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Contract Title: Implementation of Integrated Pest Management for the Elm Leaf Beetle, *Xanthogaleruca luteola* (Chrysomelidae: Coleoptera), in a Large Urban Area (Sacramento)

Principal Investigators:
Donald L. Dahlsten, Center for Biological Control
University of California, Berkeley

Jennifer Lystrup, Sacramento Tree Foundation
Martin J. Fitch, City of Sacramento
Department of Neighborhood Services

Prepared for California Department of Pesticide Regulation.

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ABSTRACT

The elm leaf beetle (ELB) is a major urban insect pest in California. This was the third year of a three-year cooperative project between the City of Sacramento Neighborhood Services, Sacramento Tree Foundation's Save the Elms Program (STEP), and U.C. Berkeley to implement an integrated pest management program for ELB. In 1998 the program focused on the implementation of a monitoring program covering half of the susceptible elms in the city so that control decisions could be made based on insect abundance. The monitoring successfully located areas of beetle infestation, and Sacramento neighborhood services personnel were trained in all aspects of monitoring. In a continuing effort to establish a biological control agent, 3,600 *Oomyzus gallerucae* "Granada strain" were released at the City cemetery between May and September 1998, but did little to provide control in the first and second generations. Community outreach and education efforts were continued by the Sacramento Tree foundation.

EXECUTIVE SUMMARY

The ELB is a major urban forest pest in California. This was the third year of a three-year cooperative project between the City of Sacramento Neighborhood Services, STEP, and U.C. Berkeley to implement an integrated pest management program for ELB. The program involved the transfer of developed monitoring methods to the city of Sacramento, developing new monitoring methods for a large urban area, evaluating new and existing control methods, as well as public education.

City and STEP personnel were trained in already developed monitoring methods. This model was effective in predicting timing of beetle stages as well as predicting beetle damage and need for treatment. STEP trained its volunteer force of 150 persons to rate ELB damage to elms throughout the year and made several presentations to neighborhood schools and homeowners associations in an effort to further awareness of elm leaf beetle. STEP and Neighborhood Services each hired a seasonal monitor to work on this project over the summer. The pair worked as a team in cooperation with U.C. and was involved in community outreach, sampling, and damage surveys. Seasonal monitors completed a citywide damage survey at the end of the first and second beetle generations. U.C. personnel surveyed third generation damage at the end of the season. The seasonal monitors also created a map of all susceptible elms in the city and collected data on beetle populations in treatment and control areas.

As in previous years, the egg parasitoid *Oomyzus gallerucae* "Granada strain" was released throughout the season primarily at the City Cemetery and Marshall School. Parasitoids were detected in the field at low levels in the second beetle generation and at much higher levels in the third generation.

Half of the susceptible elms in the city were left untreated and sampled for ELB eggs in each generation. Trees that were determined to require treatment were treated with a systemic injection of Vivid (avermectin). Because egg counts barely met the treatment threshold in these hot spots damage at the end of season did not differ significantly from control trees. The

treatment threshold will be raised in the 1999 season. A laboratory bioassay produced over 80% mortality on leaves collected from Vivid (avermectin) injected trees, while control leaves had less than 5% mortality. Leaves collected from trees injected with Imicide (Imidacloprid) one year after treatment did not differ from untreated controls.

BODY OF REPORT

INTRODUCTION

Since its introduction into California in the 1920's ELB, *Xanthogalerucae luteola,* has become a major urban forest pest. It is the most important pest of elms in California and is ranked as the second most important urban tree pest in the western U.S. (Wu et al. 1991).

The beetles overwinter as adults in sheltered places such as woodpiles, garages, attics, etc. Overwintering beetles in buildings are a nuisance and a cause of many calls to pest control applicators and extension agents. As the elm buds burst and the foliage begins to develop in the spring the adults emerge from their hiding places and feed on the foliage for one to two weeks before starting to lay eggs. Adult feeding is characterized by small circular BB-size holes in the foliage. Eggs are yellow and oblong and are laid in clusters of 15 to 20. The larvae are the most damaging stage. They develop through three instars and skeletonize the foliage, often causing the leaves to drop. When ready to pupate, the larvae crawl to holes in the trunk of the tree, limb crotches, beneath loose bark, or commonly to the base of the tree, where they gather in large numbers. Depending on climate there can be one to three generations per year in the northern part of the state and even more in southern California. When damage is noted the larval stage is usually the focal point for chemical control efforts.

