Survey for and Chemical Control of Leafy Mistletoe (*Phoradendron tomentosum* subsp. *macrophyllum*) on Shade Trees in Davis, California

THEMIS J. MICHAILIDES, Postdoctoral Research Associate VI, and JOSEPH M. OGAWA, Professor, Department of Plant Pathology, University of California, Davis 95616; JOHN R. PARMETER, JR., Professor, Department of Plant Pathology, University of California, Berkeley 94720; and SHIG YOSHIMINE, Parks and Grounds Superintendent, Davis, CA 95616

ABSTRACT

Michailides, T. J., Ogawa, J. M., Parmeter, J. R., Jr., and Yoshimine, S. 1987. Survey for and chemical control of leafy mistletoe (*Phoradendron tomentosum* subsp. *macrophyllum*) on shade trees in Davis, California. Plant Disease 71:533-536.

In a survey at Davis, CA, leafy mistletoe (*Phoradendron tomentosum* subsp. *macrophyllum*) was found on 15 species of shade trees: Modesto ash (*Fraxinus velutina* var. *glabra* 'Modesto'), Arizona ash (*F. velutina* 'Arizona'), chinese hackberry (*Celtis sinensis*), black walnut (*Juglans hindsii*), locust (*Gleditsia triacanthos*), Moraine ash (*Fraxinus* 'Moraine' = *F. holotricha* × *F. pallisae*), an alder species (*Alnus* sp.), white alder (*A. rhombifolia*), pagoda (*Sophora japonica*), acacia (*Acacia melanoxylon*), English walnut (*Juglans regia*), boxelder (*Acer negundo*), elm (*Ulmus carpinifolia*), maple (*A. saccharinum*), and zelkova (*Zelkova serrata*). Among these, Modesto ash and hackberry trees were the most frequently infected. A mixture of the herbicides 2,4-D and dicamba and the citrus abscission agent cycloheximide significantly reduced new growth of leafy mistletoe in Modesto ash, chinese hackberry, white alder, and Moraine ash trees for at least 1.5 yr after application. Posttreatment dissection of limb samples from a Modesto ash with both treated and untreated clumps of mistletoe revealed live and dead endophytic systems.

The common broadleaf mistletoe (*Phoradendron tomentosum* (DC.) Engelm. ex A. Gray subsp. *macrophyllum* (Engelm.) Wiens) (16) is an evergreen parasitic plant whose principal hosts are trees in the genera *Populus, Platanus, Salix,* and *Fraxinus* (16). It parasitizes trees in both forest and urban environments. A survey done in the city of Sacramento, CA, in 1976–1977 showed that, of 46,500 trees surveyed, 11% had mistletoe infections (13). The infected trees included 22 species, but 90% were ash, primarily Modesto and Arizona ash (14).

Problems associated with mistletoe infections are: 1) the dropping of mistletoe leaves that necessitates regular cleanup, 2) reduced vigor of the parasitized trees, 3) occasional limb breakage, and 4) cleanup of bird droppings on parked vehicles and walkways from birds feeding on mistletoe berries.

In the early 1960s, there was a growing interest in controlling *Phoradendron* on certain desert shrubs and trees of high aesthetic value, especially in the arid southwestern United States (3). Current control, however, relies on costly pruning. For example, in 1978–1979 the city of Sacramento, CA, estimated an annual cost of $1.4 million for such a program (*The Sacramento Bee*, 22 March 1979). Although leafy mistletoe may be partially controlled by annual pruning of infected limbs (3,14), this is not practical when infections occur on trunks or major scaffolds. However, a combination of pruning these mistletoes and applying a mixture of 2,4-D and dicamba (Super D Weedone foam weed control) may be practical (15). Graser (5,6) reported that spraying leafy mistletoe during the dormant season with triethanolamine salt or isopropyl ester of 2,4-D killed 50–85% of the treated mistletoe on walnut trees in Sutter County, California. Bayer et al (1) found that isopropyl ester of 2,4-D, amitrole, or atrazine with dormant oil additives gave adequate control of mistletoe on English walnuts (*Juglans regia* L.). In addition, they (1) suggested that more than 1 yr is required to obtain reliable data on English walnuts. Control of other mistletoe species was also achieved with trunk injection of 2,4-D (7).

