FIELD AND LABORATORY EVALUATIONS OF *BACILLUS THURINGIENSIS* STRAINS FOR CONTROL OF ELM LEAF BEETLE

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Abstract. The elm leaf beetle, *Xanthogaleruca luteola* (Muller), is a serious defoliating pest of elm throughout much of North America. Petrochemically-derived insecticidal sprays have been a common management practice for this insect but increasing environmental concerns and regulatory restrictions have required that alternative insecticides be considered. Recently, new strains of *Bacillus thuringiensis* ("San Diego", "tenebrionis") which have activity against leaf feeding beetles have been discovered and become available. Field and laboratory trials indicate that these are highly effective against larvae of elm leaf beetle. Some adulticidal activity also is present with these formulations. Persistence of the tested formulations on foliage was short so proper timing of treatments is important for effective control.

Résumé. La galéruque de l'orme, *Xanthogaleruca luteola* (Muller), est un sérieux défoliateur des ormes en Amérique du Nord. La pulvérisation d'insecticides dérivés de produits pétrochimiques a été une pratique commune, mais les préoccupations environnementales et les restrictions réglementaires récentes ont exigé la considération d'insecticides alternatifs. Récemment, de nouvelles souches de *Bacillus thuringiensis* ("San Diego", "tenebrionis") qui sont efficaces contre les insectes se nourrissant sur les feuilles ont été découvertes et deviennent disponible sur le marché. Des essais de terrain et en laboratoire indiquent qu'elles sont très efficaces contre les larves de la galéruque de l'orme. La répression des insectes adultes est aussi associée à ces produits. La persistance sur le feuillage des produits testés étant faible, la période d'application doit être bien évaluée pour assurer un contrôle efficace.

Elm leaf beetle, *Xanthogaleruca luteola* (Muller), has established itself as a serious pest of many elm species grown throughout much of North America. Two or more generations of the insect are typically completed in a single season often resulting in sustained defoliation. Heavily defoliated trees suffer considerable esthetic damage, loss of tree vigor, and increased branch dieback.

Foliar applications of various petrochemically-derived insecticides have been a standard elm leaf beetle management practice for many years and generally give a high level of control. However, increasing public scrutiny has focused on these treatments because of perceived safety and/or environmental concerns. Moreover, liability and regulatory restrictions surrounding pesticide applications, particularly in urban areas, have spurred interest in developing alternative pest management practices for urban shade trees.

Recently, new strains of *Bacillus thuringiensis* have been identified which have activity against certain beetles. Discovery of *B. thuringiensis* var. *tenebrionis* was announced in 1983 by Krieg et al. (3); the "San Diego" strain was later identified by Herrnstadt et al. (2). Activity of both the "tenebrionis" and "San Diego" strains is apparently similar and is limited to larvae and adults of some beetles including the yellow mealworm, elm leaf beetle, and Colorado potato beetle (4). Lepidoptera larvae, susceptible to the commonly used "kurstaki" and "thuringiensis" strains, are not affected by the *B. thuringiensis* strains which affect beetles (Coleoptera).

Both "tenebrionis" and "San Diego" strains are currently under active development by several companies, largely for control of Colorado potato beetle, *Leptinotarsa decemlineata* (Say). The Colorado potato beetle is a serious pest of potatoes throughout North America and Europe and several strains of the insect have developed high levels of resistance to currently available insecticides. Secondary development interests have also come to include "ornamental" markets, such as elm leaf beetle.

Formulations of "San Diego" strain (M-One, Mycogen Corp., San Diego, CA) and "Tenebrionis" strain (ABG-6263, Abbott Labs, Chicago, IL) became available in sufficient quantity in 1988 to allow for field and laboratory testing. These studies were conducted to determine the performance characteristics of the new *B. thur-*

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ingiensis strains for use in protecting elms against elm leaf beetle.

Methods

Field trials. Field trial tests of the M-One formulation ("San Diego" strain) were conducted at two sites within the metro Denver, CO area. Precount surveys of elm leaf beetle larvae were made June 14 on marked branch terminals. At the first site (Arvada) 6 terminals were marked on each treated tree. Experimental design was a randomized complete block with 4 single tree replications. A second site (Wheat Ridge) involved a single block treatment to 2-3 trees each with 10 marked terminals. Siberian elm, *Ulmus pumila,* was the host at both locations.