The primary impact of defoliation is the loss of shade during the summer months and economically the cost of control. Defoliation, even annually, does not normally kill trees. To keep trees with foliage various agencies and individuals have been willing to spend thousands of dollars per year. The responsibility for pest management on elm trees includes cities for street side trees, park managers for park trees, and homeowners for trees in yards.

From 1984 to 1993 a user-friendly sampling technique was developed by Dahlsten et. al. (1994). A degree-day model was created to predict best times to sample and treat ELB (Dahlsten et al. 1991). Weather data can be obtained from nearby weather stations, on-site instruments (some of which calculate DD directly), or daily maximum/minimum temperatures from a local paper. Computer programs are available to calculate DD from these data.

A 30-cm (1-ft) elm branch terminal is the sampling unit on which the monitoring system is based. ELB viable (unhatched) egg clusters were used for damage prediction because of convenience (they are stationary) and sampling them allows time to make treatment decisions before the damaging larval stage occurs. We have determined that recording presence or absence

of viable egg clusters on each sample unit provides good damage prediction. Because we found significant differences in egg density between cardinal directions but not between upper and lower crown, branches are now taken from the more easily sampled lower crown in eight segments per tree. These are north, east, south, and west, in both the inner crown (from trunk halfway to drip line) and the outer crown.

In the 1995-1997 seasons we have used 40% defoliation as the threshold of acceptable damage. After discussion with the city of Sacramento Neighborhood Services we now feel that 20% defoliation is more realistic. Therefore, when sampling at egg peak, if less than 25% of the branch samples have viable egg clusters present then the damage at the end of that generation will be in the acceptable range (less than 20% defoliated), with a probability of error of 10%.

Management of elm leaf beetle in Sacramento has historically been through treatment of all susceptible elms with systemic injection of pesticides done on a calendar basis. In 1995 the Sacramento Tree Foundation, the City of Sacramento Neighborhood Services, and the University of California began a co-operative effort to develop and implement an integrated pest management program for the elm leaf beetle. The project has focused on evaluation of new environmentally sound control techniques such as Bt and the release of a biological control agent (*Oomyzus gallerucae*) as well as adaptation of the previously developed monitoring program so that all control decisions may be based on beetle abundance. The program has also made extensive efforts to educate the people of Sacramento about the elm leaf beetle and the management program. In this final year of the program the project has focused on expansion of the monitoring program to include half the susceptible elms in the city as well as continuing efforts to educate the public.

MATERIALS AND METHODS

Transfer-developed monitoring methods

The monitoring methods and degree-day model developed by Dahlsten *et. al*. (1993) were used to monitor beetle populations in an area covering half of the city. The number of trees was increased from 474 trees in the 1997 season to 1,065 in the 1998 season. This increase in scale more closely simulates the conditions, which will be encountered as Neighborhood Services implements, a monitoring program throughout the entire city.

In order to select trees for sub-sampling in the monitoring areas, a complete map of all susceptible elms in the area was completed. Sample trees were then chosen randomly and marked with a blue paint dot for easy recognition in the field. A map was also completed of all susceptible trees in the other half of the city that will be used when the monitoring program encompasses the entire city in the 1999 season. The address and species of each of these trees was then placed into a spreadsheet database that will be incorporated with STEP's GIS system. If sample trees were found to have a proportion of samples with eggs present above the threshold level, all elms surrounding this tree were then sampled. This allowed determination of exactly which trees required treatment in the area.

Personnel from Neighborhood Services and STEP were directly involved with the monitoring so the methods could be learned first hand. Anne Fenkner from STEP, and Bob Hughes from Neighborhood Services were each responsible for recording degree-day data from a biophenometer and relaying the information to U.C. personnel. At the egg peak of each beetle generation Neighborhood Services provided three crews to complete the monitoring. Each crew was composed of one Senior Tree Maintenance Worker (permanent employee) and 4-5 Tree Maintenance Workers. U.C. personnel supervised monitoring.

Treatment of hot spots

The city of Sacramento Neighborhood Services is not interested in pursuing *Bt* as its primary treatment for elm leaf beetle for several reasons. The city believes that the county agricultural commissioner will not grant permission to spay a foliar pesticide due to an inability to keep the spray on target. *Bt* must also be applied in a narrow time window, which the city believes may be logistically impossible in the event of having to treat large numbers of trees. For this reason we have not pursued *Bt* as a treatment in the 1998 season. *Bt* treatments may still be a viable technique in areas where spray drift is not a problem, for limited tree numbers and times when crews are available. We believe our results from 1996 and 1997 have demonstrated that a double application of *Bt* spaced one week apart is an effective alternative treatment at small scales (approximately 100 trees).

