Field Trial of Diatomaceous Earth in Cotton Gin Trash against the Larger Black Flour Beetle, *Cynaeus angustus* (Coleoptera: Tenebrionidae)

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J. Econ. Entomol. 97(2): 588–592 (2004)

ABSTRACT The larger black flour beetle, *Cynaeus angustus* (LeConte) (Coleoptera: Tenebrionidae), is an agricultural and home nuisance pest in North America. In the Southern High Plains of Texas, the larger black flour beetle is associated with cotton gin trash, by-products of cotton ginning that are field stored in large piles for economic reasons. Larger black flour beetle overwinter in gin trash piles but may disperse by the millions in summer and autumn, entering houses as far as 2 km away where they cause distress to homeowners. Because >1.2 billion kg of gin trash is produced annually in Texas alone, the potential consequences of the larger black flour beetle are enormous. We conducted a field experiment that evaluated the efficacy of diatomaceous earth (DE) on the abundance of the larger black flour beetle in gin trash. There were no significant differences in numbers of larger black flour beetle among treatments and controls (mean number of adults summed over time: controls = 115.41, layered treatment = 87.60, top and bottom treatment = 96.50, bottom treatment = 115.16). There were sufficient numbers of beetles in treated piles to still pose a potential home nuisance problem, likely because the moisture content of field-stored gin trash is too high for DE to work effectively. Therefore, treating cotton gin trash with diatomaceous earth will probably be unable to prevent home infestations of larger black flour beetle. Location within a gin trash pile and season influenced pest numbers, which has implications for long-term field storage of cotton gin trash.

KEY WORDS cotton gin trash, *Cynaeus angustus*, diatomaceous earth, larger black flour beetle, Tenebrionidae

THE LARGER BLACK FLOUR BEETLE, *Cynaeus angustus* (LeConte) (Coleoptera: Tenebrionidae), is an agricultural and home nuisance pest in North America. It is most often identified as a pest of stored grain, but it also forms dense aggregations consisting of tens of thousands of individuals that enter homes, causing distress to homeowners (Hatch 1940, Barak et al. 1981, Dunkel et al. 1982, Morrison and Dunkel 1983). Although it is native to the Sonoran and Chihuahuan deserts of North America, where it is associated with decomposing yucca and agave plants (Hatch 1940, Dunkel et al. 1982), the species has spread throughout the continent since the 1920s (Hatch 1940, Dunkel et al. 1982). Before 1900, the only specimens known were from California, Arizona, Colorado, and Mexico; now, however, the species occurs as far north as Canada and as far east as the Atlantic seaboard states (Dunkel et al. 1982). On the Southern High Plains of Texas, the larger black flour beetle exhibits a recent and unique habitat association with cotton gin trash, which consists of bracts, stems, leaves, and residual lint that are by-products of cotton ginning (Morrison and Dunkel 1983).

Cotton gin trash was burned until environmental regulations ended the practice in 1972. It is now ground and sold as cattle feed, placed in a landfill, or dispersed. The costs of hauling and grinding usually exceed the value of gin trash as cattle feed, and landfill deposition is likewise cost-prohibitive. Most gin trash is thus dispersed throughout the countryside (Thomasson 1990a,b). It may be spread over fields and cultivated into the soil, but this practice is not well accepted by growers because gin trash can contain plant pathogens and weed seeds. Therefore, gin trash is usually stored in large piles until it can be dealt with in the future or until the piles decompose or erode (Morrison and Dunkel 1983; Thomasson 1990a,b).

Shortly after gin trash is produced in late summer and early autumn, larger black flour beetle colonize the piles, where they reproduce and overwinter. It is currently thought that the beetles feed on fungi that live in the gin trash piles, although exact dietary preferences and requirements are unknown (Sinha 1971, Morrison and Dunkel 1983). Multiple, overlapping generations are produced in a year, with a developmental time of 35–40 d from egg hatch to adult emer-

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gence; the adult life span in the laboratory is at least 130 d (Krall 1942). The beetles are most often encountered in the bottom 1 m of the piles and at the soil surface immediately below the piles. These deep areas are presumably the most sheltered and retain a more humid environment, and the beetles seem to prefer a slightly humid environment (at least 15–17% RH; Krall 1942, Dunkel et al. 1982, Morrison and Dunkel 1983). The next summer, adult beetles disperse, entering houses as far as 2 km from gin trash. Some homes have reported infestations of tens of thousands of beetles over a single night. Most affected homes are downwind of gin trash piles, and most infestations occur in July and August (Morrison and Dunkel 1983). The beetles are nocturnal, flighted, and thought to be attracted to artificial light (Krall 1942, Morrison and Dunkel 1983). Home-use insecticides must be applied repeatedly in heavy dosages to control larger black flour beetle aggregations, and residents must dispose of dead beetles that accumulate on floors, furniture, and food. Some homeowners have abandoned their homes for several weeks, and at least two children have required medical attention to remove larger black flour beetles from their ear canals (Morrison and Dunkel 1983).

