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ARTHROPOD MANAGEMENT

Changes in Populations of *Heliothis virescens* (F.) (Lepidoptera: Noctuidae) and *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) in the Mississippi Delta from 1986 to 2005 as Indicated by Adult Male Pheromone Traps

John J. Adamczyk, Jr.*, and Don Hubbard

ABSTRACT

The bollworm, *Helicoverpa zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (F.), are major pests of many row crops throughout the United States. These pests annually cause economic damage to non-transgenic cotton across the mid-South of the United States. From 1986 through 2005, adult pheromone traps located in Washington County, Mississippi, were used to estimate populations of both species in the Mississippi Delta. From 1986 through 1996, moth captures for both species fluctuated yearly, but typically more moths of *H. virescens* were captured than *H. zea*. Since 1997 more moths of *H. zea* than of *H. virescens* were captured each year, and adult populations of both heliothines have declined annually. This decline in adult populations of *H. virescens* has been dramatic, especially over the last 5 years. The decline in *H. virescens* may be due to wide-scale plantings of Bt cotton. Other factors that may have impacted populations of *H. virescens* and *H. zea* in the Mississippi Delta are discussed.

Helicoverpa zea (Boddie) and *Heliothis virescens* (F.) are major pests of many row crops throughout the United States. Larvae of *H. zea* cause economic damage to corn (*Zea mays* L.); soybeans (*Glycine max* L.); sorghum [*Sorghum bicolor* (L.) Moench]; and cotton (*Gossypium hirsutum* L.). Larvae of *H. virescens* typically cause economic damage to cotton and tobacco (*Nicotiana tabacum* L.). Both heliothines have traditionally been major pests of cotton in the mid-South of the United States, although their relative abundance can vary from year to year (Clower, 1980). Since commercialization in 1996, transgenic cotton plants (Bollgard, Monsanto Co.; St. Louis, MO) containing a modified form of the *cry1Ac* gene from the soil bacterium, *Bacillus thuringiensis* Berliner (Bt) have been used extensively to manage lepidopteran pests. Over 40% of the total cotton acreage in 1996 contained Bollgard during the first year of introduction in the state of Mississippi (A. Catchot, personal communication). Although this technology is highly effective against *H. virescens*, supplemental foliar insecticide applications to control *H. zea* have been used extensively in Bollgard fields (Jenkins et al., 1993; Burd et al., 1999; Williams, 2000).

Historically, adult populations of these highly vagile insects have been monitored using light traps or with synthetic pheromone lures. The use of the Hartstack style trap (Hartstack et al., 1979) has been widely adopted in the mid-South of the United States. This trap is well-suited for capturing males of both heliothine species using synthetic pheromone lures. Since 1986, these traps have been deployed in the Mississippi Delta to monitor adult populations. These traps are also widely used to monitor the occurrence of heliothine larval populations in various row crops; however, studies have shown that direct correlations between larval and adult populations fluctuate during the growing season (Hayes, 1988; Leonard et al., 1989). This manuscript reports trends in adult populations of both *H. virescens* and *H. zea* during the last 20 years, and discusses some potential explanations for why these populations have decreased.

MATERIALS AND METHODS

From 1986 through 2005, adult male pheromone traps for *H. virescens* and *H. zea* (75 - 50 cone type) (Hartstack et al., 1979) were located throughout Washington County, Mississippi. The methods for

J. J. Adamczyk, Jr., USDA, ARS, Southern Insect Management Research Unit, 141 Experiment Station Rd., Stoneville, MS 38776 (Current address: USDA, ARS, Kika de la Garza Subtropical Agricultural Research Center, 2413 E. Highway 83, Weslaco, TX 78596); D. Hubbard, USDA, ARS, Southern Insect Management Research Unit, 141 Experiment Station Rd., Stoneville, MS 38776
*Corresponding author: john.adamczyk@ars.usda.gov