When monitoring detected a group of trees with egg counts above the treatment threshold, approximately half of those trees were set aside as untreated control trees and the other half were treated with a systemic injection of Vivid (avermectin) as directed by product label instructions. Each of these areas or hot spots was treated as a block. The control and treated trees were then monitored weekly or bi-weekly for eggs, larvae, and damage for the remainder of the season. An overall tree damage rating was done at the end of the season. Two people evaluated each tree independently and the damage rating assigned to the tree was the mean of these two ratings.

Bioassays

Laboratory bioassays were performed to measure larval mortality on leaves collected from treated and control trees. Individual leaves were placed in petri dishes with moistened filter paper. Five 1st instar larvae were then placed on each leaf and observed daily for larval mortality for 5 days under controlled conditions (70°F, 16:8 (L:D) photo period). This bioassay was performed on leaves collected 4 days after treatment (n = 20) and again 14 weeks after treatment (n = 21). A similar bioassay was performed on leaves collected from trees injected with Merit (imidacloprid) one year previous (n = 40). This test was done to determine if there was any carryover activity of the material from one season to the next.

Damage surveys
A city wide damage survey was done by a combination of STEP staff, City, and U.C. personnel at the end of each beetle generation to determine if any damage had occurred to trees which we did not predict by sampling at the egg peak of the generation. These surveys were done from the ground by driving through all areas of the city with elm populations. Two people evaluated each tree independently and the damage rating assigned to the tree was the mean of these two ratings. Tree damage ratings were transferred to the elm inventory database.

STEP has an established volunteer force of over 150, dedicated to monitoring the elms of Sacramento for signs of Dutch elm disease at least five times throughout the season. This year ELB monitoring was incorporated into STEP's Dutch elm disease training process. Basic information examining the life cycle of the elm leaf beetle, the damage that they cause, and options on how to control the damage were added to STEP volunteer educational packets. This information was provided by U.C. personnel and compiled by STEP. Continuing STEP volunteers were notified of this project in the spring and were solicited for their participation in educating friends and neighbors, as well as informing STEP of locations with heavy beetle activity.

STEP volunteers are participating in this study by rating the elms in their chosen areas for levels of ELB defoliation. Volunteers participate in training sessions at the beginning of the season to familiarize themselves with the ELB damage rating system. Volunteer damage assessment is submitted at the end of the season.

Egg parasitoids
In an effort to establish a biological control agent for ELB an egg parasitoid was released. Between 1995 and 1997 a total of 41,632 *Oomyzus gallerucae* were released in Sacramento. Between May and September, 1998 a total of 3,600 *Oomyzus gallerucae* Granada strain were released at the City cemetery. Eggs were collected from each generation throughout the season and set up for parasite emergence at the U.C. insectary. Parasitism rates were recorded for all eggs collected.

RESULTS AND DISCUSSION

Transfer developed monitoring methods
The degree-day model proved effective in predicting timing of egg peaks and peaks of larval stages. City and STEP personnel are now familiar with the degree-day model and monitoring techniques. Monitoring at each generation egg peak successfully identified hot spots of beetle activity that were then treated.

Monitoring of the first generation found 42 trees that required treatment. Twenty-five of these were treated, and 17 were left as untreated controls. Monitoring of the second generation found 21 trees that required treatment. Eleven of these trees were treated and 10 were left as untreated controls. In each hot spot, in both the first and second generation, the proportion of samples with eggs present was just equal to the treatment threshold. In the third generation 21 trees required treatment. Neighborhood services felt that they were unable to leave any of these trees untreated as controls due to concerns of citizens in the area.

In the monitoring area only 84 trees out of 1,065 required treatment, and damage was limited to within acceptable levels. This represents a 92% reduction in chemical use when compared to the previous management strategy of treating all susceptible trees. This supports our hypothesis that a monitoring program may drastically reduce the number of trees injected in a given year. Three city crews were able to complete the monitoring within a two and a half day window, which is short enough to allow treatment of detected hot spots before the damaging larval stages begin to develop. In the 1999 season the city plans to use the monitoring program on all susceptible elms (with the exception of park trees which will be treated with a ground application of Merit).

