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Residual susceptibility of fifth instar *Plodia interpunctella* to cyfluthrin wettable powder *

Frank H. Arthur [1]

USDA-ARS, 1515 College Avenue, Manhattan, KS-66502, USA

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Abstract

Wandering-phase fifth instar *Plodia interpuntella* (Hübner) were exposed at 3-week intervals for 0.5, 1, 2, and 4 h on concrete treated with sprays of 100, 150, and 200 mg 20% cyfluthrin wettable powder (WP) per m^2 over a 15-week period. Pupation rate and adult emergence were not significantly different ($P \geq 0.05$) with respect to exposure interval at any application rate. Of the larvae exposed at week 0 (1 day after treatment) on concrete treated with 100 mg per m^2 cyfluthrin WP, $8.7 \pm 3.8\%$ reached the pupal stage and $3.8 \pm 1.5\%$ emerged as adults, but adult emergence at all subsequent weeks was at least 63.8%. No adults emerged from larvae exposed at week 0 or week 3 on concrete treated with 150 mg cyfluthrin WP per m^2. Pupation and adult emergence for larvae exposed at week 0 on concrete treated with 200 mg cyflutrhin WP per m^2 was 12.7 ± 6.8 and $11.4 \pm 6.6\%$, respectively, but adult emergence at week 3 was only $1.9 \pm 1.0\%$. Residual control, defined as the time when pupation and adult emergence were less than 10%, exceeded 3-week only at the intermediate label rate of 150 mg cyfluthrin WP per m^2.

Keywords: *Plodia interpunctella*; Insecticides; Cyfluthrin; Treated surfaces

1. Introduction

Malathion is not being supported for re-registration in the United States for use as a residual insecticidal treatment to flooring surfaces inside mills, processing plants, and warehouse facilities, and many pest control operators are using cyfluthrin (Tempo) as an alternative. Cyfluthrin is a pyrethroid available as an emulsifiable concentrate (EC) or a

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[1] Tel: (913)776-2783; Fax: (913)776-2792; e-mail: arthur@usgmrl.ksu.edu

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wettable powder (WP), both for dilution with water. The WP can be applied at a low label rate of 100 mg per m^2 (9.5 g per 94 m^2), or a high rate of 200 mg per m^2 (19.0 g per 94 m^2) when infestations are severe. Most indoor storage structures in the United States have floors made of concrete, and there are several literature references stating that WP formulations of many insecticides, including cyfluthrin, are more efficacious than EC formulations when applied for residual control on concrete (White, 1982; Williams, Semple, and Amos, 1983; Jain and Yadav, 1989; Barson, 1991; Arthur, 1994).

Plodia interpunctella (Hübner), the Indian meal moth, can be a serious pest of indoor storage facilities. Infestations are often undetected until fifth instar larvae disperse from protected locations and wander in search of a pupation site. If residual insecticides such as cyfluthrin are applied to flooring surfaces, wandering larvae would encounter the residues for a comparatively short time period, and may be able to escape the treated surface. The objectives of this test were to determine: (1) if cyfluthrin WP applied on concrete would prevent pupation and adult emergence of wandering-phase *Plodia* larvae exposed for short-time intervals; and (2) the residual efficacy of cyfluthrin WP applied at a range of concentrations as specified on the insecticide label.

2. Materials and methods

This test was conducted at the US Grain Marketing and Production Research Center, Manhattan, KS, using a *Plodia interpunctella* strain that had been moved to Manhattan when the Stored Product Insects Research and Development Laboratory in Savannah, GA was closed in November 1994. Prior to closure of the Savannah laboratory the *Plodia* strain had been cultured for approximately 20 years on a standard larval diet at approximately 28°C, 60% r.h., and these same conditions were maintained in Manhattan. Samples of commercial cyfluthrin wettable powder (Tempo) were obtained from Gustafson, Inc. (Plano, TX, USA), and refrigerated at 4°C for approximately 2 months before being used in the test.

Treatment arenas were constructed by building 15 0.094 m^2 (1 ft^2) plywood forms that were about 0.64 cm deep, pouring ready-mix concrete into the forms, and levelling the surfaces. Four panels were treated with 20% cyfluthrin WP at the rate of 100 mg per m^2 (20 mg [AI]), the low label rate. Treatments were made by using a spray system equipped with a Teejet nozzle ♯650033 (Spraying Systems, Wheaton, IL, USA) to spray 3.8 ml of formulated solution onto the panel, which was laid flat on the ground. One untreated panel was used as the control for this application rate, and it was sprayed with 3.8 ml of tap water.

