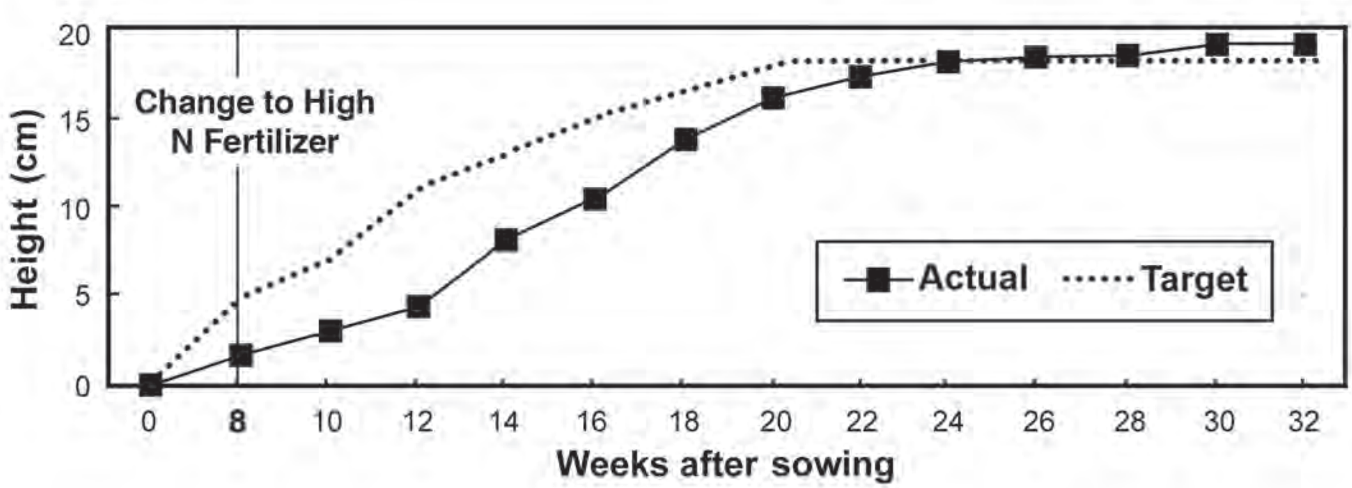


Figure 4 - Early stunting of this blue spruce container crop was only diagnosed by comparing the shoot growth to target growth curves, which were developed from past crop performance (modified from Landis and others 1999).

fungi, into the transplant nursery. The major problem is when bareroot seedlings are transplanted into another nursery (Cram and Hansen 2012); the risk of spreading root disease on container transplants is much less because of sterile growing media. So, in a typical transplanting operation, there are 2 critical control points (Figure 5A). First, the transplant stock; many nurseries either purchase seedlings for transplanting from other nurseries or they are supplied by a customer. It is very easy for pathogenic fungi to be transported on small soil particles adhering to the roots. Second, root rot fungi and nematodes can also be introduced into a bareroot nursery on cultivation or transplanting equipment. For this reason, nursery managers insist that operators clean and sterilize their equipment (Figure 3C) when it is moved from one field to another, and especially when equipment is leased or borrowed from other nurseries.

3.5 Keep crops healthy

Another important aspect of IPM is that many nursery problems can be avoided just by keeping your plants healthy. Vigorous nursery stock is much more resistant to pests, and also recovers more rapidly from environmental stresses. Root diseases are an excellent example. Although they frequently occur in bareroot and container nurseries, most common root disease fungi, such as *Pythium* spp., *Fusarium* spp., and *Cylindrocarpon* spp., are not aggressive pathogens. In a comprehensive study of *Fusarium* species on damping-off and root disease of Douglas-fir seedlings, the common nursery pathogen *F. oxysporum* only had an average rating of around 5 on a pathogenicity scale of 1 to 10 (James and others 1989). In Sweden, the fungal pathogen *Cylindrocarpon destructans* causes root rot problems of container pine seedlings. Researchers discovered 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). Predisposing environmental factors are also important in bareroot nurseries. For example, Fusarium root disease only developed where tillage pans, caused by rotary cultivators, impeded water drainage and predisposed the seedlings to invasion by the pathogen (Juzwik and others 1998). Therefore, because opportunistic pathogens do not cause disease unless seedlings are under stress (Figure 6), it only makes sense to keep your crops healthy.

