Susceptibility of Fifth-Instar Indianmeal Moth and Almond Moth (Lepidoptera: Pyralidae) to Cyfluthrin Residues on Peanuts[1]

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ABSTRACT Inshell peanuts treated with 10, 14, 18, and 22 ppm cyfluthrin were bioassayed with fifth instar Indianmeal moths, *Plodia interpunctella* (Hübner) and fifth-instar almond moths, *Cadra cautella* (Walker), after 0, 2, 4, 6, and 8 months of storage. Emergence of the adult almond moth was greater than Indianmeal moth emergence at residual bioassays of 14, 18, and 22 ppm. Regression of increasing emergence with storage time was significant for the Indianmeal moth at 22 ppm and the almond moth at 14 and 22 ppm. For both species, adult emergence decreased as cyfluthrin concentration increased and was described by quadratic regression.

KEY WORDS cyfluthrin, peanuts, Indianmeal moth, *Plodia interpunctella*, almond moth, *Cadra cautella*.

The three major insect pests of stored peanuts in the southeastern United States are the Indianmeal moth, *Plodia interpunctella* (Hübner), the almond moth, *Cadra cautella* (Walker), and the red flour beetle, *Tribolium castaneum* (Herbst). These insects enter the peanut pod via a crack or split in the shell and feed on the kernels. Malathion is the only labeled protectant for stored peanuts, but this insecticide is in reregistration and may not be labeled for stored peanuts once procedures have been completed. In addition, many local populations of all three species have developed resistance to malathion (Zettler 1982, Halliday et al. 1988, Arthur et al. 1988).

There are no labeled alternative protectants for stored peanuts. In a previous trial with chlorpyrifos-methyl, peanuts were held for 10 months and periodically infested by releasing adult beetles and adult moths into the storage shed and introducing eggs of both moth species directly on the peanuts (Arthur et al. 1988). Application rates of 20 and 25 ppm prevented infestations of all three species. However, in a later test whereby wandering-phase 5th-instar moths were introduced one day after peanuts were treated with 20 and 30 ppm

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chlorpyrifos-methyl, eventual emergence of adult almond moths was 34.3 and 28.6%, respectively, while Indianmeal moth emergence was 7.9 and 6.7% respectively (Arthur 1989). The emergence rate for both species increased when introductions were repeated at 60, 120, and 180 days post-application.

The pyrethroid cyfluthrin can be used as a residual treatment in empty grain storage bins and peanut warehouses. Several research studies have established the efficacy of cyfluthrin as a residual protectant for beetle pests of commodities held in long-term storage. Application rates of 1 and 2 ppm controlled the red flour beetle, *Tribolium castaneum* (Herbst), and the maize weevil, *Sitophilus zeamais* (Motschulsky), on stored corn (Arthur 1994a) and the lesser grain borer, *Rhyzopertha dominica* (Fab.), and the rice weevil, *Sitophilus oryzae* (L.), on stored wheat (Arthur 1994c). Application rates of 2 and 4 ppm cyfluthrin on peanuts prevented red flour beetles from becoming established in peanuts stored for 10 months (Arthur 1994b).

The previous studies with chylorpyrifos-methyl indicate that Indianmeal moth and almond moth larvae may become more tolerant to insecticide residues as they age and increase in size. Larvae are protected from residues inside the peanut shell and would become vulnerable if they left the shell during the wandering phase to seek a pupation site. The objectives of this study were to determine: 1) the residual efficacy of cyfluthrin toward wandering-phase fifth instar Indianmeal and almond moth larvae, and 2) the difference of the two moth species in response to cyfluthrin.

Materials and Methods

This test was conducted at the USDA Stored-Product Insects Research and Development Laboratory, Savannah, GA. Inshell runner variety peanuts refrigerated in cold storage (approximately 4°C) were used in the test. The peanuts were removed from storage and allowed to warm inside an enclosed warehouse for several days at ambient conditions before they were treated with insecticide. Spray solutions were formulated in distilled water from cyfluthrin 2 EC (240 mg [AI]/ml).

