VALIDATION OF BOLLWORM MIGRATION ACROSS SOUTH-CENTRAL TEXAS IN 1994-1996

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Abstract

Research was undertaken to validate estimates of long-distance flights of adult male bollworm, *Helicoverpa zea*, using a network of pheromone traps in northeastern Mexico and south-central Texas. Captured bollworm moths were examined for external contamination of citrus pollen and internal contamination of *Lycopodium clavatum* spores. Moths contaminated with citrus pollen were captured throughout the network of pheromone traps as far as 661 km from the nearest location of commercial citrus production in the Lower Rio Grande Valley (LRGV) during February and March. Moths which consumed a feeding attractant/stimulant mixture with *Lycopodium clavatum* spores were captured as far as 230 km north of treated corn fields in the LRGV in June 1996. Estimated nightly insect flight trajectories from Weslaco (LRGV) and local minimum air temperatures were well correlated with capture events of citrus pollen-contaminated bollworms in February and March 1994 ($\chi^2 = 60.556$; 3 df; $P < 0.0001$). Results show that probabilities of capture events can be estimated for specific recipient locations, and suggest that the insect flight trajectory method can be applied to other dates and source areas. These findings strongly support a need to suppress dispersal of bollworm moths that jeopardize the effectiveness of pest (and pest resistance) management on an areawide basis.

Introduction

The bollworm, *Helicoverpa zea* (Boddie), is a primary pest of cotton and other important food and fiber crops in the U.S. The flight capability of bollworm moths allows them to migrate and infest ephemeral host plant habitats that vary due to seasonal climatic trends and cultural practices. The occurrence and magnitude of bollworm migrations have been difficult to estimate because moths fly at night, at high altitudes, and over large distances. Early migration studies were based on circumstantial evidence from knowledge of the magnitude and occurrence of moths in traps, local insect population dynamics, synoptic weather conditions, and insect population dynamics and moth flight in known habitats (Johnson 1995).

Significant progress in insect migration studies was achieved by detecting exotic pollens on the exterior of captured moths. Hendrix et al. (1987) identified calliandra and Texas ebony pollen on bollworm moths captured in Arkansas, although the nearest distribution of these plants is in south-central Texas. Lingren et al. (1993, 1994) found citrus and other pollen on bollworms captured in traps in Oklahoma and with the use of estimated insect flight trajectories determined that the moths had migrated at least 700 km from southern Texas, Mexico, or the Caribbean region. These field studies proved the migratory flight capability of feral bollworm moths without the need for mark-release-recapture programs.

This paper reports research on validating estimates of the distance and direction of bollworm migration from the Lower Rio Grande Valley (LRGV) across Texas using biological markers. The objectives of this study were: (1) to identify bollworms that had migrated from the LRGV or from locations farther south in Mexico; (2) to develop a predictive model for long-distance flight of bollworms; and (3) to validate estimates of long-distance flights of bollworms for several capture events.

Methods

At least one Hartstack pheromone trap baited with a Hercon Zealure® bait was installed at numerous locations near citrus orchards, corn fields, other field crops, or pastures in south and central Texas. Trap baits were replaced every two weeks. Traps were sampled daily. Captured moths were frozen and later prepared for examination by scanning electron microscopy or light microscopy. Capture events (dates of capture of moths marked with *Citrus* spp. pollen or *Lycopodium clavatum* spores) rather than absolute numbers of capture moths were used in subsequent analyses because of possible cross contamination of moths within the pheromone trap.

Application of a biological marker was necessary in June when no known natural marker was unique to the LRGV. *Lycopodium clavatum* spores were acetolyzed (Erdtman 1960) and suspended in a feeding attractant / stimulant mixture for adult bollworms. The mixture was sprayed onto senescent corn fields at Hargill (LRGV), Texas, on the nights of 7-8 June 1996. Direct captures were made in the treated fields to determine the effectiveness of the marking technique. Captured feral bollworms were dissected and examined with light microscopy for the presence of spores in their digestive tract.

