PATTERNS OF GALL FORMATION BY THE COOLEY SPRUCE GALL ADELGID ON COLORADO BLUE SPRUCE

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Abstract. Observations were made of galling patterns by the Cooley spruce gall adelgid *(Adelges cooleyi)* on landscape and nursery plantings of Colorado blue spruce from 1985-1988. Overall incidence of galling varied widely between seasons, and appeared to be related to late winter and early spring weather conditions. Strong orientation of galls occurred with highest numbers of galls occurring along the north (37%) and east (34%) sides of the trees. Galling was also found to be consistently correlated on individual trees, suggesting a possible genetic basis for resistance. Galling was associated with tree color, being greatest on trees with greener coloration, but was not correlated with onset of spring bud break. The implication of these findings in tree siting and in identifying resistant genotypes is discussed.
Key Words. *Insecta, host plant resistance, population distribution*

Résumé. Des observations ont été faires de 1985 à 1988 sur le comportement évolutif de la galle Cooley adelgib (*Adelges Cooleyi*) de l'épinette dans des plantations d'épinettes bleues du Colorado en terrain aménagé et en pépinière. Globalement, l'incidence de la progression de la galle varie largement d'après les saisons, et semblerait être reliée aux conditions de températures de la fin de l'hiver et du début du printemps. L'orientation forte de la galle est associée au nombre le plus élevé de galles qui se déclarent le long des côtes nord (37%) et est (34%) des arbres. La formation de la galle a aussi été conséquemment correlée sur des arbres individuels, suggérant une possible base générique pour la résistance. La galle a été associée à la couleur de l'arbre, étant plus grande sur les arbres avec une coloration plus verte, mais pas correlée avec le débourrement des bourgeons au printemps. L'implication de ces découvertes dans le choix de l'emplacement des arbres et dans l'identification des génotypes de résistance est discuté.

The Cooley spruce gall adelgid, *Adelges cooleyi*, is a common insect pest of blue spruce grown in landscape and nursery plantings in Colorado. Spruce trees are annually colonized by winged sexual stages that migrate from the alternate host, Douglas-fir. Eggs produced by these migrants hatch into overwintering female forms (fundatrices) that produce eggs shortly before bud break in spring. Feeding by the overwintering female, followed by continued feeding of the gall forming nymphs (gallicolae) hatching from eggs produce the galls (1). Following insect emergence from the galls in mid-summer, the galls dry out, become highly conspicuous and often attract considerable attention and concern. Although considered to be primarily an aesthetic injury in landscape settings, insecticidal treatment for control of the Cooley spruce gall adelgid is a frequent practice throughout the Rocky Mountain region in landscape settings.

Casual observations by landscape maintenance professionals indicated a considerable range in the degree to which individual trees are infested by the Cooley spruce gall adelgid. Also, infestation patterns on single trees often appeared to be clumped. This study attempts to quantify these relationships. Such information has implications for improving the targeting of insecticide applications, for tree siting considerations during landscaping, and for identification of insect resistant genotypes.

Methods and Materials

Studies of galling patterns were conducted on nursery and landscape plantings of Colorado blue spruce maintained by Colorado State University and the City of Ft. Collins, CO. An initial study was begun in 1986 to help define research parameters. Subsequent studies were conducted on additional trees during both 1986-88.

Initial 1986 Studies. Original studies involved 22 trees located in park and campus landscape settings. All trees were in excess of 10 years of age, individually sited in open locations so that exposures were not influenced by nearby buildings or sheltering vegetation. Galls were counted from 1 m swaths, 2.5 m in height, centered on the cardinal compass points of the basal part of the tree.

Nursery Planting Studies, 1986-1988. Studies were conducted at three separate nursery plantings of Colorado blue spruce. Each location consisted of even-aged trees of identical cultural history ranging from 2.5-5 m in height. Spruce populations at each site ranged from 13-25 and a total of 57 trees was observed. Plant spacings at each site were sufficient so that interplant shading effects were not considered to be significant. At each site, trees were approximately equal age and size. However, size and vigor of trees varied considerably between the three study sites.

The sizes of the trees in the nursery study sites were such that gall counts could be made of entire trees. Each tree was sub-sampled, centered on the cardinal points. Counts of existing (1985 produced) galls were made prior to the 1986 growing season. Mid-summer examination of new galls were made in 1986-88 after the insects had migrated from the drying galls.

