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Native Plants and Integrated Roadside Vegetation Management

By William Quarles

Photo courtesy Idaho Dept. of Transportation

Native wildflowers overlook an Idaho roadside. Restoration of native vegetation can lead to fewer herbicide applications, and lower roadside maintenance costs.

There are 4 million miles (6.4 million km) of roads in the U.S., with about 12 million acres (29.4 million ha) of highway corridors and landscaping. Vegetation maintenance on this amount of land requires a significant expenditure of labor and resources. Vegetation managers must meet roadside safety requirements of good visibility and clear zones to minimize injuries from accidents. With a few exceptions, clearing of vegetation is often a single-minded task. Native plants have been some of the first casualties of this approach. Due to aggressive development and disturbance, many robust and widespread native species along U.S. highways have now been reduced to isolated stands emerging from nearly depleted seedbanks. For instance, the smooth coneflower, *Echinacea laevigata*, once occurred in 65 populations in eight states. It has now been reduced to 24 populations in four states (Olwell 2000).

There is now a movement to revegetate U.S. highways with native plants, thus recovering at least some of what has been lost. Roadside managers are seeing the advantages of native plants as part of integrated vegetation management (IRVM) programs. These programs combine mowing, mulching, controlled burns, competitive plantings, and selective use of herbicides to manage invasive weeds. At many sites, native plants can provide a practical solution to weed management, leading to a reduction in pesticide applications and to less expense in labor (Daar 1994; Henderson 2000a; Pauly 2000). Additional benefits include increased shelter for wildlife, erosion control, more biodiversity, improvement of water quality, and protection of endangered species (Harper-Lore 2000c). (See Box A. Integrated Vegetation Management.)

Roadside Zones

Vegetation strips parallel to roadways can be divided into a number of management zones, each with a different ecology and management strategy. Usually a gravel mulch is at the edge of the pavement. This allows vehicles to leave the road and park in case of trouble. Next to that, low growing vegetation and grasses are planted in a narrow strip out to the ditch. Altogether, this is called the clear zone. This zone has to be kept free of trees and other obstacles to give drivers a chance to safely regain control of cars that run off the road. Native grasses and low-growing wildflowers can be planted

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in the clear zone instead of bromegrass, *Bromus inermis*, and other non-native horticultural varieties now used (Harper-Lore 2000a).

Next to the clear zone is the ditch, which must be maintained to allow drainage from the road and backslope. Past the ditch, the right of way often slopes up to private property. This area is called the backslope. Backslopes can often be planted in native trees, shrubs and other species without impacting visibility or road safety (Daar and King 1997; Harper-Lore 2000b).

Need to Reduce Costs

Conversion to natives is being driven by a number of diverse factors. One of these is the need to reduce costs. Roadside vegetation in many areas requires intensive management, and millions of dollars are spent on herbicides and mowing. Much of this problem can be traced to an influential book written by Jessie M. Bennett in 1936—*Roadsides, the Front Yard of the Nation*. Roadside managers influenced by this book planted turfgrass along the highways, then were stuck with the all the intensive labor that comes with a well-kept lawn. In the 1930s roadside maintenance was done at a reasonable expense due to depression-era chain gangs and federal work programs. Costs of labor-intensive mowing and weeding increased after World War II. In the 1950s, herbicides were chosen as a less expensive solution to maintaining the "front yard" along U.S. highways.

Because of the energy crunch of the 1970s, costs of herbicides and mowing increased. Managers turned more toward a more careful choice of plants, and tried to find ecological solutions to management (Harper Lore 1997; Kartesz 2000).

Roots of the Roadside Native Movement

In the 1980s and 1990s the ecological solutions were combined with an increasing interest in native plants. Public interest in native plants showed a resurgence, and membership in native plant societies swelled with amateur and professional biologists. Politically, plantings of wildflowers along roadsides had received a boost from Lady Bird Johnson in 1965. Operation Wildflower, a volunteer program where garden clubs supplied seeds for roadside plantings, was started in 1973. Native revegetation received recognition from the U.S. government in 1987 with the federal Surface Transportation and Uniform Relocation Assistance Act (STURAA). This Act required that a portion of the landscaping budget for any new federal highway had to be spent on establishing roadside native plants (Harper-Lore and Wilson 2000).

Federal involvement increased with a presidential order on April 26, 1994 that required all "Federal agencies, federal projects, or federally funded projects shall incorporate regionally native plants in site design and implementation where cost effective and to the maximum extent practicable" (Clinton 1994).

What is a Native Plant?

Because the federal law mandated the use of native plants, it became necessary to find an acceptable definition. Generally, most people believe that a native plant is one that was growing in the U.S. before Columbus landed. Some introduced plants such as Queen Anne's lace, *Daucus carota*, have been successfully growing here for hundreds of years, but are not natives. Botanists also like to think of natives as very specific to a geographical site. Thus, a coastal native to California may not be native to the mountains. Native revegetation programs cannot be a one-size fits all variety. Ecological zones, including available moisture and other variables, determine what will grow in a particular area.

A federal interagency committee in 1994 came up with the following definition: "A native plant species is one that occurs naturally in a particular region, state, ecosystem, and habitat without direct or indirect human actions." Presumably, once

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a native plant is found, human actions such as actively assisting with propagation at the site are allowed without the plant losing its native status (Morse et al. 2000).

Why Natives?

Native plants are well adapted to the climate and the natural enemies of a given region. They have evolved in a delicate ecological balance, and do not pose a threat as invasive weeds. Invasive exotics are roadside problems because they thrive in disturbed situations and their populations cannot be checked by nat-

Box A. Integrated Roadside Vegetation Management

According to Daar and King (1997), “Integrated Vegetation Management (IVM) is a coordinated decision-making and action process that uses the most appropriate vegetation management methods and strategy, along with a monitoring and evaluation system, to achieve roadside maintenance program goals and objectives in an environmentally and economically sound manner.

“In practice, IVM involves the establishment of low-maintenance beneficial vegetation and the suppression of unwanted pest or problem vegetation when *monitoring* indicates *action thresholds* have been reached. The objective is to keep undesirable vegetation levels low enough to prevent unacceptable damage or annoyance. An integration of biological, cultural, manual, mechanical, chemical, and educational tactics are used with an emphasis on *prevention* of problems rather than *reaction* to them. Gradual reduction of both costs and chemical use are central goals in this process.

If treatments are needed, they are selected and timed to be:

- Most effective against the vegetation problem
- Most cost effective in the long term
- Least hazardous to humans and the environment
- Least disruptive to natural pest controls or desirable vegetation

The IVM concept has been adopted by county and state transportation agencies in a number of states including California, Illinois, Iowa, Wisconsin, Minnesota, and Texas.”

Most proponents of IRVM believe in establishing a healthy, sustainable plant community as the best way to reduce roadside maintenance. Planting native species or at least some well-adapted, low-maintenance vegetation is a proactive approach to weed control. Though several states have adopted IRVM programs, in practice, vegetation is maintained most often by mowing and herbicide applications. Henderson (2002b) surveyed managers of roadside vegetation programs in 14 states. Half of the states said they were practicing IRVM. All 14 states spent at least as much money on mowing as they spend on herbicide application. Annual mowing expenditures for these states ranged from $500,000 to $40 million per year. To save money, most mow only the clear zone. To preserve natives, Arkansas mows only a strip 10-ft (3 m) wide and leaves a strip 25- to 30-ft (7.6-9.1 m) wide "transition" zone that gets mowed just once a year. The single mowing is necessary to keep woody plants from taking over the wildflowers.

Mowing in the high-maintenance zone is timed to promote wildflowers. "Some people do not care for the reduced mowing. But now over half of public comments favor the reduced mowing." A few people are unhappy that the transition zone gets mowed at all (Henderson 2000b).

Florida DOT emphasizes mowing over spraying. Florida’s water table is often only a foot (0.3m) below the surface, so a few years ago DOT was required to reduce chemical use. Now the weeds are controlled with lots of mowing: 16 times a year (Henderson 2000b).

Jefferson County, Washington maintains roadside vegetation entirely by mowing. Due to public pressure, no herbicides are used at all (Daar 2001).

New Technology

Roadside vegetation management has received a boost from some new technologies. Global posititioning satellites make it possible to map both noxious weeds that should be destroyed and native vegetation that should be preserved. Instead of broadcast herbicide applications, spot treatments can be accurately made. Long sections of native vegetation to be left unmowed can be readily identified.

For instance, Clay County Iowa received a grant from the Living Roadway Trust Fund to buy a Digital Global Positioning System (DGPS) to be mounted in the county spray truck. The DGPS unit will allow for on-the-go mapping of a variety of information associated with the IRVM program. It will mark where spot spraying has been applied in great detail and also allow for personnel to record areas such as native prairies, soil erosion areas, noxious weed areas, and other items while performing spraying activities (Clay County 2002).

