TWENTY-THREE YEARS OF HELIOTHINE TRAP CAPTURES IN STONEVILLE, MISSISSIPPI: ASSOCIATIONS WITH INSECT CONTROL TECHNOLOGIES, CROP DIVERSITY AND INSECT ABUNDANCE

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Abstract

Populations of *Helicoverpa zea* Boddie and *Heliothis virescens* (F.) were monitored weekly from April through October 1993-2015 by pheromone trap captures near the USDA ARS Jamie Whitten Delta States Research Center in Stoneville, Mississippi. Resulting data provide retrospective examinations of historical trends in insect abundance and associations with changing crop acreage, environmental conditions, and insect control practices. Densities of *H. zea* varied from year-to-year with no clear pattern of population change over the entire study period. However, populations have steadily increased since 2002 with increased soybean and corn acreages. Densities of *H. virescens* declined significantly over the study period and were associated with changes in crop acreage, local environmental conditions and estimates of Delta insect losses and control costs. Widespread adoption of Bt cotton varieties and eradication of boll weevil (*Anthonomus grandis* Boheman) were likely linked to the declining *H. virescens* populations but were not directly studied as possible correlates with trap captures. Cotton acreage decreased and soybean and corn acreage increased during the course of the observations. Cotton yields and costs of insect control per acre significantly increased over the twenty-three years of trap observations, but these increases were offset economically with increased yield.

Introduction

Researchers began investigations of *Helicoverpa zea* Boddie and *Heliothis virescens* (F.) pheromones in the 1960s with significant improvements in pheromone blends, traps and procedures for use as populations indicators in the 1970s and 1980s (Hartstack 1979, Klun et al. 1980a, Klun et al. 1980b). In the 1980s and 1990s, pheromone traps became a routine component of management programs for heliothines and were used to estimate population densities in empirical experiments (Bell 1991, Hayes and Bell 1994), track and monitor insecticide resistance (Plapp et al. 1999) and measure insect dispersal (Schneider 1999). Adamczyk and Hubbard (2006), Allen and Luttrell (2011), Goodenough et al. (1988), Leonard et al. (1989) and Parajulee et al. (2004) report previous studies to measure trends in *H. zea* and *H. virescens* pheromone trap captures in southern cotton-growing regions.

This paper reports results of weekly pheromone trap captures of *H. virescens* and *H. zea* near the USDA ARS Jamie Whitten Delta States Research Center in Stoneville, Mississippi for April through October 1993-2015. These are potentially important metadata for many entomological studies given the abundance of insect control research in the Stoneville area by federal, state and industry scientists. The previous report by Adamczyk and Hubbard (2006) is of comparative interest as it reports pheromone trap captures for the same area for the period 1986-1996.

Methods

Procedures were essentially the same as those reported by Adamczyk and Hubbard (2006) and Allen and Luttrell (2011). Wire-cone traps similar to those described by Hartstack (1979) were located at five sites in Washington County, Mississippi near the Stoneville USDA facility. One *H. virescens* and one *H. zea* trap were placed at each trap location separated by at least 100 meters. Traps sites remained constant over the twenty-three years of observations. Traps were baited with fresh commercial pheromone lures every other week from April through October. Trap captures were collected each week with contents of each trap carefully sorted and counted. Resulting data in recent years were also forwarded to Mississippi State University entomologists for inclusion in their weekly reports of pheromone trap captures around the state.

Trap captures were studied by analysis of variance for effects of time (week, month or year) and trap location. Analyses with different units of time (week, month, or year) were conducted separately to examine the data at different temporal resolutions. All trap capture data were converted to number of moths captured per trap per night, and temporal patterns of moth captures were compared to historical data on crop acreages, insecticide use, environmental conditions and annual Beltwide estimates of insect loss and control costs for the Mississippi Delta.

