PROTECTION OF SELECT DOUGLAS-FIR FROM INSECT HERBIVORY

Roger E. Sandquist and Vicky J. Erickson

ABSTRACT

Select trees are the highest value individual trees in the forest. They are the basis for future breeding programs to provide genetically improved seedlings for reforestation. Objectives of protection are to facilitate timely production of large quantities of seed from these trees. Strategies differ, depending on the occurrence of area-wide defoliator outbreaks or the prediction of a cone crop on these trees the following year. The major defoliators are western spruce budworm, *Choristoneura occidentalis* (Freeman), Douglas-fir tussock moth, *Orgyia pseudotsugata* McDunnough, and spruce coneworm, *Dioryctria reniculelloides* Mutuura and Monroe. Other insects directly affecting seed production include Douglas-fir cone moth, *Barbara colfaxiana* (Kearfott), Douglas-fir scale midge, *Contarinia washingtonensis* Johnson, and Douglas-fir seed chalcid, *Megastigmus spermotrophus* Wachtl. Tactics include individual or group treatments with chemical or biological sprays, insecticidal injections or implants in individuals or groups, and use of fertilizers. Timing, as related to cost or logistics, is discussed.

Keywords: *Pseudotsuga menziesii,* forest tree improvement, insect herbivory, integrated pest management, *Choristoneura occidentalis,* acephate insecticide implants

INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *glauca*), both as a dominant and lesser component of forest stands, occupies over 2 million acres of productive forest land in interior Oregon and Washington. The range of the interior variety is restricted to the eastern slopes of the Cascade Range, the northeastern corner of Washington, and the Blue and Wallowa Mountains of northeastern Oregon and southeastern Washington. Isolated populations also occur to a limited extent in the Ochoco Mountains of central Oregon. Throughout this range, the species is second only to ponderosa pine (*Pinus ponderosa* Laws.) as an important source of wood products.

To meet increasing demands for forest resources on a shifting and narrowing land base, National Forests in eastern Oregon and Washington have placed great emphasis in the last decade on selection and breeding programs designed to improve the survival, stem form, and growth potential of Douglas-fir populations. Efforts thus far have concentrated largely on the selection and culturing of select trees, but emphasis is now shifting towards the establishment of progeny tests and seed orchards.

TREE IMPROVEMENT IN INTERIOR DOUGLAS-FIR

On each National Forest, ecologically similar breeding zones have been delineated for commercial tree species based on natural elevational distribution patterns. These zones span 1000 feet of elevation and are the basic unit of a Forest's tree improvement program (Table 1). Within a breeding zone, tree species are assigned to one of three program levels based on the number of available commercial forest acres occupied by that species and on projected reforestation seed needs. Program levels differ primarily in the intensity of the improvement program and subsequent seed production methods.

Table 1.—Breeding zone and parent tree statistics for interior Douglas-fir tree improvement programs in the National Forests of Oregon and Washington.

Parent Forest	Parent trees selected	No. breeding zones	No. CFL acres (M)
Oregon:			
Umatilla	899	9	181
Wallowa-Whitman	1534	14	331
Malheur	1124	15	369
Ochoco	393	12	75
Winema	513	8	34
Deschutes[1]	488	4	114
Washington:			
Wenatchee[1]	1564	14	434
Okanogan	673	7	179
Colville	1137	7	265
Totals	8325	90	1982

[1]Figures include cooperators.

In low intensity (level 1) programs, 50-100 phenotypically selected trees in wild stands are the primary source of reforestation seed. A level 2 program brings progeny or clonal material from 50-100 select trees together in an orchard situation so they can interbreed. The intensive or high-level programs include, besides seed orchards, the genetic testing of progeny of 200 or more select trees over several locations within and across breeding zones. Data generated by these field tests are used to rogue seed orchards and to determine the genetic worth of parents for advanced generation breeding.