Infrared

Though mowing is still the most widely used non-chemical roadside treatment, other approaches are being tested. One alternative, using infrared radiant heat, was studied by the Oregon Department of Transportation over a three-year period. “A prototype roadside infrared vegetation control unit, manufactured in Eugene, Oregon, applies intense heat (approximately 1500°F or 800°C) to unwanted growth. It uses liquid propane fuel to heat a radiating unit made of steel. The bottom of the deck travels 2 to 4 inches (5.1-10.2 cm) above the ground, allowing the heat to radiate without the equipment touching the vegetation. Infrared treatments repeated 4 to 6 times annually provided acceptable roadside vegetation control. The timing of treatments and the equipment speed were important variables.

“Infrared treatment could be a useful tool in the IVM program, especially where other forms of treatment are restricted or controversial. Some potential areas for use include sites near waterways, on Federal or other lands that prohibit herbicides, and around culverts and ditches. Special training in the safe use of the equipment and in proper fire suppression techniques is recommended. A fire permit may be required near forest protection districts (ODOT 2002).

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Photo courtesy Br. Alfred Brousseau

California poppy, *Eschscholzia californica*

ural enemies and diseases. As an example of exotic invasiveness, "a full 17% of our North American flora, and up to 33% of some of our individual state floras (Massachusetts) are composed of plants that are exotic or introduced from foreign lands" (Kartesz 2000).

Though native plants are more difficult to establish in competition with exotics, once established they are generally sustainable (Bugg et al. 1997). They will not cause problems by a weedy invasion of nearby cornfields. In areas where natives have been successfully established, very little maintenance is needed. Herbicide applications are reduced because the balanced plant communities resist invasion by exotic weeds (Green and Welker 2003; Daar 1994; CalTrans 2003).

Natives reduce roadside fire hazards because low-growing cool season native grasses produce less biomass and fire fuel. Native drought-tolerant plants provide erosion control, growing deep, sturdy roots that do not require irrigation (CalTrans 2003).

Integrated Roadside Vegetation in Iowa

As well as the general public and the federal government, a number of states have become involved in the push for native plants and Integrated Roadside Vegetation Management (IRVM). In 1988, the Iowa legislature adopted IRVM with idea of reducing herbicide groundwater contamination. The legislation called for the use of native species in roadside plantings, and "IRVM gave policymakers an environmentally sound way to provide safe, responsible roadside vegetation management" (Henderson 2000b). (See Box A for a definition of Integrated Roadside Vegetation Management).

IRVM in Iowa has led to 70-90% reductions in herbicide use from the $70,000 to $80,000 spent per county for broadcast herbicide spray contracts in the 1980s. IRVM programs have also substantially cut costs for ditch clean-outs, which used to total $20,000 to $160,000 annually. Mowing costs and the $25,000 to $30,000 formerly budgeted for brush control in each county have also been reduced. Some of these funds have been reprogrammed to support vegetation monitoring and replanting activities (Daar 1994; Smith 1994).

Native revegetation programs in Iowa are supported by the Living Roadway Trust Fund (LRTF) and the Resource Enhancement and Protection (REAP) program. Since 1989, LRTF has contributed $708,000 to 43 counties to buy native seed. State funding relieves pressure on county budgets and makes revegetation more attractive to county managers (Henderson 2003).

Prairie Restoration

The State of Iowa was quick to see the advantages of native roadside vegetation, not just as a way to reduce herbicides but as a last best hope for prairie restoration. Due to development, more than 99% of the original prairie vegetation in Iowa has been destroyed. The 580,000 acres of roadways are the last area where public interest can be focused to reclaim some of what was lost. Currently, about 31 of Iowa's 98 counties have a fully implemented IRVM program, and 35 have a partially implemented program (Jensen 1999; Smith 1998).

For instance, in Clay County, Iowa, "whenever and wherever possible, native grasses and flowers are planted to meet IRVM objectives. Native prairie plants help prevent soil erosion, control noxious weed invasion, provide wildlife habitat and beautify the county landscape."

Mowing, spot applications of herbicides, and controlled burns are combined with native plantings. Fire is used to maintain areas of quality prairie or to reduce woody vegetation. According to Clay County, "the best and easiest way to maintain these prairie areas is to periodically set fire to them. Fire allows for nutrients to be recycled and used for new plant growth. Some seeds need fire to germinate. Fire reduces the build up of dead plant material, and fire controls the invasion of woody vegetation into a prairie area" (Clay County 2002).

Clay County plants "native prairie grasses and flowers which will eventually defray the costs of maintenance to the county right-of-ways. Native prairie species develop an extensive root system which provides an array of roadside benefits. This extensive root system reduces soil erosion, minimizes the establishment of noxious weeds into the area, and maintains a vegetative stand of growth that provides excellent wildlife habitat for many species of birds and mammals" (Clay County 2002).

Ecological Advantages

Other than reduced herbicide applications and reduced cost, one of the big advantages of native plants is the encouragement of beneficial insects and wildlife. Roadside management profoundly affects butterfly populations. A study conducted in Iowa compared sites with native plants with those dominated by weeds or non-native grasses. Habitat-sensitive butterflies showed a 2-fold increase in species richness and a 5-fold increase in abundance at the native sites. Disturbance-tolerant butterflies were more abundant in native plantings than in stands of non-native grass. There were also fewer butterflies exiting prairie roadsides, and fewer butterfly roadkills (Ries et al. 2001).

There are even economic crop advantages to native plantings. Roadside native plantings next to cornfields in Iowa attract fewer European cornborers, *Ostrinia nubilialis*, than roadside sites planted with the non-native, bromegrass, *Bromus inermis*. Bromegrass stands had nearly 7 times as many 1st generation cornborers. Replacing bromegrass with natives could reduce the number of cornborers breeding near cornfields (Pleasants and Bitzer 1999).

Fitting Plants to the Site

Native plants, of course, are not a panacea that can be blindly implemented at every location. Plants should be chosen to fit site conditions. While some native plants are adaptable to a wide range of environmental conditions, many have specific requirements. Soil texture, pH, fertility, and moisture conditions are important.

Part of the problem is that roadside habitats are disturbed and do not reflect the original situation. Roadside environments are hotter, more compacted, more polluted from automobiles and salt. In reaction, roadside plants sort themselves out into microhabitats. Those seeking moisture end up growing in the ditch. Those tolerant of mowing show up closest to the pavement (Daar 1994). Bugg et al. (1997) identified eight topographic zones or niches for roadside plants in California: road, roadedge, roadside berm, inner ditchbank, ditchbed, outer ditchbank, fieldside berm, and field edge. Each zone ideally requires the proper plant (see Daar 1994).

Plants should be chosen consistent with their microhabitats. Local ecotype seed should be used whenever and wherever possible. Sometimes, however, the specific ecotype for a site is unavailable. Local natives adapted to wide changes in environmental conditions might be a good choice for those cases.

Fertilization and watering needs for natives are often different from those of ornamentals. According to University of Ohio Cooperative Extension (2002), "the needs of native plants may differ from conventional landscape plants. Fertilization may not be necessary with some meadow and prairie species. Over-fertilizing these plants may promote weak, spindly growth and invasion by weeds."

Plant Communities

Native plants tend to grow in communities. These areas are distinguished by a predominant vegetation, such as redwoods or oak, along with associated shrubs, grasses, and forbs. For roadside revegetation projects, plants should be chosen that fit local ecological conditions and are compatible with the local plant communities (Howell 2000). Much of this is explained in *Roadside Use of Native Plants,* a practical resource produced by the Federal Highway Administration (see Resources).

For the 48 continuous continental States, 106 potential native revegetation plant communities are defined by lists of dominant and subdominant native vegetation. These communities thrive in favorable ecological zones, and *Roadside Use of Native Plants* has state maps showing the location of these zones within each State. By consulting the plant lists, the proper native species for each ecozone can be determined. For instance, the "bluestem prairie" native plant community includes big bluestem, *Andropogon geradii*; little bluestem, *A. scoparius*; switchgrass, *Panicum virgatum*; and Indiangrass, *Sorghastrum nutans* as dominants. Other components include native wildflowers such as blazing star, *Liatris* sp. (See Table 1. Prairie community in Iowa). These communities of native vegetation tend to be diverse. California alone has 22 of these zones, ranging from wet redwood forest to dry sagebrush communities.

