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Responses by adult Nitidulidae (Coleoptera) to synthetic aggregation pheromones, a coattractant, and effects of trap design and placement

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Abstract. Aggregation pheromones of the nitidulids, *Carpophilus hemipterus* (L.), *C. freemani* Dobson, *C. mutilatus* Erichson, and *C. lugubris* Murray were field tested at two sites (one in Crawford County and the other in Knox County) in Ohio. At both sites traps baited with pheromone plus bread dough caught at least five times more adult beetles than bread dough by itself. Trap design and height influenced trap catch. In most cases the nitidulid inventory technique trap yielded more nitidulids than did the wind-oriented pipe trap or the Japanese beetle trap. Trap performance in the field was dependent upon the nitidulid species responding. Aerial traps were preferred by *C. lugubris* and *C. hemipterus*, while *C. freemani* indicated no clear preference between aerial or ground traps. Two additional nitidulid species were captured in relatively large numbers by the coattractant: *Stelidota geminata* (Say), and *Glischrochilus quadrisignatus* (Say).

INTRODUCTION

Nitidulidae (Coleoptera) occupy a wide range of habitats throughout the world. Some species are cosmopolitan, while others are very specialized in their behavior and habitat preference. These beetles are well documented pests of ripening fruits, vegetables, and grains (Hinton, 1945; Gallardo-Covas et al., 1983) and vectors of disease pathogens (Chang & Jensen, 1974; Appel et al., 1987; Lussenhop & Wicklow, 1990). Other species are predators, pollinators, and decomposers (Becker, 1992; Gazit et al., 1982; Connell, 1991).

Since most pest nitidulids attack their host as they approach maturity, insecticidal applications are limited by pre-harvest intervals set by governmental agencies. Trapping to maintain populations below threshold levels often is limited by the size of the planting, density of traps required, and the effectiveness of natural host attractants such as banana, figs, grapefruit, pineapple, or fermenting whole wheat bread dough (WWBD). Control of nitidulids by mass trapping has been tried in fig orchards utilizing fermenting fig baits and was feasible economically (Warner, 1961). Callahan (1958) used fermenting oranges as bait for the tropical strawberry sap beetle, *Lobiopa insularis* (Castelnau), in a Louisiana strawberry field. Callahan (personal communication) concluded that such trapping would keep the population below the economic threshold. Smilanick & Ehler (1978) developed and tested a synthetic version of the fermenting fruit volatiles with promising results, but no synthetic attractants are available commercially. Fermenting WWBD has been shown to be an effective nitidulid attractant (e.g., Miller & Williams, 1982; Juzwik & French, 1986; Lin & Phelan, 1991) and in this study was selected as the coattractant. The nitidulid aggregation pheromones used in these studies are emitted by adult male beetles and are attractive to both sexes. Bartelt et al. (1990a,b, 1991, 1992) first identified and synthesized aggregation pheromones in the genus *Carpophilus*, which is perhaps most important when considering pest status of Nitidulidae. At present there are more than 190 species of *Carpophilus* worldwide of which 32 are found in the United States (Williams et al., 1983). The most common pest species are cosmopolitan in distribution, probably having been spread through commerce.

One objective of this study was to evaluate the biological activity of aggregation pheromones for *Carpophilus hemipterus* (L.), *C. freemani* Dobson, *C. mutilatus* Erichson, and *C. lugubris* Murray under field conditions in north central Ohio. Pheromones were tested unaccompanied and in combination with a coattractant. In addition, information was gathered on species composition and abundance at each site.

MATERIALS AND METHODS

Aggregation pheromones for the nitidulid beetles *Carpophilus hemipterus*, *C. lugubris*, *C. freemani*, *C. mutilatus* were tested at two locations in Ohio to determine lure performance and species abundance. Pheromones were furnished by one of us (RJB). The composition of the synthetic pheromone compounds used in this research are as follows: (2*E*,4*E*,6*E*,8*E*)-3,5,7-trimethyl-2,4,6,8-decatetraene (1), (2*E*,4*E*,6*E*,8*E*)-3,5,7-trimethyl-2,4,6,8-undecatetraene (2), (2*E*,4*E*,6*E*,8*E*)-7-ethyl-3,5-dimethyl-2,4,6,8-decatetraene (3), (2*E*,4*E*,6*E*,8*E*)-7-ethyl-3,5-dimethyl-2,4,6,8-undecatetraene (4), (2*E*,4*E*,6*E*)-5-ethyl-3-methyl-2,4,6-nonatriene (5), (3*E*,5*E*,7*E*)-6-ethyl-4-methyl-3,5,7-decatriene (6), (3*E*,5*E*,7*E*)-5-ethyl-7-methyl-3,5,7-undecatriene (7). Compounds 1–4 were prepared and purified as described by Bartelt et al. (1990b); compounds 5–7 were prepared analogously. Each trap bait was prepared by adding a total of 500 µg of synthetic pheromone to a rubber septum with 300 µl of methylene chloride. The bait compositions were as follows: for *C. hemipterus*, 1, 2, 3, and 4 in the proportions by weight, 79:11:7:3, respectively; for *C. mutilatus*, 6 and 7 in the proportions, 6:94; for *C. lugubris*, 2 and 4 in the proportions, 10:90; and for *C. freemani*, 4 and 5 in the proportions, 4:96.