Forward wind trajectories were computed using interpolated wind velocity data at 500 m above ground level (AGL). An estimated insect flight displacement vector (10 knots) was computed for each hourly way point along each wind trajectory to check for possible flight of insects from the LRGV to each trap location (Westbrook et al. in press). These trajectories estimated the minimum number of hours required for insects to reach each trap nightly. One-day and two-day lagged values of estimated insect flight trajectories

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were evaluated to consider a delayed response of migrants to pheromone traps following long-distance flight. Multiple-night flight trajectories were not estimated in this study. Duration of an insect flight was assumed to be the nightly period of darkness (11 hours in February through April). A minimum air temperature threshold of 10°C was assumed for moth response to pheromone traps.

Logistic analysis (Wilks 1995) was used to derive probabilities of occurrence of capture events. These probabilities were based on multiple linear regression of capture events with seven independent variables (predictors) for 8 February - 31 March 1994. The set of candidate predictors for capture events of moths contaminated with citrus pollen included daily values of: minimum air temperature, Weslaco minimum air temperature, mean capture in the LRGV, estimated proportion of moths contaminated with citrus pollen in the LRGV, estimated number of moths contaminated with citrus pollen in the LRGV, and the minimum duration needed for insect flight from Weslaco to specific trap locations for the current night and two previous nights. The logistic regression equation derived from historical capture events (1994) was used to estimate the probability of capture events for 18-24 March 1995. Daily probabilities of a capture event were determined from the logit value (y') by the equation $P\,|y'| = \exp(y') / (1 + \exp(y'))$.

Subsamples of moths captured in traps from 21 January - 3 May 1995 were examined by scanning electron microscopy. These traps were located along three transects from Falfurrias to Richland, Gatesville to Rosenberg, and Crockett to San Marcos. The validation procedure was evaluated for three capture events (20, 22, and 24 March 1995).

Results

8 February - 3 April 1994

Citrus pollen was found on 181 of 2800 (6%) moths captured in Texas outside the LRGV (Table 1). Citrus-contaminated bollworms were captured (capture event) at each of the 21 trap locations except Rogers and Alpine. At least one citrus contaminated moth was captured on 57% of the trapping dates. The spatial distribution of capture events matched well with the distribution of mean daily capture (Fig. 1). The number of capture events generally decreased northward and westward, but a prominent maximum (14) occurred at Belmont. Capture events were reported at the northernmost locations of Gatesville, Richland, and Crockett. Duration of estimated insect flight trajectories (for the current night [TJ] and previous night [TJ1]), and local minimum air temperature (TN) were each significant predictors of capture events ($\chi^2 = 60.556$; 3 df; $P < 0.0001$). The logit value for the logistic regression equation is expressed as $y' = -2.2658 - 0.0107 * TJ - 0.00742 * TJ1 - 0.1001 * TN$. The regression coefficients differ from those reported in Westbrook et al. (in press) because interpolated values of daily captures were excluded from logistic regression analysis in this paper. Estimated daily mean capture of citrus contaminated bollworms (TRC) was initially included by forward selection of predictors at the 0.05 significance level. However, TRC was dropped from the present logistic regression equation because it was not expected to be a readily available parameter for predicting capture events and could not be used in June during peak emergence. For a selected threshold probability of 0.200, one would expect to accurately predict 30.8% of capture events and 89.6% of non-capture events. Different values of the threshold probability can be selected by decision makers to trade off between accurate event predictions and false reports.

21 January - 3 May 1995

Citrus-contaminated moths represented 13% of the subsample of moths were examined by scanning electron microscopy (Table 1). Citrus-contaminated moths were captured at 82% of examined locations and on 65% of the examined dates. Prominent maxima of mean daily capture of bollworm moths were found at Ebano (Mexico), Uvalde, Beaumont, and in the LRGV (Fig. 2). More detailed information is presented later in the Results Section for 18-24 March 1995 when bollworms were examined for citrus pollen on several dates (20, 22, and 24 March).

1-15 June 1995

The distribution of mean daily capture of bollworm moths showed a pronounced gradient with numbers decreasing westward from the coast (Fig. 3). A maximum of mean daily capture occurred in the area between Gonzales, Karnes City, and Uvalde, where corn production was most extensive. Capture of numerous moths near Agua Nueva was unexpected because the surrounding habitat is arid brushland and is more than 30 km from the nearest cultivated land (mostly dryland sorghum). No distinctive marker was available to discern the migrant status of moths collected from 1-15 June 1995.

