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TRUNK BANDING TO CONTROL ELM LEAF BEETLE

by Laurence R. Costello, Stephen R. Scott[1]; John D. Peterson[2], and Carol J. Adams[3]

Abstract. Elm leaf beetle (ELB) feeding injury was reduced by carbaryl trunk bands during a five-year study in northern California. The magnitude of injury reduction varied from year to year and appeared to be influenced by the proximity of untreated elms and yearly fluctuations in ELB populations. Banding one time per year using 1% carbaryl (Sevin SL®) was as effective as banding two times per year with a 2% concentration. Trunk banding can achieve injury reduction levels nearly equivalent to foliar sprays and is less costly. With certain limitations considered, this technique can be a useful strategy in ELB control programs.

Résumé. Les dommages par le galéruque de l'orme (ELB) lors de son alimentation ont été diminués par des bandes de carbaryl sur le tronc durant une étude de cinq ans en Californie du Nord. L'ampleur de la réduction des dommages varie d'une année à l'autre et semble être influencée par la proximité d'ormes non traités et par les fluctuations annuelles dans les populations du ELB. Le bandage une fois par année en employant du carbaryl à 1% (Sevin SL) est tout aussi efficace que le bandage duex fois par année avec une concentratic n de 2%. Le bandage du tronc peut résulter en des niveaux de réduction de dommages pratiquement équivalent aux arrosages foliaires et est moins coûteux. Sous certaines conditions limitatives, cette technique peut être une stratégie utile dans les programmes de contrôle du ELB.

The elm leaf beetle, *Xanthogaleruca luteola,* is one of the most serious pests of elms in the United States (4). Elms in California, particularly Siberian *(Ulmus pumila),* English *(U. procera),* and Scotch *(U. glabra),* are severely injured each year by elm leaf beetle (ELB). Spring and summer feeding by this insect causes leaves to become skeletonized, turn brown, and eventually fall off. By midsummer, infested trees are often rendered unslightly.

The California Department of Transportation (CalTrans) maintains a stand of elms along state highway 82 (El Camino Real) which runs through the cities of Burlingame and San Mateo in northern California (approximately 30 miles south of San Francisco). In the early 1970s, CalTrans discontinued foliar spray applications for ELB control on these trees due to public concerns regarding spray drift. Subsequent ELB feeding injury generated public and municipal complaints over the unslightly condition of the trees. In a renewed effort to control ELB, CalTrans considered trunk banding as an alternative to foliar applications.

Trunk banding is a control method that targets ELB larvae as they migate from the canopy down the trunk to pupate at the base of the tree. Insecticide is sprayed on the bark as a band around the trunk. As larvae move down the trunk, they pass over the band, absorb the insecticide, and are killed. Hall, et al (3) have found that a carbaryl band 1 meter wide is lethal to ELB larvae.

Field studies to evaluate the effectiveness of elm trunk banding have thus far led to inconclusive results. Brown and Malinoski (1) found no reduction in ELB injury from trunk banding with carbaryl in the San Fernando Valley of California. However, this was a one-year study and it may be expected that little injury reduction would occur in the first year. In another study, Olkowski and Darr (5) observed a reduction in ELB injury from trunk banding with carbaryl. However, few trees were studied and few data were collected in this one-year effort.

Considering the limitations of previous work, a five-year study was initiated to evaluate trunk banding for ELB control. The research was conducted along El Camino Real in the cities of Burlingame and San Mateo. Both cities were selected as study sites because of differences in their

1. California Department of Forest and Fire Protection, Forest Pest Management Program
2. *California Department of Transportation, Tree Management Division*
3. University of California Cooperative Extension Service

municipal ELB control programs. Burlingame has an annual ELB control program (foliar spray) for all municipal elms. San Mateo does not have a city-wide ELB control program, but does spray some trees as needed. (Neither city treats elms along El Camino Real.) It was thought that because of the difference in municipal control programs, there may be a difference in ELB activity in the two cities. Indeed, it was frequently observed that San Mateo elms experienced more ELB feeding injury each year than did Burlingame elms. Therefore, by including both cities in the study, trunk banding of El Camino Real elms could be evaluated under conditions of ostensibly greater or lesser amounts of background ELB activity.

Methods and Materials

Elms and eucalyptus trees were planted along El Camino Real in the early 1880s. Scotch elm is the principal elm species, although there are some Chinese *(U. parvifolia)*, Siberian, and American *(U. americana)* elms. Scotch elm is highly susceptible to elm leaf beetle (2) and was the only species used in this study.