The two Ohio sites were Sears Woods, a natural forested area in Crawford County, and McConnell Fruit Farm, a commercial small fruit farm growing strawberries, raspberries, blueberries and grapes in Knox County. The Knox County location is about 60 km southeast of the Crawford site. In addition to lure performance, trap type and trap placement (aerial vs ground) were studied. One of the three types of aerial traps was the wind-oriented pipe (WOP) trap, design #1 (Dowd et al., 1992) made of PVC pipe assembled in the form of a "T". Insects are trapped in a plastic cup which attaches to the opening at the bottom of the trunk pipe. This particular trap design has a wind vane attached to allow for orientation with the wind, thus aligning the volatile plume with the trap entrance. The second trap, which was used on the ground as well as in aerial positions, was the nitidulid inventory technique (NIT) trap which is a modification of the trap used by Skalbeck (1976). The NIT trap consists of a 1-quart wide mouth canning jar, with a plastic cone (a tapered drinking cup with bottom removed) inserted in the mouth of the jar which was held in place by the canning ring. A 15-cm square of 5 mm thick Masonite board is attached about 2 cm above the mouth of the jar as a rain cover. The third trap, used only as an aerial trap, was the standard Japanese beetle (JB) plastic trap produced by Trece®, except that it was white in color, and utilized a plastic bag as an insect receptacle rather than a canister. It was used in a single test in Sears Woods as a comparison since it had been used in previous nitidulid studies (Alm et al., 1989; Dowd et al., 1992).

Twenty grams of WWBD was used as the attractant or coattractant in all traps. The placement of the WWBD in the pipe traps was in the special bait compartment which is screened to exclude the beetles. In the NIT and JB traps it was placed in the bottom of the jar and plastic bag, respectively. In all traps, the WWBD was wrapped in fiberglass window screen bound with a twist tie for ease of removal and separation of insects (NIT trap only). The WWBD was replaced on a weekly basis. The septa were placed in the bait compartment of the pipe traps and in the bottom of the jar traps. Septa were left in the field for the duration of the experiment. Treatments were replicated four times in a randomized complete block design. Traps were spaced 10 m apart. Aerial traps were suspended 1 m above the ground. The attractant receptacles (quart jars) of the aerial NIT traps were covered with duct tape to keep contents dark, comparable to the ground NIT traps. Traps located on the ground were placed in holes made with a golf course cup cutter; the top of the jar was at or slightly above the ground surface. Three weekly collections at Crawford County, ran from 20 June to 9 July 1991, and the four weekly collections at Knox County began 9 July and ended 8 August 1991.

At Sears Woods, treatments were evaluated to determine the attractiveness of WWBD, as compared to the aggregation pheromones. This was done by having one treatment consisting of only bread dough and four treatments without bread dough, each containing one of the four aggregation pheromones. Aggregation pheromone treatments with no coattractant were not included in the Knox County experiment. Collection data were square root transformed and subjected to analysis of variance (ANOVA). Duncan's (1955) multiple range test was used to further separate means.

RESULTS AND DISCUSSION

Crawford County

Trapping in this wooded area indicated the presence of *Carpophilus lugubris*, *C. freemani*, *C. hemipterus* (Fig. 1). Catches were sufficient for comparisons to be made and statistically analyzed except for *C. hemipterus*. *C. lugubris* responded well to its aggregation pheromone and was separable statistically from all other treatments. In addition, more than twice as many *C. lugubris* beetles responded to the *C. hemipterus* pheromone than to the bread dough check indicating a rather strong cross attraction. *C. freemani*, even though captured in relatively small numbers, displayed a positive response to its aggregation pheromone. Some minor cross attraction by *C. freemani* to the other pheromones may have occurred since the checks captured no *C. freemani*.