Treatment of hot spots

Control and treatment trees from the first and second generation were sampled weekly from just before time of treatment until the end of the season. Analysis of damage ratings, at the end of the season, shows no significant difference between treatment and control trees in either the first or second generation. Because egg population levels that may cause only moderate damage (20%) may not result in significant differences in final damage level compared to untreated controls, we recommend increasing the treatment threshold from >20% of samples with eggs present to >30%. A second option may be to increase the number of samples per tree in a hot spot to reduce the variability in damage prediction. Both of these options are being considered for the 1999 season.

Bioassays

Mortality on leaves collected from Imicide injected trees one year after treatment did not differ from untreated controls. (Fig. 1). There appears to be no carry-over effect of Imicide from season to season. Mortality on leaves collected from Vivid injected leaves collected 4 days after treatment rose to 81% compared to 34% in untreated controls (Fig. 2). Mortality on leaves collected from Vivid (avermectin) injected leaves collected 14 weeks after rose to 75% compared to 45% in controls (Fig. 3). Laboratory results indicate that the Vivid injections can result in lethal doses to ELB larvae feeding on leaves and appears to remain active for an entire season.

Damage surveys

Surveying elms in a drive-by evaluation appears to be very effective in spotting areas of beetle damage throughout the city, and can be done in as little as three days by two people. No trees were found with damage above the acceptable level at the end of the 1998 season.

An aerial survey of the city was done October 11, 1996. Analysis of the survey found that only trees damaged over 40% could be easily distinguished on the infrared photographs. Due the cost of the survey and its inability to detect areas of low beetle damage it was decided not to continue aerial surveys in the 1998 season. Ground surveys are less expensive and more accurate.

STEP volunteers were successful in monitoring elms throughout the season for Dutch elm disease and ELB, and reported no ELB defoliation.

Egg parastioids

No parasitoids were recovered from eggs collected in May which suggests parasitoids released between 1995 and 1997 did not overwinter or did so only in small numbers. After further releases in 1998 parasitoids were recovered in low numbers in the City Cemetery in the second generation. In the third generation parasitism rates rose to 53% in the City Cemetery, and varied between 0 and 20% in other areas. Due to the repeated failure of the egg parasitoid to establish in numbers high enough to control beetle populations, the insectary colony was not maintained beyond September 1998. Innundative releases of the parasitoid early in the season may result in late season control.

Group Formation and Community Involvement

STEP and City of Sacramento Neighborhood Services each hired a seasonal monitor from mid May through mid-September. The two worked as a team under the joint direction of the three agencies. The primary focus of the team was community outreach and monitoring for beetle activity. The team also kept all three agencies in constant communication. Neighborhood Services provided the team with a vehicle throughout the summer.

Neighborhood Services involvement in monitoring increased from assisting U.C. and STEP personnel in 1997 to full responsibility for monitoring all trees with U.C. supervision in the 1998 season. This increased involvement by the tree maintenance workers has helped to improve cooperation and communication between the groups as well as help to change preconceived notions amongst the tree workers about ELB's population dynamics. That is, many workers believed that ELB will infest all trees if left untreated. By monitoring untreated trees throughout the season, workers see that only small patches of beetle activity exist.

STEP made presentations to community neighborhood associations and focused on dispelling the assumption that ELB defoliation is the same as Dutch elm disease. The seasonal monitors also gave presentations to several schools located in neighborhoods with an abundance of elms. These presentations focused on teaching the children how to recognize the beetle, the life cycle of the beetle, and some of the details of this IPM project. Guidelines for K through 6th grade presentations were assembled. Presentations were made in September at William Land Elementary School, and included the participation of a Senior Tree Maintenance Worker and a tree climber from Neighborhood Services.

Anne Fenkner from STEP gave presentations to the East Sacramento Neighborhood Association, the Elmhurst Neighborhood Association, the Capitol Avenue Neighborhood Watch Association, and the Marshall School/Boulevard Park Neighborhood Associations. The presentations focused on the life history of the beetle and the specifics of the current IPM study.

SUMMARY AND CONCLUSIONS

This was the final year of a three-year cooperative project among the City of Sacramento Neighborhood Services, Sacramento Tree Foundation's Save the Elms Program (STEP), and U.C. Berkeley to implement an integrated pest management program for ELB. In 1998 the program focused on the implementation of a monitoring program covering half of the susceptible elms in the city so that control decisions could be made based on insect abundance. The monitoring successfully located areas of beetle infestation and Sacramento Neighborhood Services personnel were trained in all aspects of monitoring. A systemic injection of Vivid (avermectin) was used as the treatment for hot spots. Due to egg counts barely meeting the treatment threshold damage at the end of season did not differ significantly between treatment and control trees. We recommend that the treatment threshold be increased. A total of 3,600 *Oomyzus gallerucae* Granada strain were released at the City Cemetery between May and September 1998, but did little to provide control in the first and second generations. Community outreach and education efforts were continued by the Sacramento Tree foundation. The city plans to use the monitoring program on all susceptible elms (with the exception of park trees) in the 1999 season.