collecting these species using sex pheromones have been described in numerous publications (Leonard et al., 1989). In brief, two traps, one baited with synthetic pheromone of *H. zea* (Hercon Environmental; Emigsville, PA) as identified by Klun et al. (1979), and one baited with synthetic pheromone of *H. virescens* (Trece Inc.; Adair, OK) as identified by Klun et al. (1979), were placed 100 m apart. The trap sites were located in an east-west line 3.2 km apart, in order to cover the entire county (ca. 1865 sq km). Each trap collection cylinder was placed in an 18.9-L bucket containing ethyl acetate to kill the insects. The moths were then counted and recorded, but not identified further. Throughout the duration of this experiment, traps were typically checked within 7 d (mean = 2.1 d), and the pheromone lures were changed every 7 to 10 d to insure a consistent output of synthetic pheromone as suggested by Hartstack et al. (1982). The number of traps established in a given year ranged from 4 to 10 pairs of traps, with the exception of 1989 (29), 1990 (40), and 1996 (44). A preliminary analysis indicated that no correlation existed between the number of moths captured and the number of traps in a given year ($r = 0.11$, $P = 0.33$).

A simple but appropriate method of analyzing these data was conducted to minimize sources of error. The mean number of moths collected per pheromone trap was calculated for each night, and a mean ± standard error of the mean (SEM) was calculated for each year. In addition, 5-yr time periods (1986 to 1990, 1991 to 1995, 1996 to 2000, and 2001 to 2005) were grouped by month (March to October for *H. virescens* and April to October for *H. zea*). These time periods were selected in order to provide as much balance of the data as possible. Means and SEMs, and a linear regression were calculated using the MEANS and REG procedures, respectively, of SAS (version 8.2; SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

During the last 20 yr, moths for both species were collected throughout the year, albeit infrequently and at very low numbers during the non-crop winter months (Fig. 1). Moths of *H. virescens* were not collected from December through February; however, a few moths of *H. zea* were collected in December (n = 6) and February (n = 2). Moths of *H. zea* were not collected throughout January. Few moths of *H. virescens* (n = 12) were collected in March compared with *H. zea* (n = 1800). The earliest moths of *H. virescens* and *H. zea* were collected in the non-crop months was on 7 Mar. 2000 and 23 Dec. 1991, respectively. Moderate numbers of moths of *H. zea* and *H. virescens* (>2/trap/night) were typically captured by 20 March and 10 April, respectively. These data corroborate previous findings that *H. zea* are typically captured in pheromone traps earlier in the spring than *H. virescens* (Chapin et al., 1997).

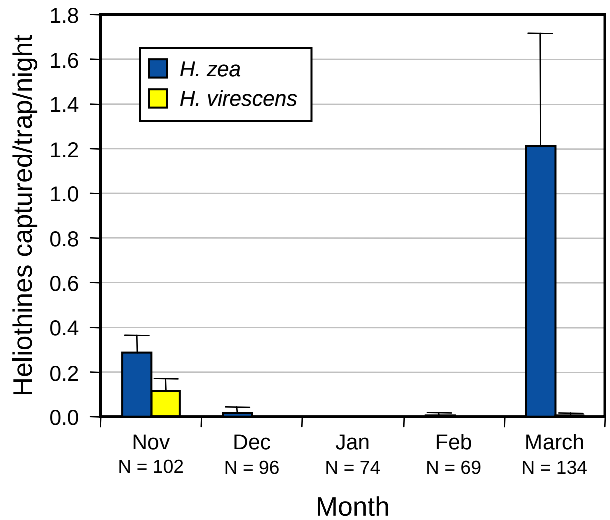

Fig. 1. Mean number of moths of *H. virescens* and *H. zea* captured during the non-crop months in the Mississippi Delta from 1986 - 2005. N = number of times traps were checked for each species in a given month.

From 1986 to 1996, moth captures for both species fluctuated yearly. Typically, more moths of *H. virescens* were captured than moths of *H. zea*. The mean number of *H. virescens* captured per trap per night was 19.5 (±1.11) with a maximum of 500 moths captured on 27 Aug. 1992. The mean number of *H. zea* captured per trap per night was 15.7 (±0.71) with a maximum of 310 moths captured on 23 Sept. 1988. In 1986, both species were captured in high numbers, which was also noted by Leonard et al. (1989) for Louisiana.