Relative timing of spring bud break and tree color were also quantified. Bud break observations were made 1-2 times per week during the spring of 1986 and 1987, allowing categorization of bud break onset. Bud break typically was completed 2-3 weeks after onset and a proportionate 5 point scale (very early, early, mid-season, late, very late) was applied to relative bud break for each tree. Tree color was similarly categorized (green, green-blue, blue) using a 3 point scale. At one nursery location (Site III), all trees were green or blue-green in color. Also at this site, the vigor and size of the trees was noticeably retarded relative to trees at the other locations.

Results and Discussion

New gall production during 1986 was very low. During this season, very warm early spring temperatures were followed by a mid-April killing frost that caused widespread injury to plants and insects. Cool temperature sensitivity of *A. cooleyi* following immediate post diapause was demonstrated by Parry (5) and is a likely explanation for the poor establishment of gall making forms of the insect during 1986. Alternatively, warmer winter and spring temperatures may have caused increased movement of overwintering stages, resulting in increased dislodgement by needle brushing. Substantially higher (7.5X) rates of galling occurred in 1987, a season noted by unusually mild winter and spring conditions. The 1988 season was also mild and gall production in 1988 was similar (-14%) to 1987 gall production. (Galling incidence was sharply reduced again in 1989, following harsh spring temperature conditions.)

Studies of trees in landscape settings showed a strong concentration of galling along the less exposed north and east sides of the trees (Table 1). This pattern continued in subsequent studies of the nursery plantings so that, overall, 37% and 34% of galls were established on the north and east sides of the trees, respectively. Similar patterns of infestation by *A. cooleyi* were noted on Douglas-fir during July by Lasota and Shetlar (2), although populations in their study became more evenly distributed as the season progressed. More concentrated gall making on less exposed aspects of blue spruce grown in Colorado may be due to overwintering survival of the insect. Parry (4) speculated that survival on Douglas-fir is related to exposure to fluctuating temperatures. Such fluctuating temperatures can be particularly extreme with the high solar radiation intensities typical of winter and spring in the Rocky Mountain region.

Because of the low galling incidence in 1986, season to season regression correlations of galling on individual trees were not significant at any sites when comparing 1986 to 1985 galling incidence. Substantially greater galling occurred in 1987 and new galling rates on idividual trees were significantly correlated with previous (1985-1986) galling on the same tree at Sites I (df 1, 17 $F=29.56$, $P < 0.01$) and II (df 1, 11, $F=15.04$, $P < 0.01$) (Fig. 1). At the poorly growing Site III the regression was non-significant, perhaps because galling rates remained con-

Table 1. Distribution of Cooley spruce galls along cardinal points of Colorado blue spruce, Ft. Collins, CO.

			Number of galls (% of total)			
Location	*N*	*Year*	*N*	*E*	*S*	*W*
Landscape	22	< 1986	904	761	223	293
Site I	19	< 1986	142	126	63	94
Site I		1986	6	13	7	7
Site I		1987	41	43	26	34
Site II	13	< 1986	95	102	38	85
Site II		1986	4	16	0	0
Site II		1987	81	87	51	43
Site III	25	< 1986	28	29	16	25
Site III		1986	1	5	6	2
Site III		1987	24	25	18	19
Total number			1326	1207	448	602
Percent of total			(37)	(34)	(12)	(17)

sistently low. However, when 1988 galling incidence was compared to previous (1985-1987) galling (Fig. 2), all three sites showed significant relationships. During the 4-year course of these studies several trees repeatedly remained galled at low levels and galls were never produced on 3 trees. Other trees were consistently galled at high levels. These observations suggest that a range in susceptibility to insect establishment and/or galling may be present within Colorado blue spruce populations.

Individual trees showed substantial year to year variation in relative time of bud break, particularly at Site II. There was significant correlation of 1987 bud break timing on individual trees with 1986 bud break timing at Sites I and III. However, galling was not correlated with earliness of bud break in either 1986 or 1987.

Tree color was signficantly correlated with gall incidence at both sites I and II during 1986 and 1987 [(Site I, $F(1, 11) = 8.26$, $P < 0.05$; $F(1, 11) = 12.34$, $P < 0.01$); Site II, $F(1, 17) = 15.43$, $P < 0.05$; $F(1, 17) = 9.68$, $P < 0.01$). As a group, trees showing a blue coloration, a desirable horticultural characteristic, tended to be less galled than greener trees. However, some individual trees of deep blue coloration also were heavily galled. This indicates that tree color alone is not responsible for galling resistance.