Success Varies with the Site

Success in planting varies with the site. A good example of this is an ongoing CalTrans study by the Jack Broadbent Office of State Landscape Architecture. At a Yuba County site in the northern part of the Central Valley, there was good soil fertility and structure. Both grass plugs and sod had high survival rates. Hydro-seeding showed low to moderate germination, and drill seeding was moderately successful. There was low germination from imprint seeding. After 9 months most species are doing well.

At a Fresno County site, conditions were gravelly and dry with poor soil fertility and structure. About half of grass plugs and most of sod planting survived. Hydroseeding showed slow germination, and drill seeding was moderately successful. There was no germination from imprint seeding. Weeds have been generally a minor prob-

Photo courtesy of John Game

California native Bigelow's tickseed, *Coreopsis bigelovii*

lem, but a portion of the site was overrun with wild sunflowers. About nine months after planting, nodding stipa, *Nassella cernua*; slender wheatgrass, *Elymus trachycaulus*; pine bluegrass, *Poa secunda*, and squirrel's tail, *Elymus elymoides* were doing poorly.

At an inland site of Monterey County, there was compacted soil/poor structure, moderate fertility, and moderate climate. However, most grass plugs and sod sections survived. Drill seeding provided quick germination, and hydro-seeding gave moderate to slow germination. There has been minimal weed competition on this site. After 9 months, all species have done extremely well.

Along the coast at San Luis Obispo there were excellent site conditions with good soil fertility and moderate structure. Most of the grass plugs and sod survived. Drill seeding gave fast germination, and hydro-seeding showed slow germination. A moderate amount of weeds were encountered during establishment. After 9 months, most plantings have done well.

At an inland desert site in Riverside County, there were poor site conditions characterized by granite soil structure, low fertility, and very dry and hot soil. Drill seeding and hydro-seeding were unsuccessful. There were no invasive weeds due to severe drought and vehicle damage to soil and plants. Two months after planting, most of the grasses did not survive the harsh conditions. (Broadbent and Robinson 2002)

Specifications and Plant Lists

According to *Roadside Use of Native Plants*, planting rates for native wildflower seed should be low, perhaps 2-5 lbs/acre (2.2-5.6 kg/ha). These tend to be expensive seeds and the flowers are intended as highlights. Native grass seeds should be sown at 7-10 lbs/acre (7.8-11.2 kg/ha) because it is less expensive and because "native grasses are the main components of a grassland" (Harper-Lore 2000d). Some consultants have a different opinion about this, recommending very large seeding rates (Dremann 2001). Successful planting may depend more on site preparation, and whether seeds are drilled or broadcast than on planting rates.

Problems

One of the major problems with native revegetation projects is the difficulty getting seed. The Nature Conservancy did a survey in Iowa of counties, water conservation districts and other stakeholders. Because of the difficulty in getting seed, Iowa counties that responded to the survey in 2001 planted about 40.4% non-native cultivars and about 54.9% plants of Iowa origin. Only 22.1% were localized Iowa natives and only 23.9% were source identified seeds. Counties spent an average $4,580 each on seeds, and a typical mix was 6 grasses and 21 forbs. Stakeholders in other states have similar difficulties obtaining seeds (SMS 2002).

This problem will become less important as more new native plant nurseries get started. In Iowa, the number of acres planted in native seeds has doubled to 3,300 acres since last year (Houseal 2003).

Organizations

As integrated vegetation management programs have matured, organizations have grown with it. There is now a national organization for roadside vegetation management, the National Roadside Vegetation Management Association (NRVMA). Although NRVMA meetings tend to be dominated by herbicide manufacturers, native plants are increasingly being spotlighted. NRVMA members are turning to IRVM as an alternative to the expense and environmental impact of programs dominated by herbicides. (See Box B. Problems with Herbicides.) Currently, 38 states have programs to preserve and restore native vegetation (Bryant and Harper-Lore 2002). A number of State Vegetation Management Societies are listed on the NRVMA webpage. Native plant societies are also helpful with native roadside revegetation (see Resources).

State-by-State Programs

In California, the University of California, Davis has received a 5-year grant from CalTrans for native plant revegetation along highways in Yolo County near Sacramento (Dremann 2003). CalTrans also operates CaliforniaWILD, a native roadside revegetation project that started in 1994. A database showcasing more than 300 native grasses and their growth profiles is available on the CalTrans website. Since 1987, CalTrans has planted native

Table 1. Components of Seed Mixes Used in Iowa*

Grasses

Common Name	Scientific Name
Big bluestem	Andropogon gerardii
Blue grama	Bouteloua gracilis
Buffalograss	Buchloe dactyloides
Canada wildrye	Elymus canadensis
Indiangrass	Sorghastrum nutans
Little bluestem	Schizachyrium scoparium
Sideoats grama	Bouteloua curtipendula
Switchgrass	Panicum virgatum
Tall dropseed	Sporobolus neglectus
Western wheatgrass	Agropyron smithii

Wildflowers

Common Name	Scientific Name
Blackeyed susan	Rudbeckia hirta
Butterfly weed	Asclepias tuberosa
Coreopsis	Coreopsis tinctoria
Golden Alexanders	Zizia aurea
New England aster	Aster novae-angliae
Ox-eye daisy	Chrysantheum leucanthemum
Pale purple coneflower	Echinacea purpurea
Partridgepea	Chamaecrista fasciculata
Prairie blazingstar	Liatris sp.
Prairie ragwort	Senecio sp.
Purple prairie clover	Trifolium petalostemon
Rattlesnake master	Eryngium yuccifolium
Rough blazingstar	Liatris sp.
Round-headed bushclover	Trifolium lespedeza
Stiff goldenrod	Solidago rigida
White wild indigo	Baptisia alba
Wild bergamot	Monarda fistulosa
Yellow coneflower	Ratibida sp.

**From Daar 1994, Harper-Lore and Wilson 2000* wildflowers at more than 100 sites statewide (CalTrans 2003).

Minnesota makes native revegetation a priority along rural roadways. Because of a state law to rotect wildlife, rural roadsides can only be mowed once a year (Benik 2003). Idaho emphasizes native wildflower plantings (Idaho 2003).

Henderson (2000b) did an informal survey of roadside vegetation managers in 14 states to assess progress with IRVM and native plants. Iowa is still the bright star of native roadside plantings. A standard native mix includes five grasses and at least a half-dozen forbs. However, not all states can proceed with the Prairie Restoration Program that was so successful in Iowa. New York DOT emphasizes native trees, shrubs, and wildflowers, but not grasses. Maine, which is 90% wooded, plants non-native bluegrass and fescue and a lot of legume non-natives. Native wildflower annuals are planted and there is some experimentation with little bluestem, *Andropogon scoparius*, plantings.

Sources for native seed are a problem in Michigan. Low-maintenance mixes tailored to site and soil conditions are mostly non-native Kentucky bluegrass, *Poa pratensis*; perennial rye, *Lolium perenne*; and creeping red fescue, *Festuca rubra*; with dune grass, *Leymus mollis*, used in some areas. Wildflower plantings are not successful because of woody invasions (Henderson 2000b).

Photo courtesy of Gary Monroe

California coastal tidytips, *Layia platyglossa*

Invasion of roadside clear zones by trees and woody vegetation is a big factor in other states. Where trees are not a problem, Montana plants a mix of four short native grasses along the paved surface in a strip 15 feet (4.6 m) wide. Beyond that strip, seven or eight grasses and one or two forbs, mostly natives, are planted (Henderson 2000b).

Florida uses a lot of native shrubs and forbs but not grasses. Maryland has two regional wildflower mixes that are diverse and include natives. There is often a problem with obtaining seeds. Maryland DOT is working with the University of Maryland and the US Department of Agriculture Plant Materials Center to produce native grasses, including little bluestem, *Andropogon scoparius*; big bluestem, *Andropogon gerardii*; Indiangrass, *Sorghastrum nutans*; switchgrass, *Panicum virgatum*; broomsedge, *Andropogon virginicus*; coastal panicum, *Panicum* sp.; and partridge pea, *Chamaecrista fasciculata*.

B. Problems and Expenses of Herbicides

According to a report from the non-profit Californians Against Toxics (CATS 1999), CalTrans and county road agencies apply more than 132,000 gallons (500,000 liters) of herbicide in liquid formulation and 91,000 pounds (41,000 kg) of dry weed killers to the 80,000 miles (129,000 km) of California roadsides in a typical year.

The state management agency, CalTrans, applies an average of about five gallons (18.9 liter) of liquid and more than two pounds (0.9 kg) of dry herbicide formulation per road-mile of the 15,000 miles (24,000 km) of highways under its jurisdiction. In addition, 51 of the state's 58 county governments also rely on chemicals, averaging more than one pound (0.45 kg) and one gallon (3.785 liters) of herbicide per mile along the 64,000 miles (103,000 km) of roads under county management. Caltrans' annual expenditures can only be estimated at $4 to $6 million for weed killing chemicals (CATS 1999).

