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Efficiency of Tank-mixing Insecticide with Defoliant Against Adult Boll Weevil (Coleoptera: Curculionidae) Populations as Determined by Late-season Field Disturbance Trapping

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ABSTRACT

Large commercial field plots were used to assess the effect of tank-mixing cyfluthrin with a defoliant applied in preparation for cotton, *Gossypium hirsutum* L., harvest on adult boll weevil, *Anthonomus grandis grandis* Boheman, populations in south Texas during 2002 and 2003. The defoliant-insecticide tank mix reduced boll weevils compared to the defoliant-only control during the time between defoliant application and harvest in only one of the two experiments. During the same time interval, multiple trap deployment reduced weevil populations by at least as much as the tank mix. Tank mixing a single-pulse insecticide-defoliant treatment to prepare the crop for harvest, and deployment of multiple traps did not consistently affect boll weevil populations, but multiple traps reduced populations throughout the duration of each year's experiment. Because of that, and logistical constraints associated with multiple trap deployment, adoption of mass trapping in cotton fields is not recommended, nor is tank-mixing an insecticide with a defoliant recommended for achieving late-season suppression of boll weevil populations.

Additional Index Words: Anthonomus grandis grandis, cotton, field disturbance, trap

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The boll weevil, *Anthonomus grandis grandis* Boheman, is originally from the tropics and subtropics of Mesoamerica (Burke et al., 1986), and its distribution extends from the United States Cotton Belt to Brazil and Argentina (Scataglini et al., 2000; Cuadrado, 2002). Although functionally eradicated throughout much of its temperate United States distribution (Barker et al., 2001), boll weevil populations can build to substantial levels by late in the cotton, *Gossypium hirsutum* L., growing season in the subtropics (Showler, 2003, 2007). Large, 5.5–8-mm-diameter, cotton squares (flower buds), preferred for both feeding and oviposition (Showler, 2005), abscise »6 d after oviposition occurs in the subtropical Lower Rio Grande Valley of Texas (Showler and Cantú, 2005) when third instars have developed (Coakley et al., 1969). Adults emerge from the fallen fruit ~10–12 d later (Showler and Cantú, 2005). Boll weevils reside within fallen cotton fruit after harvest (Showler, 2003) and some can survive there through the winter season in subtropical and tropical climates (Guerra et al., 1984; Greenberg et al., 2004). The aim of late-season control of adult boll weevils with insecticides is to reduce populations before the onset of winter (Brazzel et al., 1961). In temperate climates, winter causes substantial mortality before cotton square formation during the following spring, which is a key feature of boll weevil eradication strategy (Brazzel et al., 1961).

Because subtropical conditions permit boll weevil reproduction year-round (Guerra et al., 1982; Summy et al., 1988) on alternative reproductive hosts (plants that enable boll weevil reproduction by supplying the nutrients and sites for development to adulthood [Showler, 2008b]) and volunteer cotton (Cross et al., 1975; Summy et al., 1988; Rummel and Summy, 1997), mid- and late-season population suppression tactics applied during the cotton growing season (Showler and Robinson, 2005; Slosser, 1993; Showler et al., 2005) are important for routine crop protection. Effects on eradication efforts, however, have not been determined.

Large capacity pheromone-based boll weevil traps can measure "spikes" in boll weevil captures in the days following significant disturbances to cotton fields, particularly routine late-season operations such as defoliant application, harvest, and stalk-pulling or –shredding (Showler 2003). The technique has been used to demonstrate that substantial adult boll weevil populations remain in cotton fields even after each disturbance (Showler 2003). The purpose of this study was to assess, using the field disturbance technique, the efficiency of mixing an insecticide with the pre-harvest defoliant for suppressing adult boll weevil populations before winter.

MATERIALS AND METHODS

Two field plot experiments using Fibermax 989 cotton were conducted during the summers of 2002 and 2003 in Hidalgo County, TX. During the 2002 experiment, most of a 35-ha commercial cotton field was divided into eighteen 1.6-ha plots, each 100 rows (1-m row spacing) wide by 164 m long. In 2003, part of a 50-ha field was divided into eighteen 1.1-ha plots, each 100 rows by 221 m.