The day after treatment, rings of 2.5 mm outer diameter tygon tubing were constructed by joining the ends of a 20-cm length of tubing with a 1 cm piece of a paperclip inserted in each end, which gave an approximate ring diameter of 6.4 cm. Four rings were randomly placed on each of the five panels (4 treated + 1 untreated control), and 10 wandering-phase *Plodia* larvae were placed inside each ring. A Petri dish lid with air holes cut in the top was placed on top of the tygon ring to create a confined arena, and a 20-ml vial of water weighing 42 g was placed on top of each lid to weigh it down and ensure that the larvae could not escape the treated surface. Larvae inside the first ring on each concrete panel were removed after 0.5 h, the second ring after 1 h, the third ring after 2 h, and the final ring after 4 h. After the larvae were removed at each respective exposure period, they were placed in a standard disposable 100×15 mm Petri dish lined with filter paper. Pupation sites were not provided. The dish was covered and held inside the laboratory at approximately 22°C and 60% r.h., 9 h light:15 h dark for 1 week, and the percentage of pupating larvae was recorded for each dish. The dish was held for another 7–10 days to record adult emergence.

One week after the first set of concrete panels was treated with 100 mg cyfluthrin WP, a second set of four panels was treated with an intermediate label rate of 150 mg per m^2. An untreated control was also included for this treatment, and 1 day following treatment *Plodia* larvae were confined, exposed, and assessed as described above. The next week four of the final five panels were treated with the maximum label rate of 200 mg per m^2, the last panel was the untreated control, and *Plodia* were assayed following the same procedures. After the initial bioassays on each treatment concentration the panels were stored inside the laboratory, and residual tests were conducted at 3-week intervals for 15 weeks.

The number of larvae that pupated and the number of emerged adults were multiplied by 10 to obtain a percentage value. Treatments were corrected for control mortality using Abbott's formula (Abbott, 1925). The test was analyzed as a split plot model with concentration and exposure time (0.5, 1, 2, 4 h) as main effects and week (residual bioassays) as a repeated measure with the percentage of larval pupation or adult emergence as the determining variable. The Means Procedure of the Statistical Analysis System (SAS Institute, 1987) was used to estimate means and standard errors for each observation. Table curve software (Jandel Scientific, San Rafael, CA) was used to conduct lack of fit tests (Draper and Smith, 1981) and to estimate the parameters for either linear or non-linear regression equations on raw data, depending on model fitness. These regression equations were used to estimate the time period in which larval pupation and adult emergence were less than 10% (LT_{90}).

3. Results and discussion

The main effects concentration and exposure, the repeated measure week, and the concentration × exposure time interaction were significant ($P < 0.05$). No other interactions were significant ($P \geq 0.05$). Although exposure time was significant, regressions for decreased pupation or adult emergence (y) as exposure increased from 0.5 to 4 h (x) were not significant for any of the three concentrations ($P \geq 0.05$). Data for pupation and emergence at the four exposures for each concentration were combined, and analyses were conducted on these combined data.

Only 9% of the larvae exposed 1 day after the concrete was treated with 100 mg cyfluthrin WP per m^2 were able to reach the pupal stage (Fig. 1A). However, by week 3 nearly all larvae pupated. The percentage of pupating larvae increased to $87 \pm 9\%$ at week 3 and was 80 to 100% for the remainder of the test. At this concentration, adult emergence for the larvae exposed at week 0 averaged $4 \pm 1\%$, increased to 80% at week 3, and was 64 to 99% for weeks 6 to 15 (Fig. 1B). Data for pupation and adult emergence were described by non-linear regression, and the respective LT_{90}s calculated from the non-linear equation were only 0.01 and 0.07 week (Table 1).

