ATTRACTION OF DISPERSING BOLL WEEVILS FROM SURROUNDING HABITATS RELATIVE TO SIMULATED PHEROMONE DIFFUSION FROM TRAPS

John K. Westbrook
Charles P.-C. Suh
Ritchie S. Eyster
USDA-ARS, Insect Control and Cotton Disease Research Unit
College Station, TX

Abstract

The ability to detect populations of boll weevils, *Anthonomus grandis* (Boheman), with pheromone traps has contributed significantly in progress toward eradication of the boll weevil. However, new information is needed to aid in the interpretation of trap captures, such as identification of habitats from which boll weevils likely dispersed to the pheromone traps. A model was developed in the ModelBuilder modeling environment of ArcGIS using weather data to estimate daily pheromone plume diffusion from traps placed along the perimeter of a cotton field at Rio Medina, TX. In turn, we summarized weekly composites of daily estimated plumes and overlaid the plumes on a geo-referenced satellite image of the cotton field and surrounding landscape features. Trap data were regressed with the spatial plume coverage relative to landscape feature classes. Relationships between weevil trap data and pheromone plumes may lead eradication program managers to consider strategic changes in trapping protocols for specific locales.

Introduction

An effective trapping program is critical to the success of boll weevil eradication. Proper deployment of traps baited with grandlure and interpretation of trap data requires knowledge of the landscape surrounding the trap. In most cases, traps are located around the perimeter of cotton fields during the active phase of eradication. These traps may border other crops or cotton fields, pasture, water bodies, and other natural or man-made features.

The relative location of pheromone traps may significantly influence trap captures in two major ways. First, vegetation and other natural or man-made structures near a trap may create a windbreak that moderates the wind speed, thus accommodating weevil flight upwind to the trap (Sappington and Spurgeon 2000). Second, non-cotton landscape features, such as trees or riparian vegetation, may harbor overwintering or immigrant weevils prior to their dispersal into cotton fields. Westbrook et al. (2003) indicated overwintered boll weevils emerged from leaf litter in pulses throughout the spring, and Beerwinkle et al. (1996) reported higher captures of boll weevils in non-cropped areas than in cropped areas during the early spring. The objectives of this study were to relate the estimated weekly pheromone plume coverage to the weekly number of boll weevils captured in traps to determine which habitat(s) may be contributing weevils that infest cotton.

Methods

Geo-referenced trap data from 20 April to 24 June, 2009, were acquired from the Texas Boll Weevil Eradication Foundation, during the period of cotton plant development from cotyledon to bloom stage. The data had been collected weekly from 36 pheromone traps spaced at an interval of approximately 76.2 m (250 feet) along the perimeter of a cotton field at Rio Medina, TX. The trap locations relative to seven landscape feature classes were mapped to a georeferenced satellite image of the area (Fig. 1). Starting with trap 1 at the northeastern corner of the field and proceeding counterclockwise, eight traps each were assigned to the northern and southern traplines, nine traps to the western trapline, and 11 traps to the eastern trapline. A VantagePro weather station (Davis Instruments, Hayward, CA), located in an environment with a northern exposure at the southeastern corner of the cotton field (Medina3: 29.453°N, 98.899°W), collected hourly weather data and was used to determine daily mean wind direction. A WeatherMonitor weather station (Davis Instruments, Hayward, CA) located in an open environment 6.88 km west of weather station Medina3 (Medina1: 29.449°N, 98.970°W) was used for microclimatic comparisons.