Severe mistletoe infections on various kinds of shade trees during the 1970s in Davis necessitated the development of control methods. A cooperative study between the Davis and Berkeley campuses of the University of California and the city of Davis was undertaken to determine the species of trees involved, the extent of infection, and the feasibility of chemical control.

MATERIALS AND METHODS

Survey of shade trees in Davis. A survey was conducted from November 1976 to February 1977 by driving along the streets and recording the species of infected shade trees and the severity of infection on both sides of the street. Three severity categories were used: heavy = many mistletoe clumps in the perimeter of the canopy, on scaffolds, and main limbs, medium = several mistletoe clumps; and low = a few clumps in the perimeter of the tree canopy.

Spray tests. Trees used were two Modesto ash (*Fraxinus velutina* Torr. var. *glabra* Rehd. 'Modesto'), four chinese hackberry (*Celtis sinensis* Pers.), three white alder (*Alnus rhombifolia* Nutt.), and one Moraine ash (*Fraxinus* 'Moraine' = hybrid with putative parents: *F. holotricha* Koehne × *F. pallisae* Wilmot [A. T. Leiser, *personal communication*]). All of these trees were heavily infected with mistletoe and were older than 25 yr, with trunk diameters 35 cm or larger. Three to 12 mistletoe clumps on large limbs and branches of each tree were treated on 10 March 1981 as follows: 1) Some mistletoe clumps were stripped from the limb by hand and served as a control (Fig. 1A); 2) other mistletoe clumps were pruned to leave a 2.5-cm stub (Fig. 1B) and sprayed with 5–10 ml (88.5–177 mg a.i.) of a mixture of diethanolamine salts of 2,4-D (1.33%) and dicamba (0.44%) (Super D Weedone, pressurized foam herbicide); and 3) the remaining mistletoe clumps were stripped from the tree by hand and the resultant depression (broken shoot bases) was sprayed with about 1 ml (40 mg a.i.) of cycloheximide (Acti-Aid Component A, citrus abscission agent). All three treatments were applied to each test tree. Responses of chemically treated and untreated mistletoes were recorded on 2 October 1981 and 21 April and 20 September 1982.

Analysis of variance (ANOVA) was performed after an arc sine transformation of the data for each recording date. ANOVA and mean calculations were conducted with the Statistical Analysis Program (SAS) (12) and comparisons of treatment means for each recording date with Duncan's multiple range test.

Dissection of endophytic systems. On 20 September 1982, 28 sections of untreated and treated branches (12 controls, eight treated with 2,4-D and dicamba, and eight treated with cyclo-

Accepted for publication 20 January 1987 (submitted for electronic processing).

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

heximide) were cut from a Modesto ash tree, brought to the laboratory, sawed longitudinally (because most cortical strands and sinkers occupied a median, longitudinal position), and cut transversely, then the bark was peeled from the entire swollen area. The process was terminated whenever a green, live endophytic system was encountered. When no live strands were found, the system was considered dead. If detectable results were not evident to the eye, a dissecting microscope was used.

RESULTS AND DISCUSSION

Survey. Mistletoe was found on 15 species of shade trees: Modesto ash, Arizona ash, chinese hackberry, black walnut, locust, moraine ash, alder, white alder, pagoda, English walnut, acacia, zelkova, maple, elm, and boxelder (Table 1). Ash and chinese hackberry trees were the most frequently infected. Infections of Arizona ash and several black walnut trees with mistletoe were heavy. These results are similar to those found in the Sacramento survey, where 11% of the total infected trees were ash (13). Based on the percentages of infected trees in each species surveyed, Arizona ash, Modesto ash, black walnut, boxelder, and hackberry trees were considered the most susceptible to mistletoe, a finding that partially agrees with published results (13,14).