Analysis of data for trap type and height for *C. lugubris* trapped with its aggregation pheromone (Table 1) indicated that the NIT trap captured more adult *lugubris* beetles than the WOP trap, and aerial placement of the NIT trap captured more nitidulids than the NIT

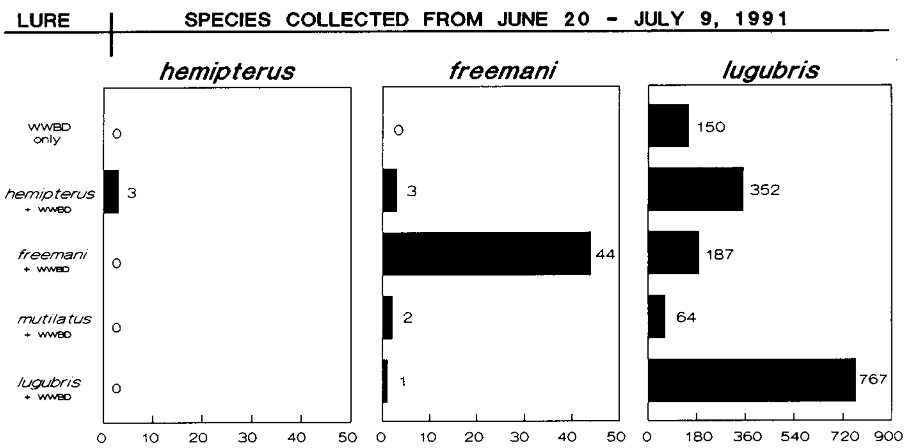

Fig. 1. Response by *Carpophilus* spp. to aggregation pheromones at Sears Woods, Crawford County, Ohio, 1991. (No *C. mutilatus* were collected.)

trap on the ground. Analysis of trap type and location for *C. freemani* trapped with its aggregation pheromone indicated a slight preference for the aerial NIT trap over the ground NIT trap. The WOP trap was intermediate but not statistically different from either of the NIT traps.

TABLE 1. Evaluation of the three nitidulid traps baited with whole wheat bread dough and *Carpophilus* aggregation pheromones at two locations in Ohio, 1991.

	Mean number of beetles collected per trap[1]					
	Crawford County			Knox County		
Species	WOP aerial	NIT aerial	NIT ground	WOP aerial	NIT aerial	NIT ground
C. hemipterus	0.0 a	0.2 a	0.0 a	2.5 a	0.5 b	0.2 b
C. freemani	1.0 ab	2.1 a	0.4 b	5.3 ab	3.9 b	8.4 a
C. lugubris	8.8 b	52.1 a	3.1 b	1.8 a	2.3 a	0.4 b
S. geminata[2]	3.0 c	24.1 b	221.8 a	0.3 b	1.4 b	28.2 a
G. quadrisignatus[2]	345.3 b	705.8 a	310.8 c	13.3 b	21.0 a	10.0 c

[1] Collection periods: Crawford, 20 June – 9 July; Knox, 9 July – 8 August.
[2] *S. geminata* and *G. quadrisignatus* were attracted only to the whole wheat bread dough.
abc Means within rows, within a county, followed by the same letter are not significantly different [P<0.05; Duncan's (1955) multiple range test.] Results of significance are based on square root transformed data.

In addition to Nitidulidae targeted with specific aggregation pheromones, the strawberry sap beetle, *Stelidota geminata* (Say) and the four-spotted picnic beetle, *Glischrochilus quadrisignatus* (Say) were captured in large numbers (Table 1). Even though neither species was attracted to any of the *Carpophilus* aggregation pheromones, they were the most abundant species captured. However, it should be noted that these two species were taken from all traps baited with WWBD. Their high numbers made it possible to compare trap types and elevation. Results indicate more *S. geminata* were captured by the aerial NIT trap than the WOP trap, however they did not separate statistically until data were transformed. Trap height proved to be important: the ground NIT trap caught about 10 times more *S. geminata* than the aerial NIT trap (Table 1). Peng & Williams (1991) also caught *S. geminata* primarily at ground level traps in an apple orchard, with only a few being captured at a maximum height of four meters above the ground.

TABLE 2. Comparison of three aerial traps for efficacy in catching the three most abundant nitidulid species in Sears Woods, Crawford County, Ohio, 1991.

Trap type[1]	Species collected[2]		
	C. lugubris	*S. geminata*	*G. quadrisignatus*
WOP	3.0 b	4.6 b	417.0 b
NIT	13.8 a	20.4 a	743.3 a
JB	3.3 b	8.8 b	207.3 c

[1] Wind-oriented pipe trap, Nitidulid inventory technique trap, and Japanese beetle trap.
[2] Mean number of nitidulids collected at whole wheat bread dough.
abc Means within columns followed by the same letter are not significantly different [P <0.05; Duncan's (1955) multiple range test]. Results of significance are based on square root transformed data.

