CONSIDERATIONS WHEN USING ETHEPHON FOR SUPPRESSING DWARF AND LEAFY MISTLETOE INFESTATIONS IN ORNAMENTAL LANDSCAPES

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Abstract. Ethephon [(2-chloroethyl) phosphonic acid] is registered for use in controlling dwarf and leafy mistletoe infestations in ornamental trees. Practical use of ethephon (as Florel® at label rate) is limited to suppression of dwarf and leafy mistletoe spread. Ethephon at label rates causes abscission of aerial dwarf mistletoe shoots and partial abscission of leafy mistletoe shoots, but in either application the treated mistletoe plants are not killed. Resprouting of mistletoe infections will occur and retreatment will be needed to continue suppression of mistletoe fruiting. Whole tree spraying is not recommended due to the potential environmental and economic damage that may occur from spray drifting onto sensitive nontargets and excessive chemical use. Due to the lack of significant benefit of whole tree or direct cluster spraying of leafy mistletoe with ethephon at label rate, its use for this purpose is not recommended.

Protection of high value ornamental trees against damage caused by dwarf and leafy mistletoes has long been a goal of arborists. Traditional suppression techniques used by landscapers and arborists are pruning out infected branches, pruning mistletoe clusters flush with the branch and wrapping them in black plastic, and spraying 2,4-D foam onto cut mistletoe stubs. Environmental concerns have eliminated use of 2,4-D foam. Due to the high cost of pruning, chemical treatments for mistletoe control are particularly alluring and many chemicals have been tested but with little success. Ethephon, under the trade name Florel®, is registered for dwarf and leafy mistletoe control, thus renewing hopes of finding a safe, cost-effective chemical for mistletoe control. Arborists and consumers are interested in how this chemical can be most effectively used. Ethephon's effectiveness was evaluated by many researchers on different hosts and mistletoe species, with various application methods. This report summarizes the results of many ethephon trials and presents guidelines for the use of ethephon for dwarf and leafy mistletoe control. Mistletoe biology and mistletoe control methods will first be briefly reviewed, for they are a prerequisite to understanding effective mistletoe control using an integrated pest management (IPM) approach.

Mistletoe Biology

Mistletoes are serious pests of conifer and many hardwood tree species (12, 37). As parasites, they harm their hosts by shunting plant photosynthate (dwarf mistletoes) or water and nutrients (both mistletoes) to their tissues at the expense of host nutritional and water needs. Dwarf mistletoes (*Arceuthobium* spp.) are leafless, yellow-orange, essentially obligate parasites on conifers (Pinaceae and Cupressaceae) (14). Leafy mistletoes are larger, green leaved hemi-parasitic plants found on many hardwood genera and occasionally on conifers (13). Two genera of leafy mistletoes are found in the United States: the native *Phoradendron* and the introduced European mistletoe, *Viscum*, found only in California (28, 37).

Health of lightly infected trees is usually not seriously affected by mistletoe presence. However, moderately to heavily infected trees may suffer from reduced tree vigor, increased susceptibility to insects and diseases, deformity—including branch dieback, and often, untimely death.

Both dwarf and leafy mistletoes can be long lived—potentially living until their host tissue dies. Dwarf and leafy mistletoes generally produce localized infections, but infection may become

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systemic in a few dwarf mistletoe host-parasite combinations (21). Both mistletoes are dioecious (have separate male and female plants), have endophytic systems within host tissues and epiphytic (external) stems for flower and seed production (14, 37). Dwarf mistletoes are highly specialized plants that have a narrowly defined host range, while leafy mistletoes have a broader host range.

Dwarf mistletoe infections develop slowly. A viscous-coated seed landing and sticking onto a needle of a host conifer may slide down the needle to a branch segment after rain, become "cemented" in place and overwinter there to germinate in the spring. A primary haustorium emerges from the seed to penetrate host tissue; usually tissue less than five years old. Haustorial (cortical) strands arise from the primary haustorium and grow longitudinally through host cortex and outer phloem. Sinkers grow into the branch phloem and xylem (2, 20). In three to four years the mistletoe epiphytic system breaks through the bark with subsequent fruit development (14). Pollination occurs by both insect transmission and wind. When mature, dwarf mistletoe seeds are disseminated by an explosive discharge mechanism that can shoot the seed, actually a naked endosperm, up to 35 feet away.