Results and General Observations

Average annual, monthly and weekly trap captures for *H. virescens* and *H. zea* are shown in Fig. 1, 2 and 3, respectively. For *H. virescens*, effects of trap location and unit of sample time (i.e. year, month, or week) were highly significant with P values ranging from 0.0002 to <0.0001. No significant interaction was detected between trap location and sample time suggesting that temporal patterns of *H. virescens* abundance were similar for all trap sites, although trap locations varied significantly in average trap captures. Average trap captures ranged from 7.7 to 17.8 moths per trap per night for the five different trap sites across the 23 years. For *H. zea*, significant interactions between trap location and unit of sample time were observed with P values <0.0001 for all units of time. Average trap captures ranged from 18.7 to 51.4 moths per trap per night for the five different trap sites. Differences in the landscape surrounding different trap sites are being studied for possible associations with the different abundances in moth captures but these analyses are not complete and are not included in this report.

Annual abundance of *H. virescens* dramatically decreased over the 23 years (Fig. 1, Table 1). The correlation coefficient (r) for year and average *H. virescens* density was -0.7286 (P<0.0001). Variability in *H. zea* abundance was noted but a trend for increase or decrease of population abundance was not measured over the entire study period (r=0.0025) (Fig. 1, Table 1). From 2002 to 2015 there was an upward trend in *H. zea* abundance (r=0.608, P=0.0220, Fig. 1) possibly due to increased acreages of soybean and corn in Washington County (Table 2).

The highest average monthly density for *H. virescens* was for September with 25.2 moths per trap per night. There was a consistent and progressive increase in abundance from April to September suggesting positive population growth in the local area (Fig. 2). The highest average monthly density of *H. zea* was in July (50.7 moths per trap per night). Over the 23 years, average *H. zea* captures increased each month from April to July and decreased each month from July to October (Fig. 2). Overall trends in weekly trap captures were similar to those observed in the monthly analysis of time, but the additional temporal resolution in the weekly analyses (Fig. 3) revealed a possible second peak in trap captures of *H. zea* in mid-October. Perhaps this is associated with a southward movement of *H. zea* moths produced in more northern latitudes of the U.S. Corn Belt (Gould et al. 2002).

Results of the correlation analyses (Table 1) illustrate the inter-connectedness between moth abundance and diversity of crops over the 23 years. Highly significant correlations were observed for increased soybean and corn acreage and decreased cotton acreage over the 23 year period. As indicated above, highly significant trends for decreased *H. virescens* abundance were also observed. Trends for changes in *H. zea* abundance were measured for the period 2002-2015 (Fig. 1, Table 2).

For *H. virescens*, trap captures appeared to be commonly correlated with crop acreage, local environmental conditions and various estimates of cotton yield losses and control costs (Table 1). This may indicate a more local impact of environment on pest abundance. The strong association with cotton acreage, and probably exposure to Bt cotton needs to be considered. The absence of similar correlations with *H. zea* abundance across the entire dataset is of interest but may be associated with the periods of time chosen for the comparisons. The significant relationship to decreased use of organophosphate insecticides in the analyses using all data is unexplained, but possibly linked to the use of these insecticides for boll weevil eradication.

An important insect management observation is the highly significant increase in cost of foliar insecticides per acre of cotton and total costs of insect control over the 23 years (Table 1). These trends are likely associated with those for decreased cotton acreage and increased yield. When the data were re-examined by comparing costs of foliar insecticides and all insect controls to average annual lb of lint produced rather than acres, there were no significant correlations (r=0.1042, P=0.6358, and r=-0.0911, P=0.6795, respectively), suggesting that the added costs were economically offset by increased yield. Regardless, the significant increases in control costs per acre may impact ecological factors and sustainability of cotton production in the Delta. Additional research should attempt to lessen these costs and capture the full ecological benefits of selective Bt cotton technologies in a cotton production system free of boll weevil. A more robust study of crop diversity and heliothine trap captures across the U.S. Cotton Belt may be possible given the widespread use of these traps in cotton production.

