Toxicity and Efficacy of Triazamate Against Turnip Aphid (Homoptera: Aphididae) on Cabbage[1]

Tong-Xian Liu, Alton N. Sparks, Jr. and Bisong Yue

Texas Agricultural Research and Extension Center, Texas A&M University, 2415 E. Highway 83, Weslaco, TX 78596-8399, USA

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Abstract Toxicity of triazamate (Aphistar®, Rohm & Haas, Philadelphia, PA) to a laboratory and a field population of the turnip aphid, *Lipaphis erysimi* (Kaltenbach), was studied on cabbage in the laboratory, and the efficacy of triazamate against the aphid was tested in the field in comparison to lambda-cyhalothrin (Warrior®, Zeneca, Wilmington, DE) and imidacloprid (Provado®, Bayer, Kansas City, MO) in 1999 and 2000. Results from the laboratory bioassays indicated that field populations of *L. erysimi* apterous adults and nymphs were significantly less susceptible to triazamate than the laboratory population. The LC_{50} values for adults, early and late instars of the field population were 6.7-, 2.7-, and 1.4-fold greater than the corresponding stages of the laboratory population, respectively. Similarly, the LC_{90} values for adults, early and late instars of the field population were 6.4-, 2.6-, and 1.7-fold greater than the corresponding stages of the laboratory population, respectively. Results from field trials in 1999 and 2000 showed that triazamate and lambda-cyhalothrin reduced the aphid population faster than imidacloprid after the first application. Triazamate was as effective as lambda-cyhalothrin with low aphid population levels on the plants throughout the season except the last 2 wks in the 1999 trial. In the 2000 trial, an extremely high aphid population was found on untreated plants, whereas two applications of triazamate, as well as lambda-cyhalothrin and imidacloprid, kept aphid population levels suppressed for the entire season.

Key Words Triazamate, aphid, *Lipaphis erysimi,* cabbage, vegetable

The turnip aphid, *Lipaphis erysimi* (Kaltenbach), is one of the most severe pests of cruciferous crops worldwide (Prasad and Phadke 1982, Liu et al. 1997). The aphid commonly attacks *Brassicae,* including cabbage (*capitata* group), broccoli (*cymosa* group), cauliflower (*botrytis* group), collard (*acephala* group), and several others. High densities of aphids may stunt or kill plants in early stages of growth, and the presence of aphids at harvest reduces the market value (Kennedy and Abou-Ghadir 1979). High aphid densities distort actively-growing leaves, causing them to curl, forming pockets and folds that offer shelter to the aphids, thus enabling them to escape insecticide treatments. Effective aphid control has diminished because of insecticide resistance in naturally-occurring populations (Moores et al. 1996). Although aphid control generally has been reestablished through the application of alternate or new aphicidal compounds, additional materials for aphid control were deemed desirable (Sweeden and McLeod 1997a,b).

Triazamate (Aphistar®, Rohm & Haas, Philadelphia, PA) is a novel triazole sys-

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temic aphicide that is highly selective and relatively fast acting, and has been tested and used against several species of aphids (McLeod 1987, 1991, Sweeden and McLeod 1997a,b). Although it has no federal registration in the United States, it was used to control sugar beet root aphid, *Pemphigus populivenae* Fitch, in sugarbeets in Nebraska, Montana and California, and root aphid, *Prociphilus americus* (Walker), on Christmas trees in California and Arizona under Section 18 registrations (R. Miller, Rohm & Haas, person. commun.). However, no data were available on the efficacy of triazamate on *L. erysimi* on cabbage in the Lower Rio Grande Valley of Texas.

The objectives of this study were to determine the toxicity of triazamate on both field and laboratory populations of *L. erysimi,* to establish baseline toxicological data for resistance monitoring and to determine the efficacy of triazamate on the aphids under field conditions in the Lower Rio Grande Valley.