According to CATS (1999), eight herbicides account for 86.5% of roadside spraying in California. The U.S. EPA recognizes six of these as possible human carcinogens, and four may cause birth defects. Seven, including glyphosate, are linked to toxicity in the liver and blood. Another, oxadiazon, is recognized by state and federal agencies as a liver and kidney toxicant which also causes birth defects and cancer. Seven exhibit varying degrees of toxicity to fish while four are harmful to birds. Four of the toxic chemicals on this list have been detected in groundwater by California's Department of Pesticide Regulation, and the University of Florida has determined that six possess a high potential for runoff (CATS 1999).

The California situation is typical of many other states. Nationwide, the most commonly used roadside herbicides include picloram, 2,4-D, dicamba, diuron, fosamine ammonium, glyphosate, hexazinone, and triclopyr. To mitigate herbicide problems, a number of states have laws that require posting and notification before herbicides are applied (Owens 1999).

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Oregon has seven major native plant communities from the coast to the high desert and everything in between, including rain forest and 3,000 ft (914 m) elevations. Plantings are tailored to the site. Where the road goes through an area with endangered species, contractors harvest local seeds. Where erosion is a problem, a vigorous rye is the solution. In Oregon as elsewhere, public perception is a very important part of native plant establishment. The public generally prefers flowering species. For this reason, Oregon uses ornamental species for high visibility city gateways.

Wyoming plants 99 percent natives. On more isolated roads, sideoats grama, *Bouteloua curtipendula*; and little bluestem are favored. On more traveled sections, three or more native forbs and native shrubs are added to the mix. Soil containing native seeds taken from road projects is salvaged and returned to the site (Henderson 2000b).

Colorado seeds extensively with natives and chooses plants that need little irrigation. Diversity is also a goal. They use six or seven grasses and a few forbs and shrubs. Mowable mixes, mostly buffalo grass; *Buchloe dactyloides*; and blue grama, *Bouteloua gracilis*; are used in urban areas (Henderson 2000b).

Conclusion

Native plants are an important component of an integrated roadside vegetation management program. Site-adapted native plants need little mowing or irrigation. Drought-adapted deep root systems can provide erosion control. Once established, they are sustainable and are generally able to compete with exotic vegetation. Native roadside revegetation can help America re-establish a living history, reduce roadside maintenance costs, and can lead to fewer applications of herbicides.

William Quarles, Ph.D. is an IPM Specialist, Executive Director of BIRC, and Managing Editor of the IPM Practitioner.

Resources

Check your State Department of Transportation and your County Roadside Maintenance Dept. for further information.

Lady Bird Johnson Wildflower Center, 4801 LaCrosse Avenue, Austin, TX 78739; 512/292-4100, Fax 512/292-4627; www.wildflower.org

Living Roadway Program, Iowa Dept. of Transportation, 800 Lincoln Way, Ames, IA 50010; 515/239-1766

National Roadside Vegetation Management Association, 6402 Betty Cook Drive, Austin, TX 78723; 512/933-9930; Fax 512/933-9971; www.nrvma.org

Native Roadside Vegetation Center, University of Northern Iowa, 113 CEEE, Cedar Falls, IA 50614; 319/273-2813

Photos of California Native Plants, http://elib.cs.berkeley.edu.photos/flora

Society for Ecological Restoration, 1955 W. Grant Rd. #150, Tucson, AZ 85717; 520/622-5485, Fax 520/622-5491; www.ser.org

U.S. Dept. of Transportation, Federal Hwy Administration, 400 Seventh St. SW, Washington, DC 20590; www.fhwa.dot.gov

Native Plant Societies

Arizona Native Plant Society, PO Box 41206, Sun Station, Tucson, AZ 85717; http://aznps.org

California Native Grass Society, PO Box 566, Dixon, CA 95620

California Native Plant Society, 1722 J Street, Suite 17, Sacramento, CA 95814; 916/447-2677; www.cnps.org

Colorado Native Plant Society, PO Box 200, Fort Collins, CO 80522; http://carbon.cudenver.edu

Florida Native Plant Society, PO Box 690278, Vero Beach, FL 32969; 772/462-0000

Georgia Native Plant Society, PO Box 422085, Atlanta, GA 30342; www.gnps.org

Iowa Native Plant Society, 720 Sandusky Drive, Iowa City, IA 52240

Maryland Native Plant Society, PO Box 4877, Silver Spring, MD 20914, www.mdflora.org

Minnesota Native Plant Society, 220 Biological Science Center, 1445 Gartner Avenue, St. Paul, MN 55108

Missouri Native Plant Society, PO Box 20073, St. Louis, MO 63144; www.missouri.edu

Native Plant Society of Oregon, PO Box 902, Eugene, OR 97440, bulletin@nps.oregon.org

Native Plant Society of Texas, PO Box 891, Georgetown, TX 78627, www.npsot.org

Virginia Native Plant Society, 400 Blandy Farm Lane Unit 2, Baya, VA 22620, www.vnps.org

Washington Native Plant Society, 7400 Sand Point Way NE, Seattle, WA 98115, 206/527-3210

Utah Native Plant Society, PO Box 520041, Salt Lake City, UT 84152; www.unps.org

Books

How to Develop and Implement an Integrated Roadside Vegetation Management Program, National Roadside Vegetation Management Association, 6402 Betty Cook Drive, Austin, TX 78723; 512/933-9930; Fax 512/933-9971; www.nrvma.org

Integrated Vegetation Management for Roadsides, Bio-Integral Resource Center, PO Box 7414, Berkeley, CA 94707 and Washington Dept. of Transportation

Roadside Use of Native Plants, B.L. Harper-Lore and M. Wilson, Office of Natural Environment, Federal Highway Administration, Island Press, Washington, DC.

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IPM News

Pesticide Restrictions in Canada

On March 5, Québec's Environment Minister announced a new Pesticide Management Code, which strictly regulates the storage, sales and use of pesticides in Québec. The Code states that, effective immediately, synthetic pesticides are prohibited in all daycare facilities and schools, and the use of cosmetic pesticides is banned on all public land. By 2005, the ban will extend to all private green spaces, with fines ranging from CAN$500-$30,000. The ban covers 23 pesticide active ingredients that—according to the U.S. Environmental Protection Agency (EPA) and/or World Health Organization (WHO)—are known or possible carcinogens or endocrine disruptors, including lindane, malathion, MCPA, permethrin, benomyl, captan and 2,4-D.

In addition to the ban, the Code also increases buffer zones around open water, outlaws application of mixtures of pesticides and fertilizers, requires sale and use permits for pesticide applicators, requires golf courses to present pesticide use reduction plans, and provides a list of less-toxic and organic pest control products. English or French copies of Québec's Pesticide Management Code can be ordered at (800)463-2100.

—From Pesticide Action Network Updates Service

Pesticide Body Burdens

According to two reports released in late January 2003, many people in the U.S. are carrying dozens of pesticides and other chemicals in their bodies. For one of these reports, the Centers for Disease Control and Prevention (CDC), tested thousands of people for the presence of 116 chemicals, 34 of them pesticides. Results were published in the *Second National Report on Human Exposure to Environmental Chemicals.* The report lists the chemical body burden of three major types of pesticides: organochlorines, organophosphates, and carbamates. CDC scientists also tested for a few widely used weed killers and other pesticides. Nineteen of the 34 pesticides tested for were detected in the blood or urine of test subjects.

Two specific pesticide-related findings are highlighted. First, concentrations of chlorpyrifos metabolites are nearly twice as high in children (age 6-11) as in adults. Most home uses of chlorpyrifos were recently banned by the U.S. Environmental Protection Agency (EPA), but an estimated 10 million pounds (4.5 million kg) of the pesticide continue to be used each year in agricultural production.

The second CDC highlight relates to the organochlorine pesticide DDT, which was banned in the U.S. in 1972. DDT breakdown products (DDE) were found in Mexican Americans at levels more than three times that of non-Hispanic whites. DDT use for malaria control continued in Mexico until its phaseout in 2000. In addition, DDE was present in the bodies of youth aged 12-19 born after the U.S. ban, indicating continued exposure from residues in the environment.

The second study, *Body Burden: The Pollution in People*, was led by Mount Sinai School of Medicine in New York and conducted in collaboration with Environmental Working Group and Commonweal. Researchers found 167 industrial chemicals, pesticides and pollutants in the blood and urine of nine adult subjects. Each subject carried an average of 91 chemicals. Seventeen of the chemicals found were breakdown products from organochlorine and organophosphate pesticides. Other chemicals found in the two studies include polychlorinated biphenyls (PCBs), dioxins and furans (industrial by-products) and phthalates (softening agents widely used in cosmetics, toys and other consumer products).

