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# DENSITIES OF *HELIOTHIS VIRESCENS* AND *HELICOVERPA ZEA* (LEPIDOPTERA: NOCTUIDAE) IN THREE PLANT HOSTS

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ABSTRACT

Large numbers of field-collected tobacco budworms *Heliothis virescens* L., and/or bollworms *Helicoverpa zea* (Boddie) (heliothines) might be difficult to obtain depending upon host plants available to the insects. Of the >95 cultivated and wild plants that have been identified as their hosts, some are highly attractive to these insects, some are also widely available and of those, some could be used to collect large numbers of both insect species. However, the reliability of these plants in space and time in providing abundant samples of larvae and/or moths is not well understood. We studied naturally-occurring heliothine populations over a 3-year period in 2 different geographic locations in plots of garbanzo bean (*Cicer arietinum* L.), upland cotton (*Gossipium hirsutum* L.), and velvetleaf (*Abutilon theophrasti* Medikus) finding that garbanzo bean produced significantly higher numbers of tobacco budworm and bollworm larvae and adults as compared to the other 2 plant species. Tobacco budworm larvae were found in at least 1 host plant (primarily garbanzo) all the years in both locations while bollworm larvae were not. Field moth emergence represented ≤10% of its larval densities and abiotic factors made a difference on moth emergence between years. When large numbers of both insects are needed for field or laboratory studies, garbanzo bean offers a clear advantage over cotton or velvetleaf to obtain collections of heliothines.

Key Words: Tobacco budworm, bollworm, *Cicer arietinum*, *Gossipium hirsutum*, *Abutilon theophrasti*

RESUMEN

Grandes cantidades de gusanos tabacaleros (*Heliothis virescens* L.) y/o gusanos eloteros (*Helicoverpa zea* [Boddie]) pueden ser difíciles de obtener de ciertos cultivos, geografías o en determinado momento. De las ≥95 plantas cultivadas y silvestres reportadas como hospederas de estas especies de insectos, algunas son abundantes y/o son muy atractivas a ellos y pueden usarse para colectar larvas. Sin embargo no se ha establecido el nivel de confiabilidad de estas plantas en distintos lugares y a través del tiempo para obtener grandes cantidades de estos insectos. Estudiamos poblaciones naturales de *H. virescens* y *H. zea* durante tres años en dos diferentes lugares utilizando lotes de garbanzo (*Cicer arietinum* L.), algodonero (*Gossipium hirsutum* L.) y malva (*Abutilon theophrasti* Medikus) encontrando que el garbanzo produjo poblaciones de larvas y adultos de tabacalero y elotero significativamente mayores que las obtenidas en las otras dos plantas. El gusano elotero fue encontrado en al menos un hospedero (principalmente garbanzo) todos los años, mientras que el gusano elotero no siguió este patrón. Los adultos que emergieron representan ≤10% de las densidades previas de larvas, siendo los factores abióticos los que tuvieron una influencia marcada en las diferentes densidades observadas en los tres años. El uso de lotes de garbanzo puede proporcionar grandes cantidades de ambos insectos para estudios de campo y laboratorio.

Translation provided by the authors.

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Tobacco budworm *Heliothis virescens* L. infests more than 19 crops, while bollworm *Helicoverpa zea* (Boddie) infests at least 30 (Metcalf et al. 1962; Payne & Polles 1974; Martin et al. 1976; Young & Price 1977; Lopez et al. 1984; Rummel et al. 1986; Slosser et al. 1987; Kogan et al. 1989; Blanco et al. 2002; and references within). Both species have been observed feeding on at least 80

(*H. virescens*) and at least 76 (*H. zea*) uncultivated plants (Morgan & Chamberlin 1927; Isley 1935; Lincoln et al. 1967; Roach 1975; Stadelbacher 1981; Pair 1994; Suderbrink & Grant 1995; Parker 2002; and references within). Apart from the vast number of reports cited above, there are few reports that compare larvae or moth production per area under natural conditions in cotton and other plant species and even fewer studies were conducted for more than 1 growing season.