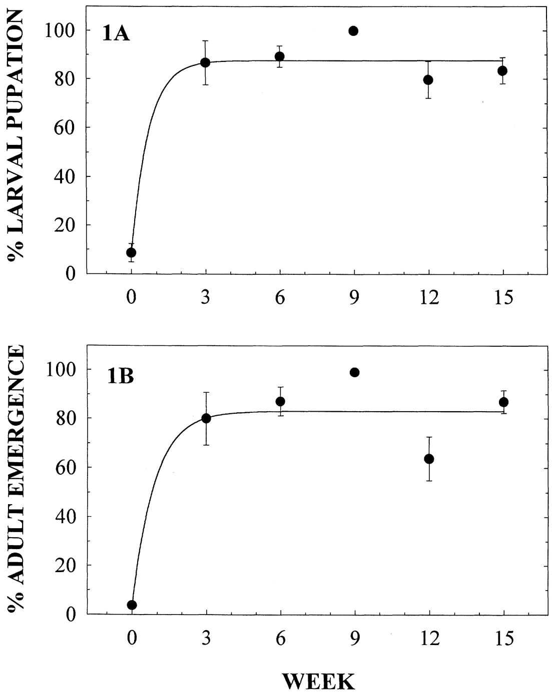

Fig. 1. Percent larval pupation and adult emergence (means ± SEM) for fifth instar *Plodia interpunctella* exposed at 3-week intervals on concrete treated with 20% cyfluthrin WP at the rate of 100 mg per m^2 (circle, observed data; solid line, fitted regression line from Table 1).

No larvae pupated after being exposed at week 0 on concrete treated with the intermediate rate of 150 mg cyfluthrin WP per m^2, and only 1% pupated after the exposures at week 3 (Fig. 2A). Pupation increased to 28% for the exposures at week 6, and was 69 to 98% for weeks 9, 12, and 15. No adult emergence occurred until week 6 (Fig. 2B). Emergence increased to 18 ± 6% at week 6, and was 46 ± 9 to 99 ± 1% thereafter. Data for pupation and adult

Table 1
Non-linear equations $y = a - be^{(-cx)}$, and linear equations $y = a + bx$, where y = the percentage of pupal survival or adult emergence and x = week from 0 to 15, for fifth instar *Plodia interpunctella* exposed on concrete treated with 100, 150, and 200 mg 20% cyfluthrin wettable powder per m^2. R^2 values are the actual R^2 and Maximum R^2 the maximum available

Concentration (mg per m^2)		*a*	*b*	*c*	R^2	Maximum R^2
100	Pupation	87.3 ± 3.1	78.9 ± 6.6	1.5 ± 2.3	0.64	0.66
	Emergence	83.1 ± 3.7	79.3 ± 3.8	1.1 ± 0.9	0.56	0.63
150	Pupation	− 14.1 ± 6.7	7.9 ± 0.7	—	0.65	0.78
	Emergence	− 19.8 ± 7.7	7.7 ± 0.7	—	0.61	0.80
200	Pupation	− 3.0 ± 4.9	6.0 ± 0.5	—	0.56	0.67
	Emergence	− 5.6 ± 5.1	5.7 ± 0.6	—	0.52	0.66

emergence were described by linear regression, and the respective LT_{90}s calculated from the linear equations fitted to the data for pupation and emergence were 3.1 and 3.9 week (Table 1).

When larvae were exposed at week 0 on concrete treated with the maximum label rate of 200 mg cyfluthrin WP per m^2, pupation averaged $13 \pm 7\%$, which contrasted with the value of 0 obtained at the corresponding time period for the 150 mg treatment (Fig. 3A). This unexpected high value for the 19.0 mg treatment can be partially explained by the fact that nearly all of the pupating larvae occurred in one replicate. Pupation at week 3 was also greater in the 200 mg than in the 150 mg treatments, but the order was reversed at week 6. After week 6 pupation was 56 ± 8 to $99 \pm 1\%$ at weeks 9, 12, and 15. Adult emergence was lower at week 3 than at week 1, but after week 6 emergence gradually increased for the remainder of the test. Data for pupation and adult emergence were described by linear regression, and the LT_{90}s calculated from the linear equations were 2.2 and 2.7 week (Table 1).