Individuals vary widely in their sensitivity to individual chemicals, and it is difficult to predict the specific health effects of long term, low-level exposures. The pesticides found in the U.S. population have a wide range of known health effects, including cancer, birth defects, neurological damage, infertility and weakened immune systems. There are insufficient studies on the possible health effects of exposure to multiple chemicals.

The pesticide body burdens found in the new studies result from a variety of exposures. Pesticide residues in food are a major source of exposure. Farmworkers and people in communities and schools located near farms where pesticides are sprayed may inhale fumes from the applications or come in contact with residues of spray drift that have settled in their yards or homes. And pesticides used in the home can be absorbed through skin contact, inhalation or accidental ingestion.

Reducing or eliminating pesticide use in the home and supporting organic agriculture are two concrete ways consumers can respond to the body burden news.

Sources: (1) CDC's *Second National Report on Human Exposure to Environmental Chemicals*: http://www.cdc.gov/exposurereport/(2) *Body Burden: The Pollution in People*: http://www.ewg.org

—From Pesticide Action Network Updates February 14, 2003

California Restricts the Herbicide Clopyralid

The California Department of Pesticide Regulation (DPR) has restricted clopyralid distribution to protect commercial compost from potential contamination (see *IPMP* October 2001). DPR will restrict sales of the herbicide clopyralid to lawn and turf professionals, instruct those licensees to assure that green waste stays onsite when the herbicide is used, and require dealers to provide written notice of the restrictions when they sell some clopyralid products. DPR will immediately begin drafting regulations to enforce those restrictions, based on concern that clopyralid residue in grass clippings could make compost toxic to non-target vegetation.

—From CA DPR Press Release April 2, 2003

National Centers to Study Children's Health

EPA and the National Institute of Environmental Health Sciences (NIEHS) are calling for applications from nonprofit institutions to establish up to six research centers on the relationship between children's health and their environmental exposures. Health impacts from environmental contaminants can be particularly detrimental for children.

Specific areas identified for research include respiratory diseases, neurodevelopment and neurobehavior, childhood cancers, birth defects and other conditions. These research centers will develop innovative strategies to measure environmental exposures in children and will conduct research to reduce hazardous exposures and their adverse health effects. An important goal of this project is to translate research findings into input for public policy, community needs and information for the health care community and general public. This Request for Applications (RFA) builds upon the work completed by 12 EPA/NIEHS Centers for Children's Environmental Health and Disease Prevention Research established in 1998 and 2002. The RFA is also a part of EPA's Science to Achieve Results (STAR) program. Applications are due by May 16, 2003. For more information, see: http://es.epa.gov/ncer/rfa/current/2003_child_health.html.

—From EPA Press Release

Baits Motel Registered with EPA

The EPA has conditionally approved the registration of the Baits Motel, Stay Awhile—Rest Forever™. This product contains the microbial active ingredient *Beauveria bassiana*. *B. bassiana* is a fungus that has been studied for years as a possible active ingredient for microbial insecticide formulations. The bait station is for use as an indoor, non-food use microbiological bait for control of fire ants and cockroaches. Other microbial baits registered in the past were based on the fungus *Metarhizium anisopliae* (see *IPMP* October 1999).

Citation: *Federal Register* Volume 68, Number 14, Pages 3025-3026 [http://www.epa.gov/fedrgstr/EPA-PEST/2003/January/Day-22/p970.htm], January 22, 2003. Contact: Shanaz Bacchus, Biopesticides and Pollution Prevention Division (7511C), (703) 308-8097, bacchus.shanaz@epa.gov.

—From EPA Press Release

Genetically Engineered Corn for Rootworm Control

EPA has approved the use of a new genetically engineered corn designed to control corn rootworm, *Diabrotica* spp., a widespread and destructive insect in the United States. The new corn pest control, referred to as "MON 863" and developed by Monsanto, produces its own insecticide within the plant derived from *Bacillus thuringiensis* (Bt), a naturally occurring soil bacterium. The Bt protein, called Cry3Bb1, controls corn rootworm, a highly destructive pest responsible for the single largest use of conventional insecticides in the United States (see *IPMP* August/September 2002).

At roughly 80 million (32.4 million ha) planted acres, corn is the largest crop grown in the United States. Use of the new pest-control tool is expected to result in major reductions in the use of numerous conventional insecticides.

In order to reduce the possibility of corn rootworm developing resistance to Bt, EPA is requiring Monsanto to ensure that 20 percent of the planted acreage of this product be set aside where non-Bt corn will be grown to serve as a "refuge." These refuge areas will support populations of corn rootworm not exposed to the Bt bacterium. The insect populations in the refuges will help prevent resistance development when they cross-breed with insects in the Bt fields. This resistance management strategy was developed as a condition of the registration, and EPA will require routine monitoring and documentation that these measures are followed. EPA is also requiring Monsanto to conduct additional research on corn rootworm to ensure that optimal long-term resistance management practices are maintained.

As with all similar products, EPA has approved MON 863 for time-limited use which will be subject to reevaluation in several years. For more information on EPA's regulation of these products, see: http://www.epa.gov/pesticides/biopesticides/

—From EPA Press Release

Phaseout of Arsenic-Treated Wood

On March 17, EPA granted the voluntary cancellation and use termination requests affecting virtually all residential uses of chromated copper arsenate (CCA) treated wood. Under this action, affected CCA products cannot be used after Dec. 30, 2003 to treat lumber intended for use in most residential settings. This transition affects virtually all residential uses of wood treated with CCA, including play structures, decks, picnic tables, landscaping timbers, residential fencing, patios and walkways/boardwalks. Phase-out of the residential uses of CCA will reduce the potential exposure risks to arsenic, a known human carcinogen. (see *Common Sense Pest Control Quarterly* Winter 2002; *IPMP* October 2001).

Consumers may continue to buy and use the treated CCA wood for as long as it is available. The transition to using the new generation treatment products is well underway. The Agency is deferring any action on two uses: wood in permanent wood foundations and fence posts for agriculture may continue to be treated with CCA at this time.

More information on CCA treated wood is available at: http://www.epa.gov/pesticides/factsheets/chemicals/1file.htm

—From EPA Press Release

For Control of Headaches and Snakes

EPA has granted a registration to the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) for the new active ingredient acetaminophen, to be used to control the invasive brown tree snake in Guam and the Commonwealth of the Northern Marianas Islands. The brown tree snake, a species that originated in New Guinea, is a significant and invasive exotic pest that was introduced on Guam during World War II, presumably by military transport. Native wildlife on Guam and the Marianas Islands have been under severe predation pressure by this pest for years. If the brown tree snake were to reach Hawaii or enter the continental United States, the potential for damage by this invasive species is high. Since the early 1990s, the Department of Defense (DOD) has spent over $1 million yearly to combat the brown tree snake and prevent its movement to other locations. The brown tree snake is also responsible for numerous power outages in Guam, deaths of pets, and bites (venomous) of humans, especially infants. Research and use of acetaminophen under quarantine exemptions has shown excellent results in reducing brown tree snake populations, with consumption of only one baited mouse needed to kill a brown tree snake.

Citation: *Federal Register*, Volume 68, Number 48, Pages 11839-11841 [http://www.epa.gov/fedrgstr/EPA-PEST/2003/March/Day-12/p5913.htm] March 12, 2003.

—From EPA Press Release

Conference Notes

ESA 2002 Annual Meeting Highlights—Part One

By Joel Grossman

These highlights from the Entomological Society of America's (ESA) annual meeting Nov. 17-20, 2002, in Fort Lauderdale, Florida, were selected from among over 1,800 presentations. ESA's next annual meeting is October 26-30, 2003, in Cincinnati, Ohio. For more information contact program chair Bob Wright (University of Nebraska, South Central Res. & Ext. Center, P.O. Box 66, Clay Center, NE 68933; phone 402/762-4439; rwright2@unl.edu) or the ESA (9301 Annapolis Rd., Lanham, MD 20702; 301/ 731-4535; http://www.entsoc.org).

Oriental Fruit Moth Pheromone

The Oriental fruit moth (OFM), *Grapholita molesta*, has traditionally been a major pest of stone fruit production, but infestation in apple has been on the increase since 1996. According to Maya Evenden (West Chester Univ., West Chester, PA), the pest status of OFM has increased due to the development of resistance to organophosphate insecticides.