8-22 March 1996

Daily capture averaged 1.8 adult bollworms per trap in southern Texas. Maximum values of mean daily capture (5 per trap) were found outside the LRGV at La Gloria, Alice, Cotulla, and Knippa (Fig. 4). Evidence of bollworm migration was most striking from 15-17 March, when 17 of 23 locations outside the LRGV reported at least one of the three highest local captures of the 15-day trapping period; 4 of the locations reported each of the 3 highest local captures. Pollen analyses are in progress for moths captured at the northernmost trap locations from 8-22 March 1996.

4 June - 11 July 1996

Numerous adult bollworms were observed feeding on senescent corn plants that were sprayed with a feeding attractant/stimulant mixture containing *Lycopodium clavatum* spores at Hargill (LRGV) on the nights of 7-8 June 1996. Examination of bollworms captured within 2 km of the treated corn fields indicated that 70 of 383 (18%) of the bollworms were marked internally with the spores. Some of the marked moths were captured up to 3 days after the fields were treated with Lycopodium spores. Moths marked with *Lycopodium* spores were captured at Moore Air Base, La Gloria, and Tilden, 32, 59 and 234 km from Hargill, respectively, on 11-12 June 1996 (Table 1; Fig. 5). Trapping continued until 11 July between Uvalde and Pearsall with no additional marking.

<u>18-24 March 1995 Case Study</u>

Warm dry conditions characterized the weather over south-central Texas from 18-24 March 1995. Daily minimum air temperatures throughout the trapping network remained higher than the 10°C threshold for moth response to pheromone traps with few exceptions. A strong southerly wind component provided frequent atmospheric transport for moth migration from the LRGV northward to central Texas. On 18 March, the 10°C isotherm was located along a line from Laredo, Texas, to Shreveport, Louisiana, with northwesterly wind aloft. A pocket of 10°C air persisted over central Texas on 19 March. Southerly winds developed, but a surface low pressure over South Dakota was too distant to strongly influence wind speeds over south-central Texas. On 20 March, temperatures were higher than 10°C over all but the Texas Panhandle. Strong southerly wind developed over south-central and eastern sections of Texas, south of a cold front. The cold front stalled over central Texas on 21 March, creating a barrier to northward insect flight with associated temperatures lower than 10°C. Southerly wind prevailed over the southern U.S. in the warm sector of a frontal system on 22 March; a low pressure trough induced light showers over central Texas. On 23 March, a cold front eclipsed the Texas Panhandle and an eastward-moving low pressure trough entered central Texas, each dropping temperatures below 10°C. Surface winds were light and variable, leading to fog over southeastern Texas. The cold front stalled across central Texas on 24 March, serving as a weak barrier to northward insect flight.

The population distribution of adult bollworms in northeastern Mexico and south-central Texas shifted substantially northward during the one-week case study. A maximum capture of 78 moths was reported at Heald's Valley Farms in the LRGV on 18 March, while the next highest value outside the LRGV was 6 at Belmont and Falfurrias. Several locations, including many in the LRGV, did not report on 19 March, but double-digit (mean daily) captures were reported at Karnes City (28), Falfurrias (18), and Cotulla (34). Captures in the LRGV on 20 March (Fig. 6) closely matched those on 18 March, although more stations in other parts of south-central Texas reported captures on 18 March. Bollworms marked with citrus pollen were detected at Falfurrias, Three Rivers, Karnes City, Belmont, Rockdale, and Richland along the approximate wind trajectory on 20 March. Captures on 21 March reached a maximum of 71 at Belmont (and 70 at San Marcos) in central Texas. On 22 March (Fig. 7), the northward shift in the capture distribution was evident with double-digit values as far north as Stephenville (12), as far west as San Angelo (29), and as far east as Beaumont (82). Bollworms marked with citrus pollen were captured along the approximate wind trajectory at Falfurrias, Karnes City, Bastrop, Rogers, Kosse, and Richland on 22 March. Captures of 50, 102, and 258 bollworm moths were reported on 23 March at Bastrop, Beaumont and San Angelo, respectively. More than 50 moths were reported at Rosenberg (58), Rockdale (76), and Uvalde (56) on 24 March (Fig. 8). Bollworms marked with citrus pollen were captured at Alice and Caldwell on 24 March.