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PRESENTATIONS

19 January 1996. D. L. Dahlsten. 90 minute invited talk. "Integrated Pest Management and Monitoring." Think Trees New Mexico 10th Annual Conference. Albuquerque, New Mexico, Convention Center.

5 February 1996. D. L. Dahlsten. 20 minute talk. "Biological Control Projects in Urban Forests," U.C. Santa Cruz Integrated Pest Management class visit to Gill Tract, Albany. D. Letourneau, instructor.

5 June 1996. D. L. Dahlsten. 1 hour lecture. "Two Important Beetle Pests of Elms in California (A Defoliator and A Vector of Dutch Elm Disease)." Pesticide Applications Professional Assoc. Holiday Inn Northeast, Sacramento, Calif.

15 January 1997. D. L. Dahlsten. 50 minute invited talk, "Current Research in IPM of Elm Leaf Beetle, and More." Sacramento Valley Landscape and Nursery Expo, Sacramento Community Convention Center.

11 March 1997. D. L. Dahlsten. 1 hour talk, "Biological Control of the Elm Leaf Beetle." Annual California Agricultural Commissioners and Sealers Association. Biological Control and IPM Conference, Fountain Suites Hotel, Sacramento.

15 April 1997. D. L. Dahlsten. Organized and moderated a workshop on "Urban Forest Pest Management" 48th Annual Western Forest Insect Work Conference, Prince George, British Columbia, The Coast Inn of the North, 14-17 April.

15 April 1997. A. B. Lawson. 20 minute talk, "Implementation of IPM for the Elm Leaf Beetle in a Large Urban Area." 48th Annual Western Forest Insect Work Conference, Prince George, British Columbia, The Coast Inn of the North, 14-17 April.

16 April 1997 A. B. Lawson. 20 minute talk, "IPM in the Urban Forest: Obstacles for Sampling and Implementation." 48th Annual Western Forest Insect Work Conference, Prince George, British Columbia, The Coast Inn of the North, 14-17 April.

1 May 1997. D. L. Dahlsten. Seminar, "Development of an Integrated Pest Management Program for the Elm Leaf Beetle: Model for Urban Forests." Iowa State University, Department of Forestry.

12 May 1997. D. L. Dahlsten . "Alternative Approaches to Agricultural Pest Control in Northern California." Keynote Address at Public Forum. Chico Rotary Club and Chico State School of Agriculture.

20 October 1997. D. L. Dahlsten. 35 minute lecture. “Implementation of IPM for the elm leaf beetle in a large urban center." 23rd Annual CAPCA Conference and Exposition. John Ascuaga's Nugget. Sparks, Nevada.

17 December 1997. D. L. Dahlsten. 45 minute lecture. “IPM: From Research to the Practitioner." U.C. Cooperative Extension and Marin Co. Dept. of Parks, Open Space and Cultural Services Conference-Urban IPM: Designing Plant and Pesticide Management Program. Showcase Theater, Marin Civic Center Fairground, San Raphael, California.

17 February 1998. D. L. Dahlsten. 1 hour lecture. “Integrated Pest Management in Urban Environments." Merced Community College Pest Management Update Class. Richard Dodson, instructor. Merced, California.

10-11 June, 1998. Andrew B. Lawson, Donald L. Dahlsten, David L. Rowney, Martin Fitch and Ann Fenkner. Poster presentation. “The elm leaf beetle in California: Development and implementation of an integrated pest management program." California Conference on Biological Control. Clark Kerr Conference Center, University of California, Berkeley.

9 February, 1999. Lawson, A.B., D.L. Dahlsten, D.L. Rowney, M. Fitch and A. Fenkner. Poster presentation. "The elm leaf beetle in California: Development and implementation of an integrated pest management program" U.C.-D.A.N.R. Statewide Conference, Radisson Hotel, Sacramento, California.

18 February, 1999. Lawson, A.B. 20 minute talk " Implementation of an integrated pest management program for the elm leaf beetle in Sacramento, CA". University of California Berkeley Entomology Students Organization. Berkeley CA.