Your seedlings may not be healthy just because you don't see symptoms. Even though root pathogens, such as *Fusarium* and *Cylindrocarpon*, may not cause

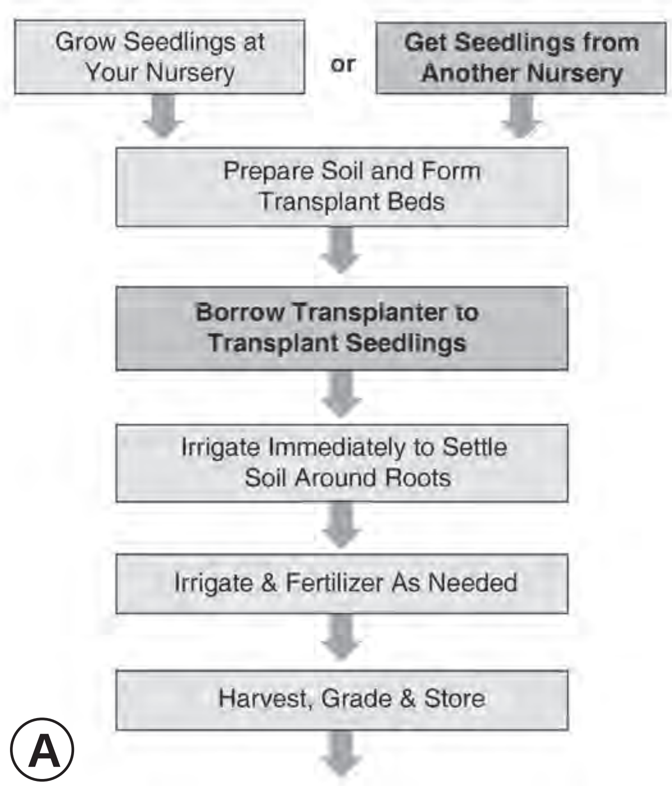


Figure 5 - Root rot fungi can easily be introduced into your nursery during transplanting so a hazard analysis should examine each step in the operation (A). The critical control points are when seedlings are purchased from another nursery, or when equipment carries infected soil from another location (B).

typical disease symptoms, such as shoot chlorosis or necrosis, they may still be reducing seedling growth. Dumroese and others (2002) found that containers reused for several growing seasons without proper sanitation allowed inoculum levels to increase and this was, despite no typical root rot symptoms, associated with significant reductions in growth and an increase in culls. Seedlings in containers that had been used for 5 crops but treated with hot water to remove inoculum were 16% taller with 10% more stem diameter and, 13% more seedlings made specification compared to those growing in non-sanitized containers.

3.6 Encourage beneficial organisms

One way to keep your crops healthy is to foster beneficial microorganisms, such as free-living fungi antagonistic to pathogenic fungi, helpful soil bacteria, and mycorrhizal fungi. Soil fungi, such as those in the genus *Trichoderma*, can help protect seedlings against root disease (Mousseaux and others 1998; Dumroese 2008) and several *Trichoderma*-based products are available commercially. The beneficial relationship between mycorrhizal fungi and nursery crops has been well known for more than 100 years (Koide and Mosse 2004). Healthy mycorrhizae confer many advantages to nursery crops including increased access to water and mineral nutrients but the one that is often overlooked is disease prevention (Whipps 2004). Microbial relationships in the rhizosphere often involve one or more "helper bacteria" that stimulate mycorrhizal formation with partner fungi (Garbaye 1994). Mycorrhizal fungi can protect roots against fungal pathogens and nematodes in four different ways (Marx 1972):

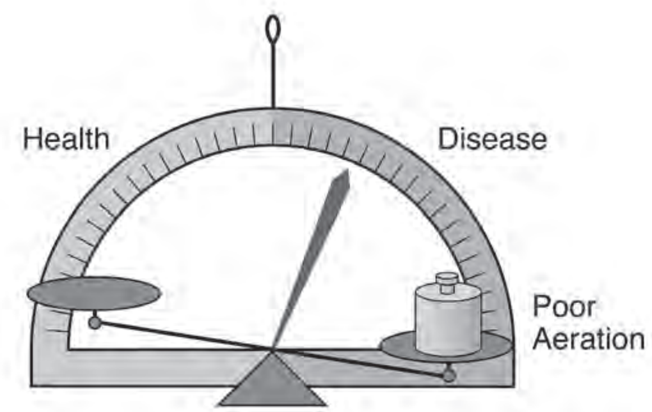


Figure 6 - Many nursery diseases are caused by environmental stresses, which stress plants and make them more susceptible to opportunistic pests. In this example, compaction of the soil or growing medium reduces aeration and provides an entry point for root diseases (Landis 2000).