Applications were made June 15 using a hydraulic tree spraying unit with a FMC 785 spray gun. A spreader-sticker (Loveland Bond) was added at the rate of 24 fl. oz./100 gallons. Three rates of M-One were tested, 3 qts, 4 qts, and 8 qts/100 gallons of water. Elm leaf beetle larvae at the time of application were predominantly (80-90%) in the first and second instars.

Evaluation of treatments was made June 20 by recounting the marked terminals used for precounts. Correction for natural background mortality was made using the formula of Abbott (1).

Greenhouse efficacy comparisons. Three greenhouse and laboratory trials were conducted to compare the application rate responses of both "San Diego" and "tenebrionis" strains. All trials involved applications to potted Siberian elm maintained in the greenhouse. Two larval evaluations involved 35 field collected elm leaf beetle larvae, in mixed instars, confined to each tree. Larvae were immediately confined to sample trees upon drying of the foliar applications. Three trees were used to evaluate each treatment rate.

Adult trials were conducted by confining 70 field collected adults upon two treated trees retained within a screened cage. Dead adult beetles and remaining alive adult beetles on foliage after 96 hours were used to assess mortality. Mortality corrections involved use of Abbott's (1) formula.

Persistence evaluation trials. Persistence of the *B. thuringiensis* strains was evaluated by sequentially treating potted trees over the course of l-7 days prior to exposing field collected larvae to the trees. Two trials were conducted, each involving 3 trees with 35 larvae per tree.

Results and Discussion

Both field trials with M-One ("San Diego" strain) indicated a high (90-95%) level of control (Table 1) when used at the 4 and 8 qt/100 gal rates. A very sharp drop-off of activity was observed between the 3 qt/100 gal and 4 qt/100 gal rates of application, suggesting that recommended field applications of this formulation should equal or exceed the 4 qt rate. At the higher rates, most of the surviving larvae were those that had hatched within a few days of the evaluation. A background of natural mortality approximating 20% was also observed during the one week course of the trial.

In laboratory and greenhouse trials, "tenebrionis" strain (ABG 6263) also showed activity against larvae of elm leaf beetle (Table 2) giving consistently higher levels of control than M-One at tested rates. Interestingly, M-One performed less well in greenhouse tests than in the field. One possible explanation is that under field conditions larvae may succumb to increased mortality due to dislodgement from trees while suffering sublethal effects of infection. In addition, an older range of larvae were used in these tests than occurred during field testing.

Table 1. Control of first generation elm leaf beetle larvae with M-One[R] *(Bacillus thuringiensis* var. *San Diego)* in two field trials, 1988. (Evaluation made 6 days after application.)

Rate formulation/100 gal spray	*Larvae in pre-count (6/14)*[1]	*Larvae in post-count (6/20)*	*% control*[2]
Site 1, Arvada, CO			
3.0 qts	1364	561	46.3%
4.0 qts	719	31	94.4%
8.0 qts	1055	94	88.3%
Untreated check	853	685	—
Site 2, Wheat Ridge, CO			
3.0 qts	104	83	0.0%
4.0 qts	8	259	96.1%
8.0 qts	12	290	94.8%
Untreated check	155	124	—

[1]Larvae counted on 6 terminals per tree in pre- and post-counts in Arvada trial; 10 total terminals in Wheat Ridge trial.
[2]Mortality adjusted by Abbott's formula (1925).

Adult beetles were also susceptible to both strains of *B. thuringiensis* (Table 3). At tested rates, (2-4 lbs) the "tenebrionis" strain formulation (ABG 6263) gave control levels exceeding 95%; similar levels of control with the "San Diego" strain formulation were achieved at the 8 quart rate of application. These data show that the adult stage of elm leaf beetle is similarly susceptible to high-end larval stage usage rates.

Persistence of both strain formulations appeared to be short (Table 4). Sharply reduced activity was evident within 24-48 hours. The addition of a spreader sticker (Loveland Bond) did not significantly affect persistence. Observations during field trial evaluations also indicated short residual activity since newly hatched healthy larvae were found on foliage within 6 days of application. This suggests that applications of the these beetle active *B. thuringiensis* strains will have to be carefully timed to coincide with the end of peak egg hatch. Future improvements in formulation which allow for increased persistence or which simultaneously kill egg stages (e.g., spray oils) may allow for greater latitude in spray timing.

Control of elm leaf beetle, especially in residential areas, is one of the most important insect control services offered by many arborists in Colorado. These applicators are generally highly visible to the public because of the location of elms in populated settings. Because of public concerns with these treatments, use of biological pesticides, such as *B. thuringiensis*, is a desirable attribute. Arborists are likely to use such materials if they meet performance requirements such as effectiveness against the target pest, non-irritation to the applicator, absence of significant staining or odor problems, and are priced competitively with alternative treatments. The tested beetle-active strains of *B. thuringiensis* ("tenebrionis" and "San Diego" strains) show substantial promise in meeting these criteria.