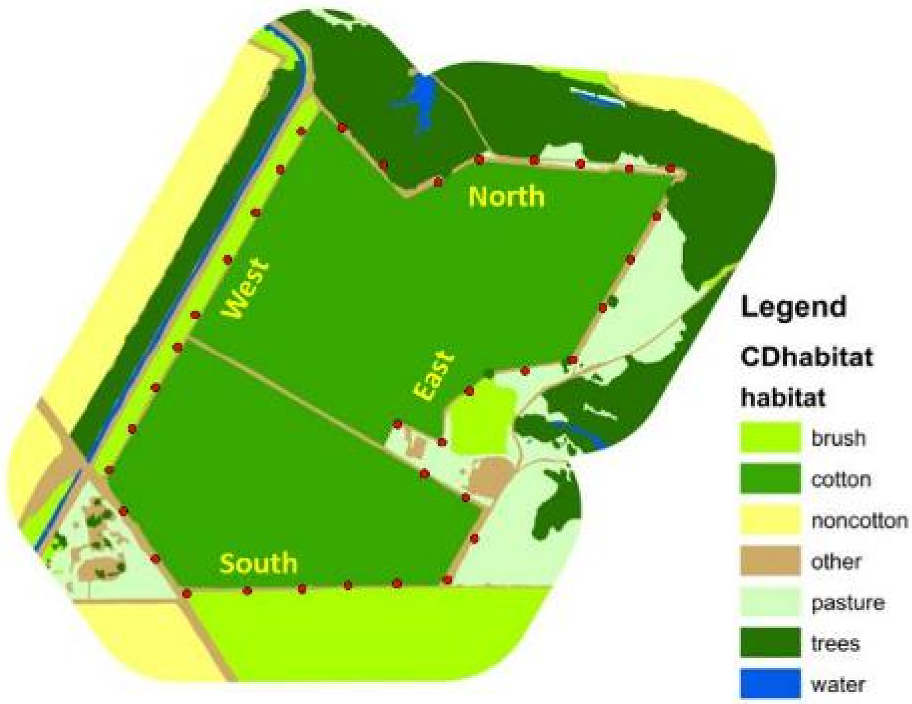

Figure 1. Geo-referenced cotton field, surrounding landscape features, and boll weevil traps (solid red circle symbols) at Rio Medina, TX, in 2009.

The ModelBuilder modeling environment in ArcGIS version 9.3.1 (Esri, Redlands, CA) was used to estimate daily pheromone plumes from each trap. Plume dimensions were constructed by assuming a 22.5° plume spread centered on the daily dominant wind direction (in one of 16 sectors) and a hypothetical effective weevil attraction range of 100 m. The coverage of pheromone plumes into one or more of the seven landscape feature classes (i.e., cotton, non-cotton crops, trees, brush, pasture, water, and other) were estimated for each trap using a constant value of the prevailing wind direction. Weekly composites of daily estimated plumes were constructed and overlaid on the geo-referenced satellite image of a cotton field and surrounding landscape.

Results

Overall, the highest weekly mean capture of boll weevils (3.0 per trap) occurred during the week of 23-29 April. Maximum capture of boll weevils in the northern and western traplines also occurred during the week of 23-29 April. In comparison, the greatest numbers of weevils captured in the southern and eastern traplines occurred the week of 28 May – 3 June (Table 1). However, trap data were unavailable during the period from 30 April to 14 May, apparently due to data recording errors.

Table 1. Weekly mean (SEM) number of boll weevils captured in pheromone traps at Rio Medina, TX, in 2009.

	Boll Weevils (no. / trap)				
Date	Northern	Western	Southern	Eastern	Total
20-22 April	0.3 (0.3)	0.2 (0.2)	0.1 (0.1)	0.9 (0.9)	0.4 (0.3)
23-29 April	4.0 (0.9)	5.8 (1.8)	1.3 (1.0)	1.0 (0.3)	3.0 (0.6)
30 April – 14 May	n/a	n/a	n/a	n/a	n/a
15 – 20 May	1.9 (0.8)	1.2 (0.6)	0.6 (0.4)	1.2 (0.5)	1.2 (0.3)
21 – 27 May	0.1 (0.1)	1.3 (0.5)	0.9 (0.7)	0.7 (0.4)	0.8 (0.2)
28 May – 3 June	1.1 (0.6)	4.0 (1.5)	1.4 (0.7)	2.0 (0.6)	2.1 (0.5)
4 – 9 June	1.5 (1.0)	0.2 (0.1)	0.4 (0.2)	1.3 (0.6)	0.9 (0.3)
10 – 16 June	0.3 (0.2)	0.6 (0.3)	0.3 (0.2)	0.4 (0.2)	0.4 (0.1)
17 – 24 June	0.4 (0.3)	0.0 (0.0)	0.6 (0.4)	0.1 (0.1)	0.3 (0.1)