Four cyfluthrin rates, 10, 14, 18, and 22 ppm were applied at the rate of 19 ml of formulated spray per 12.7 kg (28 lbs) peanuts. Untreated controls were treated with 19 ml distilled water. Treatments were accomplished using an insecticide delivery system equipped with a Teejet #650033 nozzle (Spraying Systems, Wheaton Il.) to spray individual replicates of peanuts as they fell from a conveying chute into a 0.042 m^3 (1.5 ft^3) cardboard box. Each insecticide treatment and the untreated control was replicated four times. Treatments were completed on 28 October (month 0).

After treatments were completed the peanuts were sampled by removing enough peanuts from each replicate box to completely fill each of two 2-liter jars (approximately 500 g). Fifty fifth-instar Indianmeal moths and 50 fifth-instar almond moths were introduced into separate jars, than all jars were placed in a control room (28 ± 1°C, 60 ± 2% RH). The jars were held until adult emergence was completed, then all adults, live and dead, were recorded. The justification for this procedure was that adult emergence may occur on the treated peanuts, but the adults will die very quickly because they are much more sensitive to insecticide residues than the fifth instars. However, since the adults can mate and lay eggs within a few hours after emergence, adult mortality may be a confounding factor in a field situation. The peanuts were discarded after adult emergence was tabulated.

The boxes containing the treated peanuts were held in a laboratory storeroom (25°C) and resampled as described above on 3 January (2 months), 2 March (4 months), 2 May (6 months), and 1 July (8 months). Emergence was recorded as described above. Raw data were multiplied by 2 to obtain percentage values, and the General Linear Models Procedure of the Statistical Analysis System (SAS Institute 1987) was used to obtain treatment means and to regress emergence on storage time for each concentration. The *t*-test procedure was used to determine differences between Indianmeal moth and almond moth emergence at each concentration.

Results and Discussion

There were no significant differences in Indianmeal moth emergence versus almond moth emergence for untreated controls and the 10-ppm cyfluthrin treatment, with the exception of the 10-month bioassay for the 10-ppm treatment (Table 1). However, almond moth emergence was significantly greater than Indianmeal moth emergence at all residual bioassays of 14, 18, and 22 ppm. Maximum Indianmeal moth emergence at 18 and 22 ppm was 17.5 ± 2.1 and 15.5 ± 5.1%, while maximum almond moth emergence at these rates was 72.2 ± 0.2 and 73.0 ± 2.9%.

Several researchers have presented data suggesting that the Indianmeal moth may be more susceptible than the almond moth to residual insecticides used in stored product environments. In residual bioassays with wandering-phase larvae exposed on peanuts treated with 5, 10, 20, and 30 ppm chlorpyrifos-methyl, almond moth emergence was greater than Indianmeal moth emergence at all rates when larvae were exposed one day after application. However, there were no differences in bioassays conducted at 60, 120, and 180 days post-treatment (Arthur 1989). Subramanyam and Harein (1986) reported LD_{50} values of 13.8 μg/g for Indianmeal moth and 24.6 μg/g for almond moth larvae treated with cyfluthrin by topical application. In addition, Indianmeal moth knockdown and mortality on filter papers treated with 1.0 g AI cyfluthrin/m^2 was 100%, while corresponding knockdown and mortality at the same rate for almond moth was 43 ± 5 and 33 ± 9%. Zettler (1982) reported lower LD_{50} values in pesticide-susceptible Indianmeal moth versus almond moth larvae treated by topical application with malathion (0.315 vs 2.85 μg/g). and pirimiphos-methyl (116.0 vs 168.9 μg/g) but not for dichlorvos (41.7 vs 22.8 μg/g). A similar study by Arthur et al. (1988) gave lower LD_{50} values for Indianmeal moth versus almond moth for dichlorvos (20 vs 74 μg/g), pirimiphos-methyl (100 vs 224 μg/g), and chlorpyrifos-methyl (115 vs 160 μg/g).