Pathogen exclusion. This is the best known and most obvious benefit and is most easily seen with ectomycorrhizae that form a protective sheath around plant root tips (Figure 7). When young seedlings are inoculated with mycorrhizal fungi at the time of germination, a fungal mantle surrounds plant root tips and prevent damping-off during establishment, and root rot fungi later in the growing cycle. For example, when red pine (*Pinus resinosa*) container seedlings were inoculated with the mycorrhizal fungus, *Paxillus involutus* and subsequently with *Fusarium oxysporum*, damping-off disease was effectively prevented (Table 1) and seedling growth improved (Chakravarty and others 1990).

Enhanced plant vigor. Mycorrhizal fungi help produce larger, healthier seedlings that will be more resistant to pathogens and environmental stresses. For example, broadleaf tree seedlings inoculated with appropriate ectomycorrhizal fungi were better able to maintain physiological activity during water stress

Table 1 – Red pine seedlings inoculated with mycorrhizal fungi were protected from a subsequent inoculation with the fungal pathogen Fusarium oxysporum *(modified from Chakravarty and others 1990).*

Seedling characteristics	Non-mycorrhizal control	Pre-inoculated with *Paxillus involutus* mycorrhizae
Mortality (%)	40	0
Shoot height (cm)	3	6
Root length (cm)	5	14
Shoot dry weight (mg)	200	610
Root dry weight (mg)	92	251
Total dry weight (mg)	291	862
Mycorrhizal roots (%)	13	90

compared to non-inoculated plants (Fini and others 2011).

Production of antibiotics. Mycorrhizal fungi have also been shown to produce chemicals that repel pathogenic fungi. For example, the ectomycorrhizal fungus *Leucopaxillus cerealis* was found to produce antibiotics that were effective in controlling infections by the root pathogen *Phytophthora cinnamomi* (Marx 1970).

Mycorrhizae are not a pesticide (legally). A final reason why you probably haven't heard about the IPM benefits of mycorrhizal fungi is that the complicated and expensive legal requirements for pesticide registration are the main reason that mycorrhizal inoculum may never be considered a pesticide (Whipps (2004).

3.7 Apply timely and appropriate control measures

One of the key tenets of the IPM approach is that no control measures should be initiated until pest damage has reached a point where significant economic damage is occurring (Alston 2011b). This "economic threshold" was first applied with insect pests where population levels could be easily monitored and then correlated with economic damage. The economic threshold must be determined for each different pest and, for relatively minor problems, may never be reached. Most nurseries utilize an oversow factor of 5 to 10% to account for these minor losses (Thompson 1984). For particularly aggressive pathogens like *Phytophthora ramorum* that require quarantine, however, the economic threshold is zero. Once this pest is detected in a nursery, their crops are subject to rigorous testing and restrictive and expensive quarantine measures must be implemented (Suslow 2006). Determining economic thresholds for your nursery and your crops is a good opportunity to fully assess your overall cultural program in context with pest management. A list of nursery-specific pests, threshold levels, and control measures can then be made (Table 2).

Table 2. Examples of pest threshold damage levels and subsequent treatments (modified from Dumroese and Wenny 1992).