Select Tree Selection

During the first phase of the program, exceptional individuals are selected from natural stands widely distributed throughout

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

the breeding zone. The selection of parent trees is based on the comparison of the candidate with its neighbors or on the application of certain minimum standards relating to volume, growth, and stem form (Zobel and Talbert 1984). The distribution of selected trees by National Forest is summarized in Table 1. All seed collections made for seed orchards, progeny tests, and gene conservation purposes are processed and stored at the Pacific Northwest Region (Region 6) Dorena Tree Improvement Center near Cottage Grove, Oregon. Currently, the center has an inventory of seeds from over 3000 selected families of interior Douglas-fir (36% of total).

Seed Orchard Establishment

A major component of the Douglas-fir Tree Improvement Program is the establishment of seed orchards to produce high-quality, genetically improved seed in quantities to meet reforestation needs. A total of 36 interior Douglas-fir seed orchards, (over 355 acres), are planned for development in Region 6 (Table 2). Seed orchard development is currently underway, with 41% of these acres established to date. Individual Douglas-fir orchard blocks range from 7-15 acres and usually are part of an orchard complex containing other species (e.g., ponderosa pine, western white pine [*Pinus monticola* Dougl.], or western larch [*Larix occidentalis* Nutt.]) or elevational zones of Douglas-fir.

Douglas-fir orchards in interior Oregon and Washington have thus far been established with seedling material, owing to severe graft incompatibility problems and the lack of rootstock adaptable to east-side conditions. In 1983, the Colville National Forest working with Don Copes of the Pacific Northwest Research Station (Corvallis, OR), began a screening program to develop graft-compatible Douglas-fir for east-side seed orchards. From this effort, 12 trees (18%) were 90-100% compatible (D. Copes, pers. comm.). We think that within the next several years, controlled crosses from these trees will provide enough seed to meet the rootstock requirements of most interior Douglas-fir tree improvement programs.

Progeny Test Establishment

In high-priority Douglas-fir breeding zones (level 3 programs), 6-8 test sites averaging 12-15 acres in size will be established. Plans call for the eventual establishment of about 125 Douglas-fir test sites in eastern Oregon and Washington (Table 3). Data collected from these field tests will be used to estimate the value of each parent tree and to rogue existing seed orchards. Due primarily to a critical lack of seed, no test sites

Table 2.—Seed orchard statistics for interior Douglas-fir tree improvement programs in the National Forests of Oregon and Washington.

	Seed Orchards					
	Planned			Established		
National Forest	No.	Acres	Families	No.	Acres	Families
Oregon:						
Umatilla	6	55	900	0	0	0
Wallowa-Whitman	7	65	1100	1	7	109
Malheur	3	30	300	1	14	108
Washington:						
Wenatchee[1]	11	126	900	9	96	771
Okanogan	5	44	452	2	4	92
Colville	4	35	978	4	24	554
Totals	36	355	4630	17	145	1634

[1]Figures include cooperators.

Table 3.—Progeny test statistics for interior Douglas-fir tree improvement programs in the National Forests of Oregon and Washington.

	Progeny Tests					
	Planned			Established		
National Forest	No.	Acres	Families	No.	Acres	Families
Oregon:						
Umatilla	24	228	600	0	0	0
Wallowa-Whitman	32	384	800	0	0	0
Washington:						
Wenatchee[1]	25	225	726	25	225	726
Okanogan	8	96	260	0	0	0
Colville	36	360	978	0	0	0
Totals	125	1293	3364	25	225	726

[1]Figures include cooperators.

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

in Oregon and only 25 in Washington (Wenatchee National Forest, Table 3) have been established to date. Sufficient seed should be available soon, however, with progeny test establishment becoming the dominant focus of Douglas-fir tree improvement programs in the years to come.