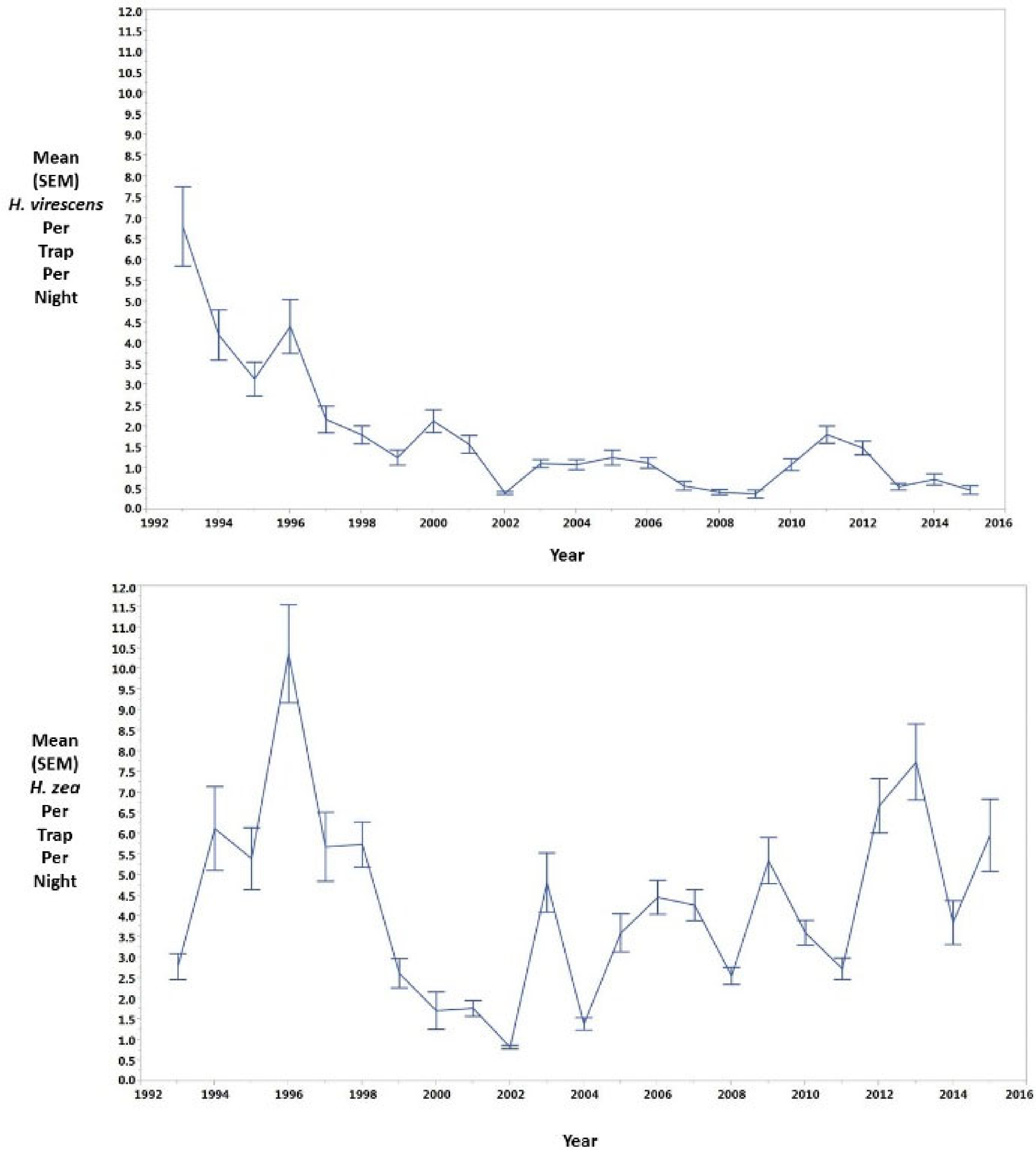

Figure 1. Mean (SEM) *H. virescens* and *H. zea* moths captured per trap per night averaged over years for the period 2003-2015.