Materials and Methods

Host plants and aphids. Cabbage (Grand Slam Hybrid) was seeded in styrofoam germination trays with 5 seeds per cell (2.5 by 2.5 by 7.5 cm) in a greenhouse. Seedlings were thinned to 1 per cell when the plants were 2.5 cm high. These seedlings were transplanted individually to plastic pots (15 cm diam) when ≈8 cm high with 5 to 6 leaves. Some of these seedlings were maintained in the greenhouse, and others were maintained in an insectary as host plants for the aphid colony. *Lipaphis erysimi* were collected from field-grown cabbage on the Research Farm, Texas Agricultural Experiment Station, Texas A&M University at Weslaco. Aphids were cultured on cabbage plants in an insectary with a photoperiod of 14:10 (L:D) h at 25 to 28°C and 55 to 60% RH. The laboratory colony was maintained without insecticide exposure for >1 yr. Cabbage plants were replaced as needed.

Clear plastic Petri dishes (12.5 × 1.2 cm) were used as aphid rearing arenas. Eight layers of paper tissues were placed on the bottom of the Petri dishes and saturated with water. A cabbage leaf disk (≈8.0 cm diam, 30 to 40 cm^2 leaf area) with the adaxial surface facing up was placed on the water-saturated paper tissue in each Petri dish. A water saturated cotton strip was placed along the outer edge of each leaf disk to keep the leaf fresh and to prevent aphids from escaping. Nymphs were obtained by transferring 15 apterous adults from potted plants in the insectary into a rearing arena. After a 24-h period, adults were removed and neonate nymphs were maintained in the rearing arena. Young nymphs (first and second instars) used in the bioassays were held in the rearing arena for another 2 d. Older nymphs (third and fourth instars) were obtained by allowing them to develop for 5 d after the adults were removed.

The field population of *L. erysimi* was collected directly from a cabbage field on the Research Farm at Weslaco where no insecticides had been used during the season. Apterous adults were collected from the leaves. Early (first and second) and late instars (third and fourth) were collected from the plants and visually separated based on a combination of body size (Hsiao 1999) and cornicle length (Rajendra and Srivastava 1989) under a stereomicroscope.

Laboratory triazamate bioassay. The bioassay was conducted in spring 1999. Apterous adults and early (first and second) and late (third and fourth) instars from the laboratory colony and from the cabbage field were bioassayed separately. Before treatment, early instars (first and second), late instars (third and fourth), and adult aphids collected from either the laboratory or the field were introduced on the cabbage leaf or leaf disk in Petri dishes (12.5 cm diam, 1.2 cm deep) for 2 to 4 h. Based

on preliminary tests, the concentrations of triazamate (Aphistar 50 WSP) used for the laboratory population were 0.15125, 0.3125, 0.625, 1.25, 2.5 and 5.0 mg (AI)/l, and those for field populations were 1.5625, 3.125, 6.25, 12.5 and 25 mg (AI)/l. The dilutions were sprayed on the cabbage leaf or leaf disk, with aphids present, to runoff using a hand-spray pump (Spritzer, Bel-Art Products, Pequannock, NJ). Water (reverse osmosis, 7 ppm solid) was used as a control. After air-drying for 2 h, the leaves with the treated aphids were moved into rearing arenas (40 aphids per Petri dish). Each Petri dish was covered with a lid modified with a 4-cm diam screened opening (40 mesh) for ventilation. There were three replicates for each treatment. Aphid mortality was checked at 24 h.