The percentage of emerged adults was usually slightly less than the percentage of pupating larvae at each bioassay week for each concentration, but none of the three application rates of cyfluthrin WP gave residual control of wandering-phase *Plodia* larvae past about 4 weeks. Previous studies at these same temperature and humidity conditions have shown that the lowest label rate of 100 mg cyfluthrin WP per m^2 will kill *Tribolium confusum* (du Val), the confused flour beetle, exposed for 30 min on treated concrete (Arthur, 1998b). One-to-two-hour exposure periods were required to give equivalent kill of *Tribolium castaneum* (Herbst), the red

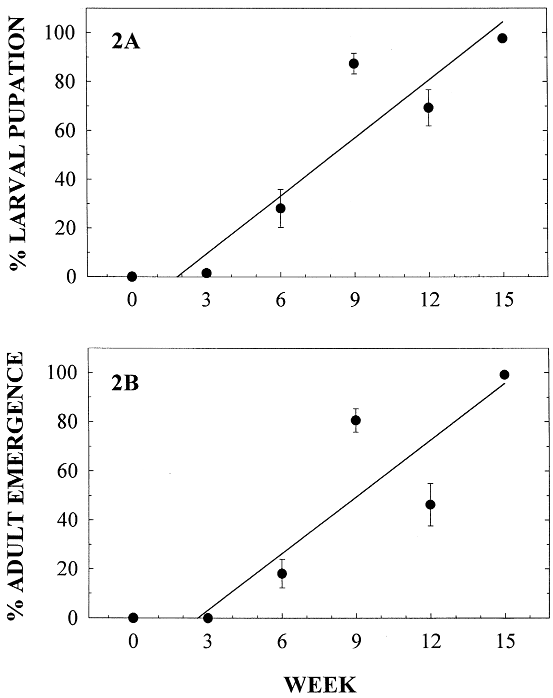

Fig. 2. Percent larval pupation and adult emergence (means ± SEM) for fifth instar *Plodia interpunctella* exposed at 3-week intervals on concrete treated with 20% cyfluthrin WP at the rate of 150 mg per m^2 (circle, observed data; solid line, fitted regression line from Table 1).

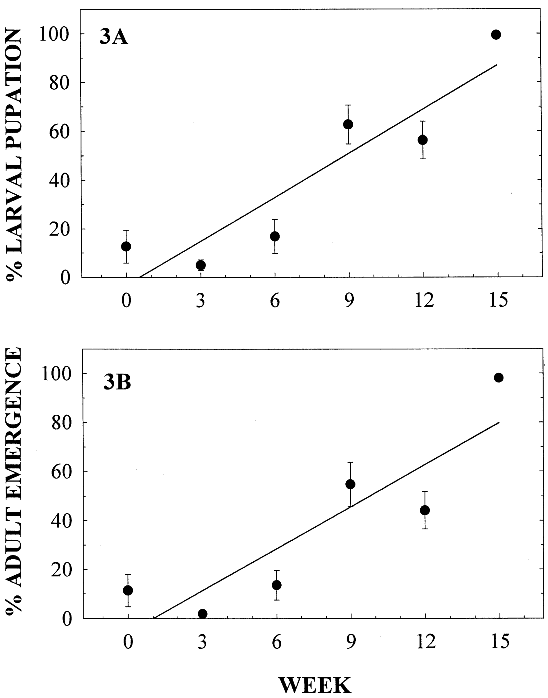

Fig. 3. Percent larval pupation and adult emergence (means ± SEM) for fifth instar *Plodia interpunctella* exposed at 3-week intervals on concrete treated with 20% cyfluthrin WP at the rate of 200 mg per m^2 (circle, observed data; solid line, fitted regression line from Table 1).

flour beetle, depending on the exposure interval (Arthur, 1998a). Cyfluthrin also exhibited a delayed toxic effect towards *T. confusum* and *T. castaneum*, because beetles that were still mobile when they were removed from treated concrete eventually died even though they were no longer directly exposed to the treated surface. In contrast, there was neither an increase in toxicity with increased exposure interval nor any evidence of delayed toxicity for *Plodia* larvae.

Similar results have been documented in previous studies which showed that insecticidal concentrations which controlled adult coleopterans, including *T. confusum* and *T. castaneum*, did not give residual control of wandering-phase *Plodia* larvae (Arthur, 1988, 1995, 1997a,b). A few published reports do indicate control of stored-product moths P. *interpunctella* and *Cadra (Ephestia) cautella* (Walker), the almond moth, with rates of various insecticides that also control beetles, but the moths in these studies were exposed as eggs on treated commodities (Bengston et al., 1980, 1987). Even if eggs and early instar *Plodia* are susceptible to insecticides used as residual surface treatments, adult females within an indoor facility may lay eggs in a protected site, and early instar larvae would not be exposed to cyfluthrin residues on a treated surface. They would encounter these residues only when they begin wandering in search of a pupation site, and may be able to escape the treated surface, pupate, and emerge as adults to maintain the infestation.

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