Susceptibility of *Alphitobius diaperinus* (Coleoptera: Tenebrionidae) from Broiler Facilities in Texas to Four Insecticides

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J. Econ. Entomol. 101(2): 480–483 (2008)

ABSTRACT Lesser mealworm, *Alphitobius diaperinus* (Panzer) (Coleoptera: Tenebrionidae), adults were collected from six eastern Texas broiler facilities and examined for susceptibility to four formulated insecticides. Data indicate that *A. diaperinus* adults exposed to filter papers treated with the label rates of the insecticides exhibit some level of recovery. Approximately 20% or less *A. diaperinus* adults treated with Tempo SC Ultra (8 ml/92.9 m^2, 11.8% β-cyfluthrin) or Talstar WP Insecticide/Miticide (23.3 ml/92.9 m^2, 10% bifenthrin) and recorded as moribund at the 4-h observation period recovered by the 24-h observation period. *A. diaperinus* adults treated with Tempo SC Ultra and Talstar WP also had the greatest percentage of mortality for both observation periods. *A. diaperinus* adults treated with Dragnet SFR (49.7 ml/92.9 m^2, 36.8% permethrin) had the greatest level of recovery at ≈50–60% overall, which was similar to that recorded for the water-only control. Additionally, five of the six *A. diaperinus* populations treated with Dragnet SFR resulted in <10% mortality for both observation periods. Unlike the other insecticides examined, Talstar Professional Insecticide (10 ml/92.9 m^2, "Talstar Pro," 7.9% bifenthrin) resulted in ≈50% more *A. diaperinus* mortality at the 24-h than the 4-h observation period due primarily to increased mortality recorded for Farm F. *A. diaperinus* adults from farm D had ≥87% knockdown 4 h after treatment to all compounds examined, indicating a high degree of sensitivity to these compounds. However, ≈90% of the *A. diaperinus* adults from this population treated with Dragnet SFR and recorded as moribund recovered by the 24-h observation. *A. diaperinus* adults from this population treated with the other insecticides exhibited limited recovery. Susceptible adult *A. diaperinus* populations are still present in Texas, based on the populations examined. But, identifying these populations is difficult and time-consuming. Consequently, screening populations before treatment might not be feasible. However, newer generation pyrethroids examined in this study seem to be suitable for suppressing *A. diaperinus* populations in broiler facilities.

KEY WORDS lesser mealworm, *Alphitobius diaperinus*, insecticide resistance, knockdown, recovery

The lesser mealworm, *Alphitobius diaperinus* (Panzer) (Coleoptera: Tenebrionidae), is one of the key insect pests in the poultry industry. This beetle was originally a pest of dried meats and stored grains (Goodwin and Waltman 1996). However, modifications, such as higher bird densities and improved ventilation patterns, in the poultry industry since the 1950s have resulted in the emergence of this insect as the most commonly encountered beetle in broiler facilities (Lambkin 2005).

The damage done by *A. diaperinus* larvae searching for a pupation site is primarily responsible for their label as a "pest species" in poultry facilities (Axtell and Arends 1990). Prepupae bore into insulation of the facility, and adults increase the amount of damage when emerging. However, the importance of this species as a pest within poultry facilities is not limited to structural damage. *Alphitobius diaperinus* is a known reservoir for many human and poultry pathogens (Axtell and Arends 1990). *Salmonella typhimurium*, *Escherichia coli*, tapeworms, avian leucosis virus, and turkey enterovirus are just a few examples of pathogens known to be transmitted by this species (Avancini and Ueta 1990, Axtell and Arends 1990, McAllister et al. 1996).

Control methodologies for *A. diaperinus* are limited and not very successful (Axtell and Arends 1990). Cultural control methods, such as scheduled manure removals and periods of inactivity (no birds within a house) are known to reduce beetle population levels (Arends 1987). However, reducing the number of flocks annually obviously translates into reduced production for the facility.