Mechanical seed dispersal limits spread of dwarf mistletoe to within the host tree and closely adjacent trees; and due to the large numbers of seeds per mistletoe plant, very high host infection potential exists. Some plants may produce several thousand fruits per year. Birds and rodents may be incidently involved in dwarf mistletoe spread, accounting for new infections in previously uninfested areas.

In leafy mistletoes, the berries serve as food for birds, particularly in winter. Berries usually contain a single seed which is surrounded by a fleshy pulp. The berry pulp is digested by the bird and the seeds are evacuated onto branches, or the sticky seeds are inadvertently transported from their beaks and feet onto branches elsewhere. A wetted seed produces a viscous coating that cements the seed in place when dried, and in the spring the germinating radicle penetrates into living host tissue (37). Infection occurs primarily through young bark, however older wood with deeply furrowed bark may also become infected. Haustorial development follows a similar course as for dwarf mistletoe, however, epiphytic shoots are normally developed within one year. The plant may start producing berries in three to four years.

Since leafy mistletoe is disseminated by birds, there is a different host infection pattern from that of dwarf mistletoe. New infections are most often found in the larger trees of an area, in isolated trees, and in bird-favored susceptible roosting trees.

Mistletoe Control Methods

Pruning out infected branches, tree removal, and favoring nonsusceptible tree species are all useful techniques for managing mistletoe. Biological control with diseases and parasites of dwarf mistletoe has been tried without success (19).

Pruning out infections is not always desirable or possible. Conifers are difficult to prune for mistletoe control without significantly detracting from their expected form in the landscape. Also, latent and very young or small infections are easily overlooked during pruning. Small infected branches can often be removed without affecting tree appearance, but removing large branches may well affect host symmetry. Bole infections cannot be removed without seriously threatening tree health and integrity. In hardwoods, small infected branches can be removed without affecting tree appearance. Judicious removal of some larger branches may not detract from tree appearance, but wounds created in the process may provide entrance courts for decay organisms.

The difficulty and cost of pruning has inspired pest managers to search for chemical methods for mistletoe control. Through 1978, over 60 different chemicals have been tested for use in controlling dwarf mistletoes, but none has proven effective (19). 2,4-D foam (no longer marketed) and black plastic have had some practical use for topical treatment of pruned leafy mistletoe infections in hardwoods (5, 23, 38), and asphalt-based pruning paint has provided control of mistletoe regrowth when sprayed onto freshly cut leafy mistletoe branch stubs and surrounding host tissue (24, 25).

Recent research with ethephon has renewed hope for an effective chemical for mistletoe control. Ethephon releases ethylene during absorption by plant tissue, this enhances the natural ripening process leading to abscission of mature dwarf and leafy mistletoe shoots. Ethephon is marketed by Rhone-Poulenc Ag Company under the name Florel®. Florel has a "Caution" warning on the label. It is a strong acid and is harmful if absorbed through the skin and eyes, inhaled, or swallowed. Health hazards associated with ethephon are mainly due to its irritant properties on mucosal surfaces. Mutagenicity studies "in vivo" and "in vitro" were negative. The active ingredient has been shown not to be teratogenic or carcinogenic in animal studies (35). It is damaging to swamps, wetlands, and marshes and is not to be applied through irrigation water. Plants sprayed with Florel often flower 7 to 10 days earlier, may experience temporary growth inhibition, premature needle drop, and foliage burn or yellowing (35). At high concentration it can damage acrylic plastics, metals and paints (such as car finishes).

The Florel Brand labeled as "FRUIT ELIMINATOR" states, as one of its uses, that is used "as a foliar spray on ornamental conifers and ornamental deciduous trees for removal of dwarf mistletoe shoots and seeds" (29). The label goes on to advise "Applications made in conjunction with silvicultural dwarf mistletoe management will prevent spread of the mistletoe parasite to other parts of the tree and to other trees", and to treat any dwarf and leafy mistletoe regrowth before seed dispersal occurs.

