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ARTHROPOD MANAGEMENT

Efficacy of Field-Aged Bait Sticks Against the Boll Weevil

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INTERPRETIVE SUMMARY

The commercially available boll weevil bait stick, Boll Weevil Attract-and-Control Tube, uses attractive color and odor to lure weevils to its surface. The bait stick's colored coating is impregnated with a mixture of feeding stimulant and insecticide, reported to kill weevils that land on it. However, the value of the bait stick in boll weevil control and management programs is not clear because test outcomes have depended upon how those tests were conducted.

The most consistent indications of the bait stick's capability to kill weevils have come from studies in which weevils were placed directly on the device. After a specified period, these weevils were removed, held in the laboratory, and checked later to determine how many died. A recent study has suggested the bait stick is more likely to kill weevils forced into contact with it than to kill weevils that land on it naturally. However, that study did not account for different ages of the bait sticks tested. In this study, the ability of the bait stick to kill both weevils forced to walk on it and those landing on it naturally was evaluated for bait stick ages of 0, 1, 3, 5, and 7 wk.

In a 1998 study to determine the number of weevils killed by forced contact, weevils were placed on the uncoated end of the bait stick and made to walk onto the treated surface. After 30 s these weevils were removed and held in the laboratory until they were checked for mortality at 24 and 48 h after exposure. In the tests of weevils landing naturally, weevils that landed on the bait stick in the field were timed to determine how long they remained on the device. As those weevils flew from the bait stick, they were captured and transported to the laboratory where mortality was evaluated after 24 and 48 h. Also, on seven dates in late August and early September records were kept of the numbers of weevils that flew to the bait stick but did not land on it.

The length of time that naturally landing boll weevils stayed on the bait stick before they flew tended to increase as the bait stick age increased from 0 wk old (1.73 min) to 7 wk old (7.94 min). Most of these weevils stayed on the bait stick for less than 5 min, but the numbers staying for more than 5 min tended to increase with increasing bait stick age. Weevil mortality was observed only after exposure to bait sticks that were no more than 1 wk old. However, no more than 10% of the weevils died on any age of bait stick, whether having been forced to contact the device or having landed on it naturally. Further, 74% of weevils that flew to the bait stick did not land on it. These results suggest: (i) the bait stick is unlikely to provide a significant level of control of field populations of the boll weevil; and (ii) future tests should involve either naturally landing weevils or a forced contact method that does not rely on unnatural or excessive contact of the weevil with the treated bait stick surface.

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ABSTRACT

The role of the commercial boll weevil bait stick (Boll Weevil Attract-and-Control Tube) in boll weevil *(Anthonomus grandis grandis* Boheman*)* management is poorly understood. This study evaluated the influence of bait stick age on weevil mortality and behavior. Bait sticks were assayed after aging 0, 1, 3, 5, and 7 wk in the field. Efficacy was estimated in the field by allowing weevils to land on the bait stick, capturing them as they departed, and holding them to determine mortality after 24 and 48 h. Weevils captured in traps were used in forced contact assays of the same bait sticks

used in the field, and as unexposed controls. Average duration of exposure to the bait stick in the field tended to increase with bait stick age, from 1.73 min (0-wk-old) to 7.94 min (7-wk-old). Most weevils remained on the bait stick for <5 min, but this proportion tended to decrease with increasing bait stick age. Mortality in either assay type (0–10%) was not different from the controls. No mortality was observed when bait stick age was >1 wk. Seventy-four percent of weevils responding naturally to the bait stick failed to land on the device. Low observed mortality and failure of most weevils to land on the bait sticks suggest the bait stick is unlikely to provide significant control or suppression of field populations. These results emphasize that meaningful evaluations should include methods that do not involve unnatural or excessive contact of the weevil with the treated bait stick surface.

The commercially available boll weevil bait stick, Boll Weevil Attract-and-Control Tube (Plato Industries, Houston, TX), uses color and a pheromone lure to attract adult boll weevils *(Anthonomus grandis grandis* Boheman*)*, and a malathion-impregnated cottonseed-based feeding stimulant to kill responding weevils. Estimates of bait stick efficacy have varied widely, depending on the procedures used. Large-scale unreplicated studies, in which bait stick efficacy was assessed against very low weevil population levels on the basis of captures by pheromone traps or the timing and number of producer-applied pesticide applications, generally have indicated significant control by the bait stick (McGovern et al., 1993, 1996). Smaller, replicated evaluations involving low to moderately high weevil population levels, assessed using both pheromone trap captures and fruit damage estimates, have indicated little or no efficacy (Fuchs and Minzenmayer, 1992; Karner and Goodson, 1995; Parker et al., 1995). Thus, conclusions based on field evaluations of bait stick efficacy have been inconsistent.