Larger black flour beetle home infestations in association with nearby cotton gin trash have been reported since 1978, all in the Southern High Plains of Texas (Hatch 1940, Morrison and Dunkel 1983). This area of Texas produces both irrigated and dryland cotton. The dryland crop often receives fewer insecticide applications and often no harvest aid chemicals (defoliants, desiccants, and boll openers). The lack of insecticide residues and harvest-aid chemical residues on cotton gin trash may favor the establishment of larger black flour beetle (F. V. Dunkel, unpublished report). Because >1.2 billion kg of gin trash is produced annually in the Southern High Plains alone (one of the primary cotton-producing areas of the world, producing >$730 million in cotton per year on 4 million acres and accounting for approximately one-fifth of the world's cotton production), the potential legal and economic consequences of the larger black flour beetle are enormous (Moore et al. 1982).

There has already been at least one lawsuit for larger black flour beetle infestation of a private residence, so local cotton ginners are understandably concerned about their liability for home damages, the well-being of homeowners, and their standing in the community. Infested trash cannot simply be treated with insecticides because it is sometimes sold later as livestock feed or compost. No insecticide has a federal registration for use on gin trash, and hence any insecticide use would be in violation of federal statutes. The complexity and expense of the federal labeling process are so great that it is unlikely any insecticide will be labeled for use in this regional market. Even if an insecticide were available, it would have to be incorporated into the entire pile. Top dressing an insecticide would be relatively ineffective because very few beetles would encounter it, and environmental factors would degrade the active ingredient quickly. Frequent reapplication would be necessary to provide even marginal insect control during the months of storage.

Diatomaceous earth (DE) is used as a stored grain protectant to kill insects (including larger black flour beetle) in grain bins, where it is used in place of synthetic pesticides (DE has a federal tolerance in food). It abrades the waxy cuticle of the insect exoskeleton, inducing death by desiccation (Korunic 1998). As gin trash pile decomposition occurs, beetles may move downward to the gin trash/soil interface in search of moisture and/or food. In addition, the beetles are thought to overwinter in the gin trash and in the soil beneath the piles. We speculated that introducing DE to cotton gin trash would prevent larger black flour beetle from moving vertically within the piles and between the piles and the soil underneath.

There has been no prior evaluation of field control of the larger black flour beetle. Our objectives in this study were to 1) assess the efficacy of field-treating cotton gin trash with diatomaceous earth to allow field storage of trash without generating large numbers of larger black flour beetle, thereby reducing the potential for home infestations (and thus liability and litigation of ginners); and 2) gain more knowledge about a poorly understood but important pest species.

Materials and Methods

We established three treatments and a control (each with four replicate gin-trash piles 5 by 5 by 2 m and separated by 10 m, forming a square design; Fig. 1) at the Texas Agricultural Experiment Station (Halfway, TX) on 16 May 2001. We used Protect-It DE (Hedley Technologies Inc., Mississauga, ON, Canada), which is DE infused with silica gel (see description in Rigaux et al. 2001). Our treatments consisted of 1) gin trash placed atop 4.53 kg (10 lb) of DE (the "bottom" treatment); 2) gin trash placed atop 4.53 kg of DE with a top dressing of 4.53 kg of DE ("top and bottom"); and 3) gin trash layered with DE in two 2.26-kg layers (one at the soil surface, the other 2.5 m up), with 4.53 kg of top dressing ("layered"). We used gin trash from the previous harvest season, and piles were assigned to treatments at random. Control piles were not treated with DE but were otherwise identical to the treatment piles. We specifically built our treatments to imitate the conditions under which cotton ginners create gin trash piles in the field. There is no way to evenly and economically mix DE with gin trash during commercial pile construction, so layers of DE were used instead. This system is very different from the way DE is applied in a more uniform fashion to grain. A 10 by 10 by 5-m pile of 3-yr-old larger black flour beetle-infested gin trash was placed at the center of the experimental square to seed the experimental piles (for natural inoculation of our experimental piles).