All plots were defoliated with s,s,s-tributylphospohorotrithioate (Bayer, Kansas City, MO) at a rate of 1.6 kg (AI)/ha, on 22 July 2002 and on 1 August 2003 using a tractor-mounted boom. During each year, six plots were also sprayed with 0.4 ml (AI)/liter cyfluthrin (Baythroid, Bayer, Kansas City, MO) tank-mixed with the defoliant. Applications were made through 16 Teejet 8003E nozzles, two angled toward each row, and two 47-cm drop nozzles sprayed the sides of each row at a pressure of 3.5 kg/cm^3 (1.6 liters/min/nozzle). Large capacity traps (Showler 2003) were deployed on a 15.25 x 30.5-m grid pattern, constituting a "multiple traps" treatment, throughout six other plots to assess impacts of mass trapping on late-season populations. The remaining six plots, controls, did not have multiple traps or cyfluthrin in the defoliant. The treatments were arranged in a randomized complete block design.

Harvest was conducted using six-row mechanical spindle harvesters on 30 July 2002 and on 13 August 2003. Shredding, using a six-row flail shredder, was conducted on 7 August 2002 and 27 August 2003, and stalk-pulling occurred on 10 and 30 August in 2002 and 2003, respectively.

Two large capacity boll weevil traps (Showler, 2003) were placed 20 m apart on the leeward edge of each plot 2 July – 25 August 2002 and 27 July – 2 September 2003. Boll weevil captures were recorded from those traps every 2 d.

Three 3-m-long screens, each wide enough to span a furrow between row tops, were placed in randomly selected sections of furrow in every plot and left there for 7 d after the defoliant was applied. Screens were checked daily for the presence of dead boll weevils, including body parts, and for ants that might have been scavenging for dead weevils.

Repeated measures ANOVA was used to detect treatment differences in numbers of adult boll weevils collected on the sampling traps, and means were separated using Tukey's HSD (Analytical Software, 1998). One-way ANOVA was used to detect treatment differences between cumulative numbers of adult boll weevils collected on the sampling traps before, between, and after field operations (i.e., defoliant application, harvest, and shredding/stalk pulling) (Analytical Software, 1998).

RESULTS

During 2002, numbers of weevils collected on the sampling traps were greater in the control and lower in the multiple trap treatment than in the tank-mix treatment over the two sampling times between defoliant application and harvest (F = 49.50, df = 2, 15, P < 0.0001) (Fig. 1A). Mean numbers of weevils collected on the sampling traps in the multiple trap treatment were lower than in the insecticide treatment across the seven sampling times between harvest and shredding (F = 4.88, df = 2, 90, P = 0.0092) and greater than in both other treatments and across the six sampling times after stalk pulling (F = 23.03, df = 2, 75, P < 0.0001) (Fig. 1A). Cumulative numbers of adult boll weevils collected on the sampling traps between defoliant application and harvest were 2.4-fold greater in the control than the multiple trap treatment (F = 7.78, df = 2, 10, P = 0.0092) (Fig. 2A). After stalk pulling, the insecticide treatment yielded 2.6-fold more (F = 4.71, df = 2, 10, P = 0.0363) cumulative weevils than the multiple trap treatment (Fig. 2A).

During 2003, treatment differences were not detected before or during defoliation, between harvest and shredding, or after stalk pulling (Fig. 1B), nor were treatment effects observed for cumulative numbers of adult boll weevils (Fig. 2B). No boll weevils or ants were found in any of the furrow screens during either year.

DISCUSSION

A mark-recapture study reported boll weevils as moving out of small cotton plots in the days leading up to defoliant application (Sappington et al., 2002). Another report, based on vacuum sampling in small plots for adult boll weevils, concluded that boll weevil populations among cotton plants treated with s,s,s-