The logistic regression equation developed from capture data in 8 February - 3 April 1994 accurately estimated six of 14 (43%) capture events for 20, 22, and 24 March 1995. Additionally, three of 14 capture events were associated with estimated insect flight from the LRGV. A capture event at Caldwell on 24 March could have been estimated by insect flight from the LRGV two days earlier.

<u>Discussion</u>

Citrus pollen and *Lycopodium clavatum* spores were used successfully as markers to identify the geographic range of migratory flight of bollworm moths. Early-season captures revealed a flight range of at least 660 km and substantial dispersal. Bollworm flights from senescent corn in the LRGV in June revealed similar flight characteristics which corroborate the tracking of migrating insects from the LRGV to San Antonio by airborne radar (Wolf et al. 1990). Capture events were well correlated with estimated moth flight at 500 m AGL, although wind data from twice-daily National Weather Service rawinsonde profiles may underestimate the strength of the nocturnal wind (Westbrook et al. 1995). Trajectory estimates will be improved by using continuous nocturnal wind profiles from the NEXRAD national network of operational doppler weather radars (Crum and Alberty 1993). One might also consider multiple-night flights by individual moths because moths were often captured beyond the range of estimated one-night insect flight trajectories. A maximum number of capture events near Belmont suggests that this area was frequently a one-night way point for migrants from the LRGV. The anomalously dry and warm climatic conditions over south-central Texas from 1994-1996 may limit the ability of the logistic regression to estimate daily capture events during normal and wet climatic periods. New technologies and techniques are needed to more efficiently differentiate between migrants and nonmigrants, from which to determine the seasonal impact of migrant insect pests on crop productivity. Insect dispersal will become increasingly important as insects develop resistance to chemical and biological insecticides, and vector the resistant genes among pest populations in distant cotton production areas.

Acknowledgment

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Table 1. Capture of marked bollworms in pheromone traps outside the Lower Rio Grande Valley in south-central Texas in 1994-1996.

Proportion	Detected proportion of marked bollworms[a]		
	2/8-4/3, 1994[b]	1/21-5/3, 1995[b]	6/4-7/11, 1996[c]
total	181:2800	49:373	3:268
locations	19:21	14:17	3:16
dates	31:54	11:17	2:8

[a] Complete sample of captured moths was inspected in 1994; subsamples of moths captured at selected locations and dates were inspected for other periods.
[b] Marked externally with *Citrus* pollen
[c] Marked internally with *Lycopodium* spores applied at Hargill in the Lower Rio Grande Valley

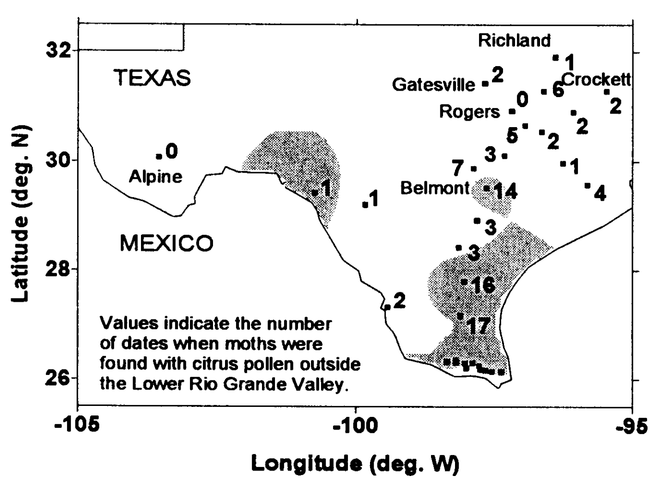

Figure 1. Areas (shaded) of mean daily capture of marked and unmarked bollworms exceeding 10 moths per pheromone trap in Texas from 8 February - 3 April 1994.