Forced-contact assays of laboratory-strain boll weevils (Villavaso et al., 1998) have provided the most positive indications of bait stick efficacy. Results of these assays have served as the basis for support of the bait stick as the primary control technology in suppression programs encompassing environmentally sensitive areas. These findings contrast with those of Spurgeon et al. (1999), who reported that the forced-contact assay did not accurately reflect the level of bait stick–induced mortality achieved in the field and that little efficacy was observed against naturally responding weevils. However, bait sticks used by Spurgeon et al. (1999) were stored in the laboratory between observation sessions, and thus were of known age only during initial observations. Although product directions recommend bait stick replacement after 50 to 60 d, no information is available to indicate how field aging influences bait stick efficacy against naturally responding weevils. The objectives of this study were to better understand the capabilities of the commercially available bait sticks for boll weevil control by examining the effects of bait stick aging in the field on mortality and selected behaviors of responding weevils.

MATERIALS AND METHODS

A case of 60 bait sticks[1] manufactured in April 1998 were obtained from Mid Valley Chemical Co., Weslaco, TX, during June 1998 and randomly divided into 20 equal groups. Each group was placed within two heavy-duty plastic garbage bags, sealed with tape, numbered, and stored at about 10ºC until they were placed in the field for aging. Four groups of bait sticks were randomly assigned to each age class of 0, 1, 3, 5, and 7 wk. Age classes represented the week of aging. For example, bait sticks of age class 3 were >3 but <4 wk old at the time of assay. Bait sticks were aged in a mowed, grassy area shielded from prevailing winds to minimize contamination by blowing soil. Beginning on 22 June with a group to be aged 7 wk, groups of the various age classes were placed in the aging area weekly in a manner that permitted simultaneous assay of all age classes between 10 Aug. and 4 Sept. The 0-wk groups were not placed in the field until the weeks of their respective assays.

Responses of feral boll weevils to the bait sticks were assessed simultaneously at two or three observation stations spaced at 50-m intervals on a canal bank adjacent to a plowed field. Most data were collected between 0900 and 1100 h and between 1300 and 1500 h (Central Daylight Time) on days when wind speeds were <16 km h^{-1}. Until 28 Aug., the individual bait sticks used in each

[1] This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement for its use by USDA.

1.5- to 2-h observation session were chosen randomly without replacement, using a two-step procedure. First, the age classes for examination were selected, then an individual bait stick within each of the chosen age classes was selected. This procedure was adopted so that a given age class or bait stick within an age class would not be assayed repeatedly. By 27 Aug., the numbers of observations for bait stick age classes of 0, 1, or 7 wk were substantially smaller than for age classes 3 or 5 wk. Therefore, between 28 Aug. and 4 Sept., age classes of 0, 1, and 7 wk were assayed more frequently than the other age classes. Bait sticks were baited with accompanying 60-mg pheromone lures during observation sessions. Lures were stored in a freezer when not in use. Two or three observers were positioned equidistantly and about 4 to 5 m from each bait stick. Observers recorded the time each weevil landed on the bait stick and, when possible, the duration of exposure. Observers also used light-duty insect collecting nets to capture departing weevils in flight. Captured weevils were placed individually in plastic 29.5-mL rearing cups, each containing a water-saturated cotton ball and closed by a labeled cardboard lid. Cups containing weevils were held in a chilled cooler until they were transported to the laboratory, where they were held 48 h at room temperature (~24ºC). Mortality was assessed at 24 and 48 h after capture. When several weevils responded to the bait stick simultaneously, it was difficult to accurately determine their respective durations of exposure. Thus, exposure duration was not recorded for some weevils. However, these weevils were included in efficacy samples when they were captured.