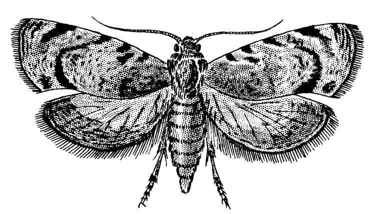
Fortunately, OFM mating disruption pheromones are commercially available. An "attract and kill" (pheromone + pesticide) strategy also holds promise, as it works against other tortricids such as the codling moth, *Cydia pomonella*, and the light brown apple moth, *Austrotortrix postvittana*, in New Zealand.

In 2002, Last Call™ attract-and-kill formulations were tested in seven Pennsylvania apple orchards. Traps were placed in trees 15 m (49 ft) apart and 1.5 m (5 ft) above ground. The number of field trap captures of OFM male moths were significantly influenced by pheromone dose and date. The presence of 6% permethrin insecticide had no effect on pheromone attraction, and there was no pheromone-insecticide interaction.

Last Call OFM formulations should be competitive with calling females under field conditions, as formulations containing 0.016 and 0.16% OFM pheromone with 6% permethrin were as effective as virgin females in attracting males in wind tunnel experiments.

Oriental Fruit Moth Mating Disruption in North Carolina

Over the past two years, OFM mating disruption has been successfully implemented in North Carolina apple IPM programs. However, Orkan Kovanci (North Carolina State Univ, Gardner Hall, Raleigh, NC) said that "low levels of late season fruit damage have occurred in some orchards treated in late May with Isomate M100 pheromone dispensers due to inadequate dispenser longevity." Isomate M100 pheromone dispensers applied in late May emit pheromone only through mid-August, leaving fruit unprotected after mid-September.



Oriental fruit moth, *Grapholita molesta*

Late May application of Isomate M100 dispensers for OFM mating disruption was compared to: 1) late May Isomate M100 plus late August 3M sprayable pheromone; 2) late June Isomate M100; 3) early April Isomate Rosso dispensers; 4) an average of five organophosphate sprays for season-long OFM control. Orchards were also treated with organophosphate insecticides in late June and early July for apple maggot, *Rhagoletis pomonella*. One wing-style Pherocon™ 1C trap per acre (2.47/ha) in the upper third of the canopy monitored OFM flights.

Overall, Isomate Rosso dispensers, and Isomate M100 plus 3M sprayable pheromone at late season provided season-long management of OFM. As an alternative to Isomate dispensers, 3M sprayable pheromone applied at a rate of 5 and 10 g/acre (12.4-24.7g/ha) also provided season-long control.

Pheromones for Multiple Species

Philipp Kirsch (IPM Tech Inc, 4134 N. Vancouver Ave, suite 105, Portland, OR) talked about leafrollers and pheromones. Multiple leafroller species require separate applications of pheromones if no one species is predominant. Blending pheromones of obliquebanded leafroller (OBLR), *Choristoneura rosaceana*; and pandemis leafroller (PLR), *Pandemis pyrusana*; suppresses OBLR attraction, so leafroller mating disruption has had limited success. Observations of the attraction of the two leafroller species to pheromone sources shows a linear response. This linear response to pheromones suggests that an attracticide tactic might be useful.

In wind tunnel tests, OBLR and PLR moth response increased with increasing pheromone concentration. In the field, moth catch was highest at a 16% dispenser pheromone concentration. Adding permethrin to the pheromone did not lessen moth attraction. Blending two leafroller pheromones into the attracticide formulation suppressed the attraction of OBLR but not PLR. According to Kirsch, "these data indicate a good possibility for developing an effective attracticide formulation for the management of OBLR and PLR in the western U.S."

Wet springs in Michigan fruit orchards preclude sprayable pheromone formulations. Pheromone

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timing issues are complicated by the varying life cycles of obliquebanded leafroller, oriental fruit moth and codling moth. The combined OBLR/CM dispenser is considered a standard. Other dispensers combine CM and OFM pheromone. Shinetsu's new triple dispenser formulation of OBLR, OFM and CM pheromones, which has been tested in 10 acre (4 ha) blocks in three regions, is an alternative, said Peter McGhee (Michigan State Univ, Center for Integrated Plant Systems, East Lansing, MI).

The big question with multiple species pheromone dispensers is when to apply them, as the pest species have overlapping generations during a 110 day season. Bloom applications last until late August. Pre-bloom application is better for codling moth, but misses the beginning and ending flights of the other species. These kinds of complications make it hard to reduce fruit damage at harvest, particularly when the key pest cannot be determined in advance.

Sprayable pheromone formulations for all three species have both rain-fastness and longevity issues. With high OFM pressure, NuFilm 17 spreader-sticker increased effectiveness and longevity. Though heavy rain washes sprayable pheromones off vegetation, one farm had success with both high and low dose formulations. Low rates of sprayable pheromone must be applied every 10-14 days, whereas three sprays (i.e. at the beginning of each pest generation) are sufficient with high application rates. There was virtually no fruit injury with pheromone treatments, and the pheromone results were equal to the pesticide block results.

Fourth National IPM Conference

Over 500 pest management professionals attended the 4th National IPM Symposium, which was held April 8-10 in Indianapolis, IN. The emphasis of the conference was "building alliances for the future of IPM." A number of the speakers invited have been successful with organizing alliances to promote IPM in schools, urban situations and in agriculture. Special sessions covered IPM education and outreach, marketing, urban IPM, IPM in organic systems, biological control, biorationals, invasive species and other topics. Part of the program was the presentation of the National IPM Roadmap. The Road Map includes the goals of the National IPM Program, which are to improve the economic benefit of IPM, and to reduce human health risks and environmental impacts of pests and pest management. Focus areas of the National program include IPM implementation in agriculture, protection of natural resources and recreational environments through IPM, and implementation of IPM in urban areas. For information on specific sessions, including abstracts, summaries, and presentations, visit cipm.ncsu.edu/symposium. For photos visit www.ps.uiuc.edu.—*Bill Quarles*

NOW Mating Disruption in California

"The navel orangeworm (NOW), *Amyelois transitella*, is one of the two main insect pests in California figs, and is also a major pest of almonds, pistachios and walnuts," said Charles Burks (USDA-ARS, 9611 S. Riverbend Ave, Parlier, CA). In the nut crops NOW is the target of insecticide treatments both in the orchard and postharvest. In figs, no feasible insecticide is available for use during the growing season, and growers are entirely dependent upon postharvest fumigation.

NOW mating disruption is difficult, because *Z,Z*-(11,13)-hexadecadienal, the only identified NOW sex pheromone component, is both chemically unstable and inferior to virgin females in attracting males. However, an aerosol formulation holding the pheromone in a solvent until it is emitted overcomes these problems. Timed-release aerosol pheromone emitters are typically placed around the perimeter, rather than in a grid arrangement, to save labor costs. In both almonds and walnuts, this practice has effectively shutdown female-baited flight traps, thus making mating disruption a success. In a 40 acre (16 ha) block of figs, peripherally placed timed-release pheromone emitters also successfully disrupted NOW mating.

Gypsy Moth Mating Disruption

Gypsy moth, *Lymantria dispar*, pheromone mating disruption was carried out with flakes (with and without sticker), flake slurry, lure-tape and 3M microcapsules. Portable electroantennogram devices were used to measure disparlure (pheromone) levels in treated plots to correlate pheromone levels with air speed, canopy height and amount of mating disruption. "Compared to the control plot, reduction in trap catch exceeded 97.9 in all treated plots," said Kevin Thorpe (USDA-ARS Insect Biocontrol Lab, Bldg 306, BARC-East, Beltsville, MD). "No egg masses with more than 5% fertile eggs were found in any of the treated plots. More than 14% of the egg masses from the control plot contained over 5% fertile eggs. Based on these results, all treatments were highly successful."

Neem Injections Stop Tree Pests

Neem seed and kernel extracts with azadirachtin are highly toxic to at least 13 species of foliage-feeding Lepidoptera and sawflies attacking Canadian forest trees, and have the added benefit of low bird and mammalian toxicity, said Blair Helson (Canadian Forest Service, Great Lakes Forestry Cent, 1219 Queen St East, Sault St Marie, ON, Canada). Helson, who started working with neem and forest pests a decade ago, calculated that 200 ml (6.8 oz) of neem extract (3-4% azadirachtin) inside a large tree provided effective systemic activity. The challenge was quickly getting commercially available neem products into large forest trees. This required developing an efficient injection device.

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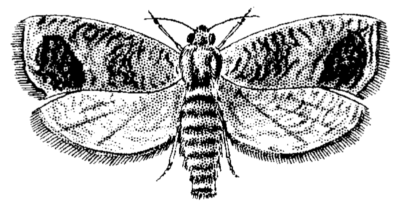
A simple starting system involved drilling a hole in a red pine tree, attaching a funnel and introducing Neemix 4.5 to combat pine false webworm, *Acantholyda erythrocephala*; which is a sawfly. Coverage was consistently better in the upper crown (97%) than in the lower crown (83%).