Pest	Pest attributes	Damage threshold	Preventative treatment(s)	Treatment(s) when threshold surpassed
Mice	Eat freshly sown seeds. Clip seedlings in fall for bedding.	Any damage exceeds threshold.	Maintain vegetation-free and junk-free buffer zone around greenhouse and headhouse.	Continual baiting and trapping.
Fungus gnats	Larvae feed on organic matter and seedling roots.	Ten adults per block per week.	Set out yellow sticky-cards to trap and monitor adults.	Reduce irrigation frequency if possible. Soil drench with parasitic nematodes once each week for 3 consecutive weeks.
Algae	Algae on floor makes them hazardous to employees and guests.	More than 20% of area is covered.	Power-scrub floors each spring to remove build-up from previous crop.	Treat floors with diluted bleach solution and/or power scrub.
Damping-off	This disease is often an association of many fungi.	15% of the trays in a seedlot have 3 to 5% of their cells with disease.	Surface sterilize seeds before stratification with a bleach solution. Rogue dead and dying seedlings to prevent spread. Refrain from excessive irrigation and avoid high rates of nitrogen fertilizer during germination.	Treat affected seedlot with fungicide.

Table 3 - Pesticides and modes of action for controlling fungus gnats (modified from Fisher and others 2006).

Trade name	Active ingredient	Type of pesticide
Traditional pesticides		
DuraGuard™	Chlorpyrifos	Contact Insecticide
Adept®	Diflubenzuron	Growth regulator
Distance®	Pyriproxyfen	Growth regulator
Marathon®	Imidacloprid	Systemic insecticide
Citation®	Cyromazine	Growth regulator
Safari™	Dinotefuran	Systemic insecticide
Organic pesticides		
Azatin®	Azadirachtin	Growth regulator from neem
Nemasys®	*Steinernema feltiae*	Parasitic nematode

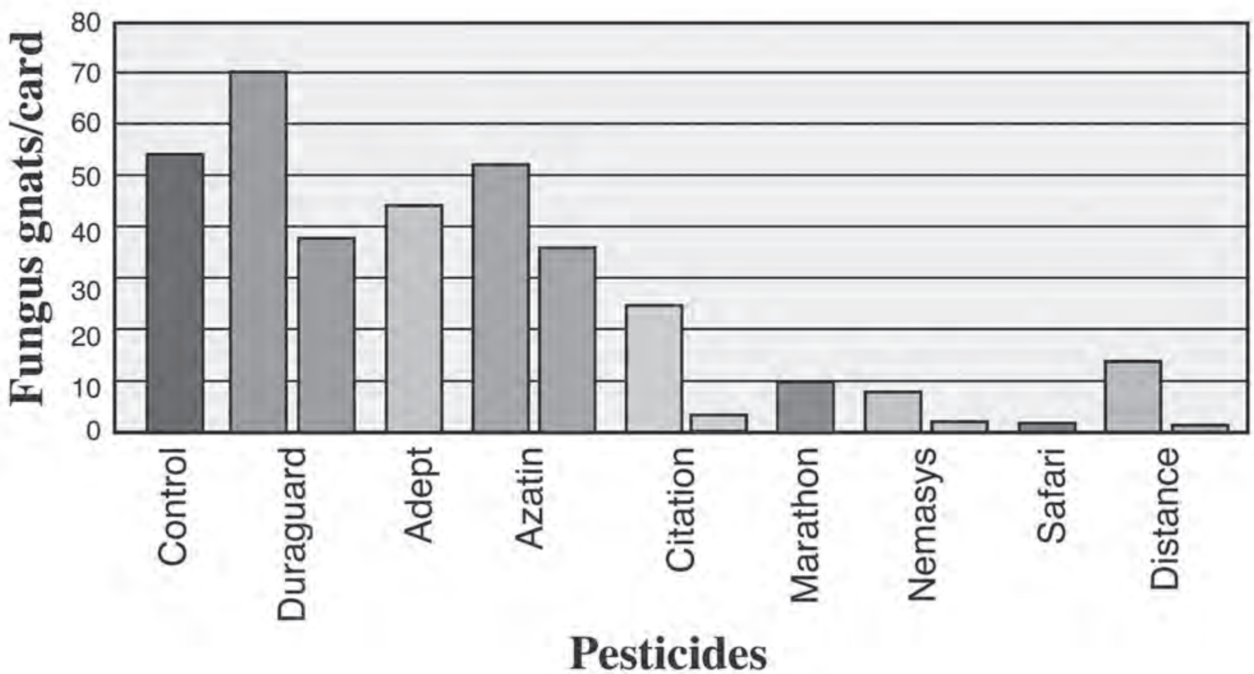


Figure 8 - Pesticide efficacy for fungus gnats after 1 or 2 drenches (modified from Fisher and others 2006)

Pesticide mode of action. Each pesticide has a unique mode of action that must be considered when developing an IPM program. For example, a range of pesticide drenches was tested as a control for fungus gnats; their modes of action ranged from contact and systemic pesticides, growth regulators, and biocontrol agents (Table 3). While one application of a chemical insecticide (Safari™) was the most effective, a biocontrol that consisted of parasitic nematodes (Nemasys®) was equally effective after two applications (Figure 8). To achieve a goal of minimal chemical use, side-by-side comparisons such as this are critically important.