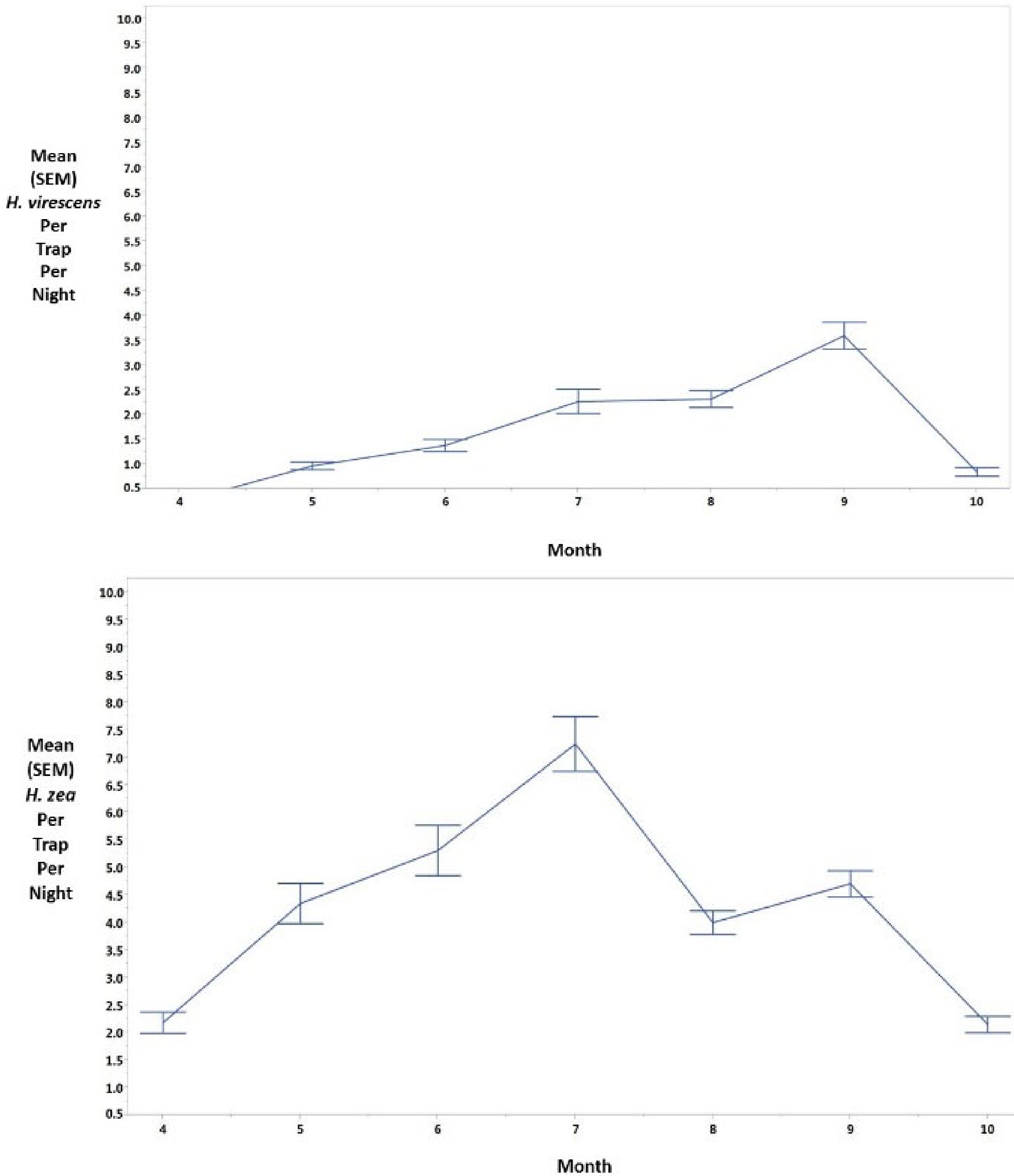

Figure 2. Mean (SEM) *H. virescens* and *H. zea* moths captured per trap per night averaged over months (months 4-10 (i.e. April-October)) for the period 2003-2015.