A more advanced systemic tree injection system uses cheap low-tech plastic tubing with a hose clamp. A spike is hammered into the tree to make a hole, and a bicycle pump pumps neem extract through the tubing into the tree. Control of three conifer pests was good to excellent with Fortune Aza™, Azatin™, Ornazin and Neemix 4.5. But these formulations could not be completely injected into one tree in one day. However, Treazin, a special tree injection formulation developed in partnership with BioForest Technology, Inc., could be completely injected into a tree most of the time. Using the systemic tree injection tube, 40-50 ml of neem extract was injected into the tree in under four hours, and was effective.

In a test injection of small white pines infested with gypsy moth, Treazin and Ornazin were persistent for 98 days. Red oak was the slowest tree to inject, though neem was still effective. Treazin reduced gypsy moth defoliation by 49%. Most other tree species were rapidly injected with neem and protected to some extent against 10 different tree pests. Treazin provided 99% (season 1) and 74% (season 2) protection against pine false webworm, *Acantholyda erythrocephala*; Ornazin provided 100% (season 1) and 86% (season 2) protection. Against pine sawfly on white pine, there was still 60% Treazin activity one year posttreatment. With birch leafminer, *Fenusa pusilla*, on white birch, neem injections reduced the number of mines per upper leaf from 15-16 to about 1.

Cambial Zone Injections

Mark Harrell (Univ of Nebraska, 103 Plant Industry, Lincoln, NE) talked about injections with the Wedgel. The Wedgel (wedge + needle) injector is a handheld heavy duty syringe with a hole on the side to prevent plugging up with tree bark. The device punches a hole 1/8 inch (3.2 mm) in diameter and 1/4 inch (6.4 mm) deep 1 mm into the phloem. When dyes are injected, the cambial zone injections are found to be absorbed into the xylem and carried up into the tree.



Codling moth, *Cydia pomonella*

Cambial zone injections work by being absorbed into the xylem. They are effective against defoliating, sucking and stem-boring pests and cause less disruption of internal xylem layers compared to drill-hole methods.

In two trials (June 1998; August 1998), imidacloprid (Pointer) was injected into white birch (relatively thin bark) to protect against bronze birch borer, *Agrilus anxius*. By Sept. 1999, injected trees had no birch borer larvae versus 45 per m2 (10.7 ft2), in untreated trees. Imidacloprid injections also significantly reduced sycamore lace bug nymphs, *Corythucha ciliata*, on sycamore, but injections are difficult on small sycamore trees with very thin bark.

Over time (2+ months) red gum lerp psyllid, *Glycaspis brimblecombei*, control on eucalyptus increased to 70-80% with imidacloprid injections. Both imidacloprid and abamectin injections significantly reduced elm leaf beetle, *Xanthogaleruca luteola*, damage to English elm: 1.8 (on a 0-10 scale) after 11 months, versus 4.7 for the control; but by 13 months the treatment effects were wearing off.

Tree wounding and chemical injury are among the objections to injections, though the new WedgeChek reduces chemical leakage. Though injections "sometimes cause injury, (it's) no more than other injection methods," said Harrell, who emphasized taking steps to minimize tree wound injuries and stress. "Low placement on the stem and newer formulations reduce or minimize the injury, and bark separation is not a problem." When injections are made low on the tree, trees compartmentalize the injury, the xylem is okay and callous tissue seals the wound. Injections do not work as well in fall or winter when the bark stiffens.

Microinjections in Boston

Feeding by the hemlock woolly adelgid, *Adelges tsugae*, reduces stem growth and eventually kills hemlock stems. In Boston, MA, where there are limits on spraying and soil injection, the Arborjet VIPER (Volume Injection Pressure Enhanced Reservoir) microinjection system was introduced to inject 10% imidacloprid into trees, said Joseph Doccola (Arborjet Inc, 2 Draper St, Woburn, MA). The compressed air tank is about 1.5 liter (88in3), the same size as a paint ball tank. A device on the pest control operator's belt regulates the pressure of injection into the xylem after a hole is drilled in the tree; as the piston injects the solution, a gauge provides feedback on PSI and amount of material injected.

The adelgid aestivates in summer in the northeastern U.S., so adelgid mortality on 24 infested Boston trees was assessed in Oct.-Dec. Hemlock is a slow-growing conifer with dense wood, and translocation is greatest with active evapo-transpiration. But hemlock woolly adelgid likes cool shady low branches where evapo-transpiration is less of an issue. Water-based active ingredients that get good distribution in the tree minimize phytotoxicity. Adelgid mortality using the VIPER system was as high as 80%, said Harrell, and tree vitality improved. Reducing adelgid populations to 1 per linear cm (0.4 in) of stem prevented stem dieback. The VIPER system works for hardwoods with good vascular systems, and is

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being tested on maples by the USDA.

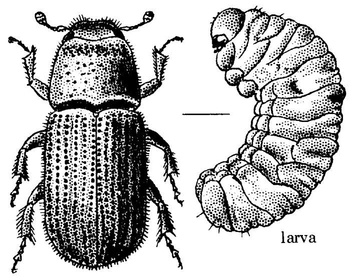
Baited Trees in British Columbia

One billion dollars a year worth of timber (8 million hectares (19.8 million acres) in 2001) is being lost to mountain pine beetle, *Dendroctonus ponderosae*, in British Columbia, Canada. The best remedies are harvesting infested logs for lumber mills and protecting small plots of trees with trap logs baited with nonhost bark volatiles and an anti-aggregation pheromone, verbenone. Factors such as geographic area and particular pine tree species complicate the use of trap logs baited with verbenone, "which works one time but not the next," said John Borden (Simon Fraser Univ, 8888 University Dr, Burnaby, BC, Canada).

Potential answers include increasing verbenone concentrations and finding nonhost volatile supplements to use in Phero Tech bubble caps. Fifty 40x40 m (131x131ft) plots, some with baited trees in the center, were established in British Columbia cattle country. Mountain pine beetle numbers on attacked trees did not vary with treatment. However, fewer trees were attacked when protected by nonhost volatiles and verbenone. With high verbenone concentrations on trees in the center of plots, the baited trees were attacked, but not the surrounding trees. In contrast, expanding bands of attacked trees were noted around center trees in unbaited plots. Though effective, high doses of verbenone (alone, or preferably with nonhost volatiles) require costly labor, and thus are most likely to be useful on high value stands of timber.

Pine Beetles in the USA

Jose Negron (USDA- FS, Rocky Mtn Res Stn, 240 W. Prospect, Fort Collins, CO) reported that trees showing reduced growth rates have increased susceptibility to bark beetle attack," said Negron is compiling historical data on mountain pine beetle, *Dendroctonus ponderosae*, in *Pinus ponderosa* in an effort to tease out attack factors. The model indicates that when ponderosa pine basal area is greater than 17.1 m/ha (23.1 ft/acre), the probability of infestation by mountain pine beetle is 0.71. When ponderosa pine basal area is equal to or less than that, then the probability of infestation is 0.21.



Western pine beetle, *Dendroctonus brevicomis*

"The southern pine beetle, *Dendroctonus frontalis*, is one of the most destructive pests in the southeastern pine forest ecosystem," said D.H. Slone (USDA-FS, SRS, 2500 Shreveport Hwy, Pineville, LA). "Its destructive behavior is characterized by periodic outbreaks in localized infestations of one to many hectares where virtually every loblolly or other susceptible pine tree is mass attacked and killed." In summer 2002 in Mississippi's Homochitta National Forest, black canvas was draped over pipe and wire frames to form cylindrical traps of varied diameters placed 20 ft (6 m) high "to present a strong vertical shape to the beetles to closely simulate the bolls of pine trees." The center part of the cylinder was wrapped by 2 ft (0.6 m) high black plastic coated with Tanglefoot (and permethrin) and baited with frontalin and alpha-pinene.

D. frontalis landed most frequently on medium-diameter (12-24 inch 0.3-0.6 m) traps, and considerably less frequently on smaller traps. Clerid beetles, *Thanasimus dubius*, were more frequently collected on smaller traps. This experiment shows that southern pine beetles simultaneously attack multiple trees during epidemics, and the attractiveness of a tree is due

Calendar

April 8-10, 2003. Fourth Natl. IPM Symposium. Indianapolis, IN. Contact: L. Braband, NYSAES, 630 W. North St., Geneva, NY 14456; 315/787-2408.

April 16, 2003. Hedgerows with Insectary Plants. Contact: Yolo County RC District, 221 W. Court St., Suite 1, Woodland, CA 95695; 530/662-2037, ext 119.

