Biorational and Conventional Plant Protectants Reduce Feeding by Adult Japanese Beetles[1]

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Abstract

Nine commercial plant protectants were tested for efficacy against feeding by adult Japanese beetles (*Popillia japonica* Newman). Treatments included an endotoxin from a bacterium [*Bacillus thuringiensis* (Berl.) var. *san diego*]; microencapsulated pyrethrum extracted from pyrethrum [*Tanacetum cinnerariifolium* (Trev.) Schultz-Bip.], two extracts from neem (*Azadirachta indica* A. Juss); an extract from cayenne pepper (*Capsicum annuum* L. var. *annuum* Longum Group); an extract from garlic (*Allium sativum* L.); rotenone extracted from galedupa (*Derris trifoliata* Lour.) and barbasco [*Lonchocarpus sericeus* (Poiret) Kunth] or timbo (*L. nicou* Aublet D.C.); carbaryl (1-napthyl methylcarbamate); and the pyrethroid, fenpropathrin. Experimental plots were located at the Horticulture Field Laboratory (HFL), Raleigh, and the Mountain Horticultural Crops Research and Extension Center (MHCREC), Fletcher, NC. Himalayan birches [*Betula utilis* var. *jacquemontii* (Spach) Winkl.] were used as host plants. Treatments were applied twice, 2 weeks apart. Five weeks after initial application, trees treated with fenpropathrin averaged 2% defoliation vs. 40% defoliation for the control trees at HFL; and 3% defoliation vs. 100% defoliation for the control trees at MHCREC. Rotenone treatments averaged 10% defoliation at HFL and 92% defoliation at MHCREC. The following treatments were not significantly different from the control at week 5 at either location: garlic extract, neem extracts, cayenne pepper extract, microencapsulated pyrethrum, encapsulated bacterial endotoxin, and carbaryl.

Index words: *Popillia japonica*, allelochemicals, antifeedants, deterrents, pest management.

Significance to the Nursery Industry

Japanese beetles have an extremely wide host range and have proven difficult to control over large geographic areas. However, it may be practical to protect valuable plants and to reduce feeding on landscape and ornamental plantings through the application of feeding deterrents (16). The pyrethroid Tame was a very effective Japanese beetle deterrent, whereas rotenone was moderately effective. Use of other products including neem extracts, garlic extract, cayenne pepper extract, pyrethrin, and endotoxin from *Bacillus thuringiensis* var. *san diego* did not provide adequate control of adult Japanese beetles with two applications.

Introduction

Japanese beetles, *Popillia japonica*, are destructive polyphagous insects that feed on over 300 different plant species, within 95 families. Since 1916, when first discovered in Riverton, NJ; the Japanese beetle (JB) has infested approximately one-half of the contiguous 48 United States and continues to spread at a rate of 8–16.1 km (5–10 miles) per year (2, 5, 7, 15).

Beginning with the work of Metzger and Grant in the United States in 1934 (19), numerous studies have been conducted to find natural deterrents for JB, as well as other insect pests (1, 6, 14, 18, 21, 26). Before discovery and success of synthetic organochlorines and organophosphates, carbamates and the more recent pyrethroids, botanical insecticides played an important role in pest management strategies. With problems of environmental persistance and public mistrust of synthetic chemicals, there has been a resurgence of interest in botanical pest control agents (3, 12).

Botanical secondary metabolites as they exist within plants are complex in their modes of action, sites of action, and their levels of response (4, 8). Since these attributes may help to provide more sustainable resistance qualities against insect pests, it is desirable to test the use of botanical compounds from plant extracts as deterrents. Furthermore, effective botanical compounds also may provide chemical structure-activity leads for synthetic pesticide development (13, 24).

Currently, products registered for use against JB include the botanicals pyrethrum, rotenone, neem, capsaicin, garlic extract, and the bacterium, *Bacillus thuringiensis*. Registered synthetics include among others fenpropathrin and carbaryl. Our objective was to evaluate the relative efficacy of these products in deterring feeding of adult JB.