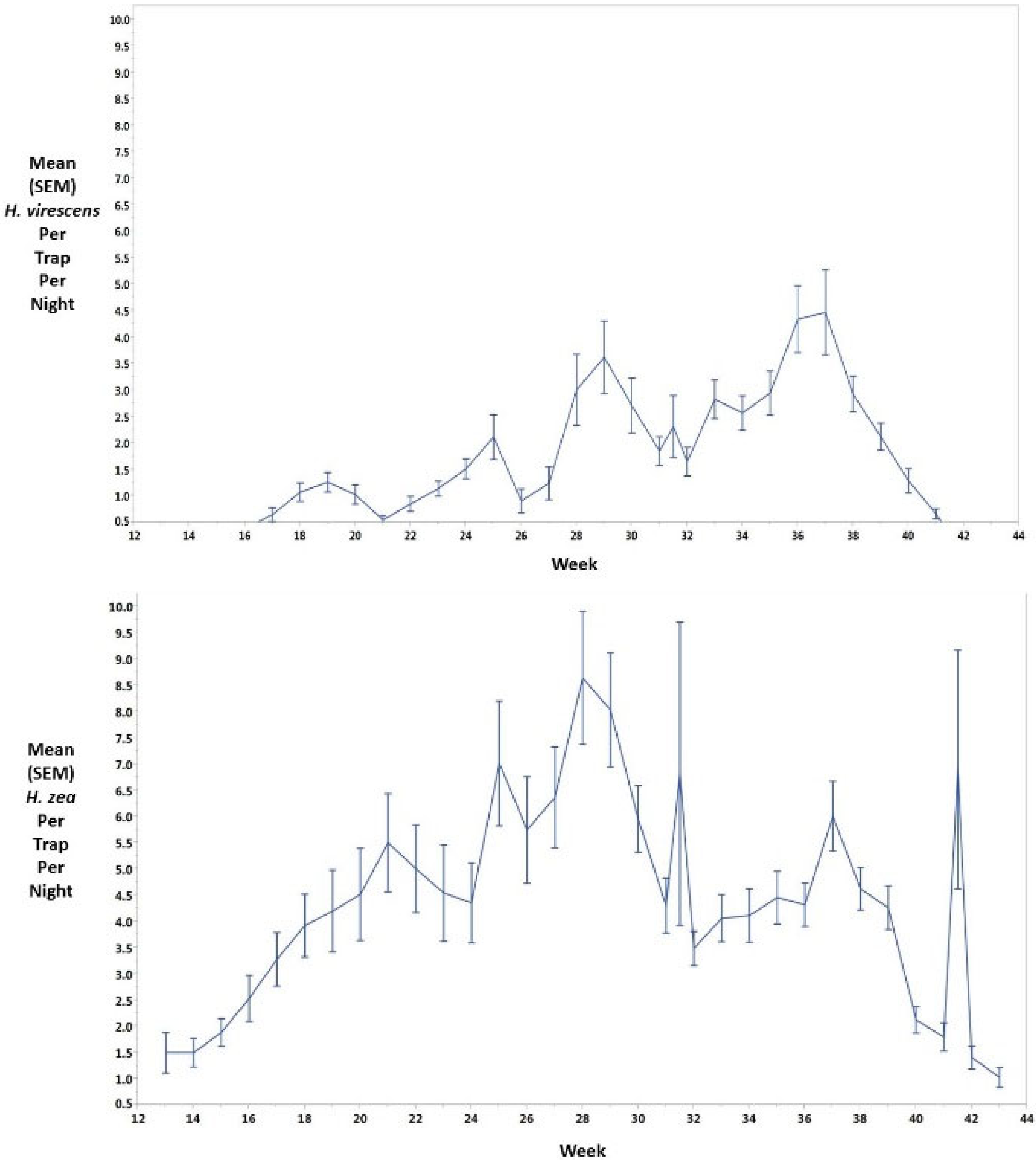

Figure 3. Mean (SEM) *H. virescens* and *H. zea* moths captured per trap per night averaged over weeks (weeks 13-43 (first week in April – last week in October)) for the period 2003-2015.