We used two methods to monitor beetle numbers in piles over time. Each pile was monitored with five probe pitfall-type traps (Storgard WB Probe II, Trécé Inc., Salinas, CA) (White et al. 1990). Four proximal

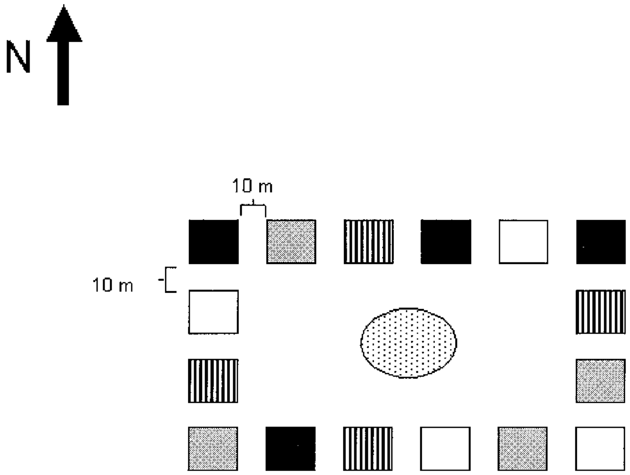

Fig. 1. Schematic diagram of the experimental design. Squares represent experimental gin trash piles. White squares represent untreated controls, black squares represent the bottom treatment, gray squares represent the top and bottom treatment, and striped squares represent the layered treatment. See text for explanation of treatments. The central circle represents larger black flour beetle-infested trash used to "seed" the experimental piles with beetles (not drawn to scale).

traps were inserted 1 m from the outside edge of the pile at each cardinal direction such that the tip of the trap was near ground level and the top of the trap was at least 10 cm below the surface of the pile. Placed in this way, traps would have collected insects present in a zone 15.2–43.2 cm above ground level. An additional trap was inserted into the top of the pile at a depth of 1 m. Traps were checked monthly from July through September 2001 (primary larger black flour beetle activity period), and this survey was repeated after a year (July 2002). We augmented these active-season data with overwintering data by collecting gin trash from five locations within each pile in December 2001 and March 2002. During these months, 20 liters of gin trash was removed from the edge of each pile at cardinal points. These samples were taken by removing a 25.4-cm swath that extended from the soil surface to the top of the pile and from the edge of the pile to ≈1 m inside the pile. We also removed a 15.2-cm-diameter core sample (20-liter volume) from the center of each pile. The samples were sifted through a coarse-mesh screen to separate beetles from larger pieces of gin trash. The resulting concentrated samples were placed in a Berlese funnel for 1 wk. All four types of piles were sampled simultaneously during all periods. Data on number of adults were analyzed using analysis of variance (ANOVA), by using month and treatment as fixed main effects. Significant models were followed by Tukey's multiple-comparisons of means tests (one-tailed) to determine differences among treatments, months, and position within a pile (Zar 1999).

Percentage of moisture content of the gin trash piles was assessed during both the activity (July 2002) and overwintering (March 2002) periods. Percentage of moisture content was assessed on the north, south, east, and west sides and center of one pile belonging to each of the three treatments + control by collecting gin trash, weighing it to the nearest 0.01 g, drying it for 72 h at 100°C, and recording differences between wet and dry weights to calculate percentage of moisture. Pile temperatures were measured quarterly with a Barnant J thermocouple thermometer.

Results and Discussion

Treating piles with DE had no effect on pest numbers (Fig. 2): gin trash piles treated with DE still had sufficient numbers of adult beetles to pose a potential home nuisance problem (ANOVA: $F_{model} = 12.42, P = < 0.0001$; $F_{treatment} = 0.54$, df = 3, $P = 0.65$). The moisture content of piles ranged from 16.8 to 38.7% (average 25.0%) during the overwintering period and

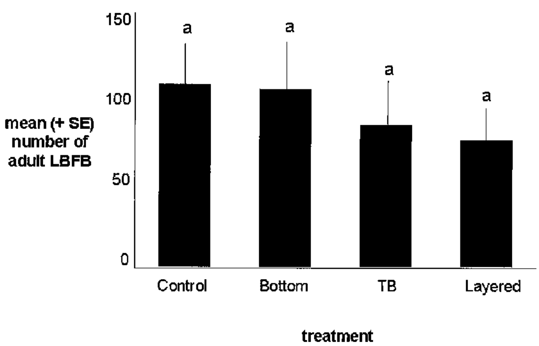

Fig. 2. Mean (+ SE) number of adult larger black flour beetle per treatment, with all months and pile positions combined, from probe-pitfall and Berlese traps. Bottom, treatment with DE applied at gin trash pile-ground interface only; TB, treatment with DE at bottom and as top-dressing; and Layered, treatment with three interspersed layers of DE. Columns denoted with the same letters are not significantly different (Tukey's test, $\alpha = 0.05$).