It is well documented that thorough application of ethephon to dwarf mistletoe shoots will cause shoot defoliation; many studies have reported reductions of between 60 and 100 percent due to application of ethephon (Table 1 references). However, contrary to the 1989 label statement concerning "dwarf mistletoe removal"(34), Florel does not remove dwarf mistletoe from the tree. What it does, is cause the abscission of adequately treated, mature shoots present at the time of treatment. Since the endophytic system of the dwarf mistletoe plant is usually not affected by ethephon treatment, new plant growth often commences following defoliation and retreatment may be required. The mistletoe plant continues to produce aerial stems at the plant margins and over the next several years will again produce fruits (15). Despite this significant limitation, with proper use ethephon can be a useful chemical for suppression of dwarf mistletoe fruiting. The following section provides background information and summarizes research work done with ethephon.

Table 1. Ethephon has been tested on the following coniferous/dwarf mistletoe (A) and broadleaf/leafy mistletoe (B) host/parasite combinations.

Taxon	Host	Location	References
(A) Arceuthobium			
americanum	Pinus banksiana	Man.	3
	Pinus contorta	CO, CA	7,30,31,36
campylopodum	Pinus ponderosa	CA, ID	9,32,33
douglasii	Pseudostuga menziesii	OR	32
laricis	Larix occidentalis	OR	32
pusillum	Picea mariana	MN	26,27
vaginatum	P. ponderosa	CO,NM	4,11,15,16,17,31
(B) Phoradendron			
macrophyllum	Fraxinus velutina	CA	23,24,25
	Gleditsia triacanthos	CA	23,24,25
macrophyllum	Fraxinus moraine	CA	10,18
(tomentosum)	Populus sp.	CA	10
	Juglans hindsii	CA	18
tomentosum	Ulmus crassifolia(?)	TX	41
	Quercus stellata(?)	TX	41
villosum	Quercus douglasii	CA	23,24,25

Dwarf Mistletoe Control

For dwarf mistletoe control, Florel's label rate is 2,700 ppm, and use of a surfactant is recommended, as is spraying to "wet" (29). Florel should be used within four hours of mixing as chemical effectiveness decreases after that length of time (29). Experimentally, ethephon has been tested at rates ranging from 1,200 - 5,000 ppm (4, 6, 7, 16, 17, 27, 30, 31, 32, 39). Ethephon is not translocated within the tree, it must be placed onto the target to be effective. Therefore treatment success is dependent upon complete mistletoe plant coverage (39).

The volume of ethephon needed for dwarf mistletoe control varies with the application method, tree size, and number of dwarf mistletoe

plants to be treated. Direct plant treatment requires the least material, whole-tree ground application requires more, while aerial application has not been successful with rates used experimentally. Frankel et al. (9) used 1000 mls. of 2700 ppm solution in a backpack sprayer to directly spray 30 individual mistletoe plants to runoff. Whole tree spraying required between 200 to 240 gallons per acre to be effective; aerial application using 10-40 gallons per acre was not effective (3, 11, 36).

Many different spray devices have been used to apply ethephon to dwarf mistletoe in conifers. Hand, backpack, gravity-fed, hydraulic sprayers and aerial application have been tested. In ground-based treatments spray applications became less effective as coverage was required higher in the tree. In our studies, we attribute this to the difficulty in fully covering higher targets. Lower targets are easier to spray and may receive additional application as chemical drips down when infections above them are sprayed (9). Due to the difficulty of adequately treating all fruiting infections in conifers, some fruiting shoots on large mistletoe plants and small fruiting infections may be missed. Chemical intercepted by needle clusters has caused incomplete target mistletoe shoot removal (9).

Timing of ethephon application in relation to dwarf mistletoe seed discharge is not critical. Application should be made prior to seed dispersion but no differences were seen for June, July, and August treatments for control of *Arceuthobium vaginatum* on ponderosa pine in Colorado (15). Windy and rainy situations should be avoided during application for environmental safety and most effective use of chemical.