Table 2. Mortality[1] of elm leaf beetle larvae on elm treated with various *Bacillus thuringiensis* strains in greenhouse trials.

Rate formulation/100 gal		*Percent mortality*
Trial 1		
ABG 6263	0.5 lb	90.4%
ABG 6263	1.0 lb	94.0%
ABG 6263	2.0 lb	96.4%
M-One	4.0 qt	67.5%
Trial 2		
ABG 6263	0.5 lb	52.0%
ABG 6263	1.0 lb	68.1%
ABG 6263	2.0 lb	92.0%
M-One	2.0 qts	(-23.9%)
M-One	4.0 qts	(-13.9%)
M-One	8.0 qts	30.0%

[1]Corrected 72 hour mortality based on Abbott's formula (1925). Mortality based on 105 late instar larvae confined (35/tree) to three trees in the greenhouse.

Table 3. Mortality of elm leaf beetle adults on elm treated with various formulations of *Bacillus thuringiensis* in greenhouse trials.

Formulation	*Rate/100 gal*	*Percent mortality[1]*
ABG 6263	2.0 lbs	97.6%
ABG 6263	3.0 lbs	100.0%
ABG 6263	4.0 lbs	100.0%
M-One	4.0 qts	61.6%
M-One	6.0 qts	79.8%
M-One	8.0 qts	94.5%

[1]Corrected 72 hour mortality based on Abbott's formula (1925). Mortality based on 70 field collected beetles confined to treated caged trees in a greenhouse.

Table 4. Mortality of elm leaf beetle larvae confined to elm trees previously treated with various "San Diego" and "tenebrionis" *Bacillus thuringiensis* strains at various intervals with and without spreader-sticker (Loveland Bond).

Formulation and rate/100 gal	*Pre-confinement interval[1]*	*Percent mortality[2]*
Trial 1		
M-One 6.0 qts	7 days	36.2%
M-One 6.0 qts + Bond	7 days	17.5%
M-One 6.0 qts	4 days	5.1%
M-One 6.0 qts + Bond	4 days	24.0%
M-One 6.0 qts	1 day	1.5%
M-One 6.0 qts + Bond	1 day	(-15.5%)
M-One 6.0 qts	0 days	79.3%
M-One 6.0 qts + Bond	0 days	59.6%
Trial 2		
ABG 6263 2.0 lbs	48 hours	32.0%
M-One 6.0 qts	48 hours	10.1%

[1]Period between foliar treatment and exposure of larvae to treated foliage.
[2]Corrected 72 hour mortality based on Abbott's formula (1925). Mortality based on 105 late instar larvae confined (35/tree) to three trees in the greenhouse.

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Abstracts

PETREE, J. 1988. **High stakes.** Am. Nurseryman 167(12):43-45.

Put bluntly, you are making a big mistake if you ignore OSHA's Hazard Communication Standard. Noncompliance can easily be a terminal mistake for your business, putting management and the company's existence at risk for decades. With such high stakes, this is one set of rules you had better pay attention to. In essence, the new law requires that all employers develop hazard communications programs. To comply, you should implement the following steps: Inventory all chemical products in your workplace. Label all hazardous chemical containers. Keep Material Safety Data Sheets in an area where they are immediately available in an emergency. Identify and train employees who could be exposed to hazardous chemicals. Develop and maintain a written program that explains how employees are informed and trained about the hazardous chemicals in their workplace.

HOLMES, F.W. 1988. **Nematodes and shade trees.** Arbor Age 8(6):26-27.

Some nematodes are parasites on higher plants or animals. Others are free-living in soil or water. Many feed on plant rootlets. Some even enter the roots and dwell there. When that happens, the nematodes may cause small galls or dead spots on the roots. They also may cause the root system to grow much more slowly than usual, or even to die. By harming roots, nematodes often cause stunting, decline, or death in above-ground parts of plants. In recent years, the pinewood nematode has also been found in the xylem vessels of certain trees. The relationship of nematodes to shade trees is in an unexplored, experimental stage. Shade-tree research scientists are happy to have opportunities to test for the presence of nematodes in samples taken where shade trees are symptomatic. But they seldom can say for sure whether even the nematodes they find in such samples caused any of the symptoms, nor can they suggest much in the way of treatment.