Over 81,000 specimens of *G. quadrisignatus* were taken in the Crawford County trials. There was a clear preference for the aerial NIT trap over both the WOP trap and the NIT trap at ground level (Table 1). More than twice as many beetles were caught in the aerial NIT trap than either of the other traps. In an additional study conducted only at Crawford County (Table 2) three aerial traps were compared (WOP, NIT, and JB). The NIT trap captured significantly more *G. quadrisignatus*, *S. geminata* and *C. lugubris*.

Knox County

Pheromone trapping (Table 1) confirmed the presence of *Carpophilus lugubris*, *C. hemipterus*, and *C. freemani*. However, no *C. mutilatus* were recovered at either location as this species is limited to warmer areas. *Carpophilus* species were most influenced by their own aggregation pheromones (Fig. 2). Cross attraction results were similar to those experienced in Crawford site (Fig. 1 and 2). Analysis of trap type and height for the Knox study is as follows: *C. lugubris* (Table 1) preferred aerial placement of NIT traps over ground NIT traps by more than five fold. When evaluating trap type aerial NIT caught a few more beetles than the WOP trap, however, statistically they were indistinguishable. *C. hemipterus* preferred aerial trap placement over ground placement, and showed a five fold preference for the WOP trap over the NIT aerial trap. *C. freemani* showed no statistical preference for aerial trap type, however, significantly more beetles were trapped in the ground NIT trap. This is in contrast to findings in Crawford County. However, numbers of *C. freemani* were considerably lower at the Crawford site.

Similar to the results in Crawford County, we collected relatively large numbers of *S. geminata* and *G. quadrisignatus* in Knox County, 2,388 and 3,542, respectively. *S. geminata* (Table 1) indicated no statistical difference between the number of beetles trapped in the WOP trap and the NIT aerial trap. However, differences were again noted in the number of beetles in the NIT trap on the ground compared to the same trap at 1 m above the ground. These results confirmed previous findings in Crawford site, i.e., *S. geminata*

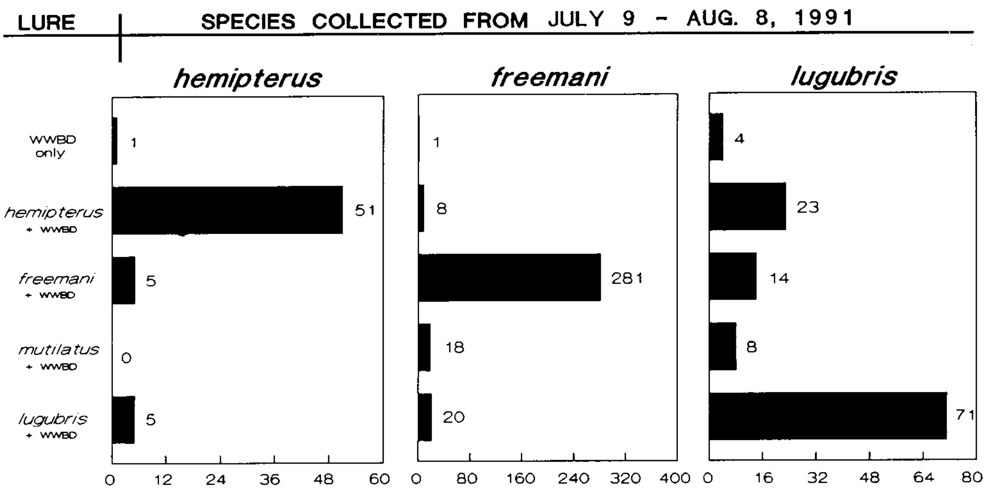

Fig. 2. Response by *Carpophilus* spp. to aggregation pheromones at Knox Woods, Knox County, Ohio, 1991. (No *C. mutilatus* were collected.)

prefer ground placement of the trap. Results for *G. quadrisignatus* (Table 1) showed statistical differences: a preference for aerial trap placement over ground placement, and the NIT trap over the WOP trap were indicated. Peng & Williams (1991) found that *G. quadrisignatus* were more abundant in traps 2 m above the ground in an apple orchard. However, in an open area where grass was mowed, they found a higher proportion of *G. quadrisignatus* at ground level. More species of nitidulids were collected at each site (Table 3). There were no discernable preferences among the pheromones indicating that attraction was attributable to the WWBD coattractant. They represented catches from all treatments and were generally caught in limited numbers. Most abundant in this group was the trilobed picnic beetle, *Glischrochilus fasciatus* (Olivier).