The tobacco budworm and the bollworm are important pests of a variety of cultivated plants in North America, especially of upland cotton *Gossypium hirsutum* L. (Luttrell 1994). Although these insects (heliothines) have been considered as the most important pest complex of cotton in 22 of the last 25 years in the U.S. cotton producing states (Williams 2005), tobacco budworm larvae in cotton plants and moths captured in pheromone traps have declined in certain areas in recent years (Parajulee et al. 2004; Blanco et al. 2005; Adamczyk & Hubbard 2006). Tobacco budworm has developed resistance to certain classes of insecticides (Sparks 1981; Luttrell et al. 1987; Hardee et al. 2001; Terán-Vargas et al. 2005), and since 1996 it has been effectively controlled, and bollworm partially controlled, by commercial varieties of cotton genetically engineered to express the insecticidal Cry proteins from the bacterium *Bacillus thuringiensis* Berliner (Bt). Because this is a valuable agricultural biotechnology, the US Environmental Protection Agency (EPA) and the Mexican Agricultural, Livestock, Rural Development, Fisheries and Nutrition Department (SAGARPA) requests Bt cotton registrants to conduct annual monitoring of Bt susceptibility in target pests (Matten & Reynolds 2003). The U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS) in Stoneville, Mississippi and the National Agriculture and Forestry Research Institute (INIFAP) in Mexico conduct monitoring programs to assist industry and regulatory agencies with their need for Bt-susceptibility information. Due to the fact that Bt-resistance frequency in tobacco budworm field populations was established as $1.5 \times 10^{-3}$ prior to commercialization of Bt cotton (Gould et al. 1997), in order to detect possible shifts from the above mentioned Bt-resistance frequency a high number of samples should be obtained and screened. Efficient trapping methods and/or plant hosts that produce high densities of tobacco budworms, ideally in synchrony with those occurring in cotton, would prove beneficial to satisfy those sampling needs.

The goal of this research was to determine population densities and synchrony of tobacco budworm and bollworm among 3 plant species that are relatively easy to establish: garbanzo bean (*Cicer arietinum* L.), upland cotton, and velvetleaf (*Abutilon theophrasti* Medikus), reported as capable of hosting large numbers of heliothines. This information could be useful for determining easier and reliable captures of naturally occurring tobacco budworms and bollworms. We also were interested in determining the contribution of each plant species to the overall insect population and moth emergence synchrony. Lastly, these data on larval-to-moth densities could be important for the development or refinement of theoretically-based models assessing mitigation of insecticide resistance in these important pests.

## Materials and Methods

This study was conducted over a 3-year period in 2 geographical locations assessing naturally occurring populations of heliothines.

### Mississippi Study Site (Washington County, 33N, 91W) (MS)

Three treatments were arranged in a randomized complete block design, as follows: (a) cotton (variety DPL491, Delta Pine and Land Co., Scott, MS), (b) garbanzo bean (Sierra variety, Tennessee Union Warehouse, Tennessee, ID), and (c) velvetleaf (Azlin Seeds, Leland, MS). Plots, replicated 4 times, were 6 (yr 2002) or 8 (yr 2003, 2004) 1.0-m center rows by 15 m long. Planting of all the treatments followed locally recommended dates for cotton on (Julian date) 135, 128 and 132 d in 2002, 2003, and 2004, respectively. Velvetleaf plots were seeded in 2002 and 2003 and volunteer plants growing in the 2003 plots were utilized in 2004. Additional same-size garbanzo plots were seeded on d 187 (yr 2003) and d 195 (yr 2004) in order to have actively growing plants for the entire duration of cotton-growing cycle and potentially capture the last heliothine generation of the year. Plant populations assessed at ≥first white cotton flower averaged 7.5 (cotton), 2.6 (garbanzo bean) and 0.5 (velvetleaf) plants per row-meter. Pesticide treatments consisted of aldicarb (105 g ai/ha, Bayer CropScience, Research Triangle Park, NC) incorporated at planting in cotton plots only to control early season sucking insects, and clethodim (120 g ai/ha, Valent USA Corporation, Walnut Creek, CA) in all plots for grass control. Weekly larval counts were made in 12 randomly chosen places per plot by shaking plants into a 1-m drop cloth. All heliothines regardless of developmental stage were counted and left in the plot. Identification of heliothine species (Brazzel et. al. 1953) was made with the adults species proportion emerging from a weekly larval sample of field-collected larvae reared in artificial diet under laboratory conditions (26°C, 65-85% RH and 14h of light/d) taken from an edge row. Four conical emergence traps (Blanco & Houston 2005) were set-up randomly in each plot when field larvae reached ≥fourth instar for each heliothine generation. Traps were left in place until the initiation of the following year's experiment. Traps were checked 3 times per week after the first moth was captured and weekly during winter to early spring. Collected moths were identified to species.