CULTURE AND MANAGEMENT OF SELECT TREES

As Douglas-fir tree improvement programs advance into the seed orchard and progeny test establishment phase, a high priority is being placed on cultural and protection activities designed to enhance seed production in field-selected parent trees. Competing vegetation is typically removed within a distance of twice the crown radius of the select tree to reduce competition for sunlight, water, and nutrients and to help protect seed crops from squirrels. Slash is removed from the vicinity of the select tree, and all branches within reach of the ground are pruned. After thinning, aluminum squirrel bands are placed around the bole of the tree about 6 feet above the ground. To promote flowering, nitrogen fertilizer in the form of ammonium nitrate (24-0-0) or urea is applied to Douglas-fir parent trees every 2-3 years, depending on seed needs. About 400 pounds of nitrogen per acre (calculated on a per tree area basis) is applied in a doughnut shape, with the inner edge one-half the radius of the crown from the bole. The fertilized area extends to one-half the radius of the crown beyond the dripline. Fertilizer applications are made in late fall when trees are fully dormant or in early spring before vegetative bud flush. Partial stem girdling to stimulate cone production in select Douglas-fir trees also is used to a limited extent. Even with culturing and careful management, a tremendous amount of variation in Douglas-fir cone and seed production is observed among years and sites within the range of the species. Besides the natural variation in male and female flowering patterns, the principal factors causing infrequent and sporadic seed crops in interior Douglas-fir are frost-related cone and pollen mortality and destruction caused by various insect pests.

PEST INSECTS

Currently, the most serious insect pests to Douglas-fir forests are the western spruce budworm (*Choristoneura occidentalis* Freeman), and the spruce coneworm (*Dioryctria reniculelloides*). Besides being serious defoliators, these insects are extremely destructive to developing cone buds, young cones of the current year, and the reproductive primordia of succeeding cone crops.

Western spruce budworm has been a particularly serious problem in recent years for Douglas-fir in the Blue Mountains and parts of the Wallowa Mountains of northeastern Oregon. The amount of forest land in the area affected by the infestation exceeds 3 million acres. Because of this infestation, no collectable seed crops have occurred in Douglas-fir for much of the past 10 years. Tree improvement programs thus have been brought to a virtual standstill because seed and healthy scion material have not been available to establish seed orchards and progeny tests.

Other insects directly affecting seed production include Douglas-fir cone moth, *Barbara colfaxiana* (Kearfott), Douglas-fir scale midge, *Contarinia washingtonensis* Johnson, and Douglas-fir seed chalcid, *Megastigmus spermotrophus* Wachtl. (Hedlin *et al.* 1980). When cone production problems caused by western spruce budworm cease, these insects will likely reduce seed production.

PROTECTION STRATEGIES AND TACTICS

Integrated Pest Management Strategy

Integrated pest management is a systematic decision-making process leading to management actions that consider pest-host systems and evaluate alternatives for managing pest populations at levels consistent with resource management objectives. Steps in integrated pest management include:

- Monitoring and analyzing the crop status.
- Monitoring and analyzing the pest situation.
- Determining if the action threshold is exceeded or whether preventative treatments are needed.
- Analyzing methods.
- Implementing treatments if needed.
- Evaluating treatment effectiveness.
- Continuing to monitor.

Protection of select trees from insect herbivory is specialized because each individual tree is managed as an extremely high-valued specimen. Due to the location of the parent tree, there are special logistics challenges associated with implementing pest management. The management of select trees in the forest is a relatively recent phenomenon, and information specific to this pest management situation has been developed only recently. Strategies and tactics from other pest management situations are being adapted to accomplish insect management in select trees.

Protection Tactics

The general categories of methods or tactics in insect pest management are cultural, biological, and insecticidal.[1]

Cultural techniques such as reducing competition from neighboring trees and other vegetation, fertilizing, and reducing cone predation from squirrels are used to assure a larger cone crop than what would occur in the absence of these techniques. Managing stands to improve individual tree vigor is known to reduce tree damage and growth loss from western spruce budworm (Carlson and Wulf 1989). With select trees, it is also necessary to protect the reproductive structures and scion wood. There is no published information to suggest that cultural tactics are beneficial in reducing insect damage to Douglas-fir reproductive structures.

[1]The mention of commercial products does not constitute endorsement by the USDA to the exclusion of other products that may be suitable. The pesticides reported on and recommended here were registered for the use described at the time this manuscript was prepared. Because registration of pesticides is under constant review by State and Federal authorities, a responsible State agency should be consulted as to the current status of these pesticides.

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

Conservation or augmentation of natural enemies of insect pests has been shown to reduce and maintain low population levels of defoliating insects such as western spruce budworm (Brookes *et al.* 1987) and Douglas fir tussock moth (Brookes *et al.* 1978). There is no information, however, to suggest that natural enemies of depredating insects can reduce damage to reproductive structures.

