COMPETITIVE INTERACTIONS AND RELATIVE ATTRACTANCY OF BOLL WEEVIL PHEROMONE TRAPS AND BAIT STICKS

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Abstract

Mechanisms of boll weevil bait stick (BWACT) activity, including attractiveness relative to traps, competition between traps and bait sticks, and behavior and mortality of weevils responding to the bait stick, were studied in the Lower Rio Grande and Brazos valleys of Texas. Adhesive-coated bait sticks captured two to four times as many weevils as adhesive-coated trap bases; a difference that was not fully explained by the 1.5 fold greater lateral surface area of the bait stick relative to that of the trap base. Overall reductions in trap captures because of competitive interactions with bait sticks were not demonstrated. However, examinations of the temporal patterns of capture suggested that competition from bait sticks may have reduced trap captures during the first 8 to 14 days of trapping, when bait stick pheromone sources were fresh. Weevils responding to bait sticks did not feed or probe the surface of the stick, and when stationary assumed a departure posture with the tip of the abdomen held low and the head held high. Responding weevils contacted the bait stick for an average of 9.4 min, but nearly half remained on the bait stick for less than 5 min. Exposure to the bait stick resulted in 2.2% mortality in 96 h while 3.6% mortality was observed in the unexposed weevils during the same time period. Thus, the bait stick did not supply measurable efficacy against responding weevils.

Introduction

The boll weevil bait stick has been the source of considerable controversy since the first reports of its use in 1990. Many reports of field efficacy do not contain enough methodological detail or data to allow the reader to adequately assess the findings (e.g., Daxl *et al* 1995, Plato *et al*. 1996). Other, more detailed reports have primarily involved two fundamentally different experimental approaches. Most evaluations supplying positive reports of bait stick efficacy have been relatively large-scale, unreplicated studies on very low (sometimes barely detectable) population levels and with efficacy assessments based largely on pheromone trap captures and/or timing and number of producer applied pesticide applications (e.g. McGovern *et al.* 1993, McGovern *et al.* 1996). These studies also have been commonly confounded by differential applications of pesticides for either boll weevil or other pests, unusual boll weevil spring emergence patterns, or wide spatial separation and differences in cultural practices between treated and control areas. A second experimental approach generally indicating little or no bait stick efficacy has involved replicated, field-by-field evaluations involving relatively small acreages, subjected to low to moderately high weevil populations, and relying on both pheromone trap captures and fruit (square) damage estimates for evaluation (e.g., Fuchs and Minzenmayer 1992, Parker *et al*. 1995, Karner and Goodson 1995). Consequently, researchers have been unable to reach a consensus regarding efficacy of the bait stick.

Criticisim is frequently leveled at large-scale studies for their lack of replication and the use of pheromone traps as the primary evaluation tool. McKibben *et al.* (1991) indicated that use of pheromone in the bait stick interferes with operation of the traps. Although Villavaso *et al.* (1993) concluded that interference with the traps by bait stick pheromone lures played only a minor role in the bait stick's apparent effectiveness, the data presented indicated that roughly one-half of the trap capture reduction supplied by the bait stick was explained by competition from the bait stick pheromone. Despite these reports, subsequent large-scale studies have continued to rely on the pheromone trap as the primary evaluation tool. Smaller scale studies under conditions of higher boll weevil population levels have been criticized for their lack of isolation and failure to adequately account for immigration events. McKibben *et al.* (1994) suggested that either complete isolation or areawide usage is necessary for successful use of the bait stick, and acknowledged the difficulty in designing and conducting a statistically appropriate evaluation. Further, McGovern *et al.* (1995) opined that pheromone-based technologies are less effective when used against extremely high populations of boll weevils. Thus, controversy regarding the bait stick has involved not only its efficacy *per se* but also appropriate means of evaluation. Although the authors have been involved in several cooperative efforts to design a scientifically adequate efficacy evaluation, to date no evaluation has been proposed that was fully acceptable because of restrictions imposed by the various interested parties. These restrictions have included the need for replication with adequate controls while maintaining areawide application of the bait sticks, presence of low boll weevil population levels, and use of evaluation criteria independent of trap captures and preferably supplying direct measurements of the target population. Even designs that accomodated these needs were met with disagreement over funding, appropriate geographical areas for the evaluation, and suitability of personnel to conduct the study.