Spray tests. Posttreatment readings showed that most of the chemically treated clumps of mistletoe did not produce new growth (Table 2), whereas most of the non-chemically treated clumps (controls) grew, even as soon as 6 mo after the beginning of the experiment (Table 2). After 18 mo (20 September 1982), growth occurred in several treated clumps (Table 2). Even so, the percentage of control of chemically treated clumps was significantly higher than that of the non-chemically treated ones ($P < 0.05$ [Table 2]). All the non-chemically treated clumps of the white alder and the Moraine ash trees had new growth as early as 6 mo after treatment (Table 2). However, the ANOVA indicated that there were no significant differences among the different species of shade trees (Modesto ash, hackberry, and white alder trees) for any of the recording dates ($F = 2.45$, 1.79, and 2.91, df = 2, $P > 0.05$ for data of 2 October 1981 and 21 April and 20 September 1982, respectively). The one Moraine ash tree was not included in this analysis. Results for each treatment were averaged and individual trees (total of 10 [Table 2]) were used as replicates. These results indicated that, for at least 1.5 yr, the tested chemicals effectively prevented regrowth of mistletoe clumps.

The herbicide 2,4-D in different formulations has effectively controlled other species of mistletoe (4). For example, Greenham and Brown (7) killed 50% of the clumps of a *Loranthus* sp. on eucalyptus trees in Australia by injecting host trees with a solution of triethanolamine salt of 2,4-D.

Where mistletoe infections are established near the ends of small limbs, pruning below the point of infection is effective. French (2) reported that, to remove mistletoe mechanically, one must prune 30 cm below the mistletoe infection; however, infected trunks or main limbs cannot be sacrificed. Therefore, a combination of cutting off or severily pruning the clumps and applying cycloheximide or a mixture of 2,4-D and dicamba can be used in this case. The mixture of 2,4-D and dicamba is currently registered for mistletoe control (15). Graser (5) successfully used triethanolamine or isopropyl ester of 2,4-D herbicide to control mistletoe infections on trunks and main limbs of walnuts. At the end of the first year, all clumps of mistletoe sprayed with isopropyl ester of 2,4-D were killed; in the second year, about 50% of the clumps showed signs of new growth (5), indicating that their endophytic systems were still alive. In our study, similar regrowth occurred on treated clumps in the second year but to a lesser degree (19–29%) (Table 2).

Bayer et al (1), who used different formulations of 2,4-D with different additives to control mistletoe on English walnuts in California, found that 2,4-D as well as amitrol and atrazine provided the most satisfactory control of mistletoe 5 yr after treatment.