The use of chemical insecticides remains the primary and most effective method for reducing insect damage to select trees and their seed crops. Three tactics are currently available: individual tree ground sprays, injection of systemic insecticides, and implants of systemic insecticides.

Carbaryl, *Bacillus thuringiensis (B.t.)*, methomyl, and naled are registered for individual tree treatment using hydraulic sprayers from the ground. Although registered, methomyl and naled are not generally recommended because they are more hazardous to fish, wildlife, and bees than is carbaryl. *B.t.* is registered for use at 4-8 Billion International Units in 378 liters (100 gal) of water. Carbaryl emulsifiable concentrates are registered for use at 454 grams (1 lb) of active ingredient in 378 liters (100 gal) of water.

Injector units (plastic feeder tubes attached to pressurized plastic cartridges) containing liquid oxydemeton-methyl are registered to be placed in holes drilled approximately 1.3 cm (1/2 in) beyond the cambium. The rate of application is one injector unit containing 1.5 gram of actual oxydemeton-methyl for each 15 cm (6 in) of tree circumference. Injector units must be removed after the chemical has passed into the tree, usually 2-6 days. Proper disposal of empty injectors is required.

Acephate applied by implanting into tree trunks is registered and found very useful in reducing both defoliation and seed losses. Capsules containing 1 gram of acephate are placed every 10 cm (4 in) around the circumference of the trees. The plastic capsules remain in the tree, resulting in no need for disposal. The implants have minimal potential nontarget effects compared to ground sprays of chemical insecticides. Although not as potentially safe as *B.t.*, they are more consistently efficacious.

Advantages of implantation and injection methods:

- Minimal exposure to the environment. Insecticide is confined to tissues of host trees, not broadcast into the environment. There is no drift, and contamination of nontarget organisms is minimized. In addition, residues degrade rapidly and do not accumulate in the food chain. These applications are less sensitive politically.
- Minimal exposure to the user. These insecticides are prepackaged. For maximum protection, the user needs only rubber gloves, coveralls, and a facial visor. For implants, use of rubber gloves is the only recommendation.
- Trees can be treated under a broad range of sites and climatic conditions. Inclement weather, including rain, snow, and wind, does not affect the ability to treat trees or effectiveness of the insecticide.
- Cost-effective in natural stands. There are no limits on the height of trees that can be treated. Insecticides and equipment required are portable and can be easily used in remote areas where trees are widely scattered. No heavy equipment is required.
- Easy storage and disposal. Little space and no special facilities are required to store the implants or applicator units.
- Minimal training is required. The method of application is simple and straightforward; the users can be trained in less than 15 minutes.
- Methods are effective. Insecticides injected or implanted in trees have achieved good control over cone and seed insects, have protected scion material, and have reduced defoliation effects to keep trees in a vigorous condition. These methods have sometimes produced better results than hydraulically applied chemical sprays.

Additional Research Findings From Oregon

Protecting Douglas-fir foliage by acephate implants against western spruce budworm defoliation was studied in 1985 on the North Fork John Day Ranger District of the Umatilla National Forest, Oregon. The implants were highly effective, and timing of treatment was important to the degree of protection (Koerber and Sandquist 1988). Implanting before cone buds begin to enlarge or more than 3 weeks before vegetative bud burst resulted in twice as many undefoliated shoots (52%) as did implanting after bud burst (25%). Ninety percent of the new shoots in the untreated control trees were completely defoliated.

Carry-over effects of acephate were evaluated one year after Douglas-fir were implanted (Sandquist and Erickson, in press). Trees had protection from western spruce budworm the year after treatment. Foliage protection with implants installed one week after vegetative bud burst was similar to its protection the first year. Foliage protection with implants installed 3 weeks before vegetative bud burst was less than its protection the first year, less than the later implants, and slightly more than untreated controls.

Koerber and Sandquist (1988) found that implanting in the fall after trees become dormant is equally as effective as treating before cone buds begin to enlarge or more than 3 weeks before vegetative bud burst.

