Suppression of Adult Lesser Mealworm (Coleoptera: Tenebrionidae) Using Soil Incorporation of Poultry Manure

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ABSTRACT The effectiveness of manure incorporation in reducing the numbers of adult lesser mealworms emerging from caged-layer poultry manure applied to agricultural fields was examined in summer 2002 and 2004. Incorporation treatments included control (no incorporation), disk (7-cm depth), harrow (15-cm depth), chisel plow (30-cm depth), and moldboard plow (33-cm depth) on silt loam soils in New York state. An estimated 55,192 and 183,500 live adult lesser mealworms were applied to the field in 2002 and 2004, respectively. Mortality due to the action of the manure spreader was 32.4% in 2002 and 6.5% in 2004. No significant differences were observed between treatments in 2002. However, moldboard plowing significantly reduced beetle emergence compared with no tillage in 2004. Peak beetle flight was observed 10 and 17 d after manure application in 2002 and 2004, respectively.

KEY WORDS darkling beetle, *Alphitobius diaperinus*, litter beetle, poultry manure, IPM

THE ADULT LESSER MEALWORM, *Alphitobius diaperinus* (Panzer), is the primary premise pest of the poultry industry (Axtell 1999). This pest can occur in exceptionally large populations in caged-layer poultry systems (Pfeiffer and Axtell 1980). The adult beetle is very long lived and can survive burying in soil in excess of 28 d (Calibeo-Hayes et al. 2005).

The lesser mealworm is a known reservoir of a variety of avian pathogens and parasites, including *Salmonella typhimurium*, *Escherichia coli*, tapeworms, avian leucosis virus, turkey coronavirus, and turkey enterovirus (Avincini and Ueta 1990, Axtell and Arends 1990, Despins et al. 1994, Goodwin and Waltman 1996, McAllister et al. 1996, Watson et al. 2000). Mature beetle larvae, seeking pupation sites, climb building walls and chew into building support structures and insulation (Vaughan et al. 1984; Despins et al. 1987). The resultant beetle damage to building support posts can weaken the structure and result in costly building repairs.

Producer options for manure disposal are dictated by many factors, including time of year; field availability and nutrient status; federal, state, and local restrictions; and the proximity of the field to residential areas. The adult stage of the beetle is an extremely important pest when manure is spread on fields during warmer months. The adult is capable of flight and will move en masse toward artificial lights generated by residences near fields on which beetle-infested manure has been spread (Axtell 1999). This behavior has resulted in poor community relations and may result in very costly litigation. Producers are aware of neighbor relations, and many attempt to mitigate negative impacts of their operations. The development of new methods for reducing the presence of arthropod pests in the manure destined for field applications can only aid in preserving positive relationships.

Control of lesser mealworms in caged-layer systems is difficult, due in part to manure accumulation times often in excess of 1 yr and the abundance of protected beetle larval habitat. For these reasons, chemical control is largely confined to when manure has been removed from the facility. Several biological control agents have been identified, including protozoans, fungi, nematodes, and mites; however, none have been found to be consistently effective (Steinkraus et al. 1991, 1992; Geden et al. 1987; Steinkraus and Cross 1993). Calibeo-Hayes et al. (2005) documented the effectiveness of mechanical incorporation of turkey litter on reducing adult lesser mealworm emergence from North Carolina field soils.

Our study examined the emergence of adult lesser mealworms after land application and subsequent mechanical incorporation of caged-layer poultry manure into New York field soils.

Materials and Methods

Caged-layer manure used in the 2002 trial originated on a farm in Cayuga County, New York, whereas manure used in 2004 originated on a farm in Wayne

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County, New York. In both instances, insecticides had not been used in either facility within the past 6 mo; manure had been accumulating in the facilities for a minimum of 1 yr and was heavily infested with adult lesser mealworms.

Manure was trucked to the field site, loads of manure weighed, and manure applied to the field with a rear-delivery New Holland 190 manure spreader (New Holland, Racine, WI). Manure was trucked 24 km in 2002 and 120 km in 2004 with minimal impact on adult beetle survival; however, mortality was assessed when manure was applied to the field. After transport to the incorporation site and placement into the manure spreader, adult lesser mealworm density was determined by taking a minimum of four samples with a bulb-planter (400 cc) (Kaufman et al. 2002). Live and dead adult lesser mealworms were recorded from each sample.