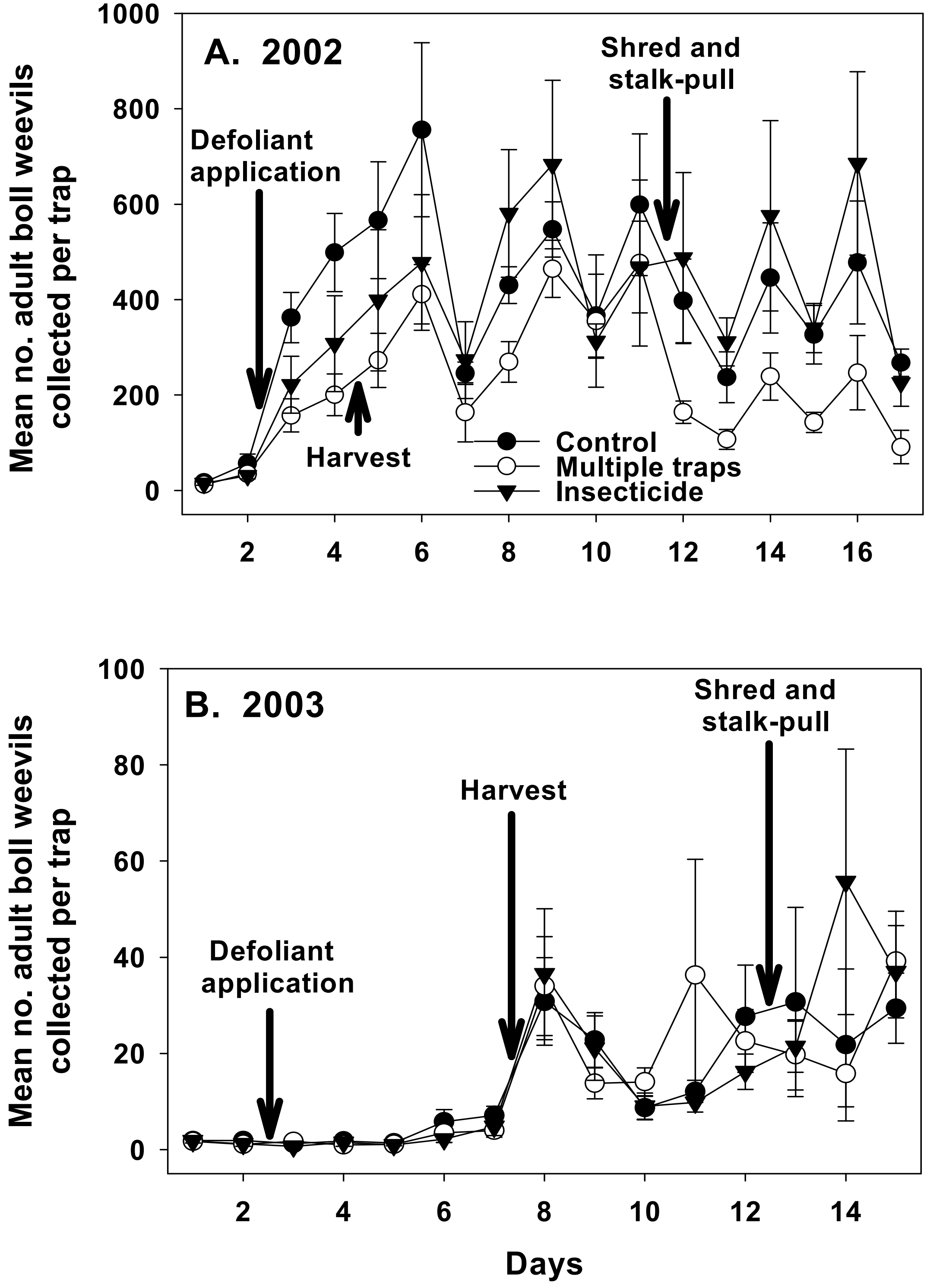

Fig. 1. Mean (±SE) numbers of adult boll weevils collected per sampling trap (n = 12 per treatment) during routine late-season field operations in August 2002 (A) and 2003, Hidalgo County, Texas (B).