Tamaulipas (Mexico) study site (Cuauhtemoc Municipality, 22N, 97W) (TAM)

Unless specified, experimental conditions followed what was described for MS. Three treatments were used in this location, as follows: (a) cotton (Sure Grow 747 [yr 2001], Deltapine 5415 [yr 2002 and 2003] Delta Pine and Land Mexico varieties), (b) Insecticide-sprayed cotton refuge (yr 2001, Sure Grow 747 applied with lambacyhalothrin [Syngenta Agro, Mexico] on d 264 [35 g ai/ha] and d 270 [42 g ai/ha], yr 2002 Deltapine 5415 applied with deltamethrin [12.5 g ai/ha, Bayer de Mexico] on d 282 and 303, yr 2003 Deltapine 5415 applied with deltamethrin [12.5 g ai/ha] on d 254), referred to as 'sprayed cotton', and (c) garbanzo (Sururato variety). Plots (20 rows [0.76 m centers] 25 m long) were established in 2 grower's fields in 2001. In 2002 and 2003 plots were 12 rows (0.76 m centers) by 30 m long established in a research station. No velvetleaf plots were established in TAM. Treatments were planted on d 223 and d 203 in 2002 and 2003, respectively. Two emergence traps (2 × 2 m-base pyramidal wooden structure with a collection jar [500 mL] on top) were set-up at random in each plot. The proportion of heliothine species was derived from the moths captured in emergence traps.

Dates in tables are expressed as number of weeks after cotton was planted to better represent cotton phenological stage at both locations. Statistical analyses consisted of ANOVA for randomized complete block design and means were compared with LSD by SAS version 9.1 (SAS Institute, 2001). Analyses were made with the cumulative number of larvae or moths over the entire season. Initially, all treatments were analyzed independently for their significant difference from treatments with zero. Finally, since in certain years some of these treatments in some years were zero, they were not included in the final analysis in order to preserve the assumption of common variance required for ANOVA. LSD at $P \leq 0.05$ were used to determine significant differences in means between treatments. Data presented on tables were extrapolated to insects per hectare.

## RESULTS

### Tobacco Budworm Densities

*Heliothis virescens* average annual larval densities were ≈5 and ≈4 times higher in garbanzo (287,000 larvae/ha) than in cotton (56,290 larvae/ha) or velvetleaf (62,775 larvae/ha), respectively. Significant differences in MS were obtained in 2002 (LSD = 244; $F$ = 131,629, $P$ < 0.0001, $df$ = 6), in 2003 (LSD = 416; $F$ = 101,121, $P$ < 0.0001, $df$ = 3), and in 2004 (LSD = 1,625; $F$ = 130.0, $P$ = 0.001, error $df$ = 3) (Table 1). Larval densities were significantly higher in garbanzo in TAM in 2002 (LSD = 17,126; $F$ = 501, $P$ < 0.0001, $df$ = 6) and 2003 (LSD = 5,080; $F$ = 1,898, $P$ < 0.0001, $df$ = 6). Significantly higher number of larvae were found in cotton than in sprayed cotton in 2001 in TAM (LSD = 20,393; $F$ = 17.9, P = 0.02, $df$ = 3) (Table 2).

Average *H. virescens* moths densities emerging from garbanzo (20,180 moths/ha) were ≈13 and ≈35 times higher than moths emerging from cotton (1,550 moths/ha) or velvetleaf (575 moths/ha), respectively. Significant differences were obtained in MS in 2002 (LSD = 447; $F$ = 36.4, $P$ < 0.009, $df$ = 3) and in 2003 (LSD = 3,547; $F$ = 47.6, $P$ = 0.006, $df$ = 3) but in 2004 no significant differences were obtained from the number of tobacco budworm moths emerged from garbanzo and velvetleaf (LSD = 377, $F$ = 7.2, $P$ < 0.07, $df$ = 3) (Table 3). In TAM no significant differences in moth emergence were obtained from cotton and sprayed cotton in 2001 (LSD = 1,193; $F$ = 2.7, $P$ = 0.19, $df$ = 3). In 2002 significantly higher number of moths emerged from garbanzo than from cotton (LSD = 1,002; $F$ = 230.5, $P$ < 0.0001, $df$ = 6) as well as in 2003 (LSD = 1,372; $F$ = 108.4, $P$ < 0.0001, $df$ = 6) (Table 4).