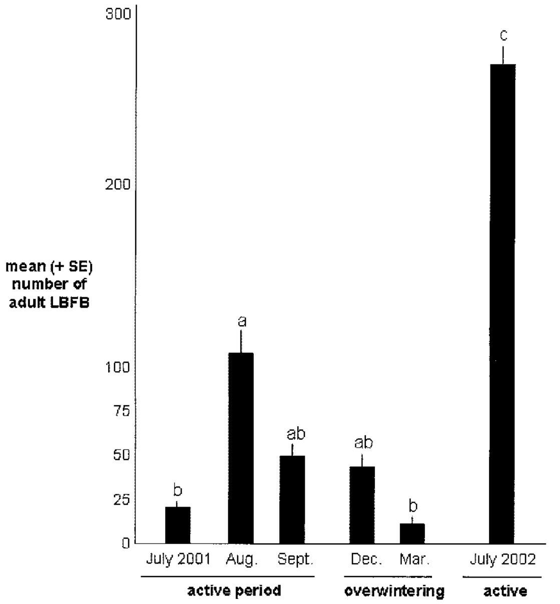

Fig. 3. Mean (+ SE) number of adult larger black flour beetle per month (all pile positions combined) from probe-pitfall and Berlese traps. Columns denoted with the same letters are not significantly different (Tukey's test, $\alpha = 0.05$).

from 11.5 to 32.2% (average 15.3%) during the active season.

There were effects of season (Fig. 3; $F_{date} = 16.40$, df = 5, $P = < 0.0001$) and location within a pile (Fig. 4; $F_{position} = 15.58$, df = 4, $P = < 0.0001$) on larger black flour beetle abundance. Pile temperatures ranged from a low of 4.39°C in March to a high of 52.33°C in September (average 7.09°C in March, 20.74°C in April, 26.74°C in July, 30.57°C in August, and 28.47°C in September), and beetles were most abundant during the warmest times of year (Fig. 3). Larger black flour beetles did overwinter in the piles and at the pile/soil interface. Many more beetles were found in the core of gin trash piles as opposed to locations nearer the surface (Fig. 4). These central positions averaged 6–30°C warmer than other locations. West-facing locations were warmer than other positions by 1–2°C; north-facing ones were coolest.

Based on our results, treating piles with diatomaceous earth will still allow pest numbers of beetles to survive. DE was likely ineffective because the natural moisture content of the gin trash (11.5–38.7%) was too high for DE to work effectively (effective range 0–15%; Fields and Korunic 2000, Rigaux et al. 2001). These values are higher than is commonly found in grain elevators where DE is used. In addition, some members of the Tenebrionidae have been shown to exhibit tolerance to DE (Rigaux et al. 2001). Larger black flour beetle numbers were lowest immediately after gin trash pile deposition (mean ± SE, over all treatments = 17.06 ± 3.08 adults; range 0–152) and did not become potentially problematic until the next summer (mean ± SE, over all treatments = 249.34 ± 32.10 adults; range 2–1179). Cotton ginners should dispose of gin trash during the second winter of storage or the subsequent early spring before pest problems can arise, thereby minimizing their risk of liability from home nuisance infestations of larger black flour beetle.

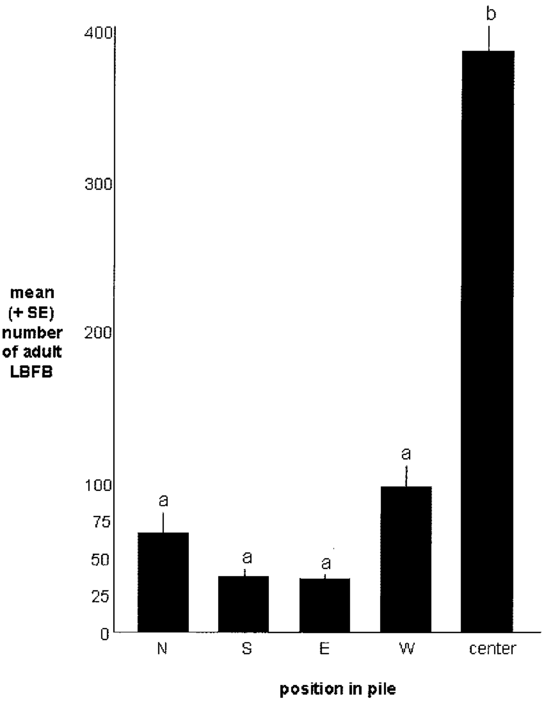

Fig. 4. Mean (+ SE) number of adult larger black flour beetle per position in pile (N, north; S, south; E, east; W, west; center, middle of pile), over all months, from probe-pitfall and Berlese traps. Columns denoted with the same letters are not significantly different (Tukey's test, $\alpha = 0.05$).