Examples of the estimated daily plumes diffusing from pheromone traps are shown for 23-29 April (Fig. 2a) and 28 May – 3 June (Fig. 2b). Mean weekly trap captures are denoted by a circular symbol at each trap location; a small circle indicates no capture, and a larger circle indicates a capture of one or more. The distinctive gray-scale patterns of each plume represent the feature classes of habitats into which the plume was estimated to have diffused. The maximum capture of boll weevils in the western trapline on 23-29 April occurred when plumes diffused away from the cotton field. Substantial plume diffusion away from the cotton field occurred on 28 May – 3 June when traps in the eastern trapline captured a maximum number of boll weevils.

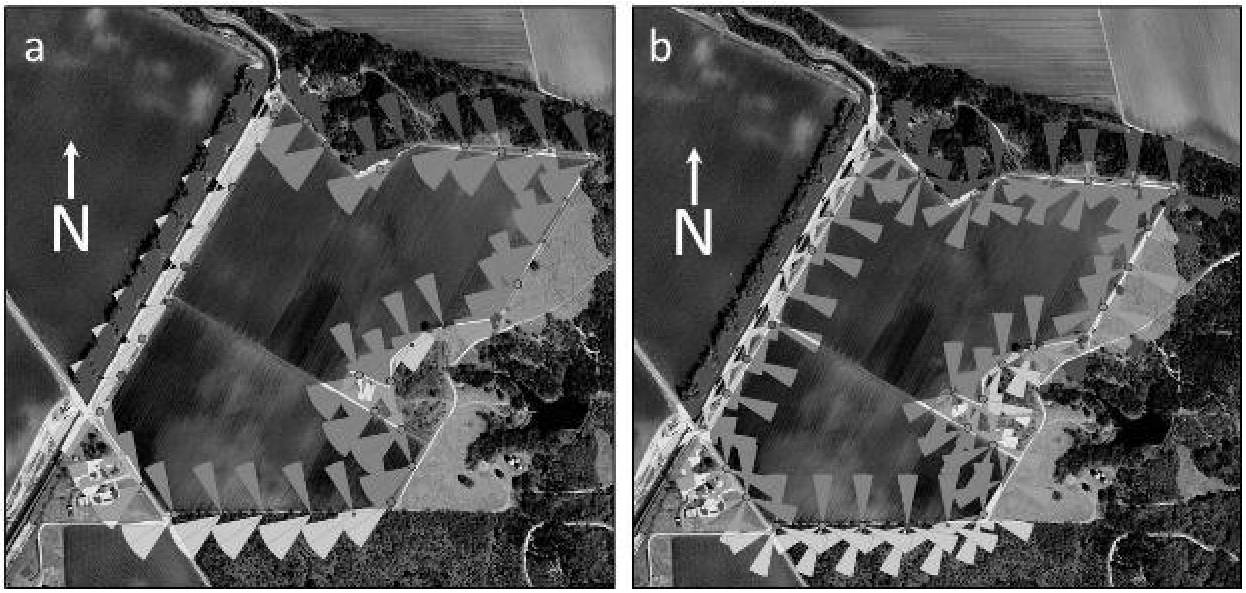

Figure 2. Simulated diffusion of pheromone plumes from boll weevil traps at Rio Medina, TX, on (a) 23-29 April 2009 and (b) 28 May – 3 June 2009.

Mean boll weevil captures varied as a function of the habitat coverage by the estimated pheromone plumes. Captures in the eastern, northern, and southern traplines were positively correlated with the percentage coverage of pastures, while coverage of trees and brush combined and non-cotton crops were negatively correlated (Table 2). The regression of boll weevil captures and estimated plume coverage was significant for the eastern and southern traplines, but not significant for the northern and western traplines (Table 2).

Table 2. Linear regression of mean weekly boll weevil captures and estimated weekly pheromone plume coverage of habitats at Rio Medina, TX, from 20 April – 24 June, 2009.