Separate fallow fields at the Thompson Research Farm, Freeville, NY, served as the site for the studies. The soil at the 2002 plots was a deep, somewhat poorly drained Erie Channery silt loam with a strongly expressed fragipan at 25–30 cm. The soil at the 2004 plots was a somewhat poorly drained Rhinebeck silt loam, which is a heavy textured, deep soil formed in calcareous clay lake laid material. In 2002, individual plots were 3.05 by 10.7 m and in 2004 plots were 3.05 by 15.25 m each. Using a randomized complete block design, 20 plots were assigned to one of five treatments: control (no incorporation), disk (7-cm depth), harrow (15-cm depth), chisel plow (30-cm depth), and moldboard plow (33-cm depth). Disk and harrow plots were incorporated with two passes of the implement, whereas chisel plow and moldboard plow plots were incorporated with one pass. The 2002 trial was incorporated on 23 July, whereas in 2004 incorporation occurred on 15 June.

Manure was applied to the field perpendicular to the treatment layout as done by Calibeo-Hayes et al. (2005). In 2002, two passes with the manure spreader were made, whereas in 2004, four passes were made. To estimate the numbers of both live and dead adult beetles applied to the plots, trays (31 by 21 cm) were placed in line with each other, one per plot per spreader pass. The tractor and manure spreader straddled the trays as the manure was delivered to the plots. The numbers of live and dead adult beetles were determined for each tray and subsequently, each plot. An estimate of the numbers of live beetles applied to the field was obtained as mean live beetles per field = (field area) / (tray area) × mean number of live beetles per tray. After beetle enumeration, the plots were incorporated. To estimate the mortality attributed to the spreading of the manure, the percentage of dead adult beetles was assessed from the trays and compared with the ratio gathered from the prespreading samples. This percentage was corrected for prespreading beetle mortality by using the method of Abbott (1925).

To assess adult beetle response after incorporation, four sampling methods were used: tile, pitfall trap, cylinder, and alsynite sticky trap (Calibeo-Hayes et al. 2005). In each plot, 10 of each tile, pitfall, and cylinder traps were randomly distributed, leaving a minimum 0.3-m buffer from the plot edge. White vinyl floor tiles (30 by 30 cm) were placed on the soil surface, whereas plastic drink cups (340 ml) served as pitfall traps and were buried in the soil with the top edge of the cup at the soil surface level. Cylinder traps consisted of sheet metal stove pipe (15 cm diameter) cut to 15-cm lengths and pressed into the soil with a 1-liter plastic food container cap. Alsynite cylinders (90 cm in length by 30 cm in diameter) were mounted on a 1.52-m length of conduit and covered with a sticky, transparent acetate sheet. To monitor beetles flying from the plot, the sticky cylinders were placed at the ends of each plot, with three along each end plot, yielding 46 total sticky cylinders.

All traps were monitored on days 1, 3, 7, 10, 14, 17, 21, 24, and 28 after incorporation. At each monitoring, all beetles were counted and removed from each trap. Soil (15-cm depth), and ambient air temperatures were monitored with a HOBO H8 external data logger (Onset Computer Corp., Pocasset, MA), whereas rainfall was monitored at the research farms' weather station.

In each trial, emergence data from the tile, pitfall, and cylinder traps were pooled for each plot. Percentage of adult beetle emergence was determined by dividing the total number of recovered beetles by the estimated number of beetles applied to the respective plot. Data were examined after a $\log(x + 1)$ transformation. A multifactorial analysis of variance was performed separately by year on transformed data and examined for treatment differences with a Tukey's mean separation (SAS Institute 1996).

Results and Discussion

Prespreading adult lesser mealworm mortality was 15.7% in 2002 and 9.1% in 2004. This mortality is likely the result of two factors: 1) beetles that were killed during handling and transport as described previously, and 2) cadavers of beetles that had died previous to our trials. The higher mortality in 2002 is most likely due to an older beetle population and a resultant increase in associated cadavers as the manure in the facility had been accumulating for a much longer duration.

An estimated 55,192 live adult lesser mealworms were applied to the 20 field plots in 2002 and an estimated 183,500 live adult lesser mealworms were applied to the plots in 2004. Mortality attributed to passage through the manure spreader was 32.4% in 2002 and 6.5% in 2004. The discrepancy in the mortality may be due to the differences in manure moisture between the two trials. In 2002, manure moisture averaged 28%, whereas manure moisture in 2004 was 50%. Calibeo-Hayes et al. (2005) reported ≤30% mortality of lesser mealworm adults in relatively dry turkey litter applied through a rear-delivery manure spreader.