### Bollworm Densities

In general bollworm larvae were not as abundant in both sites as compared with tobacco budworm densities. However, annual larval average in garbanzo plants (96,000 larvae/ha) exhibited similar trend, ≈5 and ≈6 times more larvae than in cotton (17,700 larvae/ha) or velvetleaf (14,300 larvae/ha) respectively. In MS significant differences were found in bollworm larval densities among all the plant species in 2002 (LSD = 3,650; $F$ = 65.9, $P$ = <0.0001, $df$ = 6). Bollworm larval densities in garbanzo were significantly higher in 2004 (LSD = 440, $F$ = 42.4, $P$ = 0.0003, $df$ = 6). In 2003 in MS bollworm larvae were observed only on cotton (Table 1). In TAM in 2002 significant differences were found between garbanzo and cotton (LSD = 4,783, $F$ = 615.9, $P$ < 0.0001, $df$ = 6) and in 2003 (LSD = 1,229; $F$ = 1,562.9, $P$ < 0.0001, $df$ = 6). No bollworm larvae were observed in TAM in 2001 (Table 2).

Low densities of bollworm moths emerged from plots in both locations. In MS they only emerged in one year (2003) not finding significant differences between garbanzo (205 moths/ha/yr) and cotton 275 moths/ha/yr) plots (LSD = 401; $F$ = 3.0, $P$ = 0.18, $df$ = 3) (Table 3). Bollworm moths emerged in TAM in two years not finding significant differences in 2002 (LSD = 370; $F$ = 0.53, $P$ = 0.61, $df$ = 6) and significant differences in 2003 (LSD = 230; $F$ = 9.0, $P$ = 0.01, $df$ = 6) (Table 4).

TABLE 1. *HELIOTHIS VIRESCENS* AND *HELICOVERPA ZEA* LARVAL DENSITIES IN PLANT HOSTS DURING 3 YEARS IN WASHINGTON COUNTY, MISSISSIPPI (MS).

| | | *H. virescens* larvae | | | *H. zea* larvae | | |
|---|---|---|---|---|---|---|---|
| Year | Week[a] | Cotton | Garbanzo | Velvetleaf | Cotton | Garbanzo | Velvetleaf |
| 2002 | 9 | 0 | 0 | 0 | 0 | 0 | 1,875 |
| | 11 | 0 | 2,225 | 1,200 | 13,125 | 82,687 | 10,350 |
| | 13 | 31,050 | 125,000 | 41,000 | 17,812 | 0 | 0 |
| | 15 | 22,500 | 87,500 | 81,875 | 16,875 | 0 | 0 |
| | 16 | 12,825 | 56,875 | 46,750 | 7,256 | 22,406 | 28,687 |
| 2003 | 4 | 0 | 3,750 | 0 | 0 | 0 | 0 |
| | 5 | 625 | 625 | 0 | 0 | 0 | 0 |
| | 6 | 0 | 1,875 | 0 | 2,625 | 0 | 0 |
| | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8 | 0 | 16,250 | 0 | 0 | 0 | 0 |
| | 9 | 0 | 5,625 | 0 | 0 | 0 | 0 |
| | 10 | 0 | 7,500 | 0 | 0 | 0 | 0 |
| | 11 | 1,250 | 18,750 | 0 | 312 | 0 | 0 |
| | 12 | 1,875 | 75,000 | 0 | 0 | 0 | 0 |
| | 13 | 2,500 | 35,000 | 0 | 0 | 0 | 0 |
| | 15 | 30,625 | 31,250 | 0 | 0 | 0 | 0 |
| | 16 | 1,250 | 10,625 | 0 | 0 | 0 | 0 |
| | 17 | 1,250 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 4 | 0 | 437 | 0 | 0 | 750 | 0 |
| | 5 | 0 | 625 | 1,500 | 0 | 750 | 0 |
| | 7 | 0 | 0 | 0 | 0 | 750 | 0 |
| | 11 | 0 | 500 | 125 | 375 | 750 | 0 |
| | 12 | 0 | 1,000 | 0 | 0 | 0 | 0 |
| | 13 | 0 | 250 | 0 | 0 | 0 | 0 |
| | 16 | 0 | 1,375 | 0 | 0 | 0 | 0 |
| | 17 | 0 | 16,875 | 0 | 0 | 0 | 0 |
| | 18 | 0 | 3,500 | 2,500 | 0 | 0 | 0 |
| | 19 | 0 | 2,875 | 1,250 | 0 | 2,000 | 250 |
| | 20 | 0 | 2,000 | 875 | 0 | 0 | 0 |
| | 21 | 0 | 5,500 | 8,000 | 0 | 0 | 0 |
| | 22 | 0 | 1,500 | 500 | 0 | 0 | 0 |
| | 23 | 0 | 5,375 | 0 | 0 | 0 | 0 |
| | 24 | 0 | 0 | 0 | 0 | 1,750 | 0 |
| | 26 | 0 | 0 | 2,750 | 0 | 0 | 1,750 |