Field efficacy trials. Field efficacy trials were conducted in spring of 1999 and 2000. In both years, cabbage was direct-seeded in single rows on 1-m beds. After emergence, seedlings were thinned to 25 cm apart. Experimental plots were 5 m long double-beds. Each plot was separated from adjacent plots by two rows of sorghum and 0.5 m alley down the row. The experimental design was a randomized complete block design with 4 replications. Triazamate (Aphistar 50WSP) was used at 140 g (AI)/ha. Insecticides used for comparison included imidacloprid (Provado 1.6F; Bayer, Kansas City, MO) at 52.5 g (AI)/ha and lambda-cyhalothrin (Warrior T 1SC; Zeneca, Wilmington, DE) at 28.0 g (AI)/ha. The materials were applied 3 times in 1999 (29 Jan, 10 and 22 Feb) and 2 times in 2000 (25 Jan and 18 Feb) using a CO_2 pressurized back sprayer at 206.8 kPa with 3 TX10 hollow cone nozzles per row (1 over the top of the plants, 2 on drops) with 187 l/ha. In 1999, aphids were counted 2 d before the first application, and on days 3, 6 and 10 after the first application. After the second application, aphids were sampled on days 2, 3, 6, and 10. Aphids were counted on days 2, 6, 7, 21, 26, 29, 32, and 35 after the third application. In 2000, aphids were counted 1 d before the first application, and on 2, 3, 5, 7, 11, 14, 17, 22, and 25 d after the first application. Aphids were sampled on days 4, 6, 8, 11, 14, and 20 after the second application. Aphids were sampled by counting all nymphs and adults per plant from 5 randomly selected plants in each plot on each sampling date.

Data analysis. Toxicity of triazamate to both field and laboratory populations of *L. erysimi,* including LC_{50} and LC_{90} with related parameters [95% fiducial limits (FL), slope, and SE], was determined using POLO (LeOra Software 1994). Numbers of aphids on cabbage plants from field trials were analyzed using analysis of variance (ANOVA), and means were separated using the least significant difference test (LSD) following a significant *F*-test at $P = 0.05$ (SAS Institute 1996).

Results and Discussion

Laboratory bioassays. Results from laboratory bioassays for both the field and the laboratory populations are shown in Table 1. Differences of LC_{50} or LC_{90} between treatments were separated based on non-overlapping of 95% FL. Percentage mortality of adults, early and late instars treated with water for both laboratory and field populations was low, with 0, 1.21 ± 0.45% and 1.27 ± 0.57%, respectively, for the laboratory population, and 0, 4.24 ± 0.86% and 2.87 ± 0.81% for adults, early and late instars, respectively, for the field population. Apterous adults and nymphs of the field population were significantly less susceptible to triazamate than the laboratory populations. The LC_{50} values of the field population were 6.7-, 2.7-, and 1.4-fold higher for adults, late instars and early instars than the corresponding stages of the laboratory population, respectively. Similarly, the LC_{90} values of the field population were 6.4-,

Table 1. Toxicity of triazamate against field and laboratory populations of *Lipaphis erysimi* on cabbage (Spring 1999, Weslaco, TX)

Treatment	LC_{50} (95%FL)	LC_{90} (95% FL)	Slope	SE	χ^2	DF
Field population						
Apterous adults	8.84 (8.12-9.64)	19.58 (17.11-23.25)	3.71	0.19	78.44	28
Nymphs (1st-2nd instars)	1.54 (1.22-1.85)	3.14 (2.87-3.89)	3.18	0.27	15.19	28
Nymphs (3rd-4th instars)	5.17 (4.56-5.73)	10.72 (9.47-12.73)	4.05	0.22	141.49	25
Laboratory population						
Apterous adults	1.32 (1.13-1.52)	3.05 (2.47-4.21)	3.51	0.26	48.36	13
Nymphs (1st-2nd instars)	0.89 (0.83-0.96)	1.81 (1.65-2.03)	4.17	0.15	185.05	37
Nymphs (3rd-4th instars)	1.90 (1.73-2.08)	4.21 (3.69-4.96)	3.71	0.30	13.52	13

2.6-, and 1.7-fold higher for adults, late instars and early instars than the corresponding stages of laboratory population, respectively. One of the possible explanations is that the laboratory population had not been exposed to any pesticides for >1 year. Although the field population was not exposed to any insecticides during the season, the aphids might have obtained reduced susceptibility through direct or indirect exposures to other pesticides and chemicals around the field.