Trapline	Regression	r^2	df	F	Prob > F
Eastern	Y = 0.05*Pasture - 0.03*TreesBrush - 0.27	0.91	2,5	24.59	0.0026
Northern	Y = 0.08*Pasture + 0.07	0.39	1,6	3.86	0.0970
Southern	Y = 0.08*Pasture - 0.06*NonCotton - 0.18	0.98	2,5	103.92	< 0.0001
Western	Y = 0.05*Water - 0.15	0.33	1,6	3.00	0.1342

An example of diverse relationships between boll weevil captures and pheromone plume coverage of habitats is shown for cotton and for trees and brush combined (Fig. 3). During the week of 23-29 April, boll weevil captures were positively correlated with pheromone plume coverage of trees and brush, but negatively correlated with pheromone plume coverage of cotton.

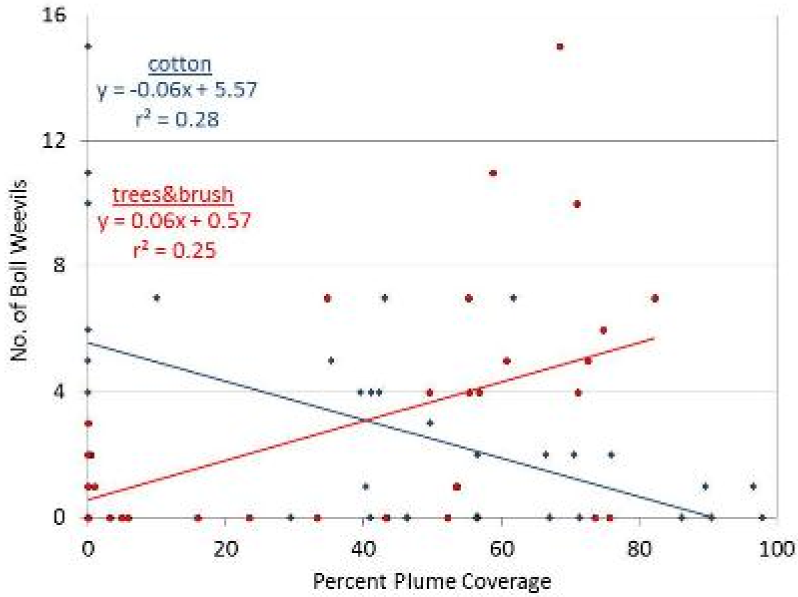

Figure 3. Capture of boll weevils in traps relative to estimated coverage of pheromone plumes into (a) trees and brush and (b) cotton at Rio Medina, TX, on 23-29 April 2009.

Comparison of wind direction measurements from two proximal weather stations near Rio Medina revealed a significant influence of brush and trees in creating a substantial wind break for prevailing east-southeast winds (Fig. 4). A weather station, located in an open environment (Medina1), recorded a consistent pattern of wind speed with a daily maximum of 5-8 m s^{-1}. However, the weather station with a northern exposure (Medina3) located on the perimeter of the cotton field study site recorded wind speed values greater than 1 m s^{-1} only when the wind had a northerly component.