The probe traps sometimes filled with infiltrated rainwater, and some holes became plugged with fine cotton gin trash dust, making them of limited practicality for large-scale long-term larger black flour beetle monitoring. However, they were very effective at determining larger black flour beetle presence over a relatively short period of time (<1 mo between checking), were easy to install, and were economical in cost. They also trapped very few other species of arthropods. Therefore, use of probe traps to verify the presence of larger black flour beetle in cotton gin trash is feasible, and they can provide ginners an early warning of piles that may soon generate pest numbers of larger black flour beetles.

Acknowledgments

We are grateful to the following people and institutions for facilities and supplies: Scott Graham, Nat Collins, and Timothy Collins (Graham Service Center); Bill Mason (Quarterway Gin); Craig Jakob (Hedley Technologies Inc.); Kyle Meers (Meers Pest Solutions); Doug Nesmith (Texas Cooperative Extension in Halfway); and Jaroy Moore (Experiment

Station Director, Lubbock). We thank Lisa Longhofer for laboratory assistance. We thank the Texas Cotton Ginners' Association (especially Kelley Green) for support. This research was funded by the Texas Department of Agriculture's Integrated Pest Management Grants Program (IPM 01-013) and through a Texas Tech University Research Enhancement Fund grant to N.E.M.

References Cited

Barak, A. V., F. V. Dunkel, and P. K. Harein. 1981. Emergence of the larger black flour beetle as a major pest of farm-stored grain in Minnesota. J. Econ. Entomol. 74: 726–729.

Dunkel, F. V., A. V. Barak, and P. K. Harein. 1982. Geographical distribution of *Cynaeus angustus* LeConte (Coleoptera: Tenebrionidae) and its association with stored products. J. Biogeogr. 9: 345–352.

Fields, P., and Z. Korunic. 2000. The effect of grain moisture content and temperature on the efficacy of diatomaceous earths from different geographical locations against stored-product beetles. J. Stored Prod. Res. 36: 1–13.

Hatch, M. H. 1940. Stored grain beetles in western Washington, with special reference to the tenebrionid, *Cynaeus angustus* LeC. Pan-Pac. Entomol. 16: 34–35.

Korunic, Z. 1998. Diatomaceous earths, a group of natural insecticides. J. Stored Prod. Res. 34: 87–97.

Krall, J. L. 1942. The biology of *Cynaeus angustus* LeC., a tenebrionid. M.S. thesis, Iowa State College, Ames.

Moore, D. S., R. D. Lacewell, and C. Parnell. 1982. Economic implications of pelletting cotton gin trash as an alternate energy source. Tex. Agric. Exp. Stn. Publ. B-1382.

Morrison, W. P., and F. V. Dunkel. 1983. *Cynaeus angustus* (LeConte) as a nuisance pest associated with cotton gin waste. Southwest. Entomol. 8: 90–93.

Rigaux, M., E. Haubruge, and P. G. Fields. 2001. Mechanisms for tolerance to diatomaceous earth between strains of *Tribolium castaneum.* Entomol. Exp. Appl. 101: 33–39.

Sinha, R. N. 1971. Fungus as food for some stored-product insects. J. Econ. Entomol. 64: 3–6.

Thomasson, J. A. 1990a. A review of cotton gin trash disposal and utilization. Proceedings of the Beltwide Cotton Production Research Conferences, 9–14 January 1990. Nat. Cotton Council Am., Las Vegas, NV.

Thomasson, J. A. 1990b. A summary of research in cotton gin trash disposal. Cotton Gin Oil Mill Press 91: 8–9.

White, N.D.G., R. T. Arbogast, P. G. Fields, R. C. Hillmann, S. R. Loschiavo, B. Subramanyam, J. E. Throne, and V. F. Wright. 1990. The development and use of pitfall and probe traps for capturing insects in stored grain. J. Kans. Entomol. Soc. 63: 506–525.

Zar, J. H. 1999. Biostatistical analysis, 4th ed. Prentice-Hall, Upper Saddle River, NJ.

Received 8 April 2003; accepted 26 November 2003.