Field efficacy trials. In 1999, all three insecticides significantly reduced the *L. erysimi* populations throughout the season compared with that in the untreated control ($F = 12.26\text{-}117.53$; df = 3, 64; $P < 0.0001$) (Fig. 1). After the first application, aphid populations on the plants treated with triazamate or lambda-cyhalothrin declined rapidly, whereas aphid population reduction was delayed on the plants treated with imidacloprid. However, 3 wks after the third application, aphid populations increased gradually in all treated plants, although at a much lower rate compared with that on the untreated plants. Among the three insecticides, plants treated with either lambda-cyhalothrin or triazamate had the lowest numbers of aphids on all sampling dates throughout the season. Triazamate had statistically similar efficacy to lambda-cyhalothrin on all sampling dates except the last two (22 and 25 March), 32 and 35 d after the third application (Fig. 1). On the last two sampling dates, more aphids were found on plants treated with triazamate than those treated with lambda-cyhalothrin ($F = 58.85\text{-}117.53$; df = 3, 64; $P < 0.0001$). Although imidacloprid was as effective against *L. erysimi* as lambda-cyhalothrin and triazamate on most of the sampling dates (11 out 17 dates), apparently, it did not persist as long as the other two insecticides.

In 2000, *L. erysimi* populations were extremely high throughout the season (Fig. 2). Although triazamate had the lowest number of aphids per plant throughout the entire season, the three insecticides provided statistically similar efficacies on most of the sampling dates. Triazamate and imidacloprid reduced aphid populations sharply after the first application from 26 aphids per plant 1 d before treatment to 0.6 aphids

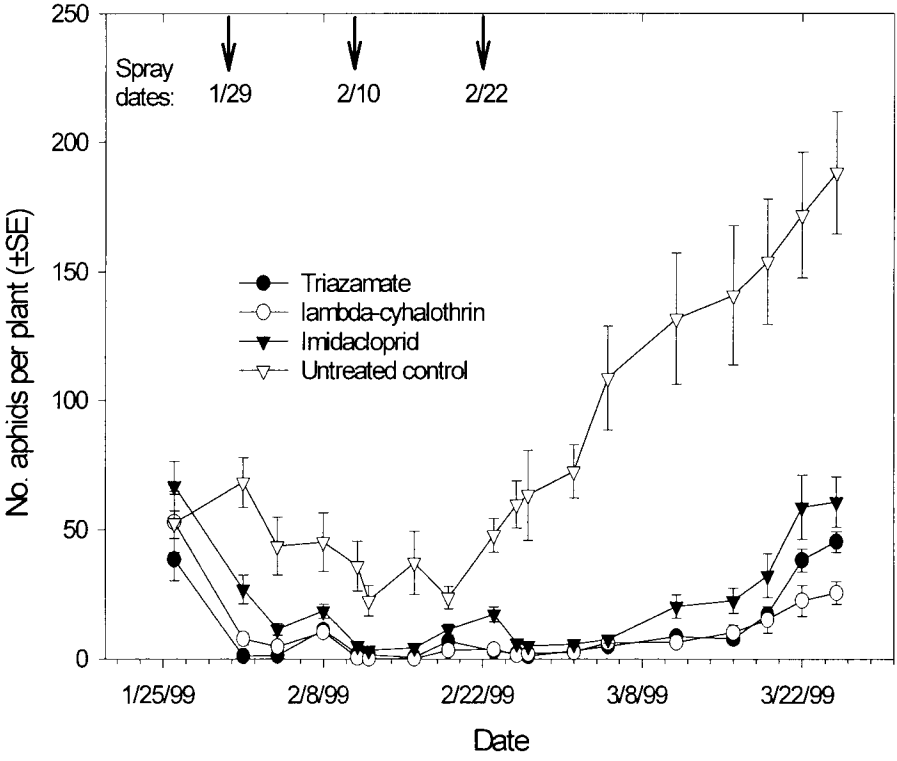

Fig. 1. Efficacy of triazamate, lambda-cyhalothrin and imidacloprid against *Lipaphis erysimi* on cabbage, 1999 (Weslaco, TX).

per plant at 2 d after treatment and 0.2 aphids per plant at 3 d after treatment for triazamate, and from 33.6 aphids per plant to 8.3 and 2.0 aphids per plants at 2 and 3 d after treatment, respectively, for imidacloprid. Aphid populations on all treated-cabbage plants remained relatively low throughout the rest of the test, despite a large increasing population in the control plots.