Timing of pesticide application. The timing and frequency of pesticide applications must coincide with the damage threshold (Figure 9). Applying pesticides too early (A) is uneconomical, whereas applications when pest levels or economic damage have reached a critical point (B) are ideal. Applying "revenge" pesticide treatments when pest populations are already declining (C) may make growers feel better but are a waste of money as serious damage has already occurred. In other words, the cost of the chemical and labor to apply it may be greater than the cost of the damage caused by the pest if the economic threshold is not crossed. And, similarly, applying revenge treatments is just wasting money because the damage is done and the financial lost already incurred.

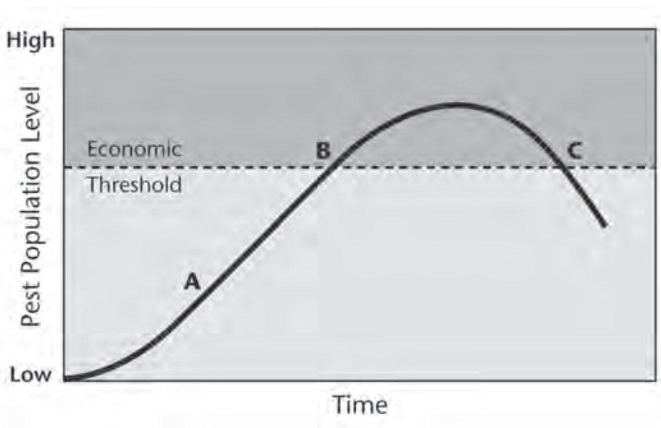


Figure 9 - Pesticide applications should be made based on when crop damage reaches the economic threshold: Application A is too early, Application B is perfect, Application C is too late ("revenge treatment") (modified from Daar and others 1992).

4. Developing and following an IPM plan

Developing an IPM program for each nursery pest is a systematic approach that is effective and economic. Many nursery managers already practice IPM without formally calling it that. IPM is a management philosophy that reflects the goals and values of the nursery manager; therefore, it is impossible to provide an IPM "recipe" for all nurseries as each nursery has unique goals and different ideas of what constitutes acceptable pest populations or economic damage thresholds (Dumroese 2012). An IPM plan should be dynamic, evaluated and updated each year as more data becomes available from history plots, new pests emerge, and new control methods become available.

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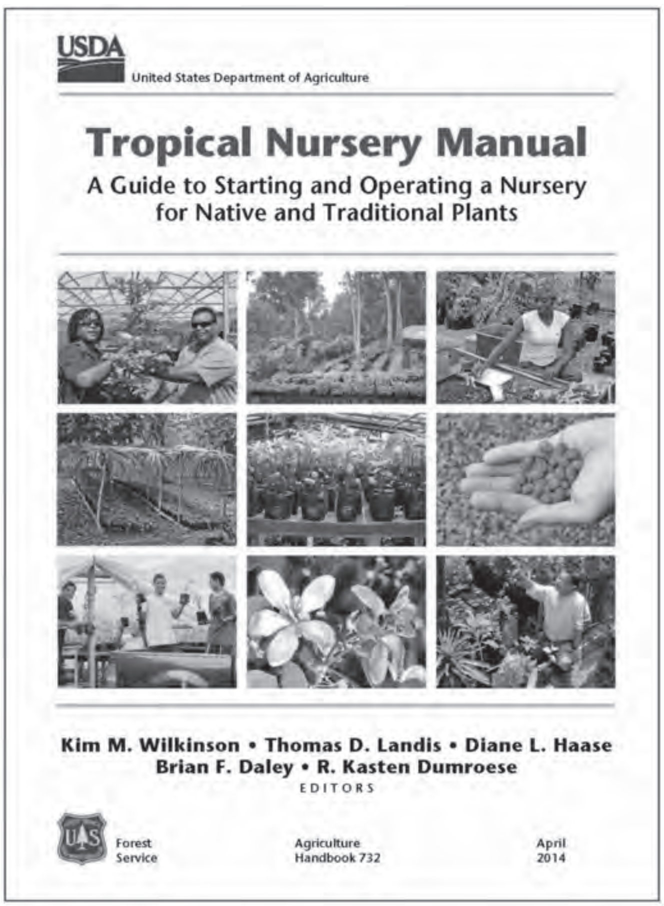