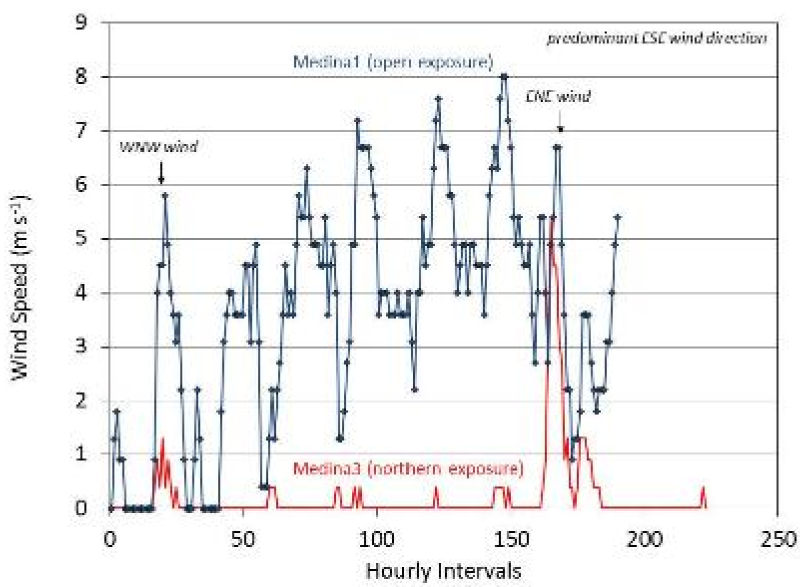

Figure 4. Wind speed measurements at an open-exposure (blue line with marker symbol) and a northern exposure (red line) location at Rio Medina, TX, on 20-29 April 2009.

Discussion

Daily trap data are needed to improve the resolution of seasonal relationships between boll weevil captures and plume coverage of landscape features. Influences of air temperature, lure age, and lure formulation on the release rate of grandlure from traps (Westbrook and Suh 2010, 2012) are known to affect the release rate of pheromone from traps. Further, wind speed influences the plume spread and consequently the effective area of attraction. Incorporating estimated daily release rate of pheromone from lures could alter the effective range of the pheromone plume in plume model simulations. Also, when the prevailing wind direction is aligned with a trapline, more boll weevils tend to be captured by upwind traps than by downwind traps (Sappington 2002).

In our study, a plume simulation model was developed and applied to estimate the plume coverage of proximal set of landscape features around each boll weevil trap. Increased plume coverage of specific proximal landscape features (e.g., pasture) was found to be associated with increased captures of boll weevils. Interestingly, the greatest number of weevil captures occurred in traps along the western side of the field when the pheromone plume was diffusing away from the cotton field. These results suggest weevils captured in the traps originated from outside of the field. Consequently, captures of weevils in traps during the early growing season may reflect weevils coming to fields rather than weevils that are already in the fields.

The study demonstrated that a pheromone plume diffusion model can aid in the interpretation of boll weevil trap data. Relationships between boll weevil trap data and pheromone plumes may lead to identification of local habitats (e.g., overwintering landscape features) and strategic modification of trapping protocols (e.g., placement of additional traps such that pheromone plumes substantially diffuse into suspected boll weevil habitats) to enhance detection of weevil populations. Consideration of pheromone plume diffusion in the placement of traps and interpretation of trap data may improve eradication progress in South TX, and provide eradication program managers with information to make sound decisions regarding trap spacing and placement during post-eradication.

Acknowledgment

Mike O'Neil and Derrick Hall provided field technical assistance. Larry Smith, Darrell Dusek and Hans Lewis of the Texas Boll Weevil Eradication Foundation provided the boll weevil trap data. Rodney Sams and Joey Lamon arranged access for the installation of a weather station near a cotton field at Rio Medina, TX. Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

References

Beerwinkle, K.R., J.D. López, Jr., and G.H. McKibben. 1996. Seasonal responses of boll weevils to pheromone traps in cropped and adjacent uncropped areas of east-central Texas. Southwestern Entomol. 21: 407-419.

Sappington, T.W. and D.W. Spurgeon. 2000. Variation in boll weevil (Coleoptera: Curculionidae) captures in pheromone traps arising from wind speed moderation by brush lines. Environ. Entomol. 29: 807-814.

Sappington, T.W. 2002. Mutual interference of pheromone traps within trap lines on captures of boll weevils (Coleoptera: Curculionidae). Environ. Entomol. 31: 1128-1134.

Westbrook, J.K., D.W. Spurgeon, R.S. Eyster, and P.G. Schleider. 2003. Emergence of overwintered boll weevils (Coleoptera: Curculionidae) in relation to microclimatic factors. Environ. Entomol. 32: 133-140.

Westbrook, J.K. and C.P.-C. Suh. 2010. Investigation of pheromone-based factors that may reduce capture of boll weevils in traps. Proc. Beltwide Cotton Conf. pp. 994-998.

Westbrook, J.K. and C.P.-C. Suh. 2012. Influence of temperature on the rate of grandlure released from boll weevil pheromone lures. Proc. Beltwide Cotton Conf. pp. 921-927.