Methods and Materials

Plant material. Himalayan birches were used as highly susceptible host plants for JB (22). In March 1997, 100 bareroot trees were planted in a randomized complete block design with 10 replicates at both the Horticulture Field Laboratory (HFL), Raleigh, and the Mountain Horticultural Crops Research and Extension Center (MHCREC), Fletcher. At planting, trees had an average crown diameter of 76 cm (30 in), and a height and caliper of 2.0 m (6.5 ft) and 1.3 cm (0.5 in), respectively. Trees were spaced 2.4 m (8 ft) apart both in

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Table 1. Treatments applied twice at 2 week interval.

Product	Active substance	Rate of product	
Garlic Barrier	garlic extract	31.0 ml/liter	(12.5 fl oz/gal)
Triact 90EC	neem oil extract	6.5 ml/liter	(0.85 fl oz/gal)
Neemazad 4.5EC	azadirachtin	0.6 ml/liter	(0.15 fl oz/gal)
Rotenone 5WP	rotenone	24.0 ml/liter	(3.3 oz/gal)
Hot Pepper Wax	capsaicin	31.2 ml/liter	(4.0 fl oz/gal)
PT70 X-CLUDE	pyrethrin	15.6 ml/liter	(2.0 fl oz/gal)
M-Trak	*Bacillus thuringiensis* var.*san diego*	23.4 ml/liter	(3.0 fl oz/gal)
Tame 2.4EC	fenpropathrin	0.9 ml/liter	(0.35 fl oz/gal)
Sevin 4F	carbaryl	3.9 ml/liter	(0.5 fl oz/gal)
Control	water	—	—

rows and between rows. Aisles were planted in tall fescue [*Festuca arundinacea* (Schreb.)] that was mowed as needed. After planting, 142 g (5 oz) of 10N–4.4P–8.3K (10–10–10, Powell and Powell Co., Fuquay-Varina, NC) granular fertilizer were applied to a 2.7 m^2 (9 ft^2) area surrounding each tree. Supplemental irrigation was provided as needed until treatment application. Fertilizer and irrigation were applied to minimize any confounding effects due to limited nitrogen or water (20, 25).

Treatments included six plant derivatives: Garlic Barrier (100% garlic extract from *Allium sativum*, Garlic Research Labs, Glendale, CA); two extracts from neem (*Azadirachta indica*): Triact 90 EC (90% clarified hydrophobic extract of neem oil, Thermo Trilogy Corporation, Columbia, MD) and Neemazad 4.5 EC (4.5% azadirachtin, W.R. Grace & Co., Columbia, MD); Rotenone 5WP [extracted from galedupa (*Derris trifoliata*) and barbasco (*Lonchocarpus sericeus*) Kunth or timbo (*L. nicou*), Bonide Products Inc., Yorkville, NY]; Hot Pepper Wax [extracted from cayenne pepper (*Capsicum annuum* var. *annuum* Longum Group), The Wilder Agriculture Products Inc., New Wilmington, PA]; and PT 170 X-CLUDE (1.1% microencapsulated pyrethrin from *Tanacetum cinerariifolium* Schultz-Bip., plus 2.2% technical piperonyl butoxide plus 3.7% N-octyl bicycloheptene dicarboximide, Whitmire Micro-Gen Research Labs, Inc., St. Louis, MO). The remaining treatments included: M-TRAC [10% delta endotoxin of *Bacillus thuringiensis* var. *san diego* (10) encapsulated in killed *Pseudomonas fluorescens* , Mycogen Corp., San Diego, CA]; a synthetic pyrethroid, Tame 2.4 EC (33.6% fenpropathrin, Valent USA Corporation, Walnut Creek, CA); a synthetic carbamate, Sevin 4F (43% Carbaryl, Rhone-Poulenc Co., Research Triangle Park, NC); and a control (water).