Following ethephon application, dwarf mistletoe resprouting occurred after different lengths of time depending upon application rate and host-species combination. Three to four weeks after fall treatment of western dwarf mistletoe on Jeffrey pine, emerging aerial shoots were observed on both treatment and control plants at Latour Demonstration State Forest in northern California (8). Lodgepole pine dwarf mistletoe treated in an adjacent stand did not resprout for over one year (9). Johnson (15) noted development of small immature ponderosa pine dwarf mistletoe shoots one year after ethephon application and production of mature shoots and fruits four years after treatment with 2200 and 2700 ppm ethephon. Parks and Hoffman (32) noted some resprouting in Douglas-fir which varied with ethephon application rate: 37% of the 1,260 ppm treatment infections resprouted, while no resprouting occurred in the 5,000 ppm treatment. Label rate of 2,700 ppm appears to be adequate for shoot defoliation on ponderosa pine provided mistletoe plants are thoroughly wetted (7), but does not seem to provide long term control (8). No resprouting occurred in tests at 5,000 ppm (32).

Some toxicity to host trees has been observed after Florel application. Needle yellowing and branch dieback was found on black spruce (27) and lodgepole pine (7).

Leafy Mistletoe Control

Ethephon has been tested for use as a direct, spray-applied application on intact mistletoe clusters for shoot removal and as a treatment applied to pruned mistletoe stubs for the prevention of regrowth. Spray application timing is critical for successful shoot reduction of leafy mistletoe. Host dormant treatments were effective for shoot removal, however, ethephon application with temperatures below 40°F or after mistletoe growth had begun (March-April) were ineffective (6). Laboratory experiments determined that ethephon is rapidly absorbed by leafy mistletoe and indicate that ethephon treatment results would not be affected with at least a 1 hour interval between application and rainfall (10).

Spray Application. Direct spray application rates of 0.21-2.0% a.i. (2,100-20,000 ppm) have been evaluated for leafy mistletoe shoot removal. Defoliation levels ranged from 33-100%; increasing as chemical concentrations increased (39, 40). The label rate for leafy mistletoe removal with Florel is 0.5% a.i. which does not consistently promote total defoliation of leafy mistletoe (22).

Ground spray application is easier than direct plant application, but has the disadvantages of increased spray drift leading to risk of human exposure, and undesirable drift of chemical onto neighboring plants and cars (causing defoliation

of evergreens and exfoliation of vehicle paint). Also, problems of incomplete mistletoe plant target coverage, and application of excessive amounts of chemical are likely to occur. Direct application onto clusters is labor intensive, however smaller amounts of chemical are required and complete coverage is assured. Host injection of ethephon in the summer gave unpredictable mistletoe suppression results, and damaged host foliage (22).

Stub Treatment. Experimentally, Lichter and Berry (23) have achieved effective control of leafy mistletoe regrowth through ethephon treatment to cut mistletoe stubs during the host dormant season. A 10% a.i. ethephon solution applied to freshly cut stubs of two species of leafy mistletoe on three host species greatly reduced mistletoe regrowth, providing over 90% control after two growing seasons. Treatments with 2% a.i. ethephon provided a lower degree of control (64% after two growing seasons). No host damage due to ethephon treatment was observed. In these studies similar treatment with asphalt-based pruning paint also provided effective control (100% after one growing season) while stub treatments with glyphosate (Roundup®, Monsanto Chemical, St. Louis, MO) gave inconsistent results and damaged host foliage.

Guidelines for Ethephon Application

After reviewing research results and observing ethephon trials, we recommend the following guidelines for mistletoe control.

Before any dwarf or leafy mistletoe control work is begun, present and future mistletoe impact in the landscape should be evaluated. Mistletoe reinfestations from within and surrounding the planting must be considered for the risk they present. Present mistletoe infection levels should be determined for all susceptible trees; for dwarf mistletoe, the Hawksworth 6-Class Rating System is useful for this task (1).

Severely infested conifers and hardwoods must be judged for their value in the landscape when evaluated for mistletoe control or removal. Older, heavily infected trees are likely to decline over time and become "centers" for insects and disease. Younger, vigorous trees are generally more amenable to severe pruning to reduce or eliminate mistletoe infection than are older trees. Pruning should be done following standards published by the Western Chapter of the International Society of Arboriculture (ISA) (40), or similar, before any chemical treatment of mistletoe is begun.