By the mid-1980s, *H. virescens* had become highly resistant to the pyrethroid class of insecticides commonly used to control the larval stage in cotton (Graves et al., 1988; Luttrell et al., 1987; Leonard et al., 1988). This may explain the high numbers of moths of *H. virescens* compared with *H. zea* captured during this era. Leonard et al. (1989) attributed the shift in increased abundance for *H. virescens* relative to *H. zea* in the mid-to-late 1980s in Louisiana to resistance of *H. virescens* to pyrethroids. This trend continued well into the 1990s (Chapin et al., 1997).

These findings appear similar, since there was an increased abundance of moths for *H. virescens* relative to *H. zea* captured in the Mississippi Delta especially during the early-to-mid 1990s (Fig. 2).

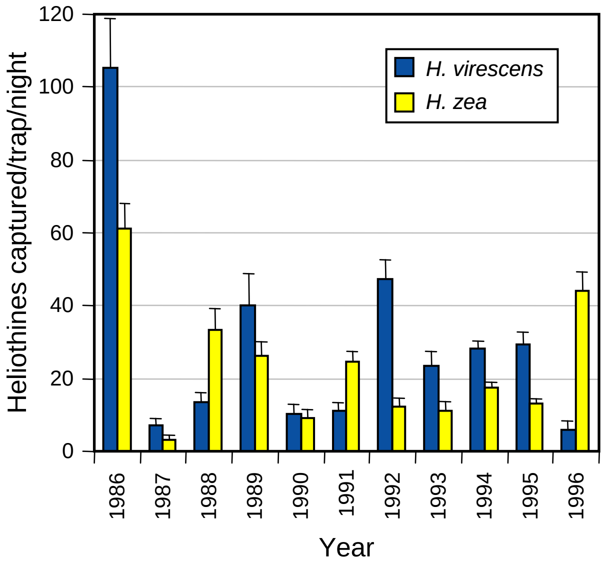

Fig. 2. Annual trends in adult populations of *H. virescens* and *H. zea* captured in the Mississippi Delta from 1986-1996. No significant linear relationship ($P > 0.05$) was observed for moth captures across time.

Since 1997, populations of *H. virescens* and *H. zea* have been declining annually in the Mississippi Delta area around Washington Co., Mississippi (Fig. 3). Based on the regression analysis, this decline appears to be similar for both species. Furthermore, more moths of *H. zea* were captured in a given year than moths of *H. virescens*. The mean number of moths of *H. zea* captured per trap per night was 6.2 (±0.52), with a maximum of 70 moths captured on 31 Aug. 1997. The mean number of moths of *H. virescens* captured per trap per night was only 2.9 (±0.24), with a maximum of 25 moths captured on 24 July 1997. From 2003 through 2005, the number of captured moths for both species was very low. The number of *H. zea* averaged less than 4 captured moths per trap per night, while *H. virescens* averaged less than one captured moth per trap per night.

Wide-scale introduction and subsequent adoption of transgenic Bt cotton has been rapid in the Mississippi Delta. It should be noted that moth numbers for both species should be interpreted with caution for 1996 since this was the introductory year for this technology and accurate information concerning the amount of acreage planted in the Mississippi Delta is limited (A. Catchot, personal communication). Larvae of *H. virescens* are highly