[a]Weeks after cotton was planted.

## DISCUSSION

A clear advantage for the field collection of tobacco budworm larvae is presented by garbanzo bean plots. Significantly higher densities of this insect were observed on this plant in all years in both locations during 85% of the garbanzo's growing season (120 d). On cotton tobacco budworm was observed only 19% of the time of the 160 d of its growing season, while velvetleaf hosted this insect during 51% of its 150 d growing season. A disadvantage for using cotton or velvetleaf as a reliable source of *H. virescens* is the fact that this insect was not found on them every year. Tobacco budworms present in garbanzo coincided with larvae present in cotton or velvetleaf during most of the study, except in TAM in 2003. *Heliothis virescens* moth densities followed closely what was previously described, showing this time overlap in TAM in 2003 between moths emerging from garbanzo and cotton. The presence of *H. zea* larvae and moths in all three plant hosts was more sporadic compared with *H. virescens*. There was less bollworm larval overlap on all the plants hosts.

Although comparisons of insect populations between years and geographies are influenced by regional annual cropping systems, the intrinsic movement capacity of the species and habitat suitability (Kennedy & Storer 2000), heliothine densities recorded in this study are similar to those of reports that evaluated naturally-occurring populations in North America. Tobacco bud-

TABLE 2. *HELIOTHIS VIRESCENS* AND *HELICOVERPA ZEA* LARVAL DENSITIES IN PLANT HOSTS DURING 3 YEARS IN CUAUHTEMOC MUNICIPALITY, TAMAULIPAS, MEXICO (TAM).