Treatment solutions were applied using labeled rates for each product (Table 1). Each tree received 0.3 liters (10 fl oz) of its particular treatment solution applied via a diaphragm-type backpack sprayer (Solo model #475, Newport News, VA) from a single hollow cone nozzle at 276 kPa (40 psi). A preliminary study indicated this volume (0.3 liters) was adequate to wet the upper and lower leaf surfaces on each tree. A portable shield was constructed to eliminate spray drift. Treatments were applied between 7:00 AM and 9:00 AM June 19, 1997, at HFL and June 25, 1997, at MHCREC. Treatments were reapplied 2 weeks after initial application. At HFL, climatic conditions at application were partly cloudy, 18.3–21.1C (65–70F), and wind of 0–8 KPH (0–5 MPH) on both dates. Conditions were similar at MHCREC except temperatures were 15.5–18.3C (60–65F). All damaged leaves were removed prior to initial treatment application.

Ratings. Two observers visually rated each tree weekly for foliage injury during the 5 week period following initial application at each site. The rating system was based on an 11 point scale corresponding to feeding injury (skeletonization) from 0% to 100% (17). Data were averaged over both evaluators at each location and subjected to analysis of variance (ANOVA). Treatment means were separated using the least significant difference (LSD) test at P = 0.05.

Results and Discussion

There was a significant treatment × location × time interaction so weekly evaluation data are presented for each location (Fig. 1). Two weeks after treatment initiation, trees treated with the pyrethroid Tame showed significantly reduced feeding injury compared to the controls at both locations (Figs. 1A and 1B). Five weeks after initial application, trees treated with Tame averaged 2% and 3% defoliation compared to 40% and 100% defoliation of the control trees at HFL and MHCREC, respectively. Trees treated with rotenone also showed significantly reduced Japanese beetle damage compared to the controls from weeks 2 through 4 at both locations. Rotenone-treated trees averaged 10% defoliation at HFL after 5 weeks, whereas at MHCREC they averaged 92%. At HFL, from 3 to 5 weeks after initial application, trees treated with Neemazad and X-CLUDE also showed reduced feeding damage compared to the control trees. At HFL, Hot Pepper Wax, Garlic Barrier, M-Trak, Sevin, and Triact were never significantly different from the controls (data not presented). At MHCREC, none of the treatments excluding Tame and Rotenone were significantly different from the controls. There were no symptoms of phytotoxicity on any of the trees.

Differences in treatment responses between HFL and MHCREC may have been due partly to differences in Japanese beetle abundance and rainfall. The HFL received 0 cm (0 in) of rain during treatment applications (weeks 2 and 4), whereas MHCREC received 10 cm (4 in) and 5 cm (2 in), respectively, during those weeks. Throughout the entire 5 weeks after initial application, total rainfall at HFL was 5.3 cm (2.1 in) as compared to 18.2 cm (5.3 in) at MHCREC (Table 2).

Though neem is reportedly effective against coleopteran pests (23), Isman (12) reported that it has greater variability among species in its behavioral efficacy compared to efficacy as an insect growth regulator. Neem also has variable systemic action and since it has poor contact toxicity, it must be ingested to be effective. Results with rotenone showed effectiveness with little or no rainfall. The synthetic pyrethrin, Tame, was significantly more effective compared to