Efficacy of the bait stick against feral weevils also was estimated in forced-contact assays on the same dates that natural response was assayed. Weevils collected from Hercon Scout traps (Hercon Environmental Co., Emigsville, PA) previously established in the vicinity of the bait stick tests were destroyed at the beginning of each bait stick observation session. Newly captured weevils were collected from these traps at the end of each session and divided into a control group and forced contact groups used to assay the same bait sticks observed in the field. Weevils from the control group were introduced directly into the rearing cups upon arrival in the laboratory. Initial efforts to introduce weevils from the forced contact group to the treated portion of the bait stick were unsatisfactory because many of the weevils fell repeatedly, failed to grasp the treated surface, or feigned death when handled. To avoid excessive or unnatural exposure to the treated surface, weevils were introduced to the untreated base of the bait stick and subsequently prompted to walk over the treated surface. Weevils were exposed to the treated surface for 30 s, then carefully removed with forceps. On occasions when a weevil flew before completion of the 30-s exposure period, timing was stopped until the weevil was reintroduced to the bait stick. Forced contact and control weevils were held and evaluated in the same manner as those from the natural response assay.

Additional data regarding the proportion of weevils responding to the bait stick but not landing were recorded on seven dates (26, 27, 28, 31 Aug.; 1, 2, 4, Sept.). Weevils approaching from the downwind side of the bait stick and flying between the observers and the bait stick but not landing, or landing on the observers, cooler, or soil around the bait stick, were recorded as responding but not landing.

Mortality resulting from exposure to the bait sticks could not be analyzed in contingency tables due to low expected cell counts or zero counts. Likewise, the normal approximation for binomial data could not be used to examine differences in mortality among bait stick age classes because the proportions of weevils dying were too small relative to the sample sizes. Thus, comparisons of mortality among bait stick age classes and the control were assessed on the basis of 95% confidence intervals calculated from the respective binomial proportions using the F distribution method (Zar, 1984). The influence of bait stick age on duration of exposure of naturally responding weevils was examined in two statistical tests. Differences in the mean durations of exposure among bait stick age classes were examined by analysis of variance of the square root–transformed durations of exposure using the SAS procedure PROC GLM; means were separated using the REGWQ option (SAS Institute, 1988). This relationship also was examined in a contingency table (PROC FREQ, SAS Institute, 1988), initially with bait stick age classes as rows and duration of exposure expressed in 5-min classes as columns. Because cell counts were low for duration classes >10 min, the table subsequently was collapsed into two time classes (<5 min; >5 min). Sources of differences were interpreted with assistance of the CELLCHI2 option of PROC FREQ (SAS Institute, 1988). Observations of the propensity of responding weevils to land or not land on the bait sticks were not extensive enough to permit examinations of differences among bait stick age classes. Therefore, 95% confidence intervals for the proportions of weevils responding but not landing were calculated for each observation date, using the same procedures used in the assessment of mortality.

RESULTS AND DISCUSSION

Mortality of boll weevils exposed to the bait sticks was extremely low, regardless of the type of assay (Table 1). The only confidence intervals that did not span zero were those for 0-wk-old bait sticks at both 24 and 48 h after exposure, 1-wk-old bait sticks at 48 h after exposure, and the unexposed controls. Confidence intervals for weevils exposed to bait sticks of all age classes by either method overlapped each other and those for the unexposed controls.

The low levels of mortality observed in response to forced contact assays in this study were not consistent with reports of such assays by Villavaso et al. (1998) and Spurgeon et al. (1999), which indicated nearly complete mortality from forced contact with the bait stick. However, weevils were introduced directly to the treated bait stick surface in those studies. In the present study, weevils were introduced to the untreated portion of the bait stick and prompted to walk onto the treated surface. This procedure probably allowed a more natural response and may have minimized weevil contact with the toxicant. In contrast, observations reported herein of mortality resulting from natural response were consistent with the only other report of similar assays (Spurgeon et al., 1999). The combined results of these studies suggest that assay procedure can greatly influence estimates of bait stick efficacy, and that accurate estimates of efficacy may best be accomplished in field assays involving naturally responding weevils. Regardless of the method of assay, results of the present study indicated levels of efficacy unlikely to provide control or suppression of weevil populations.

Duration of exposure was recorded for 181 of the 275 boll weevils observed to land on the bait sticks. Despite the wide range of exposure times observed for all age classes, analyses indicated that mean time of exposure differed among bait stick age classes ($F = 6.23$; df = 4, 176; $P < 0.001$). Mean exposure time was shorter for 0-wk-old bait sticks than for any other age class except 1 wk old (Table 2). No differences in mean exposure time were demonstrated among age classes >1 wk old. The mean times of exposure observed in this study were somewhat shorter than that reported by Spurgeon et al. (1999) for bait sticks of unknown age, although the ranges in times of exposure were equivalent.