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Because of the difficulties in evaluating efficacy of the bait stick directly, we conducted studies involving the mechanisms of bait stick activity. We considered that such studies need not be subject to the same constraints as efficacy studies and should improve our understanding of the potential efficacy of the devices and appropriate means of their evaluation. Our objectives were to determine the attractiveness of the bait stick (BWACT) and the bait stick 60 mg pheromone lure (Plato Industries, Inc., Houston, TX) relative to that of the Hercon Scout pheromone trap and the standard Hercon 10 mg lure (Hercon Environmental Co., Emigsville, PA), examine competitive interactions between the bait stick and the pheromone trap, and quantify the behavior and mortality of weevils responding to the bait stick. Such observations regarding the original bait stick formulation using cyfluthrin as the toxicant have been reported, but similar reports of the commercial bait stick containing malathion are not currently available.

Materials and Methods

Relative Attractiveness

Attractiveness of the BWACT relative to the Scout trap was evaluated using a randomized complete block design with six replications divided between two locations (farms) at Weslaco, and six replications at a single location at College Station, TX. Four treatments were evaluated: 1) BWACT with 60 mg lure, 2) BWACT with 10 mg Hercon lure, 3) Scout trap base with 60 mg lure, and 4) Scout trap base with 10 mg lure. All combinations of devices and pheromone lures were used to facilitate separating attractancy of the devices from differential effects of the respective pheromone lures.

BWACTs, shipped directly in mid-July from Plato Industries Inc. to Mid Valley Chemical Co., Weslaco, TX, were first covered with clear plastic tape to minimize exposure of workers to the malathion toxicant. The taped BWACTs were then covered each day with plastic wrap, holes in the sides of the devices were cleared of plastic wrap and tape, and adhesive insect trap coating (Tangle-Trap paste formulation, The Tanglefoot Co., Grand Rapids, MI) was applied. Plato pheromone lures were installed in BWACTs according to accompanying directions. The Hercon lure was fastened in the tops of BWACTs using paper clips. Trap bases were used without the screen cone and capture container and were similarly coated with adhesive. A metal clip mounted on the top of the trap base retained the pheromone lure.

Treatments (devices) were separated by 50 m within blocks and positions were randomized daily. Devices were installed in mid-morning and removed by placing in a sealable plastic bag (trap bases) or wrapping in a plastic sheet (BWACT) after a 4 to 6 h exposure. The shorter exposure times were used on days when weevil response was high because we observed early in the experiment that the trap surface tended to become saturated with responding weevils in less time that did the BWACTs. Captured weevils were counted in the laboratory. Coated trap bases were discarded after data were collected while BWACTs were reused after replacing the plastic wrap. Pheromone lures were stored in a freezer when not in use. Data was collected only on days when wind speeds were about 10 mph or less at the time devices were to be placed. Data were collected at Weslaco on 10 days between 30 July and 28 August, 1997, and at College Station on 7 days between 29 August and 10 September, 1997.

Data were analyzed by analysis of variance using the SAS procedure PROC GLM (SAS Institute 1988). Main effects of the ANOVA models were device, lure, block, date, and location at Weslaco, and device, lure, block, and date at College Station. Means of main effects were separated using the REGWQ option of PROC GLM.

Competitive Interactions

Effects of BWACT pheromone sources on trap captures were evaluated using a randomized complete block design with four replications (fields) in commercial cotton both south of San Benito and near College Station, TX. Three treatments were evaluated: 1) standard BWACT (toxic), 2) the BWACT coated with tape (nontoxic), and 3) the Scout trap with the standard 10 mg pheromone lure. The order of treatments around each field was randomized. Each BWACT treatment used 20 BWACTs and four traps. Devices were spaced at 100 ft intervals with each fifth position occupied by a trap. Four traps were spaced at 500 ft intervals in the traps alone treatment. Treatments were established late in the production season (San Benito, 25 July; College Station, 25 August) and were observed for about 6 weeks. Weevils were removed weekly from traps near San Benito, and at 2- to 5-d intervals at College Station. Trap pheromone lures were replaced every 14 d.

Data were analyzed by analysis of variance using the SAS procedure PROC GLM (SAS Institute 1988). Main effects of the ANOVA model were treatment, block (field), and date. Means of main effects were separated using the REGWQ option of PROC GLM.

Behavior and Mortality

Observations on behavior and resulting mortality of boll weevils responding to BWACTs were recorded on eight days between 3 and 22 September at Weslaco, TX. A single BWACT was installed on a canal bank near a recently plowed cotton field. The canal bank was maintained weed-free by disking. One observer monitored the BWACT for responding weevils and when a weevil alit, noted the behavior of the weevil and duration of contact with the BWACT. Two additional observers with nylon collecting nets captured departing weevils. Because more than one weevil could not be timed simultaneously, weevils that were not timed were also captured to increase the sample size for mortality estimates. Captured weevils were placed individually in labeled 30 ml plastic cups each with a watersaturated cotton ball and placed in a chilled cooler until they were transported to the laboratory.