The concentrations of galling on individual trees has implications in both siting landscape trees and in applying preventive treatments for control of overwintering fundatrices. Location of trees with respect to areas of human traffic can have great effect on the amount of perceived galling. For example, along a walkway, trees exposing south and west aspects may be commonly observed to have only about a third of the galling of trees exposing north and east aspects. Applications of insecticides to control the overwintering females should similarly concentrate on these less exposed sides of the tree where galling is greatest.

Demonstration that some blue spruce trees show a high level of resistance to galling (Fig. 1) indicates that gall resistant genotypes are likely to be readily available for selection. High levels of resistance to the eastern spruce gall aphid, *Adelges abietis*, were similarly noted by Thielges and Campbell (7), apparently related to presence of certain phenols (8). In blue spruce, the desirable horticultural characteristic of blue color is also often associated with *A. cooleyi* resistance. Development of effective and economical propagation techniques, similar to those proposed by Thielges and Campbell (7), for Colorado blue spruce could rapidly allow the production and distribution of gall resistant trees that would not require supplemental pest management for *A. cooleyi*.

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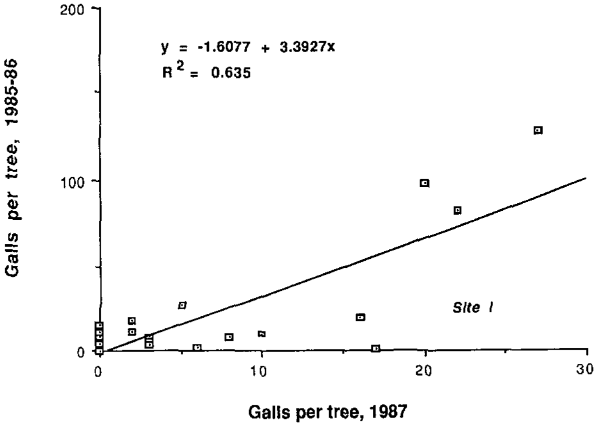

Fig. 1. Correlation of *Adelges cooleyi* galling in 1987 with previous seasons on individual Colorado blue spruce at 2 landscape plantings.

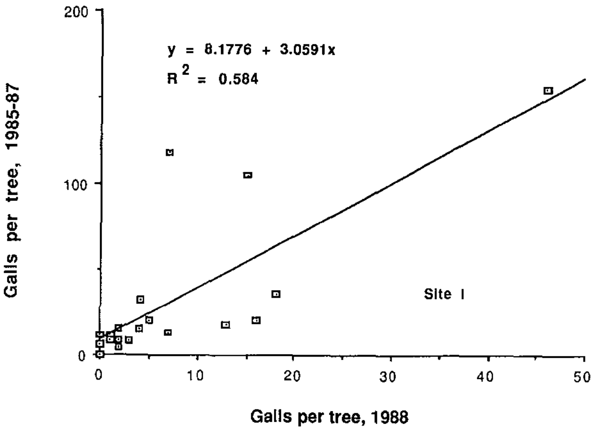

Fig. 2. Correlation of *Adelges cooleyi* galling in 1988 with previous seasons on individual Colorado blue spruce at 3 landscape plantings.

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Abstracts

STONER, M.F. 1989. **Diagnosis of tree diseases.** Landscape Contractor. January p. 35.

The first, and most important, step toward control or management of a tree disease is proper diagnosis. Proper diagnosis depends chiefly on (1) identification of the sick tree; (2) thorough observations of the problem and its environmental context; (3) collection of suitable samples; and (4) careful examination of diseased material. Consult a qualified plant pathologist when solutions are not readily apparent. Diagnosis benefits from a systematic approach that serves to progressively narrow the range of possible causes. Once a diagnosis is obtained, you have the essential insights to see the logical targets for control—including cultural corrections for long-term management.

FEUCHT, J.R. 1989. **Recognizing living hazard trees.** Colorado Green 5(1):16-18.

Living hazards in trees are not always easy to detect. Structural weaknesses are frequently hidden beneath sound bark and layers of healthy wood. There are, however, some signs one can look for that help to determine potential hazard. Tree location: Where is the tree with respect to potential "targets" such as building, sidewalks, and other public areas? Tree architecture: Do trees lean and appear out of balance? Cracks in branches and trunks: Look for cracks or splits in branches and trunks. Toadstools: The presence of toad stools (mushrooms) on roots, branches and trunks is a sign of internal decay. Cankers: Cankers formed by fungi and bacteria will result in a structural weakness in limbs or trunks.