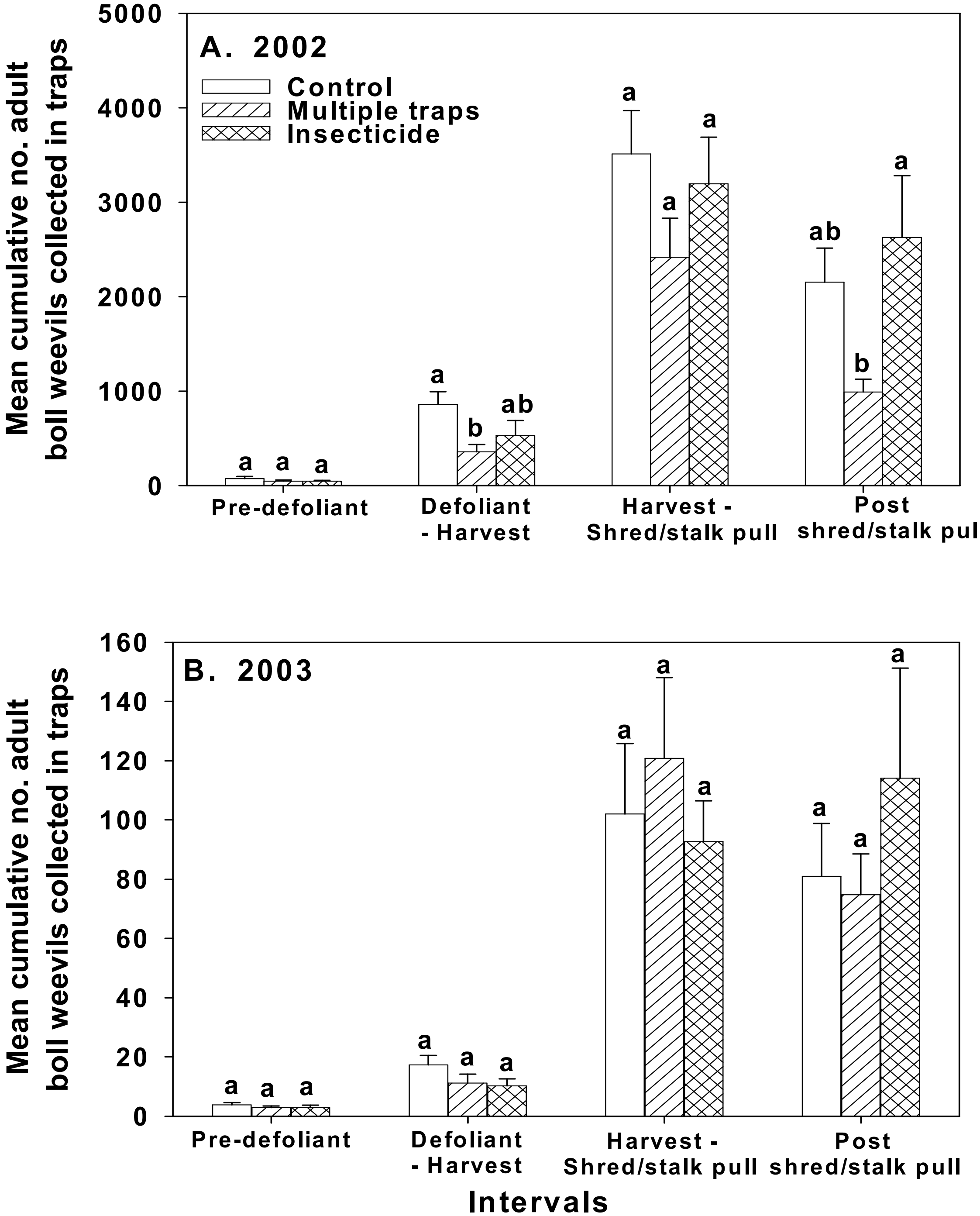

Fig. 2. Mean (±SE) cumulative numbers of adult boll weevils collected per sampling trap (n = 12 traps per treatment) during routine late-season field operations in August 2002 (A) and 2003, Hidalgo County, Texas (B).

tributylphospohorotrithioate decline by three days post-treatment (Greenberg et al., 2002). S,s,s-tributylphospohorotrithioate is only slightly toxic to boll weevils (Greenberg et al., 2001), and the reduction in populations after treatment of plots with s,s,s-tributylphospohorotrithioate was attributed to dispersal (Sappington et al., 2001; Greenberg et al., 2002). Dispersal occurs to some extent when the cotton plants desiccate (Showler, 2003), but large-scale movement away from late-season cotton fields undergoing harvest-related operations is gradual (Showler, 2006, 2007). Sappington et al's (2001) findings, however, are problematic because their field plots were six rows wide by 112 m long to assess the impact of seven different chemical treatments and a control, each replicated only three times, and the mark-recapture experiment relied on pheromone traps placed exclusively on the outermost edges of the fields (Sappington et al., 2002). Greenberg et al. (2002, 2004), also using narrow plots (six rows), reported that defoliant-insecticide (insecticides applied at half recommended rates) combinations provided “control” of boll weevils, based solely on dead adults found on 3-m-long furrow screens, as well as insecticides applied at their full rates. Given the mobility of adult boll weevils, particularly during and after defoliant application (Showler, 2003), the small plot sizes used by Sappington et al. (2001) and Greenberg et al. (2002, 2004) confound the ability to accurately measure dispersal or mortality in such close proximity to other treatment plots.

Two defoliants, s,s,s-tributylphospohorotrithioate and thidiazuron, applied in combination with either lambda-cyhalothrin or azinphosmethyl caused adult boll weevil mortality in the laboratory (Greenberg et al., 2004). Mortality under field conditions from the same treatment was measured using stationary screens laid in furrows to collect dead weevils (Greenberg et al., 2004) but low adult movement between the narrow plots was assumed based on a flawed mark-recapture experimental design (Sappington et al., 2001). The furrow screens used in the field portion of that study collected cumulative maximums of only 1.5 weevils across three days in the Lower Rio Grande Valley where late-season adult populations are large (Showler, 2003). In our study, using screens of approximately the same size, no dead boll weevils were observed, even in the plots receiving the recommended rate of cyfluthrin combined with the defoliant.