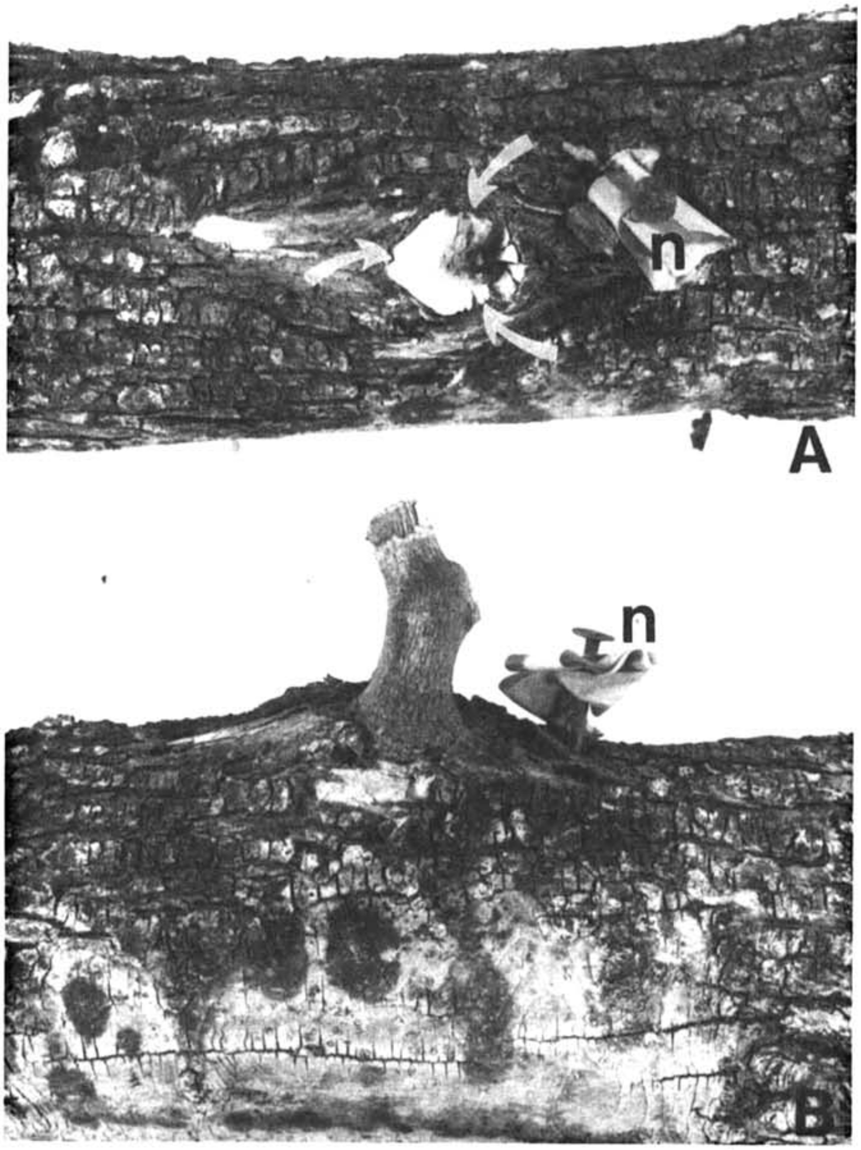

Fig. 1. (A) Leafy mistletoe (*Phoradendron tomentosum* subsp. *macrophyllum*) clump that was removed by hand, leaving a depression (indicated by arrows). **(B)** Pruned clump with a stub 2.5–3.0 cm that was subsequently covered with foam of herbicide mixture of 2,4-D and dicamba (n = flat-headed nail holding different colored flagging tape for easy determination of treated and untreated clumps).

Neither test chemical caused significant phytotoxicity to the host, perhaps because thick bark on treated limbs (Fig. 1) prevented absorption of the chemicals; however, on one white alder tree, a few twigs died on limbs near those treated with the mixture of 2,4-D and dicamba. This may have been due to drift of foam during application. Graser (6) also reported no phytotoxicity from spraying and thoroughly wetting the walnut bark with triethanolamine or isopropyl ester of 2,4-D; however, injecting a solution of triethanolamine salt of 2,4-D into the trunks of eucalyptus trees for control of a *Loranthus* sp. resulted in partial defoliation (7). The two chemicals tested were equally effective (no significant differences [$P > 0.05$] between them), resulting in 58–100% (2,4-D and dicamba) and 63–100% (cycloheximide) reductions of new growth 1.5 yr after treatment.