TABLE 3. Other Nitidulidae species and Proctotrupidae collected in all traps during the trapping period, Ohio 1991.

Species collected	Crawford County June 20–July 9	Knox County July 9–August 8
Amphicrossus ciliatus	1	0
Carpophilus brachypterus	1	23
Carpophilus corticinus	9	0
Carpophilus marginellus	0	4
Carpophilus sayi	2	0
Carpophilus spp.	200	270
Cryptarcha ampla	0	23
Cryptarcha concinna	0	7
Epuraea rufa	1	0
Epuraea spp.	29	1
Glischrochilus fasciatus	110	458
Glischrochilus sanguinolentus	117	2
Lobiopa undulata	0	1
Omosita colon	2	22
Pallodes pallidus	0	3
Phenolia grossa	1	0
Colopterus spp.	51	20
Brachyserphus abruptus[1] females	596	0

[1] The parasite, *Brachyserphus abruptus* (Say) (Hymenoptera: Proctotrupidae) attacks nitidulid larvae.

Brachyserphus abruptus (Say) (Hymenoptera: Proctotrupidae) parasitizes the larvae of several species of nitidulids (Williams et al., 1992). The parasite appears to have no attraction to the aggregation pheromones but rather is attracted to the WWBD. These parasites usually begin to appear at this latitude in mid-July. However, 1991 was an extremely early season and catches in Crawford County went from zero on 27 June to six on 2 July to 590 9 July. We speculate that the reason the parasite was never collected at the Knox County site was due to the agricultural setting and that the peak of abundance had already passed at the time of those collections.

In comparing the NIT trap to the WOP trap it is important to know the objective of the trap. Will it be used to monitor or deplete a population? Is the target nitidulid more abundant on the ground or a strong flier more likely to be caught at aerial traps? Is it a species that shows preference for a specific trap? If a particular site were heavily populated with an active flier, and the objective was to monitor the population, the WOP trap would have the advantage. It is an effective survey tool, catching representative samples, thus not overtaxing the scout with cumbersome numbers of beetles to be counted. It definitely will save time in determining trap contents. In addition, the contents of the pipe traps are likely to be drier, and easier to handle and sort. On the other hand, the NIT has the capability of catching greater numbers in the air and the flexibility of serving as a ground trap.

Certain species seem to prefer one trap over the other. For example, five times more *C. hemipterus* were caught in the WOP trap at the Knox site. *C. freemani* did not show a clear preference. However, if totals were combined from both sites; 97 were captured in the WOP trap and 87 in the NIT. When sheer numbers are desired to deplete a population of *S. geminata* or *G. quadrisignatus* then ground NIT and aerial NIT, respectively, would be the choices according to our findings.

Considerations not addressed in these studies include the viable life of the coattractant (WWBD) and modifications in odor quality. The odor produced by fermenting material probably changes over a week because of biochemical modifications. In the present case WWBD is replaced on a weekly basis and is therefore subject to such modifications. In hot weather WWBD will become dry and relatively unattractive in only a few days in the pipe traps. The same bait in the NIT trap should last longer where it is protected from direct air movement and this should reduce dehydration of the WWBD. It also appears that the pipe traps were relatively more effective in the open area (McConnell Fruit Farm) vs. forested Sears Woods. This may be due to the greater air movement in the open area which is likely to better disperse odors from a WOP trap. In a study of nine different traps in an unsprayed apple orchard, Peng & Williams (1991) found the Lindgren funnel to be most efficacious in catching large numbers of nitidulids but concluded that they would recommend the NIT because it is inexpensive and works well. Their tests did not evaluate the WOP trap.

Even though a specific pheromone shows attraction to one species and sometimes those related to it, its effect on other genera is not clear. Data obtained in this study were analyzed to determine if the *Carpophilus* pheromones exhibited any cross attraction to *Glischrochilus quadrisignatus* or *Stelidota geminata.* This analysis resulted in no separable differences, however both *G. quadrisignatus* and *S. geminata* responded in greater numbers to treatments containing pheromones versus the check. The *C. lugubris* pheromone attracted an average per trap of almost twice as many *S. geminata* beetles (118) than did the WWBD alone (63). The difference in *C. lugubris* attracting *G. quadrisignatus* was less, with only 402 at the WWBD and 512 at the pheromone plus WWBD. Since these differences are not statistically significant we can not assume attraction to these other genera. Pheromones for *G. quadrisignatus* and *S. geminata* have yet to be identified.

These newly discovered aggregation pheromones seem to play an important part in communication between insects. The ability to locate and distinguish their own kind from others is a critical factor in assuring successful propagation and continued success within their environment.

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