Results from these studies showed that triazamate was very effective against *L. erysimi* on cabbage under field conditions in the Lower Rio Grande Valley. Although the laboratory data indicated that the field population was significantly less susceptible than the laboratory population, the magnitude of difference was relatively small, yet consistent. The field data indicated that resistance is not a problem, but the shift in susceptibility of the field population suggested a potential for development of resistance. The fact that this shift was detected prior to commercial use of triazamate would further suggest potential cross-resistance with other carbamates or organophosphates. The LC_{50} and LC_{90} values determined in the laboratory bioassays will serve as benchmarks for evaluation of potential resistance development in the future.

Triazamate was proven efficacious against *L. erysimi* in our studies. Triazamate also was reported to be effective against several species of aphids, including *M. persicae* on spinach (McLeod 1987, 1991, Sweeden and McLeod 1997a,b); the cot-

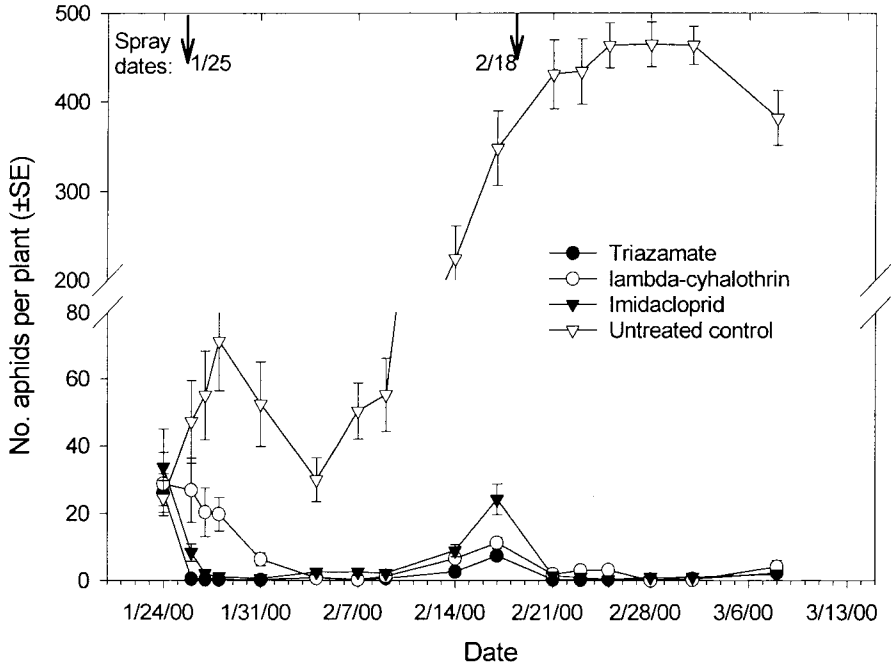

Fig. 2. Efficacy of triazamate, lambda-cyhalothrin and imidacloprid against *Lipaphis erysimi* on cabbage, 2000 (Weslaco, TX).

ton aphid, *Aphis gossypii* Glover (Fuson et al. 1995, Moores et al. 1996); the sugarbeet root aphid, *Pemphigus fuscicornis* Koch on sugarbeets (Ioannidis 1996, Westwood et al. 1997); and the rosy apple aphid, *Dysaphis plantaginea* (Passerini) (Pasqualini et al. 1996). Triazamate has also been found not harmful to predatory mites, *Amblyseius andersoni* (Chant) (Costa-Comelles et al. 1996) and other beneficial arthropods (Grolleau et al. 1993), which increases its utility in a biologically intensive IPM program. An additional advantage of triazamate is that it translocates both upward and downward in the treated crops thus enabling growers to make foliar applications to control both foliar-feeding and root-feeding aphids (McLeod 1991, Grolleau et al. 1993, Francois 1994). However, because triazamate is a carbamate, changes in the regulatory process associated with the Food Quality Protection Action of 1996 may inhibit future registrations for its use in field crops, particularly vegetable crops.

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