Study trees were single row street trees ranging in height from 60 to 80 feet and spaced 60 feet apart in San Mateo and 40 feet apart in Burlingame. Blue gum *(Eucalyptus globulus)* and manna gum *(E. viminalis)* trees were situated between the elms in Burlingame. As noted, no program to control ELB had been conducted on El Camino Real elm trees in about 12 years.

Treatments. Banding treatments included 2 applications and 2 concentrations of Sevin SL® (carbaryl): one application at 2% a.i.; one application at 1% a.i.; two applications at 2% a.i.; and two applications at 1% a.i. Control trees were untreated. From 27 to 33 trees were used for each treatment in Burlingame, and because the elm population was lesser in San Mateo, only 9 to 10 trees per treatment were selected there. Treated trees were in common groups so treatment effects would not overlap, i.e., treatment 1 trees were located next to treatment 1 trees only. Other treatment trees were likewise situated in common groups. Control trees, also in common groups, were spatially separated from treatments by one half-mile or more. In San Mateo, 7 control trees were selected, while 12 were chosen in Burlingame.

Sevin SL® was mixed in separate tanks with 100 gallons of water for each concentration: 1% (8 quarts) and 2% (16 quarts). A surfactant (Unifilm 707®) was added to each tank, and solution pH was adjusted to 7.0 using TriFol®

Band applications were made using a hand-held spray wand equipped with a flat fan nozzle and attached by a 50-foot hose to a 300-gallon capacity tank. Tank pressure was maintained at 20 psi to ensure an even spray of relatively large droplets. Applications were made from a 8 to 10-foot trunk height to ground level, starting at the top and moving around the tree and downward. Applications provided maximum coverage without runoff.

All treatment elms were banded in mid June of each year prior to first generation larval migration downward. Trees receiving a second application (treatments 3 and 4) were banded in mid-August. Applications were made between 4 and 7 AM to minimize interference with traffic.

Sampling and injury evaluations. Five trees were sampled per treatment in each city in mid June and August. All sample trees were located midway within their respective treatment groups. The same trees were sampled each year for the duration of the study.

Leaf samples were collected for ELB injury ratings using a 55-foot aerial lift truck. Shoots approximately 18 inches long, and having 15 to 30 leaves each, were collected from mid-canopy height (35 ft) at each of 5 canopy points: center, NW, NE, SW, and SE. Samples were taken from designated points only, without regard for amount of ELB feeding injury occurring elsewhere in the tree.

ELB feeding injury was evaluated using an injury index adapted from Brown and Malinoski (1). Leaf injury was scored from 1 to 5 based on the following scale: 1 = 0% leaf area skeletonized; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%. Ten leaves of equal size were removed from sample shoots soon after collection and each was assigned an injury score based on the above scale. The same evaluator was used for all injury ratings through the course of this study. Treatment injury ratings were calculated by combining and averaging scores of each of five samples from each of five treatment trees (Table 1).

Split-plot in time analyses of variance of leaf injury were run for each location to compare treatments, years, months (June and August) and to test for interactions. The five trees sampled for injury in each treatment were the replicates, treatments were the main-plot factor, and year and month were the sub-plot factors. In addition, one-way analyses of variance were run for each sample time at each location to compare treatments, including the comparison of control versus banding treatments, for injury ratings and for injury relative to 1985 starting values.

Results

Differences in leaf injury ratings were found for the two locations (Burlingame and San Mateo), for the dates sampled (June and August) and for the years of treatment (Table 1). Higher injury ratings were consistently found in San Mateo. Leaf samples taken in August always showed more injury than those taken in June. Injury ratings tended to decline for both the treatments and controls from 1985 to 1987, at both locations, and then increase slightly in 1988 and 1989. The exception to this trend was in 1986 when the Burlingame control trees showed greater injury than 1985 levels.

Treatment effects were somewhat variable between locations and in rate and application frequency comparisons. Treatments 2, 3, and 4 were not significantly different from one another either by year or location. The highest rate and application frequency (2%/2x) was essentially no different from the lowest rate and frequency (1%/1x). Treatment 1, however, resulted in consistently higher injury ratings than other treatments in Burlingame trees, but the lowest injury ratings found among treatments in San Mateo trees. Essentially, treatment 1 was the most effective treatment in San Mateo and the least effective in Burlingame.

Since there were no clear differences among treatments 2, 3, and 4 in either location, and an inconsistent result for treatment 1 in the two locations, all treatment data were averaged to analyze effects relative to controls (Figs. 1 and 2). No significant differences between treatments and controls were found in 1985, the first year of treatment. Subsequently, significant differences were found in 1986, 1987, and 1989 in Burlingame and in 1986 and 1988 in San Mateo. Greatest treatment effects were found in 1986 when control trees showed high injury ratings. As control injury ratings declined to their lowest values in 1987 for San Mateo and in 1988 for Burlingame, treatment effects likewise diminished in magnitude and significance. As control ratings increased again in 1989 for Burlingame trees, treatment effects again became significant. Control ratings also increased in San Mateo in 1989, but treatment effects were still not significant.