In summer 2002, between 2.44 and 5.18% of the adult beetles introduced to the plots were recovered

Table 1. Estimated number of adult lesser mealworms applied to a field and percentage of recovery and emergence after various types of manure incorporation during studies in 2002 and 2004

Yr	Treatment	Total beetles applied[a]	% recovered[b]	Mean emergence[c]	Between treatment variation		
					df	F	P
2002	No tillage	14,235	2.44	4.89 ± 2.45a	7, 19	1.66	0.210
	Disk	9,990	4.52	14.88 ± 8.75a			
	Harrow	8,741	5.18	9.64 ± 2.29a			
	Chisel plow	13,985	3.12	4.69 ± 1.52a			
	Moldboard plow	8,241	2.50	5.92 ± 2.90a			
2004	No tillage	36,439	16.97	22.02 ± 3.44a	7, 19	3.77	0.022
	Disk	28,758	14.75	20.13 ± 3.51a			
	Harrow	46,733	7.28	12.00 ± 3.02ab			
	Chisel plow	35,621	10.08	13.47 ± 1.95ab			
	Moldboard plow	35,949	6.09	8.17 ± 0.96b			

[a] Estimated total no. of live adult lesser mealworms applied per four plots.
[b] Percentage of adult lesser mealworms recovered after manure incorporation.
[c] Within a column and study year, means followed by the same lower case letter are not significantly different ($\alpha = 0.05$, Tukey's multiple range test). Data log transformed for analysis.

(Table 1). Significant differences were not observed between any of the treatments ($F = 1.66$, df = 7, $P \leq 0.210$). This agrees with the spring trial findings of Calibeo-Hayes et al. (2005).

The low recovery of adult beetles from the control plots (4.89 ± 2.45) may be partially explained by the circumstances that were present at the time the trial was initiated. Immediately after the application of manure to the field and counting of beetles in the trays, a strong thunderstorm occurred, depositing 1 cm of rain within a 20-min period. When we returned to the field and begin incorporation and set up the survey tools, adult beetles were no longer evident on the surface of the plots. It is presumed that they either took shelter within the plots or were relocated among the plots.

In 2004, between 6.09 and 16.97% of beetles dispersed across the plots were recovered (Table 1). Mean adult beetle emergence from the treatment plots document that significantly fewer beetles emerged after incorporation with a moldboard plow (8.17 ± 0.96) compared with the control (22.02 ± 3.44) or disk treatments (20.13 ± 3.51) ($F = 3.77$, df = 7, $P \leq 0.022$).

House fly emergence after caged-layer poultry manure incorporation also was not significantly different for similar treatments (Watson et al. 1998). In their summer studies, Calibeo-Hayes et al. (2005) reported that all tillage practices reduced adult beetle emergence compared with surface application without tillage in clay soils and that disk and moldboard plow tillage practices were superior to no tillage on sandy soils. Our summer 2004 data support their conclusions with respect to the moldboard plow, however, the disk treatment performed poorly in both of our studies.

More than 87% of beetles recovered from tiles, pitfall, and cylinder traps during the course of the 2002 trial were collected the day after the incorporation of the manure (Fig. 1A). However, temporal distribution of beetle recovery in 2004 was different from 2002 (Fig. 1B). Only one-third of the adult beetles recovered during the trial were collected from in-plot traps the day after incorporation. Within the first 7 d after incorporation, 73% of the recovered beetles had been captured. After day 7, similar numbers of beetles were collected at each sample date.

These data suggest that, unlike house flies (Watson et al. 1998), lesser mealworm adults emerge within a relatively short time period after incorporation. Watson et al. (1998) documented limited house fly