Individual observation sessions were typically limited to 1.5 to 2 hr in order to minimize both observer fatigue and the length of time captured weevils were held in the cooler. Multiple sessions were conducted on most days. Weevils which served as unexposed controls for mortality estimates were obtained from traps placed in the general vicinity of the test. Weevils were collected from these traps between observation sessions. A total of 10 BWACTs, numbered from 1 to 10, were used in a rotation during observation sessions with a substitution made each session.

Observations of behavior were qualitative with emphasis on feeding or probing of the BWACT surface. A mean and standard error were computed for exposure time but no statistical comparison between exposed and unexposed weevils was warranted.

Results

Relative Attractiveness

A higher number of weevils were captured on adhesive-coated BWACTS than on coated trap bases. At Weslaco, mean daily capture of weevils by adhesive-coated trap bases (34.5 weevils day^{-1} $device^{-1}$) was 51% of that for coated BWACTs (67.8 weevils day^{-1} $device^{-1}$) (F=44.86; df=1, 40; p<0.001). The significant device by day interaction (F=3.71; df=9, 40; p=0.002) indicated the relative captures of trap bases and BWACTs differed among dates. Trap bases captured a low of 29.7% of the BWACT capture on 7 July and a high of 84.0% of the BWACT capture on 25 August. At College Station captures by trap bases was only 26.2% of captures by BWACTs (trap bases, 36.5 weevils day^{-1} $device^{-1}$; BWACT, 139.3 weevils day^{-1} $device^{-1}$; F=353.90; df=1,72; p<0.001). The device by day interaction at College Station (F=43.63; df=6.72; p<0.001) also indicated variation in the relative captures of the devices among days, and captures by the trap bases ranged from 5.6 to 36.8% of those by the BWACTs.

Weevil response to the 60 mg Plato pheromone lure was also greater than to the standard 10 mg lure. At Weslaco, mean daily capture for the standard 10 mg lure (41.0 weevils day^{-1} $device^{-1}$) was 66.8% of that for the 60 mg lure (61.3 weevils day^{-1} $device^{-1}$) (F=16.80; df=1, 40; p<0.001). Mean daily capture for the 10 mg lure (81.7 weevils day^{-1} $device^{-1}$) was 86.8% of that for the 60 mg lure (94.1 weevils day^{-1} $device^{-1}$) at College Station (F=5.16; df=1, 72; p=0.026). Although the relative captures for the respective pheromone lures differed between Weslaco and College Station, device by pheromone lure, and day by pheromone lure interactions indicated that the relative performance of respective lure types was consistent regardless of device or day of observation.

Competitive Interactions

Mean weekly trap captures near San Benito (nontoxic BWACT, 166.3 weevils $week^{-1}$ $trap^{-1}$; toxic BWACT, 147.2 weevils $week^{-1}$ $trap^{-1}$; trap alone, 128.9 weevils $week^{-1}$ $trap^{-1}$) did not indicate a detrimental effect of the BWACT pheromone sources on trap captures. In fact, trap captures in the absence of BWACTs was less than in their presence (F=9.84; df=2, 210; p<0.001). Mean daily trap captures at College Station indicated a different trend (nontoxic BWACT, 34.9 weevils day^{-1} $trap^{-1}$; toxic BWACT, 57.2 weevils day^{-1} $trap^{-1}$; trap, 45.0 weevils day^{-1} $trap^{-1}$), with traps alone resulting in captures that were intermediate between those of the two BWACT treatments (F=59.87; df=2, 570; p<0.001). The treatment by block (field) interactions at both locations (San Benito, F=23.19; df=6, 210; p<0.001; College Station, F=9.59; df=6, 570; p<0.001) indicated that relationships among trap captures differed among fields. Thus the respective treatments did not perform similarly among fields. Also, date by treatment interactions (San Benito, F=4.34; df=10, 210; p<0.001; College Station, F=5.60, df=30, 570; p<0.001) at both locations indicated that the treatments did not behave similarly among dates. Highest captures were recorded in the traps alone treatment for the first two weeks at San Benito and for the first 8 days at College Station in all fields.