| | | *H. virescens* larvae | | | *H. zea* larvae | | |
|---|---|---|---|---|---|---|---|
| Year | Week[a] | Cotton | Garbanzo | Sprayed Cotton | Cotton | Garbanzo | Sprayed Cotton |
| 2001 | 5 | 5,434 | N. A. | 0 | 0 | N. A. | 0 |
| | 6 | 21,739 | N. A. | 0 | 0 | N. A. | 0 |
| | 7 | 5,435 | N. A. | 0 | 0 | N. A. | 0 |
| | 8 | 10,870 | N. A. | 0 | 0 | N. A. | 0 |
| | 9 | 5,435 | N. A. | 0 | 0 | N. A. | 0 |
| | 10 | 57,065 | N. A. | 2,717 | 0 | N. A. | 0 |
| | 11 | 16,304 | N. A. | 5,435 | 0 | N. A. | 0 |
| | 16 | 2,717 | N. A. | 2,717 | 0 | N. A. | 0 |
| 2002 | 4 | 0 | 6,332 | 0 | 0 | 2,174 | 0 |
| | 5 | 1,151 | 4,030 | 0 | 493 | 1,727 | 0 |
| | 6 | 576 | 2,303 | 576 | 247 | 987 | 247 |
| | 7 | 576 | 2,303 | 2,303 | 247 | 987 | 987 |
| | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 9 | 4,603 | 0 | 576 | 1,974 | 0 | 247 |
| | 10 | 2,878 | 0 | 576 | 1,234 | 0 | 247 |
| | 11 | 4,030 | 0 | 2,303 | 1,727 | 0 | 987 |
| | 12 | 5,181 | 576 | 0 | 2,220 | 247 | 0 |
| | 13 | 1,727 | 0 | 576 | 740 | 0 | 247 |
| | 14 | 6,332 | 9,786 | 1.151 | 2,714 | 4,199 | 493 |
| | 15 | 1,151 | 7,484 | 576 | 493 | 3,207 | 247 |
| | 16 | 4,605 | 14,391 | 4,605 | 1,947 | 6,168 | 1,947 |
| | 17 | 6,332 | 46,053 | 5,181 | 2,714 | 19,737 | 2,220 |
| | 18 | 4,030 | 3,964 | 7,484 | 1,727 | 14,556 | 3,207 |
| | 19 | 8,636 | 31,661 | 7,484 | 3,701 | 13,569 | 3,207 |
| | 20 | 4,030 | 40,296 | 5,181 | 1,727 | 17,270 | 2,220 |
| | 21 | 3,454 | 13,816 | 1,727 | 1,480 | 5,921 | 740 |
| | 22 | 4,030 | 18,421 | 4,605 | 1,727 | 7,895 | 1,974 |
| | 23 | 576 | 6,908 | 0 | 247 | 2,961 | 0 |
| | 24 | 0 | 8,059 | 0 | 0 | 3,454 | 0 |
| | 25 | 0 | 17,845 | 0 | 0 | 7,648 | 0 |
| | 26 | 0 | 35,115 | 0 | 0 | 15,049 | 0 |
| | 27 | 0 | 80,592 | 0 | 0 | 34,539 | 0 |
| | 28 | 0 | 71,382 | 0 | 0 | 30,592 | 0 |
| | 28 | 0 | 40,872 | 0 | 0 | 17,516 | 0 |
| | 30 | 0 | 74,260 | 0 | 0 | 31,826 | 0 |
| | 31 | 0 | 37,993 | 0 | 0 | 16,283 | 0 |
| 2003 | 7 | 9,211 | | 8,059 | 3,947 | 0 | 3,454 |
| | 8 | 4,605 | | 1,151 | 1,974 | 0 | 493 |
| | 9 | 2,303 | | 1,151 | 987 | 0 | 49 |
| | 10 | 1,151 | 0 | 0 | 493 | 0 | 0 |
| | 11 | 2,303 | 0 | 1,151 | 987 | 0 | 493 |
| | 12 | 8,059 | 0 | 1,151 | 3,454 | 0 | 493 |
| | 13 | 13,816 | 0 | 5,757 | 5,921 | 0 | 2,467 |
| | 14 | 0 | 0 | 2,303 | 0 | 0 | 987 |
| | 16 | 0 | 0 | 1,151 | 0 | 0 | 0 |
| | 21 | 0 | 1.151 | 0 | 0 | 493 | 493 |
| | 22 | 0 | 1,151 | 0 | 0 | 493 | 0 |
| | 23 | 0 | 5,757 | 0 | 0 | 2,467 | 0 |
| | 24 | 0 | 2,303 | 0 | 0 | 987 | 0 |
| | 25 | 0 | 9,211 | 0 | 0 | 3,947 | 0 |
| | 26 | 0 | 19,572 | 0 | 0 | 8,388 | 0 |

[a]Weeks after cotton was planted, N.A. = Treatment not available that year.

TABLE 2. (CONTINUED) *HELIOTHIS VIRESCENS* AND *HELICOVERPA ZEA* LARVAL DENSITIES IN PLANT HOSTS DURING 3 YEARS IN CUAUHTEMOC MUNICIPALITY, TAMAULIPAS, MEXICO (TAM).

| | | *H. virescens* larvae | | | *H. zea* larvae | | |
|---|---|---|---|---|---|---|---|
| Year | Week[a] | Cotton | Garbanzo | Sprayed Cotton | Cotton | Garbanzo | Sprayed Cotton |
| | 27 | 0 | 11,513 | 0 | 0 | 4,934 | 0 |
| | 28 | 0 | 26,480 | 0 | 0 | 11,349 | 0 |
| | 29 | 0 | 8,059 | 0 | 0 | 3,454 | 0 |
| | 30 | 0 | 6,908 | 0 | 0 | 2,961 | 0 |
| | 31 | 0 | 21,875 | 0 | 0 | 9,375 | 0 |
| | 32 | 0 | 86,346 | 0 | 0 | 37,007 | 0 |
| | 33 | 0 | 87,500 | 0 | 0 | 19,243 | 0 |
| | 34 | 0 | 44,901 | 0 | 0 | 3,947 | 0 |
| | 35 | 0 | 9,211 | 0 | 0 | 0 | 0 |
| | 36 | 1,644 | 0 | 0 | 0 | 0 | 0 |

[a]Weeks after cotton was planted, N.A. = Treatment not available that year.