Because of the lack of alternative methods, producers primarily rely on insecticides for suppressing *A. diaperinus* populations in broiler facilities (Lambkin 2005). A variety of insecticides are registered for suppressing *A. diaperinus* populations in poultry operations, such as Ravap (tetrachlorvinphos + dichlorvos),

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Table 1. *A. diaperinus* knockdown ($n = 3$) 4 h after initial exposure to filter paper treated with the label rate of target insecticides

Farm	Chemical					Statistical results
	Dragnet SFR	Talstar Pro	Tempo SC Ultra	Talstar WP	Control	
A	1.0 ± 1.0a	49.3 ± 19.3b	60.3 ± 29.3b	64.0 ± 2.3ab	0.0 ± 0.0a	$F = 4.03$; df = 4, 10; $P = 0.0336$
B	1.0 ± 1.0a	39.3 ± 12.1ab	75.6 ± 24.3b	69.6 ± 16.5b	2.3 ± 2.3a	$F = 7.07$; df = 4, 10; $P < 0.0057$
C	2.3 ± 2.3a	64.3 ± 11.3b	100.0 ± 0.0c	94.6 ± 3.9c	1.0 ± 1.0a	$F = 64.21$; df = 4, 10; $P < 0.0001$
D	87.0 ± 5.8a	100.0 ± 0.0b	100.0 ± 0.0b	100.0 ± 0.0b	25.6 ± 8.0c	$F = 54.73$; df = 4, 10; $P < 0.0001$
E	9.0 ± 2.5a	35.6 ± 10.6b	90.0 ± 3.6c	95.3 ± 4.7c	17.0 ± 9.5ab	$F = 26.59$; df = 4, 10; $P < 0.0001$
F	2.3 ± 2.3a	8.3 ± 0.9b	46.0 ± 2.6c	18.3 ± 4.9b	2.3 ± 2.3a	$F = 81.96$; df = 4, 10; $P < 0.0001$

Means in rows with different lowercase letters indicate significant difference ($P \leq 0.05$; F-test).

cyfluthrin, carbaryl, permethrin (Salin et al. 2003), and Talstar Professional Insecticide (bifenthrin). Extinosad (spinosad) by Elanco Corporation also is registered for suppressing *A. diaperinus* in poultry facilities, and it seems to hold much promise as a method for suppressing this species (Lambkin and Rice 2007). However, the accumulation of dust on the treated surfaces of the building reduces the effectiveness of many treatments (Steinkraus et al. 1991), and field applications of the insecticides are costly and result in poor control (Vaughan and Turner 1984, Weaver and Kondo 1987).

An additional concern regarding the heavy reliance on insecticides for suppressing *A. diaperinus* populations is the development of resistance to these insecticides. Lambkin (2005) determined that a majority of 27 Australian poultry operations investigated contained *A. diaperinus* populations with resistance levels to fenitrothion 25- to 75-fold greater than that recorded for a susceptible laboratory *A. diaperinus* population. In this study, we examined the susceptibility of *A. diaperinus* adults from six poultry operations in eastern Texas to four insecticides registered for use in or around broiler facilities in the United States.

Materials and Methods

Approximately 1,000 *A. diaperinus* adults were collected from each of six broiler farms located in Titus County, TX, on 1 September 2005, and they were examined for susceptibility to four insecticides. Facilities examined were using Tempo SC Ultra (8 ml/92.9 m^2, 11.8% β-cyfluthrin, Bayer Corp., Shawnee, KS) and Durashield CS (20% chlorpyrifos, Whitmire-Microgen Research Laboratories, St. Louis, MO) for suppressing *A. diaperinus* populations.

The compounds examined in this study were Dragnet SFR Termiticide/Insecticide (49.7 ml/92.9 m^2, 36.8% permethrin, FMC Corp., Philadelphia, PA), Talstar Professional Insecticide (10 ml/92.9 m^2, "Talstar Pro," 7.9% bifenthrin, FMC Corp.), Talstar WP Insecticide/ Miticide (23.3 ml/92.9 m^2, 10% bifenthrin, FMC Corp.), and Tempo SC Ultra. Water served as the control. Dragnet SFR is not registered in the United States for *A. diaperinus* control in broiler facilities; however, it is registered as a spot treatment to walls and ceiling as residual treatment of poultry and livestock facilities for suppression of house fly, *Musca domestica* L. (Diptera: Muscidae), and stable fly, *Stomoxys calcitrans* (L.) (Diptera: Muscidae), populations. Therefore, it is suspected that an *A. diaperinus* population in a facility treated with this compound is exposed to it.