Since 1985 can be considered a "pretreatment" year (i.e., no treatment effects would be expected since feeding injury precedes larval control by trunk bands), subsequent injury ratings can be analyzed relative to 1985 values (Figs. 3 and 4). Using percent relative injury values, significant differences between control and treatment

Table 1. Leaf injury ratings for samples taken in June and August in Burlingame and San Mateo. Values are sample means for 5 trees per treatment. Leaf injury was scored from 1 to 5 based on the following scale: 1 = 0% leaf area skeletonized, 2 = 25%, 3 = 50%, 4 = 75%, 5 = 100%.

Treatment	*Burlingame*										*San Mateo*									
Year	*1985*		*1986*		*1987*		*1988*		*1989*		*1985*		*1986*		*1987*		*1988*		*1989*	
Month	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*	*June*	*Aug*
1) 2% carbaryl 1x	2.0	3.2	1.4	2.4	1.3	1.6	1.2	1.8	1.4	1.9	1.8	3.3	1.4	2.0	1.2	1.3	1.2	1.4	1.2	1.7
2) 1% carbaryl 1x	2.0	2.5	1.2	1.6	1.2	1.2	1.2	1.2	1.1	1.2	2.4	4.5	1.5	2.4	1.5	2.1	1.6	2.1	2.0	2.7
3) 2% carbaryl 2x	1.6	2.2	1.1	1.5	1.0	1.0	1.0	1.2	1.0	1.1	2.4	3.9	1.6	2.3	1.4	1.9	1.4	2.2	1.5	2.4
4) 1% carbaryl 2x	1.5	2.3	1.1	1.6	1.0	1.1	1.2	1.3	1.1	1.1	2.6	4.5	1.5	2.1	1.5	2.3	1.4	1.9	1.9	2.7
5) CONTROL	1.5	2.4	1.8	3.0	1.7	1.8	1.4	1.7	1.4	1.9	2.2	3.7	1.7	3.2	1.6	2.0	1.8	2.3	1.8	2.9
Foliar* (fluvalinate applied in June)			1.3	1.5	1.1	1.2	1.1	1.2	1.3	1.3										

Leaf injury ratings

**Foliar applications were not a formal treatment in this study. Values are presented to give a relative injury rating comparison with trunk banding. Applications were made in Woodside, California (Approximately 15 miles SW of San Mateo).*

trees were found in Burlingame from 1986 to 1989. Again, as control injury ratings declined, significance of treatment effects also diminished. Percent relative injury ratings are also significantly different between control and treatment trees in San Mateo for all years and dates, except June 1987.

Numerous dead larvae were found at banded trunk bases after first and second generation feeding.

Discussion

Differences in injury levels and treatment effects between the two locations, Burlingame and San Mateo, were thought to be related to the number of elms harboring ELB populations in areas of close proximity to treatment trees. As noted, San Mateo does not have a city-wide ELB control program, while Burlingame has an annual foliar treatment program. Consistently, San Mateo trees in this experiment had greater injury levels than comparable Burlingame trees. Although ELB populations were not monitored in either location, it seems probable that the foliar treatment program in Burlingame reduced beetle populations in areas adjacent to treatment trees, thus resulting in lower injury levels.

Changes in leaf injury ratings in both control and treatment trees from year-to-year indicate that annual fluctuations in beetle populations may occur. After the initial high injury ratings in 1985 and 1986, ratings declined in 1987 and 1988 for

Fig 1 Burlingame

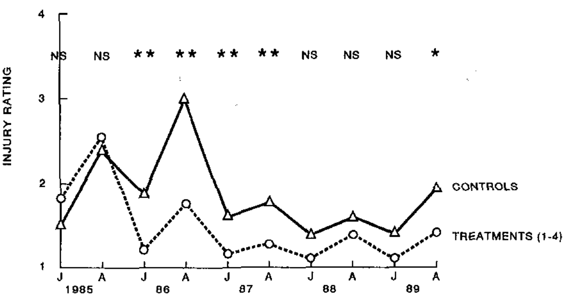
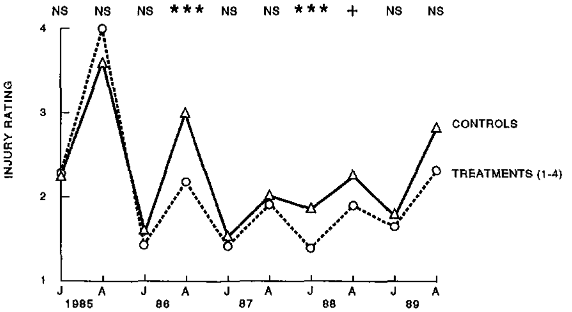