Indianmeal moth emergence fluctuated during the test and regression on time was significant for only the 22-ppm treatment ($P = 0.0298$, $y = 15.0 - 3.1x + 0.24x^2$, $R^2 = 0.34$), all other concentrations $P > 0.05$). Almond moth survival also fluctuated and regression was significant for 14 ppm ($P = 0.0007$, $y = 82.0 - 5.8x + 0.30x^2$, $R^2 = 0.57$) and 22 ppm ($P = 0.0081$, $y = 68.4 - 11.7x + 1.21x^2$, $R^2 = 0.43$), all other concentrations $P > 0.05$). The lack of significance with time for Indianmeal moths exposed to 10, 14, and 18 ppm and almond moths exposed to 10 and 18 ppm may indicate a relative stability of cyfluthrin on inshell peanuts. However, the fluctuating values for adult emergence and the lack of uniformity among concentrations prevent conclusions concerning residual persistence. Also, the 8-month testing period may not have been long enough to measure loss in cyfluthrin residual activity. When all sample months

Table 1. Percentage (mean ± SEM) adult Indianmeal moth (IMM) and almond moth (AM) emergence from fifth instars introduced on untreated inshell peanuts and inshell peanuts treated with 10, 14, 18, and 22 ppm cyfluthrin.

		Months After Treatment				
Concentration	Species	0 (9/28)	2 (1/3)	4 (3/3)	6 (5/2)	8 (7/1)
Untreated	IMM	92.0 ± 2.2	91.5 ± 2.5	82.7 ± 5.5	89.3 ± 7.0	92.0 ± 2.9
	AM	81.5 ± 4.6	93.5 ± 2.2	82.5 ± 4.6	92.5 ± 1.3	86.0 ± 3.3
10 ppm	IMM	77.5 ± 3.1	82.5 ± 4.3	80.5 ± 7.8	81.0 ± 5.8	89.5 ± 2.1
	AM	84.0 ± 2.6	85.5 ± 3.4	81.0 ± 1.7	82.5 ± 5.7	77.0 ± 2.4*
14 ppm	IMM	20.5 ± 6.0	35.0 ± 7.0	25.0 ± 2.4	29.0 ± 4.6	23.5 ± 1.7
	AM	83.5 ± 2.1**	67.5 ± 7.5*	67.5 ± 2.5**	57.0 ± 5.3**	54.5 ±3.9**
18 ppm	IMM	11.0 ± 4.4	17.5 ± 2.1	16.0 ± 2.2	14.5 ± 2.1	16.5 ± 1.7
	AM	72.0 ± 2.2**	44.0 ± 1.6**	70.5 ± 6.0**	55.0 ± 3.4**	49.0 ± 3.4**
22 ppm	IMM	15.5 ± 5.1	10.0 ± 1.8	2.5 ± 1.0	9.5 ± 1.2	3.5 ± 1.7
	AM	73.0 ± 2.9**	37.0 ± 6.0**	52.0 ± 5.8**	40.0 ± 2.6**	51.5 ± 5.2**

* Adult emergence rate significantly different between species at $P \leq 0.05$.
** Adult emergence rate significantly different between species at $P \leq 0.01$.