Table 1. Correlation coefficients between average annual *H. virescens* and *H. zea* moth trap captures in Washington County, Mississippi between 1993 and 2015 and recorded county crop acreages, average environmental indicators for Stoneville, Mississippi, estimated insecticide use (2008-2013 only), and estimated Beltwide insect control losses and costs for the Delta.

	H. virescens Trap Captures	*H. zea* Trap Captures	Year
Washington County Crop Acreage			
Cotton Acreage	0.4389*	-0.2040	-0.787***
Cotton Yield (lb lint/acre)	-0.418*	0.2396	0.608**
Soybean Acreage	-0.4988**	0.1479	0.844***
Corn Acreage	-0.5713**	0.1798	0.800***
Estimated Insecticide Use on Washington County Cropland 2008-2013			
kg pyrethroids/crop ha	-0.1593	0.2355	0.3703
kg organophosphates/crop ha	-0.1985	-0.8944**	-0.8375*
kg neonicotinoids/crop ha	-0.2925	0.0281	-0.1777
Average Annual Environmental Conditions			
Mean 7d Average Temperature (°F)	0.6394**	-0.1027	-0.4427*
Mean 7d Rainfall (inches)	-0.7083**	-0.0807	0.5535**
Mean 7d Relative Humidity (%)	0.6117**	-0.0729	-0.3637
Beltwide Cotton Insect Loss and Insect Control Cost Estimates for Mississippi Delta			
Est. Delta Cotton Acreage	0.4725*	-0.3357	-0.7586***
Est. Delta Cotton Yield (lb lint/acre)	-0.5227*	0.2180	0.7817***
Est. Delta % Cotton Crop Loss to Insects	0.6330**	0.1893	-0.2115
Est. Delta No. Foliar Insecticides/acre	0.4764*	0.3816	-0.0209
Est. Delta Cost of Foliar Insecticides ($/acre)	-0.0274	0.2854	0.5596**
Est. Delta Total Cost of Insect Control ($/acre)	-0.7485***	0.0346	0.8523***

*, **, and *** indicate significant correlations at P=0.05-0.01, P=0.01-0.001, and P<0.001, respectively.

Table 2. Correlation coefficients between average annual *H. virescens* and *H. zea* moth trap captures in Washington County, Mississippi between 2002 and 2015 and recorded county crop acreages for Washington County, Mississippi, and estimated Beltwide insect control losses and costs for the Delta.

	H. virescens Trap Captures	*H. zea* Trap Captures	Year
Washington County Crop Acreage			
Cotton Acreage	0.1493	-0.4418	-0.8139**
Cotton Yield (lb lint/acre)	-0.0940	0.1713	0.3665
Soybean Acreage	-0.1143	0.4213	0.8600***
Corn Acreage	-0.1493	0.4349	0.5397*
Beltwide Cotton Insect Loss and Insect Control Cost Estimates for Mississippi Delta			
Est. Delta Cotton Acreage	0.2210	-0.5404**	-0.8834***
Est. Delta Cotton Yield (lb lint/acre)	0.2656	0.3063	0.5490
Est. Delta % Cotton Crop Loss to Insects	0.0337	0.3063	0.6749**
Est. Delta No. Foliar Insecticides/acre	0.3083	0.3955	0.5582*
Est. Delta Cost of Foliar Insecticides ($/acre)	0.2713	0.5131*	0.7741**
Est. Delta Total Cost of Insect Control ($/acre)	0.2468	0.5071*	0.7166**

*, **, and *** indicate significant correlations at P=0.05-0.01, P=0.01-0.001, and P<0.001, respectively.

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