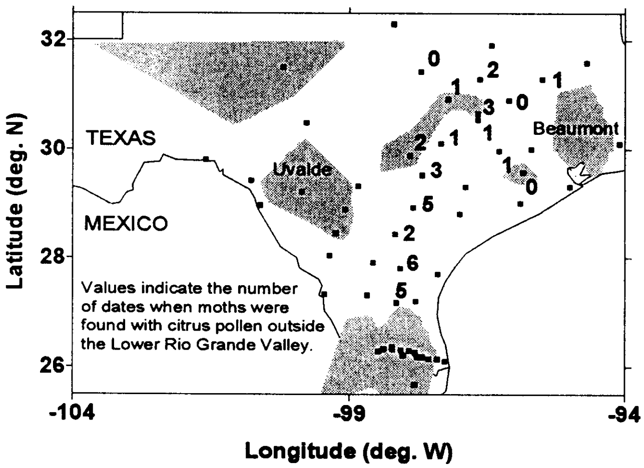

Figure 2. Areas (shaded) of mean daily capture of marked and unmarked bollworms exceeding 5 moths per pheromone trap in Texas from 21 January - 3 May 1995.

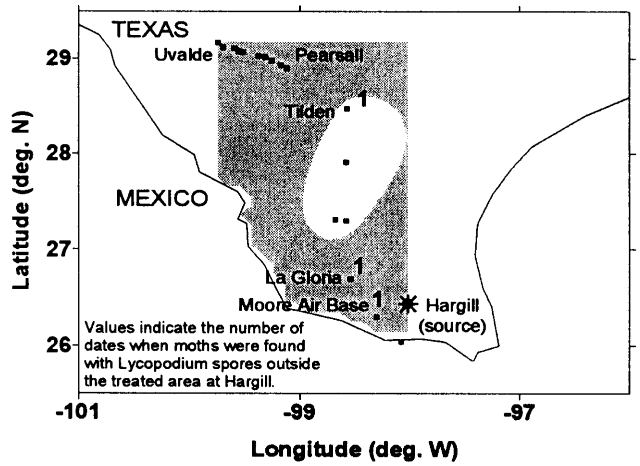

Figure 5. Areas (shaded) of mean daily capture of unmarked bollworms exceeding 10 moths per pheromone trap in Texas from 4 June - 11 July1996.

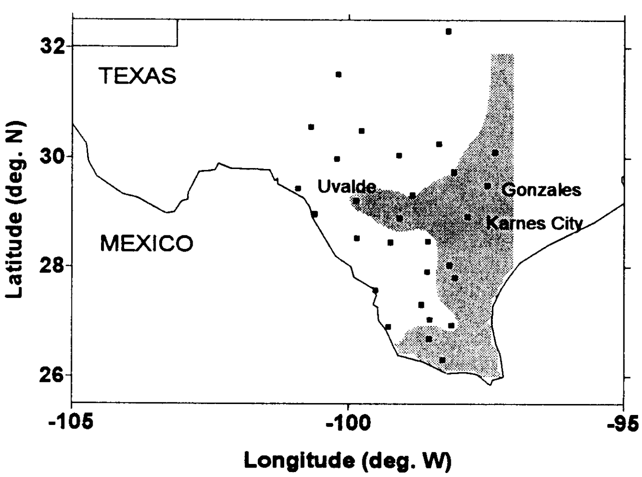

Figure 3. Areas (shaded) of mean daily capture of unmarked bollworms exceeding 50 moths per pheromone trap in Texas from 1-15 June 1995.

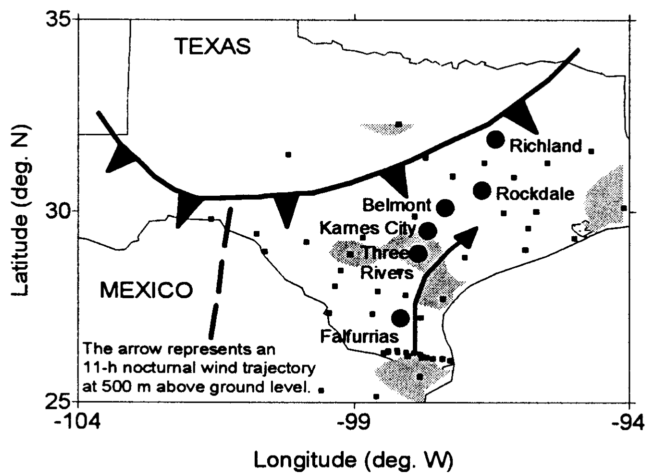

Figure 6. Areas (shaded) of daily capture of unmarked and marked bollworms exceeding 10 moths per pheromone trap in Texas on 20 March 1995. Solid circles indicate locations where citrus pollen-contaminated bollwroms were captured. Synoptic weather conditions were valid at 0600 Central Standard Time.