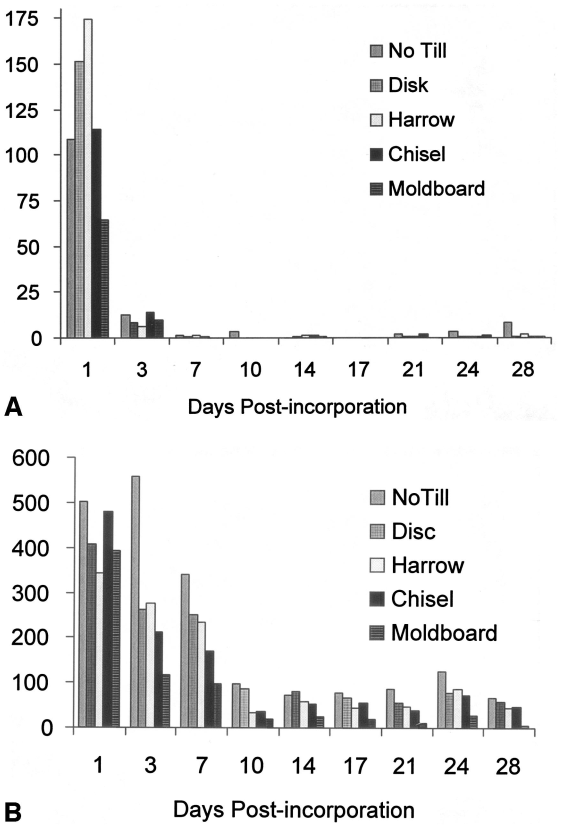

Fig. 1. Mean emergence of adult lesser mealworms after mechanical incorporation of poultry manure into field soil in New York during July 2002 (A) and June 2004 (B).

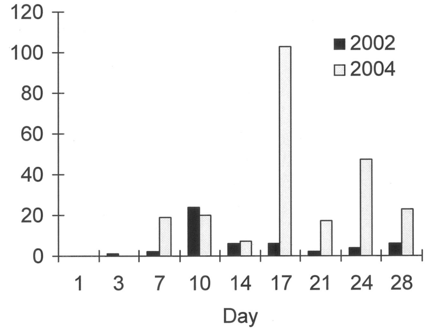

Fig. 2. Number of adult lesser mealworms collected on 46 alsynite sticky cylinders surrounding a field where poultry manure had been incorporated into the soil during 2002 and 2004.

recovery until 10 d after incorporation. Our data most closely match Calibeo-Hayes et al. (2005) results from spring and fall studies. However, as documented in Fig. 1, beetles are very capable of surviving and emerging after burial for up to 28 d in field soils.

Lesser mealworm dispersal from the field by flight also provided differing results from each year. During 2002, most beetle flight was observed on day 10 (Fig. 2). However, peak flight did not occur in the 2004 trial until day 17. At the time of each peak flight period, recovery of beetles from ground-based sampling had dramatically dropped, suggesting that beetles were still present in the plots but that they were not being collected in emergence traps.

Ambient temperatures during the 2002 trial averaged 24.4°C (range 16.2–35.4°C). During 2004, ambient temperatures averaged 20.1°C (range 12.7–29.6°C). Temperatures recorded at the 15-cm depth in the soil were 23.1°C in 2002 and 20.2°C in 2004. Calibeo-Hayes et al. (2005) observed flight only during the summer with soil temperatures of 25–26°C. Although they observed similar temperatures in their spring trial, they did not observe beetle flight. Soil temperatures in our studies during the time period of peak of flight averaged 24.7°C in 2002 and 21.6°C in 2004. The numbers of beetles collected on sticky traps were considerably lower than observed by Calibeo-Hayes et al. (2005), even though the numbers of beetles applied to our field were similar (2002) and considerably higher (2004). Appreciable rainfall occurred on day 0, 1, and 2 before peak flight on day 10 in 2002 and on sample days 2, 7, and 13 before day 17 in 2004. Based on limited data, it would seem that rainfall did not play a major role in stimulating adult beetle dispersal or emergence (Figs. 1 and 2). It is unknown whether the lack of rain stimulates beetle dispersal or emergence from the soil. Additionally, the presence of a poultry facility within 40 m of the field in the Calibeo-Hayes et al. (2005) study may have influenced beetle flight.

In 2004, we removed an estimated 1% of the manure from a 120,000-bird poultry building for the incorporation trial. Based on the numbers of beetles we distributed to the field, we also estimate that the building contained ≈19 million adult lesser mealworms. Given this estimate of beetle abundance, the numbers of adult beetles that producers can expect to transport to field sites can be extremely large. Due to the importance of beetle dispersal from field sites, producers must be vigilant in their prespreading practices so to avoid unintended conflicts and resulting litigation with nearby neighbors.

Our results suggest that if lesser mealworm populations are of concern and if manure must be removed from buildings during the warmer months, poultry producers in the northeastern United States should strongly consider incorporation of manure after field application. Moldboard plowing of the manure should provide the greatest reduction in adult lesser mealworm emergence and subsequent potential emigration. Given the high variability and the relatively low mortality of beetles (6–30%) applied to the fields in manure using a rear-discharge manure spreader, producers should not solely rely on this technique for reducing survival of adult lesser mealworms.

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