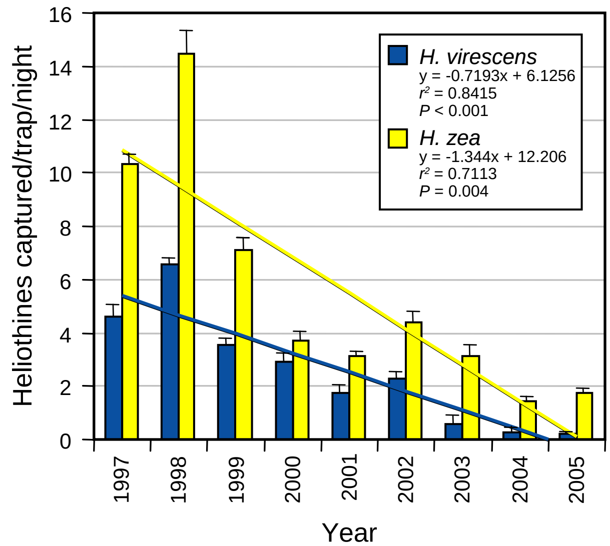

Fig. 3. Annual trends in adult populations of *H. virescens* and *H. zea* captured in the Mississippi Delta from 1997-2005. A significant negative linear relationship was observed for moth captures across time ($P < 0.05$).

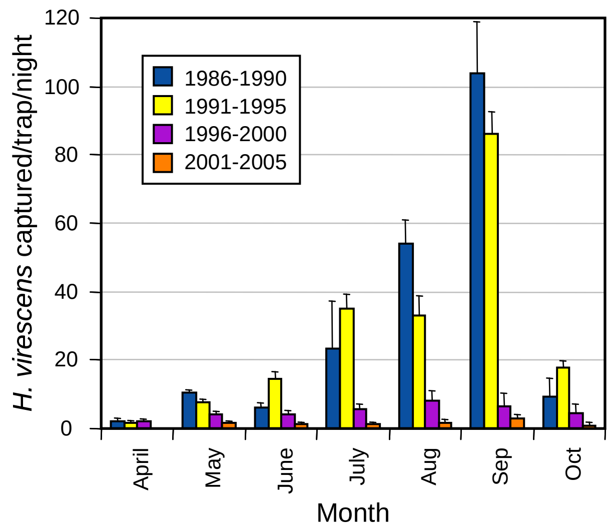

Fig. 4. Mean number of moths of *H. virescens* captured for each month (April – October). Five-year time periods were grouped by month to provide as much balance of the data as possible.

susceptible to Bollgard cotton and control is greater than 99.9% (MacIntosh et al., 1990; Jenkins et al., 1993). This population decrease during the last 10 yr has been especially observed during the summer months (June through September) (Fig. 4). The primary host for *H. virescens* in the Mississippi Delta during the summer months is cotton and few other wild or cultivated hosts are available (Stadelbacher et al., 1972). Prior to 1996, only non-transgenic cotton was commercially grown in the United States. Since

2002, Bollgard cotton has been grown on >85% of all cotton acreage in the Mississippi Delta (A. Catchot, personal communication), so the dramatic reduction in adult moths of *H. virescens* during the summer could be partially explained by loss of a larval food host (i.e. non-Bt cotton) due to the wide-scale plantings of Bollgard cotton. Over time, this chronic effect could have impacted over-wintering populations and the number of moths emerging from diapause in the spring. In addition, the continued adoption of Bollgard in Texas and Mexico could affect migration of *H. virescens* in the spring (Sparks, 1979).

From 1996 to 2000, adult populations of *H. zea* decreased during the summer months compared with the pre-Bt cotton era (i.e. 1986 to 1995), although not as dramatically as observed for *H. virescens* (Fig. 5). In fact, during this period, spring populations (March through June) were higher than the pre-Bt cotton era. This could be partially explained by the increased corn production in the Mississippi Delta during this period, a primary host for larvae of *H. zea* (Jackson et al., 2003). In addition, larvae of *H. zea* are only sub-lethally affected by the Cry1Ac transgene in Bollgard cotton, and survival to adulthood can occur (MacIntosh et al., 1990; Luttrell et al., 1999).