Dissection study of endophytic systems. Eight of 10 chemically treated clumps had healthy shoots, buds, or endophytic systems, whereas two appeared dead. Among eight clumps treated with each chemical, live endophytic systems were detected in five (treated with 2,4-D and dicamba) and six (treated with cycloheximide) clumps; the remainder were dead. These results suggest that the treatments had essentially no effect on the endophytic systems, and complete eradication of mistletoe with these chemicals should not be contemplated. The use of 2,4-D and dicamba or cycloheximide, however, will effectively suppress vegetative mistletoe development for over 1 yr, thus reducing labor and cost in maintaining trees in streets and parks. Moreover, delay of new growth should limit secondary spread and reduce mistletoe seed production. Livingston et al (9,10) reported that ethephon sprayings of dwarf mistletoe (*Arceuthobium pusillum* Pk.) on black spruce (*Pisea mariana* (Mill.) B.S.P.) prevented spread of the disease for at least 2 yr. Ethephon was also effective against broadleaf mistletoe in deciduous ornamentals (8).

Our experiments demonstrate that a combination of pruning and applying either 2,4-D and dicamba or cycloheximide can delay growth of mistletoe on shade trees for at least 1.5 yr. Therefore, these treatments have potential for preventing seed production of the parasitic plant for at least 1.5 yr. Meanwhile, other chemicals should be tested, particularly those affecting the endophytic systems of mistletoe. In new housing and recreational developments, planting mistletoe-resistant shade trees should be considered. Use of Modesto ash, particularly in the Davis area, should be discouraged because it also is highly susceptible to anthracnose disease (11).

Table 1. Survey of shade trees parasitized by mistletoe (*Phoradendron tomentosum* subsp. *macrophyllum*) in Davis, CA (1976–1977)

Species of shade tree	Total no. of trees infected	Percent trees in each severity category[a]		
		Heavy	Medium	Low
Modesto ash (*Fraxinus velutina* Torr. var. *glabra* Rehd. 'Modesto')	536	20	8	72
Chinese hackberry (*Celtis sinensis* Pers.)	263	7	11	82
Arizona ash (*F. velutina* Torr.)	15	53	47	0
Black walnut (*Juglans hindsii* (Jeps.) Jeps.)	23	43	35	22
Locust (*Gleditsia triacanthos* L.)	50	4	14	82
Moraine ash (*Flaxinus* 'Moraine' = *F. holotricha* Koehne × *F. pallisae* Wilmot)	33	6	21	73
Alder (*Alnus* sp.)	17	0	6	94
Pagoda (*Sophora japonica* L.)	23	13	22	65
White alder (*Alnus rhombifolia* Nutt.), acacia (*Acacia melanoxylon* R. Br.), English walnut (*Juglans regia* L.), boxelder (*Acer negundo* L.), elm (*Ulmus carpinifolia* Ruppius ex Suckow.), maple (*Acer saccharinum* L.), and zelkova (*Zelkova serrata* Makino)	23	22	26	52
Totals	983	16	12	72

[a] Heavy = many mistletoe clumps in the perimeter of the canopy, on scaffolds, and on main limbs; medium = several mistletoe clumps only in the perimeter of the tree canopy; and low = few mistletoe clumps only in the perimeter of the tree canopy.

ACKNOWLEDGMENTS

We thank the city officials of Davis for their cooperation and for providing a lift, chainsaw, and financial support and B. June McCaskill, Department of Botany, University of California, Davis, for help in plant identification.

LITERATURE CITED

1. Bayer, D. E., Elmore, C. L., Chaney, D. H., and Buschmann, L. L. 1967. Control of mistletoe, *Phoradendron flavescens* on English walnuts in California. HortScience 2:10-11.
2. French, W. J. 1970. Experiments on chemical eradication of mistletoe. Southeast. Pecan Growers Assoc. Proc. 63d:36-37.
3. Gill, L. S. 1953. Broomrapes, dodders, and mistletoes. Pages 73-77 in: Yearbook of Agriculture, Plant Diseases. U.S. Dep. Agric., Washington, DC. 940 pp.