Comparisons of the costs of fall versus spring implanting of acephate implants were made by Victoria Rockwell (pers. comm.) in 1986. In spring, 2.8 hours of labor per tree was required when cordless drills and battery packs were used and 209 trees had to be reached on snowmobiles. The average cost per tree, including materials, vehicles, and labor was $37.29. During fall, implants were installed in 356 trees, and 275 trees were fertilized. Using power drills and generators and traveling by pickup truck, 1.4 hours per tree were required. The average cost per tree, including materials, fertilizer, vehicles and labor, was $20.63.

RECOMMENDATIONS

For the following reasons, the use of acephate implants is recommended to protect select Douglas-fir trees from defoliating insects and cone and seed insects:

- The timing of implanting is flexible; it can be done between fall and early spring while trees are dormant. If done in fall,

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.

access problems are avoided and the work can be done with other cultural activities.

- Inclement weather does not interfere with the installation or effectiveness of the implants.
- The implants may be effective for 2 years under certain management scenarios.
- There are minimal nontarget effects expected because the insecticide is confined within the tree and not broadcast into the environment.

The timing and frequency of implanting can be determined by these principles:

- Because of the carry-over of late spring acephate applications (1 week after vegetative bud burst), implanting at this time may be most effective, particularly during the early and less damaging years of a budworm infestation (e.g., years 2-5 of a 7- to 10-year infestation). If a cone crop is anticipated in 2-3 years, for example, treating parent trees in the late spring may provide adequate foliage protection for the 2 years before the cone crop. For trees with developing cone crops, fall or early spring implanting would be better to maximize foliage and cone-crop protection.
- During the later (year 6 and after) and more damaging years of an infestation, protecting select trees may be required to maintain their crown area and vigor so they can produce cones. If implanting every year is impractical or too costly, alternate years of late-spring implanting may provide minimal protection. Fall or early spring implants are still recommended if a cone crop shows up in a fall survey.
- To reduce the potential for inbreeding, pollen-producing trees surrounding selected female parents may also be protected by alternate years of late-spring implants. This treatment may assure a source of outcrossed pollen for maternal parents from which open-pollinated seed is collected.

LITERATURE CITED

Brookes, M. H., R. W. Stark and R. W. Campbell, eds. 1978. The Douglas-fir tussock moth: a Synthesis. Tech. Bull. 1585. Washington, DC: USDA Forest Service, Science and Education Agency. 331 pp.

Brookes, M. H., R. W. Campbell, J. J. Colbert, R. G. Mitchell and R.W. Stark, eds. 1987. Western spruce budworm. Tech. Bull. 1694. Washington, DC: USDA. 198 pp.

Carlson, C. E. and N. W. Wulf. 1989. Silvicultural strategies to reduce stand and forest susceptibility to the western spruce budworm. Agric. Hdbk. 676. Washington, DC: USDA. 31 pp.

Hedlin, A. F., H. O. Yates III, D. C. Tovar, B. H. Ebel, T. W. Koerber and E. P. Merkel. 1980. Cone and seed insects of North American conifers. Can. Forest Service. Ottawa, ON: 122 pp.

Koerber, T. W. and R. E. Sandquist. 1988. Timing of trunk-implanted acephate for protection of Douglas-fir from defoliation. West. J. App. For. 3(4):126-128.

Sandquist, R. E. and V. J. Erickson. [In press]. Carry-over effects of trunk-implanted acephate for protecting Douglas-fir from western spruce budworm defoliation. For. Ecol. and Manage.

Zobel, B. J. and J. T. Talbert. 1984. Applied forest tree improvement. New York, NY: John Wiley and Sons. 505 pp.

Authors

Roger E. Sandquist
Entomologist
USDA Forest Service
Pacific Northwest Region
Portland, Oregon 97208

Vicky J. Erickson
Area Geneticist
USDA Forest Service
Umatilla National Forest
Pendleton, Oregon 97801

Published in proceedings of "Interior Douglas-Fir: The Species and Its Management" held February 27 – March 1, 1990 in Spokane, WA, USA.
Compiled and edited by D.M. Baumgartner and J.E. Lotan, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0230. 301 pp.