Methods were adapted from Tomberlin et al. (2002). The label rate for each insecticide was prepared with water as the solvent. For each insecticide, 1 ml of the label rate for floor and wall treatment was applied to each of three 9-cm^2 filter papers. Each insecticide had three treated filter papers per facility.

Twenty to 30 adult *A. diaperinus* were placed on a filter paper ≈1 h after its treatment and held in a plastic petri dish. Mortality was recorded after 4 h. *A. diaperinus* adults were removed from the treated filter paper and placed in a sterile plastic petri dish labeled with the appropriate information and stored under ambient laboratory conditions. Mortality again was recorded 24 h after treatment. *A. diaperinus* adults were considered moribund if unable to walk.

Data for three replicates per insecticide per facility were analyzed. Percentage data were arcsine transformed and analyzed with PROC GLM (SAS Institute 1998). Least significant difference (LSD) test (SAS Institute 1998) was used following a significant F-test ($P < 0.05$) to separate mean differences for each variable.

Results and Discussion

Mortality at 4 h was highly variable (Table 1) across facilities for most insecticides examined. Five of the six *A. diaperinus* populations treated with Dragnet SFR resulted in ≤10% knockdown. This insecticide contains permethrin, which is one of the older generation pyrethroids used for suppressing insect pests for a number of years. Therefore, such high levels of resistance are not surprising.

Based on 4-h data, Tempo SC Ultra was the most effective at suppressing *A. diaperinus,* resulting in 75% or more knockdown in four of the six populations examined. Knockdown for *A. diaperinus* treated with Talstar WP was significantly less from that of Tempo SC Ultra in only one (farm F) of the six populations examined. Talstar Pro resulted in similar levels of *A. diaperinus* knockdown as Tempo SC Ultra for three of the six populations examined. The farm D population was highly susceptible, with 87% or more knockdown for all insecticides examined.

Table 2. *A. diaperinus* mortality ($n = 3$) 24 h after initial exposure to filter paper treated with the label rate of target insecticides

Farm	Chemical					Statistical results
	Dragnet SFR	Talstar Pro	Tempo SC Ultra	Talstar WP	Control	
A	0.0 ± 0.0a	6.7 ± 0.3b	44.3 ± 13.9c	8.0 ± 1.0b	0.0 ± 0.0a	$F = 18.95$; df = 4, 10; $P < 0.0001$
B	1.0 ± 1.0a	23.3 ± 19.9a	67.6 ± 6.2b	14.0 ± 1.0a	1.3 ± 1.3a	$F = 7.90$; df = 4, 10; $P = 0.0038$
C	3.3 ± 2.0a	39.0 ± 9.2b	90.0 ± 5.1c	53.4 ± 13.8b	1.0 ± 1.0a	$F = 22.88$; df = 4, 10; $P < 0.0001$
D	5.7 ± 2.9a	100.0 ± 0.0b	100.0 ± 0.0b	95.6 ± 4.3b	3.3 ± 3.3a	$F = 78.47$; df = 4, 10; $P < 0.0001$
E	0.0 ± 0.0a	10.7 ± 3.2b	51.3 ± 1.3c	23.6 ± 4.4d	2.3 ± 2.3a	$F = 38.58$; df = 4, 10; $P < 0.0001$
F	0.0 ± 0.0a	50.3 ± 9.5b	86.3 ± 6.1c	50.3 ± 2.7bc	0.0 ± 0.0a	$F = 28.27$; df = 4, 10; $P < 0.0001$

Means in rows with different lowercase letters indicate significant difference ($P \leq 0.05$; F-test).