worm larval densities reported here (500-57,000/ha) were estimated as 7-3,053 on cotton by Henry & Adkisson (1965), Lincoln et al. (1967), and Graham & Robertson (1970). *Heliothis virescens* larvae on velvetleaf in our study (125-81,000) also compare to 54,895-98,003 larvae/ha reported by Stadelbacher et al. (1986). Naturally-occurring tobacco budworm moth emergence has been reported as 1,008 moths from cotton by Roach & Ray (1976), while our collections ranged between 312-2,100 moths/ha. Our estimates of bollworm densities were somewhat lower than those of Henry & Adkisson (1965), Lincoln et al. (1967), Graham & Robertson (1970), Young & Price (1975 and 1977), and Jackson et al. (2003), which ranged from ≥59 up to 370,828 larvae per hectare (Rummel et al. 1986). Our bollworm densities only ranged between 247-17,000 larvae/ha. Stadelbacher et al. (1986) reported a density of 6,297 bollworm larvae/ha on velvetleaf and in this study they ranged between 125-81,000 larvae/ha. Bollworm moth emergence under natural conditions was reported by Roach & Ray (1976) as 459 moths per hectare in cotton while in this study bollworm emerging moths ranged between 300-2,100 bollworm moths/ha.

TABLE 3. *HELIOTHIS VIRESCENS* AND *HELICOVERPA ZEA* MOTH DENSITIES IN PLANT HOSTS DURING 3 YEARS IN WASHINGTON COUNTY, MISSISSIPPI (MS)

| | | *H. virescens* moths | | | *H. zea* moths | | |
|---|---|---|---|---|---|---|---|
| Year | Week[a] | Cotton | Garbanzo | Velvetleaf | Cotton | Garbanzo | Velvetleaf |
| 2002 | 18 | 874 | 4,370 | 0 | 0 | 0 | 0 |
| 2003 | 14 | 2,185 | 1,748 | 0 | 0 | 0 | 0 |
| | 15 | 0 | 12,454 | 0 | 89 | 89 | 0 |
| | 16 | 0 | 2,949 | 0 | 0 | 0 | 0 |
| | 17 | 0 | 5,134 | 0 | 0 | 0 | 0 |
| | 18 | 0 | 1,966 | 0 | 0 | 0 | 0 |
| | 19 | 0 | 2,621 | 0 | 0 | 0 | 0 |
| | 20 | 0 | 1,857 | 0 | 0 | 0 | 0 |
| | 25 | 0 | 2,949 | 0 | 0 | 0 | 0 |
| | 27 | 0 | 218 | 0 | 0 | 0 | 0 |
| | 53 | 0 | 218 | 0 | 0 | 0 | 0 |
| | 54 | 0 | 874 | 0 | 0 | 0 | 0 |
| 2004 | 6 | 0 | 223 | 223 | 0 | 0 | 0 |
| | 7 | 0 | 0 | 1,500 | 0 | 0 | 0 |
| | 16 | 0 | 111 | 0 | 0 | 0 | 0 |
| | 17 | 0 | 111 | 0 | 0 | 0 | 0 |

[a]Weeks after cotton was planted.

TABLE 4. *HELIOTHIS VIRESCENS* AND *HELICOVERPA ZEA* MOTH DENSITIES IN PLANT HOSTS DURING 3 YEARS IN CUAUHTEMOC MUNICIPALITY, TAMAULIPAS, MEXICO (TAM)