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This Tropical Nursery Manual serves people who are starting or operating a nursery for native and traditional species in the tropics. Key concepts, principles, and processes are presented, based on proven practices and the best science available. Understanding these concepts and principles will make it easier to operate a nursery successfully, and to meet project objectives in the field. Topics covered include nursery planning, plant propagation, crop production, plant care, outplanting, and ongoing learning.

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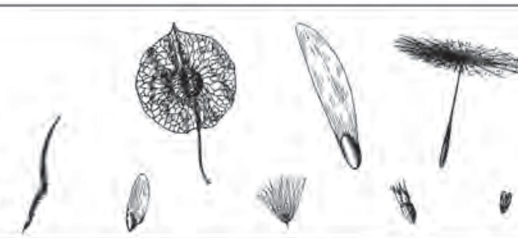

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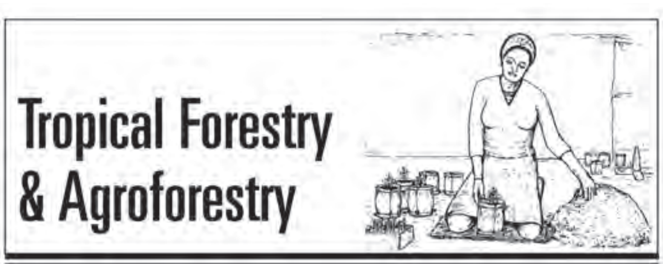

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Contact Information for Reforestation, Nurseries, and Genetic Resources (RNGR) Team http://www.rngr.net		
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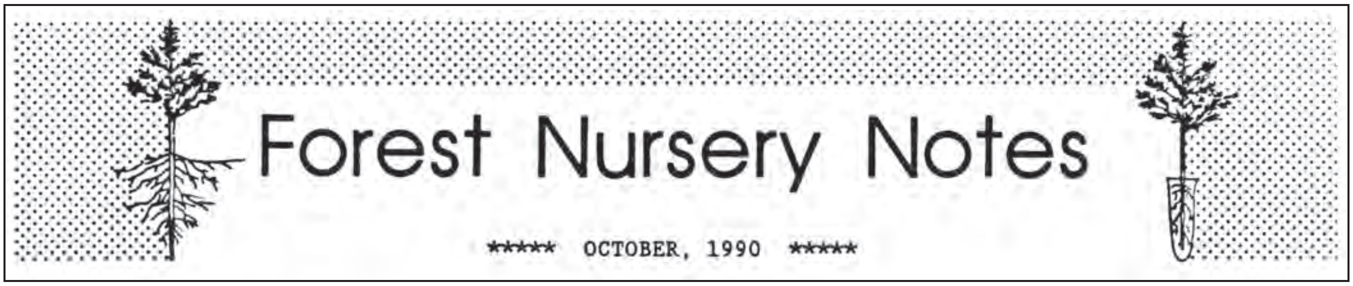
• Technical Assistance to Native Americans regarding Nurseries, Reforestation, and Restoration • Proceedings of Nursery Meetings	US and International	**Jeremy Pinto** USDA Forest Service 1221 S. Main Street Moscow, ID 83843 TEL: 208.883.2352 • FAX: 208.883.2318 E-Mail: jpinto@fs.fed.us



FNN—Where We've Been and Where We're Going

Well, it's been over 30 years since I decided to start this nursery news and information service, and it has been an interesting and rewarding experience. The idea for FNN developed when I was working at Mt. Sopris Nursery in the mountains of Colorado. I felt technologically isolated and so as one of my first technology transfer efforts, I decided to try a fix that problem. The early issues of FNN were just a list of recently published articles that I felt would be of interest to nursery managers. Subscribers could order hard copies of any of the articles to increase their libraries.