Fig 2 San Mateo



Figures 1 and 2. Elm leaf beetle injury ratings for trunk banded and control elms in Burlingame and San Mateo, California. Ratings were made in June (J) and August (A) from 1985 to 1989. Injury rating of 1 = 0% leaf skeletonized, 2 = 25%, 3 = 50%, 4 = 75%, and 5 = 100%. NS = not significant, + = P=.10, * = P=.05, ** = P=.01, and *** = P=.001. Treatment values are means for all treatments combined.

Fig 3 Burlingame

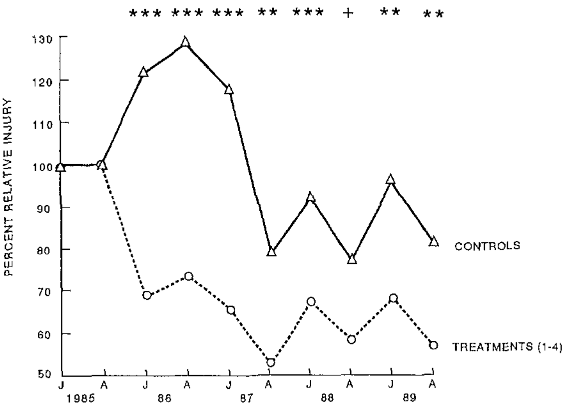
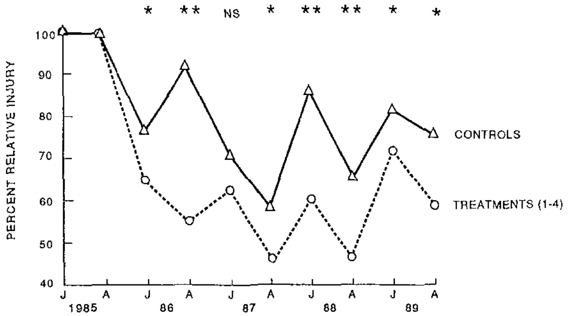


Fig 4 San Mateo



Figures 3 and 4. Percent relative ELB injury ratings for trunk banded and control elms in Burlingame and San Mateo, California. Values are percent greater or lesser injury relative to 1985 injury ratings. Ratings were made in June (J) and August (A) from 1985 to 1989. NS = not significant, + = P=.10, * = P=.05, ** = P=.01, *** = P=.001.

control trees, and then increased slightly in 1989. Treatment tree ratings also followed this trend. It was hypothesized that control trees may have been affected by banding treatments, i.e., even though controls were spatially separated from treatment trees by one half mile or more, banding treatments may have reduced beetle populations around control trees. To evaluate this possibility, untreated elms in Burlingame and San Mateo well outside of the treatment areas were sampled in 1988 and 1989. However, in both locations, these additional "controls" were found to have injury ratings essentially the same as the study controls (±8%) in both 1988 and 1989.

Since it does not appear likely that banding treatments affected control trees, it was reasoned that area-wide population changes occurred from 1985 to 1989. Although it is quite conceivable that ELB populations will fluctuate from year to year, we are not aware of any reports in the literature that document such trends. In this study, nonetheless, ELB population cycles would help explain the fluctuations in injury ratings that were found, and the nonsignificant difference between treatments and controls in 1987 (San Mateo) and 1988 (Burlingame) could be attributed to naturally low beetle populations in those years.

Also there are observations that ELB will enter diapause in response to poor host quality (Hall, personal communication). Since 1987, 1988 and 1989 were drought years in California and the study elms were never irrigated, host quality of elms may have been diminished by water stress. This would tend to result in lower injury ratings in controls and treatments, and may also explain the reduction in ELB injury found in 1987-89. It is further possible that natural population fluctuations could have been accentuated by the drought and together they resulted in lower injury ratings.

Fluctuations in injury ratings from June to August were consistent with the life cycle and feeding habits of ELB. Injury levels in June result from overwintering adult and first generation larval feeding. Injury in August was a consequence of both first and second generation feeding. This injury pattern from June to August was consistent for all five years and in both locations.