Mortality recorded at 24 h also was highly variable (Table 2) across facilities for most insecticides examined. Efficacy on average for each compound except Talstar Pro decreased across treatments, indicating some recovery. Although no significant difference ($F = 0.68$; df = 5, 30; $P > 0.6391$) was recorded (Fig. 1), Tempo SC Ultra followed by Talstar WP had the least amount of recovery. Dragnet SFR was not effective at killing *A. diaperinus* adults. *A. diaperinus* from all populations sampled and treated with Tempo SC Ultra maintained 40% mortality or more, whereas samples from three of the six populations treated with Talstar WP demonstrated 50% or more mortality. *A. diaperinus* adults from two of the six populations treated with Talstar Pro demonstrated 50% mortality 24 h posttreatment. However, it was the only insecticide investigated that resulted in increased *A. diaperinus* mortality after 24 h. In contrast, *A. diaperinus* treated with Dragnet SFR had the greatest recovery rate at ≈60% overall. Mortality for *A. diaperinus* treated with Talstar Pro was lower than for those treated with Talstar WP; however, a significant difference in level of *A. diaperinus* mortality was determined for only two of the populations.

Many insecticides used for suppressing *A. diaperinus* are applied after cleanout of broiler facilities. In such cases, mortality is achieved through direct application of the insecticide with the beetles or potentially through their contact with residual insecticides on treated surfaces. However, before this study little was known about the effects of time since treatment on *A. diaperinus* mortality. Other studies recorded mortality 24 h (Lambkin and Rice 2006), 48 h (Hamm et al. 2006), or 72 h (Lambkin 2005) after treatment. Based on data from our study, mortality recorded 4 h after exposure to treated filter paper was greater than mortality recorded 24 h after treatment. Mortality recorded at 4 h after exposure was a better indicator of knockdown, whereas data recorded 24 h after treatment provided a better indication of *A. diaperinus* mortality. Future laboratory studies should compare mortality of individuals receiving direct treatment versus those that are permitted to have contact with a treated surface, such as those methods used by Lambkin and Rice (2007). Such results would be more indicative of what occurs in the field where direct contact between the insecticide and beetles can occur.

A. diaperinus populations resistant to insecticides registered for their control is a major issue for the broiler industry in the United States and abroad. Accordingly, predicting resistance in *A. diaperinus* populations established in broiler facilities is difficult to accomplish, and producers are often left guessing which compound to use. A solution would be to develop a testing program aimed at measuring susceptibility of target *A. diaperinus* populations to available insecticides. However, implementing such a program is virtually impossible when one considers the scarcity of individuals equipped to administer such a screening program and the monetary investment required by the producer.

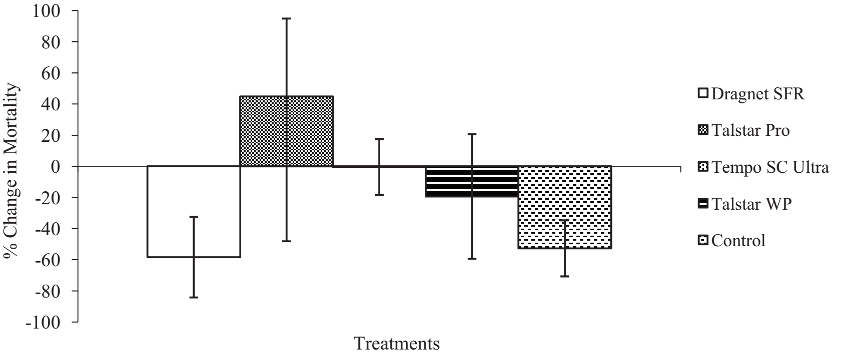

Fig. 1. Percentage of change in mortality for *A. diaperinus* ($n = 3$) from the 4- to the 24-h observation period after initial exposure to filter paper treated with label rate of target insecticides.

An alternative to developing and administering a testing program would be to develop an insecticide rotation program for implementation by the broiler industry. However, the idea of developing such a program has not been accomplished due to the limited number of compounds from different insecticide classes registered for such use. This issue is still a major concern today. However, new chemistries, such as spinosad and bifenthrin, recently have been registered for *A. diaperinus* control, which makes the development of such a program possible. Additionally, these new compounds diversify the number of insecticides available for use against *A. diaperinus* populations resistant to insecticides currently not effective. Future studies examining the effects of frequency of insecticide use and rotation pattern on resistant *A. diaperinus* populations are needed to take the first steps toward the development of such a program.

Acknowledgments

We thank FMC Professional Solutions for providing funding for this research. We also thank Nancy Hinkle (University of Georgia) and two anonymous reviewers for comments on an earlier draft of this manuscript.

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Received 24 July 2007; accepted 22 October 2007.