The next FNN step upgrade was to write review articles about subjects that I thought would be relevant to nursery and reforestation folks. In the April, 1986 article, I wrote an article on sporotrichosis and the number and variety of articles increased in future issues. You can search for articles on these and other subjects back through 1993 on the Reforestation, Nurseries, and Genetic Resources website: www.rngr.net.

Many of my FNN articles were triggered by questions from folks like you, and I'm always looking for new ideas for articles. So, I've added several lines on the bottom of the Literature Order Form so that you can send me your ideas.

The FNN mission has always been to provide easily understandable and readily appliable information for people working in forest, conservation, and native plant nurseries or those that use these plants in reforestation or restoration. We're considering establishing a blog on our website where you can ask questions and receive information on specific subjects of interest. We'd like to hear your opinion so let us know by phone, or E-mail which you can find on page 3.

Literature Order and Mailing List Update Form Summer 2014

Please fill out a separate order form for each person receiving FNN.
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Suggested topics for future issues:

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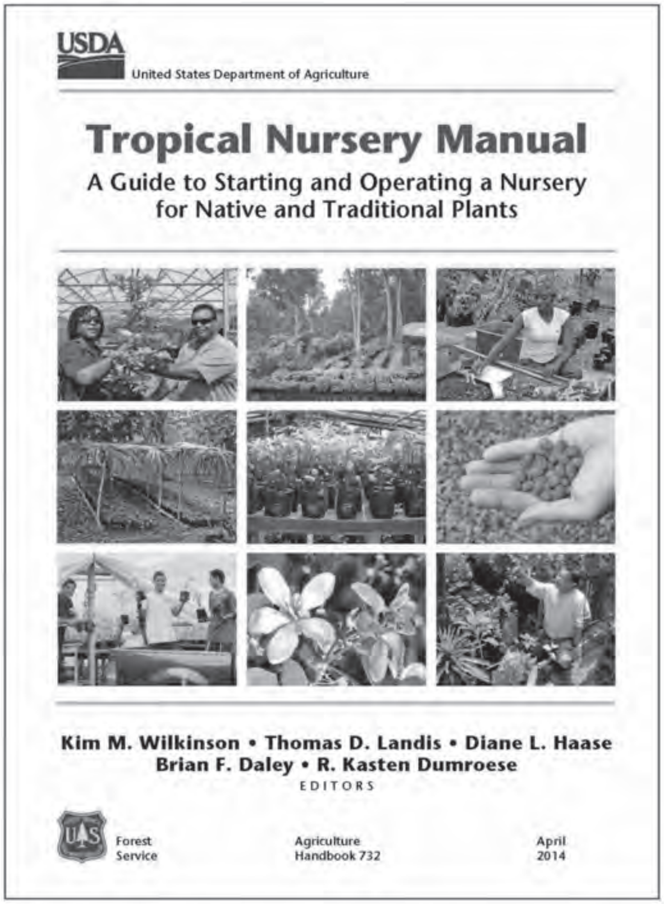

Wilkinson KM, Landis, TD, Haase DL, Daley BF, Dumroese RK. 2014. ***Tropical Nursery Manual*—A Guide to Starting and Operating a Nursery for Native and Traditional Plants.** Agriculture Handbook 732. Washington, DC: U.S. Department of Agriculture, Forest Service. 376 p.

This Tropical Nursery Manual serves people who are starting or operating a nursery for native and traditional species in the tropics. Key concepts, principles, and processes are presented, based on proven practices and the best science available. Understanding these concepts and principles will make it easier to operate a nursery successfully, and to meet project objectives in the field. Topics covered include nursery planning, plant propagation, crop production, plant care, outplanting, and ongoing learning.

This manual also recognizes that every nursery is unique. Local conditions and ingenuity, integrated with the information in this manual, combine to cultivate high-quality plants with the best chance to survive and flourish into the future.

A limited supply of hard copies are available. The entire manual, by chapter, is also available for free at: http://www.rngr.net/publications/tropical-nursery-manual

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