The frequency of mistletoe treatment needed is dependent upon the level of mistletoe infection tolerable to both host and arborist, and property owner/client. Dwarf mistletoe host reinfestation depends upon the location and number of female plants in the tree and closely adjacent susceptible trees and on seed production, while leafy mistletoe reinfestation depends upon host presence, mistletoe fruit availability and bird tree preferences. These factors must be measured against host tree age, vitality, and value. General guidelines for retreatment are necessarily site specific and will need to be developed by a pest control advisor and/or an arborist for the desired end result.

If treatment with ethephon is deemed useful, application technique and equipment should be carefully chosen to meet the conditions present in the infested area. Proper weather conditions, complete mistletoe plant coverage, and use of a surfactant are critical for satisfactory results for dwarf mistletoe shoot removal (39). Due to the hazards associated with spray drift and incomplete target coverage, spraying infected trees from the ground must be done with caution and may not be appropriate for many urban sites. Ethephon at label rate is not efficacious for leafy mistletoe control.

Conclusions

Dwarf Mistletoe. Since the endophytic system of the dwarf mistletoe plant is usually not affected by ethephon treatment, resprouting will occur following mistletoe shoot removal. Because mistletoe control is temporary, ethephon use for ornamental conifers at label rates should be intended only to inhibit seed production, thereby lessening further build-up of dwarf mistletoe in infected trees and reducing spread to adjacent trees. Female plants must be retreated periodically to afford continued relief from mistletoe infection. The female plants will produce fruit again after several years, and both male and female plants

will continue to demand ever-increasing carbohydrates, mineral nutrients and water from their hosts. Careful pruning may be used to remove some mistletoe plants without significantly affecting tree appearance.

Leafy Mistletoe. Due to the deleterious effects of leafy mistletoe on its host, this pest should be removed from high value landscape trees to avoid host stress and tree deformity. Mistletoe clusters should be removed through pruning wherever possible and appropriate in keeping with well-respected pruning standards (such as those of the ISA). Remaining mistletoe clusters—those on desirable branches or scaffolds—should be pruned flush to the host branch (without damaging the host). Experimentally, ethephon application (at 10% a.i.) to stubs of mistletoe clusters has provided effective control, as has an asphalt-based wound paint applied as an aerosol (Tree Seal®), however neither of these treatments are currently registered for use.

Disclaimer. The use of trade names is for the benefit of the reader and does not imply an official endorsement or approval of products mentioned. Application of chemical should be made by a licensed applicator. Ethephon should only be used in accordance with the label.

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Résumé. L'ethephon [acide (2-chloroéthyl) phosphonique] est enregistré pour le contrôle des infestations de faux-gui et de rouille-balai de sorcière sur les arbres ornementaux. L'utilisation pratique de l'ethephon (commercialisé sous le nom de Florel) est limitée à un rôle de suppression de la progression de ces parasites. L'ethephon, selon la concentration spécifiée sur l'étiquette, cause, selon la cas, la scission partielle ou totale des pousses attaquées par ces parasites, mais les arbres traités ne sont pas tués pour autant. L'émergence de nouvelles pousses se produira et une répétition du traitement sera nécessaire afin de continuer à éliminer les fructifications de ces parasites. L'arrosage au complet de l'arbre n'est pas recommandé en raison des dommages potentiels de nature environnementale et économique qui peuvent survenir lors de la dérive du produit vers d'autres plantes sensibles et aussi en raison de l'usage excessif de substances chimiques.

Zusammenfassung. Ethephon [(2-chloroethyl) Phosphorsäurel] ist registriert für die Anwendung bei Zwerg- und Buschchmistelbefall an Ziergehölzen. Die praktische Anwendung von Ethephon (als Florel®) ist begrenzt auf die Unterdrückung von Zwerg- und Buschmistelverbreitung. Ethephon in der vorgeschriebenen Dosierung verursacht ein Absterben der äußeren Zwergmisteltriebe und ein teilweises Absterben der Buschmisteltriebe, aber die behandelten Misteln sind nicht tot. Es kommt zu erneutem Triebschoßen und die Behandlung muß wiederholt werden um die Fruchtreife der Mistel zur unterdrücken. Das Behandeln des ganzen Baumes ist nicht empfehlenswert, wegen der potentiellen ökologischen und ökonomischen Schäden, die durch Abdrift des Spritzmittels auf empfindliche andere Pflanzen entstehen und wegen des