Table 2. Effect of the mixture of 2,4-D and dicamba and cycloheximide on leafy mistletoe (*Phoradendron tomentosum* subsp. *macrophyllum*) on four shade trees in Davis, CA

Species of shade tree (no. of trees)	Record date, treatment,[u] and percent clumps with no growth								
	2 October 1981			21 April 1982			20 September 1982		
	Control[v]	2,4-D and dicamba[w]	Cycloheximide[x]	Control	2,4-D and dicamba	Cycloheximide	Control	2,4-D and dicamba	Cycloheximide
Modesto ash (2)[y]	80	100	100	65	85	100	48	95	100
Hackberry (4)[y]	25	88	92	36	100	100	19	60	86
White alder (3)[y]	0	100	100	0	100	100	0	58	63
Moraine ash (1)[y]	0	100	100	0	100	100	0	100	75
Mean	26 b[z]	97 a	93 a	27 b	97 a	100 a	17 b	71 a	81 a

[u] Treatments were applied on 10 March 1981.
[v] Clumps were removed by hand.
[w] Clumps were pruned, leaving a stub 2.5–3.0 cm, and sprayed with the mixture of 2,4-D and dicamba.
[x] Clumps were removed by hand and sprayed with cycloheximide.
[y] The ANOVA was performed after an arc sine transformation of the data and indicated that, for all three recording dates, there were no significant differences among the different species of trees (among Modesto ash, hackberry, and white alder, $F = 2.45$, df = 2, and $P > 0.05$ for 2 October 1981, $F = 1.79$, df = 2, and $P > 0.05$ for 21 April 1982, and $F = 2.91$, df = 2, and $P > 0.05$ for 20 September 1982 data). The one Moraine ash tree was not included in this analysis.
[z] Within recording dates, any three means followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$). Treatment mean calculations were based on individual trees used as replicates.

4. Gill, L. S., and Hawksworth, F. G. 1961. The mistletoes: A literature review. U.S. Dep. Agric. Tech. Bull. 1242. 87 pp.
5. Graser, H. L. 1952. A progress report on mistletoe control in walnuts. West. Fruit Grower 6(2):23-24.
6. Graser, H. L. 1954. Methods for control of mistletoes; spot spraying in winter proves effective. Diamond Walnut News 36(1):10.
7. Greenham, C. G., and Brown, A. G. 1957. The control of mistletoe by trunk injection. J. Aust. Inst. Agric. Sci. 23:308-318.
8. Joyce, D., Rein, K., Reid, M., and Berry, A. 1986. Use of ethephon for control of broad-leafed mistletoe in deciduous trees. (Abstr.) HortScience 21:872.
9. Livingston, W. H., Blanchette, R. A., Brenner, M. L., and Zuzek, K. J. 1985. Effective use of ethylene-releasing agents to prevent spread of eastern dwarf mistletoe on black spruce. Can. J. For. Res. 15:872-876.
10. Livingston, W. H., and Brenner, M. L. !983. Ethephon stimulates abscission of eastern dwarf mistletoe aerial shoots on black spruce. Plant Dis. 67:909-910.
11. Ogawa, J. M., Bose, E. A., Manji, B. T., and Petersen. L. J. 1977. Life cycle and chemical control of Modesto tree anthracnose. Plant Dis. Rep. 9:792-796.
12. SAS Institute. 1982. SAS User's Guide. The Institute: Cary, NC. 584 pp.
13. Torngren, T. S., and Chan, F. 1978. Mistletoe control. Prog. Rep. Sacramento County. Univ. Calif. Coop. Agric. Ext. Sacramento (mimeo). 10 pp.
14. Torngren, T. S., Perry, E. J., and Elmore, C. L. 1980. Mistletoe control in shade trees. Div. Agric. Sci. Univ. Calif. Leafl. 2571. 7 pp.
15. Vogler, D. R., and Schultz, D. E. 1983. Biological evaluation of pest conditions on the Valuermo and Tujunga ranger districts, Angeles national forest. U.S. For. Serv. Pac. S.W. Reg. For. Pest Manage. Rep. 82-13. 9 pp.
16. Wiens, D. 1964. Revision of acatophyllus species of *Phoradendron*. Brittonia 16:11-54.