The contingency table analysis also indicated an effect of bait stick age class on exposure time, since a smaller proportion of the weevils tended to remain on the bait sticks for <5 min as bait stick age class increased ($X^2 = 18.815$, df = 4, $P < 0.01$; Table 2). Over all bait stick age classes, the proportion of

Table 1. Mortality of boll weevils exposed to bait sticks of different age classes in natural response and 30-s forced-contact assays.

Assay type	Bait stick age class		Mortality 24 h (95% C.I.)	Mortality 48 h (95% C.I.)
	wk		%	%
Natural response	0	40	5.00 (0.61–16.92)	10.00 (2.79–23.66)
	1	49	0 (0–7.25)	0 (0–7.25)
	3	50	0 (0–7.11)	0 (0–7.11)
	5	38	0 (0–9.25)	0 (0–9.25)
	7	47	0 (0–7.55)	0 (0–7.55)
Forced contact	0	60	1.67 (0.04–8.94)	6.67 (1.85–16.20)
	1	41	0 (0–8.60)	4.88 (0.60–16.53)
	3	60	0 (0–5.96)	0 (0–5.96)
	5	62	0 (0–5.78)	0 (0–5.78)
	7	40	0 (0–8.81)	0 (0–8.81)
Unexposed control	-	96	1.04 (0.03–5.67)	3.13 (0.65–8.86)

Table 2. Durations of exposure of boll weevils naturally responding to bait sticks of different age classes.

Bait stick age class	n	Mean exposure time†	SE	Range	Weevils exposed <5 min
wk		min		min	%
0	47	1.73 a	0.390	0.02–11.65	91.49
1	40	4.61 ab	1.576	0.02–60.50	80.00
3	25	8.46 b	3.028	0.07–73.00	56.00
5	29	4.90 b	0.851	0.17–14.13	62.07
7	40	7.94 b	2.409	0.02–94.67	57.50

† Means followed by the same letter are not significantly different (α = 0.05, Ryan-Einot-Gabriel-Welsch multiple-range test).

weevils remaining on the bait sticks for <5 min was about 72%, which was higher than the estimate of 48% reported by Spurgeon et al. (1999) for bait sticks of unknown age.

About 74% of the 268 boll weevils observed to respond to the bait stick did not land on the device. Although these weevils often continued to fly in the vicinity and even to circle the bait stick, in no instance were they observed to return and land on the bait stick. The proportion of weevils responding but not landing varied among observation dates, but computed confidence intervals for individual dates of observation were broadly overlapping (Table 3). The proportion of weevils responding but not landing was >68% on all dates when >20 weevils were observed. Estimates of the proportions of weevils responding to the bait stick but not landing are probably conservative because efforts to time and capture landing weevils may have prevented the detection of some responding weevils.

Table 3. Percentages of boll weevils responding but not landing on bait sticks in the field on different observation dates.

Observation date	Bait stick age class	n	Not landing (95% C.I.)
	wk		%
26 Aug.	7	53	69.81 (55.66–81.66)
27 Aug.	1	74	81.08 (70.30–89.26)
28 Aug.	7	42	80.95 (65.88–91.40)
31 Aug.	7	23	78.26 (56.30–92.54)
1 Sept.	0	6	50.00 (11.81–88.19)
2 Sept.	7	13	61.54 (31.58–86.14)
4 Sept.	1	57	68.42 (54.76–80.09)

These results indicate that even if a high-level of efficacy could be obtained from exposure to the bait stick, control or suppression of field populations may not be achieved due to the high proportion of weevils that do not land on the device. Thus, field studies of bait stick efficacy should incorporate estimates of field populations in addition to estimates of the numbers of weevils killed.

CONCLUSIONS

Examinations of efficacy of the commercially available bait stick against the boll weevil indicated that both bait stick age and assay method can influence estimates of efficacy. Regardless of these factors, observed levels of mortality were probably too low to influence field populations. These results, combined with observations that most boll weevils responding to the bait stick do not land on it, emphasize the need to monitor field populations as well as the numbers of weevils killed by the device in studies of boll weevil control or suppression.

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