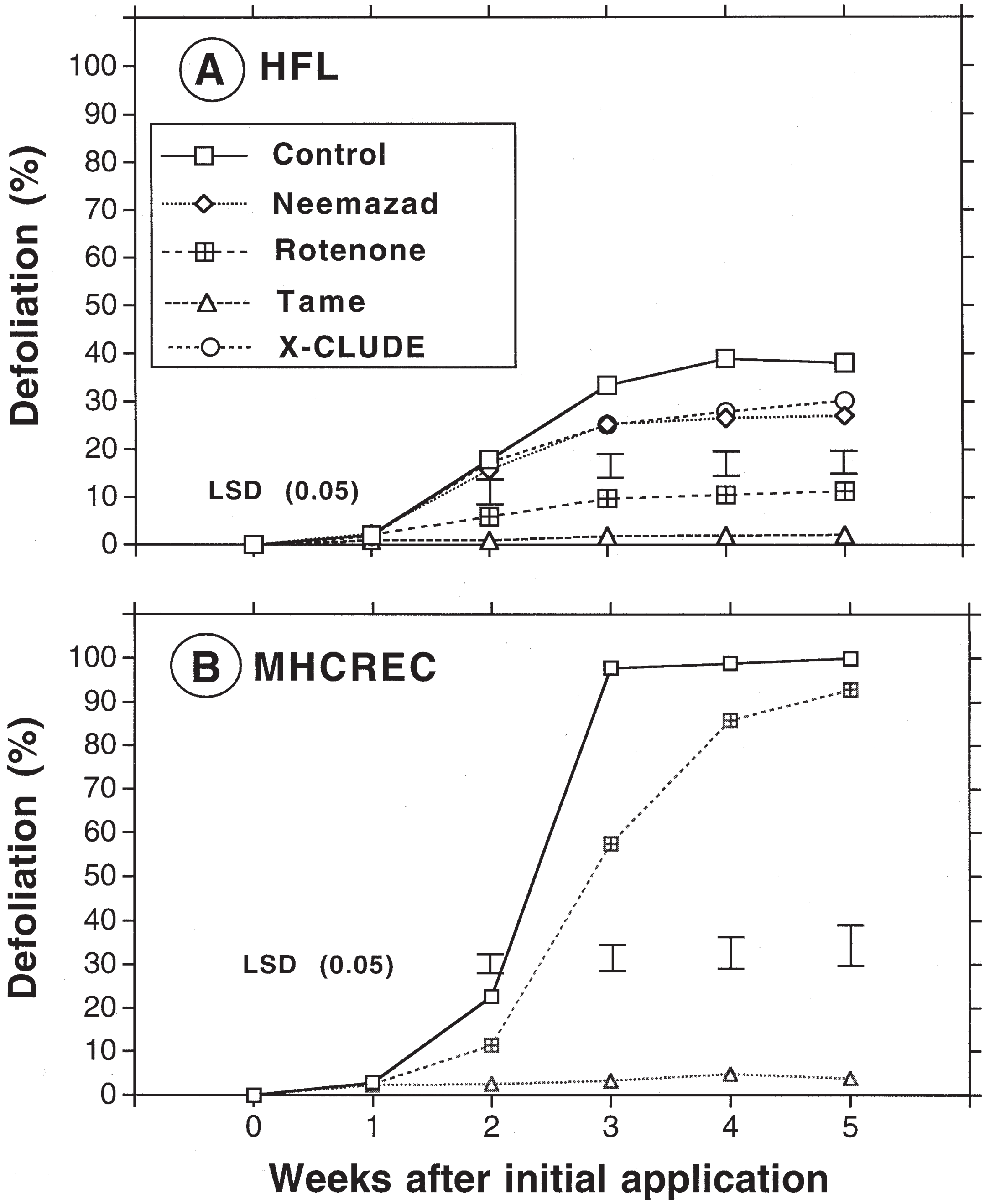

Fig. 1. Percent defoliation of Himalayan birch treated with different pesticides at (A) Horticulture Field Laboratory (HFL), Raleigh or (B) Mountain Horticultural Crops Research and Extension Center (MHCREC), Fletcher, NC. (Only treatments that differed from the controls are shown.) Symbols represent means, n = 10. Vertical lines represent least significant difference (LSD) test at *P* = 0.05.

Table 2. Rainfall (cm) received during the 5 week study period.

	Location[z]	
Week	HFL	MHCREC
1	0.00	10.34
2	1.55	0.00
3	0.00	4.80
4	0.00	0.00
5	3.86	3.35

[z]HFL = Horticultural Field Lab, Raleigh, NC; MHCREC = Mountain Horticultural Crops Research and Extension Center, Fletcher, NC.

the natural pyrethrum, X-Clude. This most likely resulted from the greater ultraviolet stability of Tame (9). However, repeated use of pyrethroids over time can be detrimental to certain beneficial arthropods and has led to increased numbers of damaging mites (9, 11).

Data herein illustrate the relative effectiveness of nine commercially available products in deterring Japanese beetle feeding on Himalayan birch. In general, the natural products provided poor control with only two applications. There is a need for further screening of low toxicity, biorational protectants that provide effective feeding deterrence of adult Japanese beetles.

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