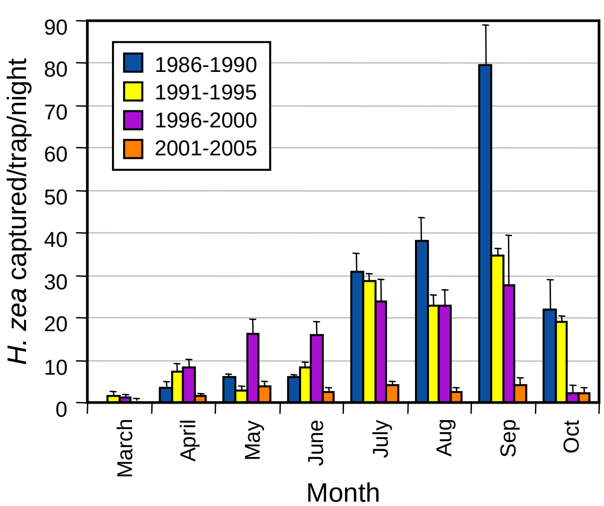

Fig. 5. Mean number of moths of *H. zea* captured for each month (March – October). Five-year time periods were grouped by month to provide as much balance of the data as possible.

In contrast, a dramatic decrease in adult populations of *H. zea* was observed for all months from 2001 through 2005 compared with populations observed in the pre-Bt cotton era, as well as the 5 yr after commercialization of Bollgard. A few agronomic changes occurred during this time period that may explain this phenomenon. First, the use of pre-plant herbicides has increased in many parts of the mid-South of the United States. Removing spring larval hosts (for review, see Stadelbacher et al., 1986) may have had an impact on reducing spring populations. Second, *H. zea* are mainly attracted to soybeans during the flowering period, with very little larval feeding post-bloom (McWilliams and Stadelbacher, 1987). Because earlier maturing cultivars are mainly planted in the mid-South, soybeans have become a minor host for *H. zea* compared with other more attractive crops (i.e. corn and grain sorghum), especially at peak-flowering during June and early July (Stadelbacher et al., 1986; Gore et al., 2001). Third, increased larval management in Bollgard cotton has occurred. Over the last 5 yr, more intensive scouting practices may have increased the amount of broad spectrum foliar insecticide applications (e.g. pyrethroids) to control this pest, as well as other pests [e.g. primarily the tarnished plant bug, *Lygus lineolaris* (Paliset de Beauvois)]. Fourth, increased planting of Bt (Yieldgard; Monsanto Co.) corn may have impacted populations of *H. zea*. Although only sub-lethally affected by Bt corn (Storer et al., 2001), increased acreage may have an effect on reducing the overall population of *H. zea*. Lastly, increased spring migration ability of moths of *H. zea* has to be considered. Because migration potential of this pest exists (for review, see Sparks, 1979), the ability of moths to migrate to northern latitudes cannot be ruled out.

Inherent problems always exist with very large historical data sets, especially when one is trying to identify and minimize many potential sources of error (over 4000 observations were recorded, resulting in the capture of over 700,000 *H. zea* and 540,000 *H. virescens*). Therefore, several assumptions used in the analysis of this data must be stated. First, the efficiency in capturing heliothine moths in Hartstack traps was assumed to have remained constant. Second, it was assumed that the synthetic pheromone lures for heliothines have remained constant in capture efficiency and specificity over the last 20 yr. Chapin et al. (1997) showed that the pheromones were highly specific for attracting the correct species, and that the small number of Heliothinae other than *H. zea* and *H. virescens* that are occasionally collected would not affect the interpretation of moth captures in pheromone traps. Lastly, because all traps were located within Washington Co., Mississippi, the adult population trends reported may or may not reflect trends in other geographical regions where these insects occur. Han and Caprio (2004) showed little spatial differentiation among populations of *H. virescens*, while recent studies suggest that moths of *H. zea* are randomly distributed across the landscape (Allen et al., 2004; Diffie et al., 2004).

Clearly, populations of both *H. virescens* and *H. zea* in the Mississippi Delta have changed over the last 20 yr, as indicated by adult pheromone captures. This paper illustrated annual and seasonal trends and provided some plausible explanations. It is not intended to fully explain all cause and effect relationships nor ecological complexities.

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