| | | *H. virescens* moths | | | *H. zea* moths | | |
|---|---|---|---|---|---|---|---|
| Year | Week[a] | Cotton | Garbanzo | Sprayed Cotton | Cotton | Garbanzo | Sprayed Cotton |
| 2001 | 13 | 500 | N. A. | 0 | 0 | N. A. | 0 |
| | 14 | 0 | N. A. | 1,000 | 0 | N. A. | 0 |
| | 15 | 2,000 | N. A. | 500 | 0 | N. A. | 0 |
| | 16 | 0 | N. A. | 1,000 | 0 | N. A. | 0 |
| | 17 | 0 | N. A. | 2,000 | 0 | N. A. | 0 |
| | 23 | 0 | N. A. | 500 | 0 | N. A. | 0 |
| 2002 | 13 | 312 | 0 | 0 | 0 | 0 | 0 |
| | 18 | 625 | 0 | 0 | 0 | 0 | 0 |
| | 25 | 0 | 312 | 0 | 0 | 0 | 0 |
| | 28 | 0 | 937 | 0 | 0 | 0 | 0 |
| | 29 | 0 | 937 | 0 | 0 | 0 | 0 |
| | 30 | 0 | 5,000 | 0 | 0 | 0 | 0 |
| | 31 | 0 | 2,187 | 0 | 0 | 0 | 0 |
| | 32 | 0 | 5,625 | 0 | 0 | 0 | 0 |
| | 33 | 0 | 7,500 | 312 | 0 | 0 | 0 |
| | 34 | 0 | 7,184 | 0 | 0 | 0 | 0 |
| | 35 | 0 | 1,250 | 0 | 312 | 312 | 0 |
| | 37 | 0 | 625 | 937 | 0 | 0 | 312 |
| | 38 | 625 | 312 | 0 | 312 | 0 | 0 |
| | 39 | 0 | 312 | 312 | 312 | 0 | 0 |
| | 40 | 625 | 0 | 312 | 0 | 312 | 0 |
| | 42 | 0 | 0 | 312 | 0 | 0 | 0 |
| 2003 | 17 | 312 | 0 | 0 | 0 | 0 | 0 |
| | 28 | 0 | 0 | 0 | 312 | 0 | 0 |
| | 29 | 0 | 937 | 0 | 0 | 0 | 0 |
| | 30 | 0 | 937 | 0 | 0 | 312 | 0 |
| | 31 | 0 | 937 | 0 | 312 | 0 | 0 |
| | 32 | 312 | 1,250 | 0 | 0 | 0 | 0 |
| | 33 | 312 | 6,250 | 0 | 0 | 0 | 0 |
| | 34 | 0 | 5,000 | 0 | 0 | 0 | 0 |
| | 35 | 0 | 9,062 | 0 | 0 | 0 | 0 |
| | 36 | 0 | 5,313 | 312 | 0 | 0 | 312 |
| | 37 | 0 | 312 | 937 | 0 | 0 | 625 |
| | 38 | 625 | 0 | 625 | 0 | 0 | 937 |
| | 39 | 0 | 625 | 625 | 0 | 0 | 0 |
| | 40 | 0 | 312 | 0 | 0 | 0 | 0 |

[a]Weeks after cotton was planted, N.A. = Treatment not available that year.

The relationship between larval densities and moth emergence under field conditions can be estimated from this study. Tobacco budworm peak larval densities yielded 1 moth for every 13, 22 and 55 larvae on garbanzo, cotton, and velvetleaf, respectively. Bollworm peak larval densities produced 1 moth for every 1,290 and 656 larvae on garbanzo or cotton, while no estimates for bollworm moth emergence were established for velvetleaf plots. This information reflects on the relative importance of these plant species as heliothine hosts. The differences between the emergence of moths from the three plant hosts could have been influenced in part by the high number and diversity of predators found in cotton and velvetleaf plots (data not shown) as compared with those observed on garbanzo bean (lower abundance and diversity, data not shown), throughout the entire growing seasons. The variation in moth emergence among years and locations might have been caused by abiotic factors such as precipitation. According to Young & Price (1968), rain in excess of 2.0 cm can cause 100% mortality in *H. zea*, while Hendricks (1991) concluded that 50% of heliothine pupae in water-saturated soil for ≥50 h die, a likely possibility in the MS study site's alluvial soils. Peak tobacco budworm larval densities in MS in weeks 9 and 13 (yr 2002), 6 and 26 (yr

2003), and 7, 16, and 17 (yr 2004) were closely followed by ≥3.0 cm of rain, indicating the possibility that this factor alone might have had in the survivorship of both insect species under natural conditions (Schneider 2003). The influence that biotic and abiotic factors have on naturally-occurring heliothine populations can be corroborated with those field-collected larvae placed in insect artificial diet in the laboratory for species identification that yielded ≈85% moths (1 moth for every 1.2 larvae placed in insect artificial diet under laboratory conditions). These estimates of moth emergence densities between field conditions and laboratory conditions provide a useful indicator for understanding heliothine densities in other studies.

Garbanzo bean, the third most important legume in the world (Romeis et al. 2004) is a minor crop in the U.S., representing less than 1% of the world production, but it is an important export commodity in Mexico representing 3% of the world production. An area that covers ≅3,300 ha (data of 2002) (Johnson & Jimmerson 2003) of this crop in North America, has a great potential in the production of heliothines.

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