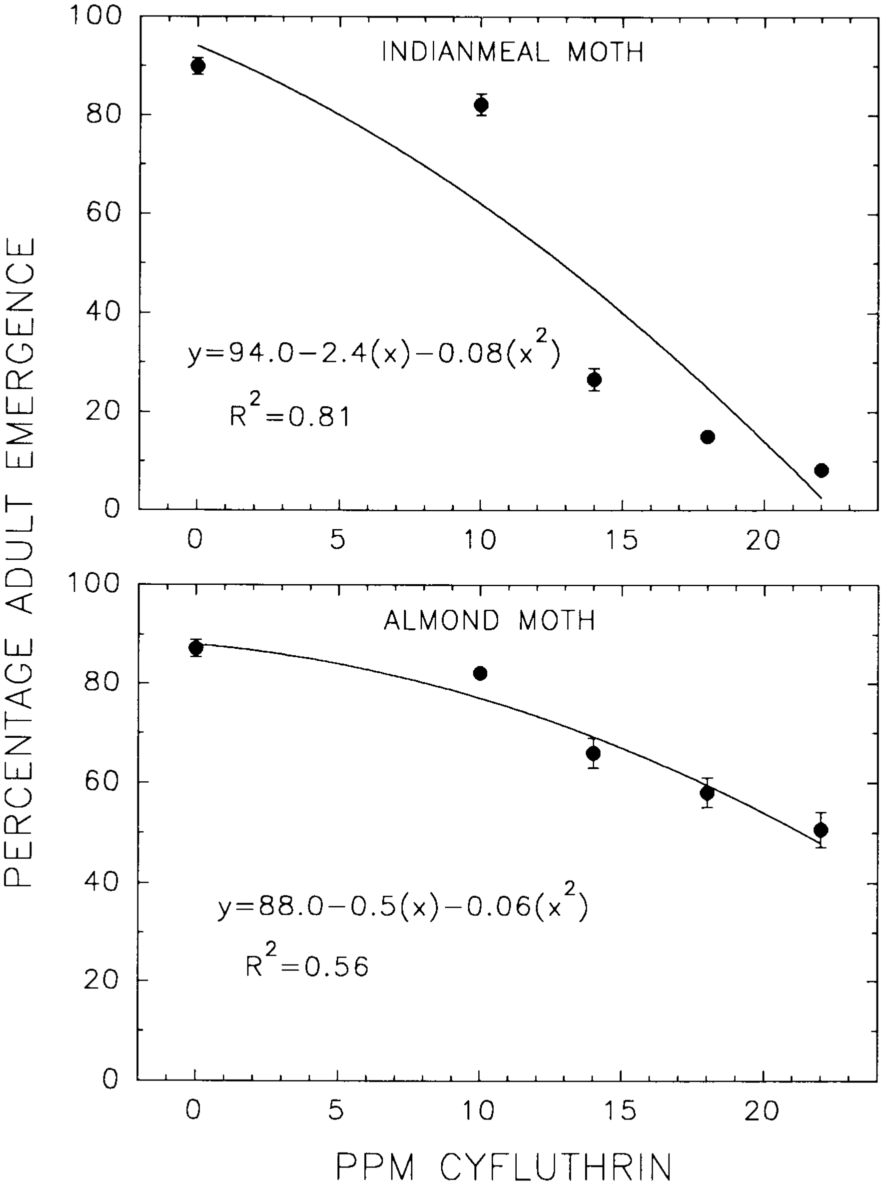

Fig. 1. Regression of percentage adult Indianmeal moth (IMM) and almond moth (AM) emergence from fifth instars introduced on peanuts treated with 0, 10, 14, 18, and 22 ppm cyfluthrin (Y = emergence, x = application rate).

were combined within each concentration, linear regression on concentration could not be fit for either species. However, quadratic non-linear regressions were significant ($P = 0.0001$) and fit the data for both species (Fig. 1).

Only the highest concentration of 22 ppm prevented adult Indianmeal moth emergence, while no concentration was effective against the almond moth. Wandering-phase Indianmeal moth and almond moth larvae in peanut warehouses may be difficult to control with protectant applications of cyfluthrin. If peanuts are heavily infested when they are loaded into a warehouse, residues may not be sufficient to kill the wandering phase larvae if they escape exposure inside a cracked pod. Once they emerge, mate, and lay eggs, the early instars would likely be killed by the residues, but there would be potential for the infestation to spread to untreated peanuts within a warehouse or peanuts that have received insufficient coverage during treatment. Once peanuts are infested to the extent that webbing is noticeable on the surface of the peanuts, supplemental applications may not eliminate the infestation unless the application rate of cyfluthrin is increased.

These data also suggest that pesticide evaluation programs should be conducted simultaneously on the Indianmeal moth and the almond moth because in many cases infestations of both species are common in the same storage environment. Management plans and monitoring programs are established to control both species, and if the almond moth has a greater tolerance than the Indianmeal moth to insecticides, differential application rates may be necessary for complete control.

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