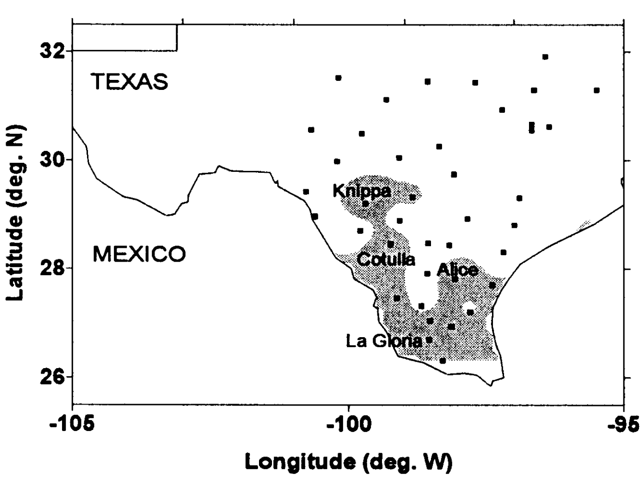

Figure 4. Areas (shaded) of mean daily capture of unmarked bollworms exceeding 2 moths per pheromone trap in Texas from 8-22 March 1996.

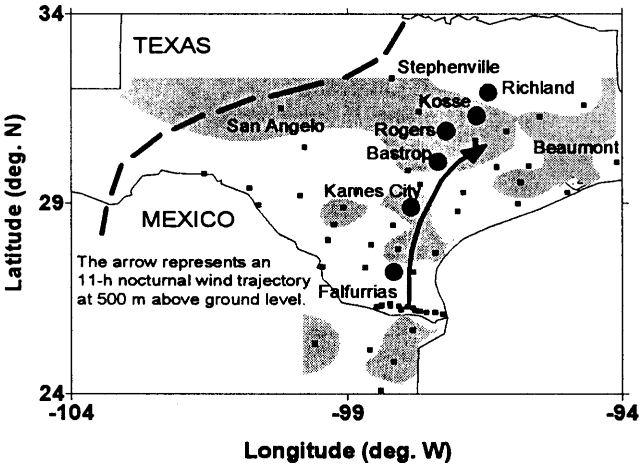

Figure 7. Areas (shaded) of daily capture of unmarked and marked bollworms exceeding 10 moths per pheromone trap in Texas on 22 March 1995. Solid circles indicate locations where citrus pollen-contaminated bollworms were captured. Synoptic weather conditions were valid at 0600 Central Standard Time.

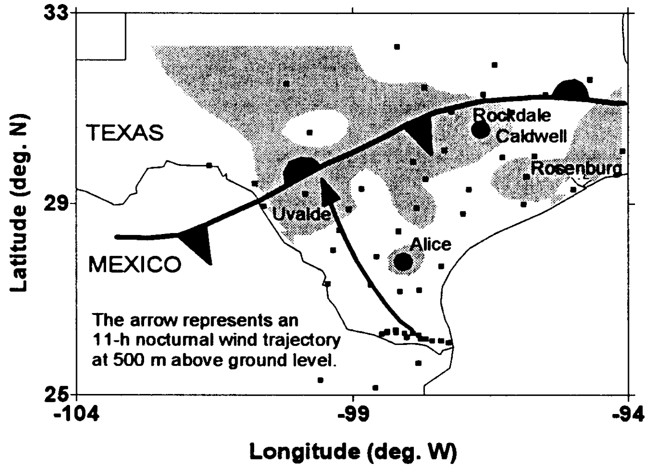

Figure 8. Areas of daily capture (shaded) of unmarked and marked bollworms exceeding 10 moths per pheromone trap in Texas on 24 March 1995. Solid circles indicate locations where citrus pollen-contaminated bollworms were captured. Synoptic weather conditions were valid at 0600 Central Standard Time.