The apparently contradictory effects of treatment 1 in Burlingame and San Mateo is difficult to reconcile. This result is inconsistent with other treatment effects, which were both higher and lower in application rates and frequency than treatment 1. It is possible that the presence or absence of nearby, untreated elms on private property produced this result. It was observed that treatment 1 trees had the fewest number of nearby private elms of any other treatment group San Mateo. In Burlingame, however, treatment 1 trees were closer to a higher number of private elms than other treatment groups. This difference in proximity of private elms may have resulted in greater or lesser amounts of ELB activity near treatment 1 trees, and conceivably caused the noted result.

Trees receiving a foliar application of fluvalinate (Mavrik Aquaflow® , 8 oz/100 gallons H_2O) in the city of Woodside, California (applied by CalTrans) were also sampled for ELB injury levels (Table 1). Since this was not a formal treatment in this study, however, statistical differences could not be determined. Only small differences in injury ratings were found between foliar and trunk banded trees. Foliar injury ratings were equal to trunk band ratings in 1987 and 1989, and 16% and 14% less in 1986 and 1988, respectively. Generally, trunk banded trees were aesthetically

Table 2. Cost comparison between bark band and foliar applications. Figures are derived from labor and equipment costs used by the California Department of Transportation.

Cost factor	*Foliar*	*Bark band*
Labor ($/hr)	$71.40 (5 persons @ $14.28/hr)	$57.12 (4 persons @ $14.28/hr)
Equipment ($/hr)	$37.00 (includes aerial lift truck)	$27.67
Materials per tree (Sevin SL + surfactant)	$0.75 (0.1% a.i.)	$1.50** (1% a.i.)
Application time per tree	12 min*	3 min
Cost per tree	$23.18	$4.99

*Time for foliar treatment of a 60-80 foot elm occurring in a row or group of trees, which will be treated. The three minute banding time should remain relatively constant regardless of canopy size. Note that additional equipment savings may be realized by banding if portable equipment (such as a backpack sprayer) is used.

**Materials cost for trunk bands can be reduced by 50 per cent or more by using narrower bands. Hall, et al (1988) found a 3.3 foot wide band effectively controlled ELB larvae. Here, the $1.50 material cost is for an 8 to 10 foot band. A 3.3 foot wide band would cost less than $0.75.

equivalent to foliar treated trees, as evaluated by whole canopy observations in Burlingame.

In this study, costs for foliar applications were found to be more than 4 times greater than bark banding costs (Table 2). Estimates were derived from CalTrans equipment and labor costs for each operation. Foliar applications were estimated to cost $23.18 per tree, and bark banding was estimated to be $4.99 per tree. Application time was the principal factor creating a cost difference between the two methods. It was estimated that banding took 3 minutes per tree (20 trees per hour), and foliar applications to take 12 minutes per tree (5 trees per hour). The banding time estimate would be expected to remain constant regardless of tree size. The foliar time estimate is for a 60 to 80 foot tree occurring in a row or group of other elms which would also be treated. This foliar time estimate will change depending on tree size and occurrence relative to other trees needing treatment. Large groups of smaller trees will require less application time, while larger trees occurring alone or in small groups will require more application time. Therefore, this cost comparison will vary, depending on the treatment conditions. Nonetheless, figures are presented to give an indication of cost differences realized here between the two treatments.

Conclusion

Trunk banding has been found to reduce ELB injury, but the magnitude of the effect (degree of control) is limited by certain factors. Although little or no control can be expected in the first year of banding, significant injury reduction can be achieved in the second and subsequent years. In years when feeding injury potential was high, trunk banding significantly reduced injury. In years when ELB activity was low, banding effects were not significant (and perhaps not necessary). Therefore, banding effectiveness may be limited by annual changes in ELB activity.

Banding effectiveness also appears limited by ELB activity in neighboring trees. Injury reduction was most pronounced when resident beetle activity was high and neighboring activity was low (e.g., Burlingame, August 1986). When neighboring ELB activity is high, then banding effectiveness is likely to be reduced. Accordingly, large groups of elms receiving trunk band treatments are likely to exhibit greater injury reductions than individually banded trees or small groups that are close to untreated trees. For example, banding a single tree that stands among untreated trees is not likely to be as effective as banding all susceptible elms in a neighborhood.

Although trunk banding appears to be an economically reasonable control method for reducing ELB injury to aesthetically acceptable levels, its effectiveness is limited. Factors limiting its effectiveness will have to be considered prior to its use in an ELB control program. Tree managers should evaluate the benefits and limitations of banding relative to other possible control methods (foliar sprays, trunk injection or implantation, biological control, resistant species and cultivars) to determine which single or combination of methods will produce desired results.

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Extension Service
University of California
146 Jordan Avenue
San Francisco, California 94118