Behavior and Mortality

Mean time of exposure of weevils responding naturally to the BWACT was 9.4 min (n=71, standard error=1.74). Exposure time ranged from 3 sec to 84.12 min. Seventy-six percent of responding weevils remained on the surface of the BWACT for <10 min while 48% remained for <5 min. Weevils usually walked over the surface of the BWACT after landing, often to its top, but were never observed to feed on the BWACT or to contact it with the rostrum. After walking, weevils typically assumed a characteristic posture with the tip of the abdomen held low and the head held away from the BWACT. This posture was usually maintained until the weevils departed by flying.

Of 90 weevils collected while departing the BWACT, none died within 72 h of collection, and only 2 (exposure times of 3 and 5.45 min, 2.2%) died within 96 h. Of 112 control weevils obtained from traps, 1 (0.9%) died within 72 h of removal from the traps and 4 (3.6%) died within 96 h. Thus, no BWACT induced mortality of responding weevils was demonstrated.

Discussion

Our data indicated that the BWACT attracted two to four times as many weevils as did the Scout trap base. However, captures on the trap bases should be considered conservative because we observed that these devices tended to become saturated with weevils sooner than did BWACTs when weevil response was at a high level. Nevertheless, the greater numbers of weevils captured on the BWACTs was not fully explained by the 1.5 times larger lateral surface area of that device compared to that of the trap base. These results are similar to those previously reported by Stewart and Williams (1997). Although McKibben *et al.* (1991) reported that the boll weevil has a "natural affinity" for the bait stick because of its shape and vertical orientation, we observed nothing unique about boll weevil response to the BWACT that would support this conclusion. Rather, because numerous reports have indicated that trap color is an important factor in weevil response (e.g., Cross *et al.* 1976, Hardee *et al.* 1972), and Leggett (1980) found differences in trap color to be most influential in competitive situations, we consider that differences in surface area, color, and brightness between the BWACT and trap base were more likely responsible for the observed differences in weevil response.

We observed increased weevil response with increased Grandlure content of the pheromone lure, but the 15% (College Station) to 50% (Weslaco) increase in weevil response was much less than expected based on calculations by McKibben *et al.* (1993). According to the model of McKibben *et al.* (1993), increasing the pheromone content of the lure from 10 to 60 mg should have increased weevil response by a factor of 4.5. Collection of additional data regarding pheromone release rates of the respective lures are planned and may shed additional light on the relationship between Grandlure content and weevil response.

In our study considerable variation was observed in relative attractiveness of devices and pheromone lures between locations but specific sources of these differences could not be identified. Pheromone trap data are notoriously variable, and it is likely that differences in trap surroundings, weevil population densities, cotton crop phenology, and weather related variables could have played a role in the differences observed between Weslaco and College Station. Additional research directed at specific influences will be required before these differences may be explained.

Our failure to demonstrate a detrimental effect on trap captures from competition or interference by BWACT pheromone sources contrasts with the statement by McKibben *et al.* (1991), that use of pheromone in the bait sticks interferes with operation of the traps, and with the data of Villavaso *et al.* (1993), although our data do suggest such an effect during the intial days of the test. This initial effect, and its subsequent disappearance, could be related to a reduction in pheromone release rate by the BWACT pheromone dispensers with increasing age. Assays of field-aged dispensers are currently underway and should aid in interpretation of these results. Also, inconsistencies among fields within locations, and between locations, suggest observed differences among treatments may not be reproducible. Further, the very high numbers of weevils responding during the study period may have masked effects that would be more evident when weevil response or population levels are lower.

The average duration of exposure of responding weevils to the BWACT was almost twice as long as that reported by McKibben *et al.* (1990). Also, we never observed weevils to feed on or probe the BWACT while McKibben *et al.* (1990) reported that 26% of the responding weevils fed on the coated stake or PVC cap of their device. However, the device evaluated in their study was considerably different, in both construction and toxicant, from the current commercial BWACT. We have found no published reports of similar data for the current commercial product. Our failure to kill naturally responding weevils would appear to indicate the commercial BWACTs we obtained did not contain adequate levels of malathion in the coating. This possibility was eliminated by laboratory bioassays in which weevils were forced to contact the BWACT surface; mortality was nearly complete by 48 h after weevils were held in contact with the BWACT for approximately 15 seconds (J. R. Coppedge, unpublished data). Field observations at College Station using the same BWACTs also indicated no mortality of naturally responding weevils. Thus, our results suggest forced-contact bioassays are not wholely appropriate for assessment of such devices, and raise questions regarding the interpretations of BWACT field trial results in which indirect or circumstantial evidence has been used to support positive assessments of BWACT efficacy.

Disclaimer

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