Despite 9–10 insecticide treatments against boll weevils from the first development of pinhead (1–2-mm-diameter) squares until a week before the defoliant was applied, adult populations in Lower Rio Grande Valley cotton fields were substantial following defoliation, harvest, and stalk-pulling or shredding operations (Showler, 2003). This study demonstrated a somewhat greater impact was apparent in the multiple trap treatment on adult boll weevil numbers than in the insecticide-defoliant tank mix treatment. Similarly, Greenberg et al. (2004) did not find reduced field populations after application of insecticide and defoliant (alone and in combination) treatments.

Cleveland and Smith (1964) claimed that cotton fields treated with s,s,s-tributylphospohorotrithioate alone, or in combination with a desiccant, reduced boll weevil populations more than insecticides, including azinphosmethyl. However, they made up to eight weekly applications after harvest when defoliants are not normally applied. Also, none of the insecticides they used are currently registered for use against boll weevils in the United States, half of their treatments were not replicated, different fields were used for each treatment rather than a single field with replicated treatment plots, and significant differences, standard errors, or other measures of variation, were not reported.

Adult boll weevils move in response to host plant disturbances, including chemical desiccation of cotton plants in large commercial cotton field plots (Showler, 2003, 2006, 2007). Pre-defoliant-application and post-defoliant-application (£5 d) large capacity trap collections, however, showed no increase in boll weevils responding to the pheromone lure or passively (without the pheromone lure) contacting the sticky surface of each trap until desiccation of the cotton plant occurred (>5 d) (Showler, 2003; Showler, 2008a). The physiological change in the host plant might represent a greater disturbance to adult boll weevils than the actual application of the defoliant.

The lack of dead boll weevils in the furrow screens indicates that adult boll weevil mortality under field conditions might have been negligible, as demonstrated by Greenberg et al. (2004). It is, however, understood that insecticides registered for boll weevil control are lethal to sprayed adult weevils within 30 min (Showler and Scott, 2004), although none of the insecticide residues are lethally toxic beyond four days, even in petri dish assays where weevils are confined with insecticide-treated leaf surfaces (Showler et al., 2002; Showler and Scott, 2004). Developing boll weevils are protected inside cotton fruit as eggs, larvae, and pupae until adult emergence from the husk, »17 d in the Lower Rio Grande Valley (Showler and Cantú, 2005). Applied to fallen fruit harboring immature boll weevil stages, insecticide effects are negligible to the weevils inside.

Densely deployed large capacity boll weevil traps on the edges of cotton fields can affect changes in adult boll weevil numbers in large field plots (e.g., 150 rows wide by 200 m long) (Showler, 2003), hence the deployment of the traps on a grid within the plots was expected to reduce boll weevil captures in the sampling traps at least to some extent.

The absence of differences between the control and the defoliant-insecticide treatment before, during, and after the routine field operations (excluding the interval between defoliant application and harvest during 2002) indicates that the tank-mix impact on boll adult weevil numbers was negligible. When the multiple traps were removed at stalk-pulling, leaving only the two sampling traps in each plot, numbers of collected adult boll weevils remained lower in those plots than in the control or the insecticide treatment during the 2002 experiment. However, rather than suggesting that multiple trapping is effective at suppressing adult boll weevil populations during routine late-season field operations (multiple trapping is logistically impractical, labor-intensive, and large populations, even if somewhat below those of the other treatments, remained), these findings demonstrate that the defoliant-insecticide tank mix did not achieve measurable suppression of adult boll weevils. Hence, tank-mixing insecticide with defoliant for late-season boll weevil population suppression is not recommended.

The tactic of in-season mass-trapping for boll weevils has produced mixed results (Hardee et al., 1971; Boyd et al., 1973; Daxl et al., 1995; Langston, 1996; Fuchs and Minzenmmayer, 1992; Karner and Goodson, 1993; Villavaso et al., 1998; Showler, 2003), which is understandable given that the point-sources of grandlure must compete with volatiles emanating from hundreds of thousands of cotton plants. However, with the knowledge that adult boll weevils accumulate during the off-season in citrus orchards and possibly other "hot spots," mass trapping of populations concentrated in those relatively compact areas without the allure of cotton might be a more effective application of that tactic.

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