April 25-27, 2003. 21st National Pesticide Forum. Toxics in the Age of Globalization. University of Texas, Austin. Contact: K. Owens, Beyond Pesticides, 701 E St. SE, Suite 200, Washington, DC 20003; 202/543-5450, Fax 202/543-4791. www.beyondpesticides.org/forum

May 10, 2003. Soil Foodweb Talk. Creative Gardens, Coupeville, WA. Contact: 800/325-5706

May 14-17, 2003. Organic Trade Association Conference. Austin, TX. Contact: Lisa Murray, 207/842-5468; ato@divcom.com; www.ota.com

May 27-30, 2003. 5th Conf. on Organic Agriculture. Havana, Cuba. Contact: V. Rodiguez, email violeta@palco.cu

June 3-5, 2003. 6th Fumigants and Pheromones Conf. Copenhagen, Denmark. Contact: D. Mueller, insectsltd@aol.com.

June 17-20, 2003. 25th Annual Exhibit Environmental Technology. Seoul, Korea. Contact: email, envex629@epa.or.kr, website, www.epa.or.kr/

July 8-9, 2003. 5th Agro Conference. Behavior of Pesticides in Air, Soils and Water. Frankfurt, Germany. Contact: fropers@akademie-fresenius.de

July 26-30, 2003. Soil and Water Society Ann. Conf. Spokane, WA. Contact: www.swcs.org

September 9-12, 2003. 4th European Vertebrate Pest Management Conference. Contact: L. Nieder, Parma, Italy. nieder@biol.unipr.it

September 12-17, 2003. 14th Intl. Meeting Virus Diseases of Grapevine. Contact: D. Boscia, Bari, Italy. email icvg2003@area.ba.cnr.it; www.agr.uniba.it

October 17-18, 2003. Xeriscape Conference. Albuquerque, NM. www.xeriscape.com
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largely to its visual profile. Whether the choice of a particular tree diameter is genetic or just random chance cannot be determined. Though larger trees with the most area for beetle brood rearing attract the most beetles, "there are enough beetles that are attracted to the opportunity of a smaller, but more easily overcome tree, that these trees do not escape attack."

D. frontalis "has population dynamics that are influenced by tree resin defenses," said Sharon Martinson (Dartmouth College, Gilman Hall, Hanover, NH). The tree defense system forces the beetles to aggregate to overwhelm the tree. Data is needed from other bark beetle species to see if the same ecological characteristics prevail with those species.

According to Richard Hofstetter (Dartmouth College, Gilman Hall, Hanover, NH), *D. frontalis* larvae feed upon mutualistic fungi that are transported by adult females. Tarsonemus mites have the potential to disrupt the interactions between bark beetles and their mutualistic fungi by transporting and introducing antagonistic fungi, *Ophiostoma* sp., into beetle galleries and surrounding phloem. Tarsonemus mites cause no direct harm to adult beetles and are dependent upon them for dispersal between trees. IPM programs might manipulate phoretic mite fecundity and density as a way to control outbreaks of *D. frontalis* and other bark beetle species.

Scale Pheromones Attract Lacewings

"Studies on attractions of natural enemies to sex pheromones of scale insects are rare," said John Nelson (US Army, CMR 470, Box 4832, APO AE 09165, Military), who tested sex pheromones of three scale insects, *Matsucoccus* sp., for use in the spruce/fir forests of eastern Tennessee's Great Smoky Mountains National Park. Of particular concern is the balsam wooly adelgid, *Adelges piceae*, a pest causing problems as far north as eastern Canada.

The pheromone traps were most effective attracting brown lacewings (Hemerobiidae), mostly *Hemerobius stigma*. Pheromone dispensers remained active 2-4 weeks in pine forests, depending on ambient conditions. The response of native predators to these scale pheromones "may encourage the use of these pheromones in biological control programs," said Nelson.

Forestry Beetle Attractants

Aggregation pheromone components of Northern spruce engraver, *Ips perturbatus,* identified by gas chromatography include ipsenol, ipsdienol and cis-verbenol. In two field behavioral assays of these and other semiochemicals, over 59,000 *I. perturbatus* were trapped at one site in south-central Alaska (Kenai Peninsula) and nearly 62,000 *I. perturbatus* were trapped at a second site in interior Alaska, said Andrew Graves (Univ. of Minnesota, 219 Hodson Hall, St. Paul, MN). The three component blend was most attractive.

Combining commercially available verbenone (84% (-)enantiomer) with conophthorin reduced flight response of *I. perturbatus* 27-37x. Conophthorin-baited traps attracted large numbers of twig beetles, *Pityophthorus nitidulus* and *P. recens*, which have also been collected under the bark of Lutz spruce, *Picea xlutzii*, infested with *I. perturbatus*. The cylindrical bark beetle, *Lasconotus borealis*, also responded to conophthorin.

"Identification of the chemical constituents of volatiles emitted by hosts and non-hosts of forest insect pests is essential to understanding the role that these compounds play in host seeking and selection," said Linda MacDonald (Canadian Forest Serv, Great Lakes Forestry Cent., 1219 Queen St E, Sault St Marie, ON, Canada). "Solid-phase microextraction (a solventless collection method using reusable polymer-coated fused silica fibers) coupled with gas chromatography/mass spectrometry (GC/MS) is an ideal technique for obtaining profiles of volatile compounds potentially perceived by an insect." Red spruce volatiles identified by GC/MS included over 40 compounds (33% monoterpenes; the rest sesquiterpenes, oxygenated terpenes, aliphatics).

In 2000 and 2001 field trials, a synthetic "Spruce Blend" lure created using the monoterpene components of red spruce cortical tissue "was significantly attractive" to brown spruce longhorned beetle (BSLB), *Tetropium fuscum*, which became established in Halifax, Nova Scotia, in 1999. "The addition of an ethanol lure significantly increased attraction of the blend," said MacDonald. In general, the sesquiterpene portion of Norway spruce profiles is more complex than red spruce. Norway spruce, a preferred BSLB host in Europe, has a volatile blend that is 59% sesquiterpenes (vs 6% in red spruce) and 7% alpha-pinene (vs 32% in red spruce) in Ontario, Canada. However, in New Brunswick, both red and Norway spruce volatiles are 35% sesquiterpenes.

According to William Shepherd (Louisiana State Univ, Life Sci Bldg, Baton Rogue, LA), "*Ips* engraver beetles are second only to the southern pine beetle, *D. frontalis*, in their destructive impact on pines" in the southeastern U.S. Hister beetles (Histeridae) make up a significant portion (6%) of the diverse *Ips* natural enemy complex. These small predaceous beetles often are found in ephemeral habitats, such as dung, carrion and under the bark of dead trees. Larval and adult hister beetles both feed on early pine bark beetle life stages, thus likely having a large impact on bark beetle populations.

Though some histerids are visually attracted to *Ips*-infested pine logs, Y-tube olfactometer assays indicate that some hister beetles, such as *Cylistus parallelus* and *Plegaderus transversus*, are attracted to *Ips* pheromones.

Poplar Mating Disruption

The brightly-colored, diurnal western poplar clearwing moth (WPCWM), *Paranthrene robiniae*, has heartwood-burrowing larvae and flies all season long. There are 3-4 flight peaks in southeastern Washington and northeastern Oregon poplar tree farms. Potlach sprays its 6,475 ha (16,000 acres) of poplars near Boardman, OR, 14 times a year to protect the trunks from being weakened and rendered useless for saw timber. Boise Cascade sprays its acreage only five times per season, as trunk damage is of less concern when trees are being pulped. "After every spray WPCWM counts drop for one week," said Neal Kittelson (Washington State Univ, 166 FSHN, Pullman, WA), who reviewed trap counts for both companies.

Kittelson said that a trap density of 1 per 200 acres or about 1/81 ha led to capture of 107,776 male moths during the 2002 season. The conventional insecticides Lorsban and endosulfan were not effective in 2002, so a sex pheromone strategy is planned against this moth in 2003. In a preliminary experiment, bucket traps on poles or in trees at 2-6 m (6.6-19.7 ft) in height monitored moth flight.

The sex pheromone used was a 4:1 ratio of (*Z,E*)-3,13-octadecadienol and (Z,Z)-3,13-octadecadienol. Male moths can move 2.82 km (1.8 mi) away from host plants to locate the pheromone source. Bucket traps baited with 10 mg of pheromone (10x) were shut-down by stapling one septum loaded with 1 mg of pheromone on every 10 trees. This fact suggests that releases of 50 mg of pheromone per acre throughout the season-long flight should control this pest. Kittleson will use membrane-release systems in one-year old trees, followed by a puffer-release system in trees less than 10 m (32 ft) in height, and finally a flowable formulation in trees between 10 and 30 m (32 & 98 ft) tall.