A New Synonym of *Helicoverpa zea* (Boddie) and Differentiation of Adult Males of *H. zea* and *H. armigera* (Hübner) (Lepidoptera: Noctuidae: Heliothinae)

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ABSTRACT The taxonomic history of *Helicoverpa armigera* (Hübner) and *Helicoverpa zea* (Boddie) is discussed. *Heliothis stombleri* Okumura and Bauer is a new synonym of *H. zea.* The best diagnostic characters occur in the vesica of the male genitalia. These include (1) number of diverticula at the base, (2) length and number of coils, (3) number of cornuti visible on the uninflated vesica inside the aedoeagus, and (4) valve length. All diagnostic characters are described and shown. Methods for examining large samples of *H. zea* for possible *H. armigera* include placing the entire sample into suitable containers of 10% KOH for 18–24 h and dissecting the genitalia and measuring the valve length. It was found that *H. zea* had a longer mean valve length than *H. armigera*, but there was some overlap. Specimens whose valve length was <5.0 mm were examined for the diagnostic characters present on the vesica.

KEY WORDS invasive species, corn earworm, old world bollworm, cotton, corn

INVASIVE SPECIES ARE NON-NATIVE to a particular geographic area or ecosystem and have an increased potential to displace native species. They are a great concern to American agriculture and forestry and potentially cause billions of dollars of economic loss to crops and forest trees. With rapid transportation of commodities by aircraft and ships around the world, the introduction of invasive species is a continuously increasing threat.

The Old World bollworm, *Helicoverpa armigera* (Hübner), widely distributed in the Old World, has not yet been detected in the United States. Detection surveys for *H. armigera* are currently being conducted in cotton-producing areas in Texas and in corn-producing areas in Oregon by the use of pheromone traps. *H. armigera* is a close relative of the corn earworm, *H. zea* (Boddie), and the same pheromone compounds are found in both species. The two main compounds are Z11–16A1 and Z11–16OH, which occur in different concentrations between the two species as well as between populations within species (Witzgall et al. 2004). The use of corn earworm pheromones were used for the possible detection of the Old World bollworm in pheromone sampling schemes; however, Oregon used lures formulated for *H. armigera* by the USDA/APHIS/PPQ-OTIS Pest Survey, Detection, and Exclusion Laboratory in Massachusetts. In the United States, the greatest economic loss from the corn earworm occurs in corn and cotton.

There were 20 interceptions of *H. armigera* by the Animal Plant Health Inspection Service (APHIS) at U.S. ports-of-entry in 2003. All were larval interceptions and were found on a variety of cut flowers as well as mint and basil. Countries of origin and numbers of interceptions were Bosnia (one), Israel (six), Japan (two), Lebanon (one), Netherlands (eight), New Zealand (one), and Zimbabwe (one) (SELIS database maintained by Systematic Entomology Laboratory).

Helicoverpa armigera is considered omnivorous, with the larvae attacking at least 60 cultivated and 67 wild host plants from numerous families including Asteraceae, Fabaceae, Malvaceae, Poaceae, and Solanaceae (Fitt 1989). At least 34 plant families are hosts in Australia (Matthews 1999). The most important cultivated plants damaged are grain sorghum, maize, and cotton (Reed 1965, Roome 1975, Hackett and Gatehouse 1982). Larvae feed on the flowers and fruits of hosts; oviposition occurs during flowering of the host plant. In tropical areas where there are multiple generations, different generations damage different crops. For example, in Tanzania, first-generation *H. armigera* larvae feed on *Cleome* sp.; second generation on maize, sorghum, *Cleome* sp., and other legumes; third generation attack early sown cotton, maize, and legumes; and fourth generation are again found on cotton, maize, and legumes (Reed 1965).

The potential economic loss by *H. armigera* to corn and cotton in the United States would exceed that of *H. zea* if *H. armigera* became established. Other crops that are susceptible to corn earworm and Old World bollworm include tomatoes, lima beans, soybeans, to-

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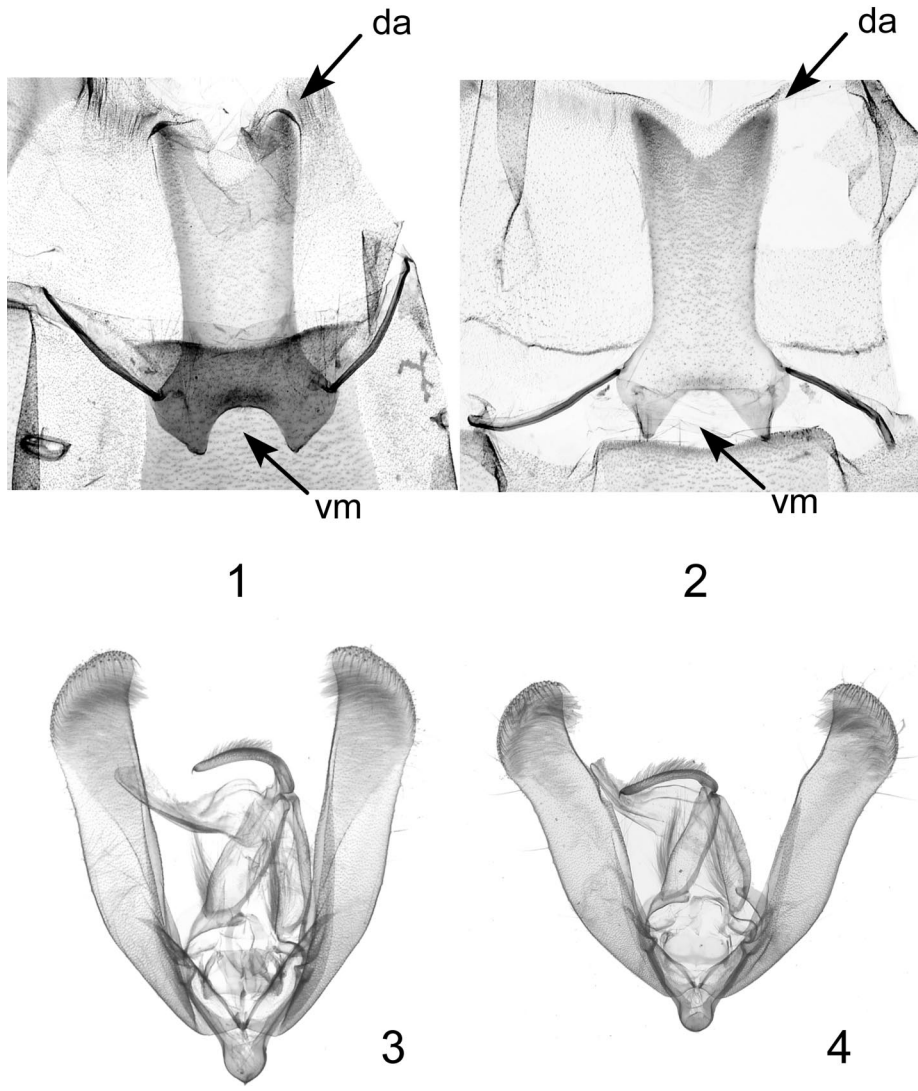
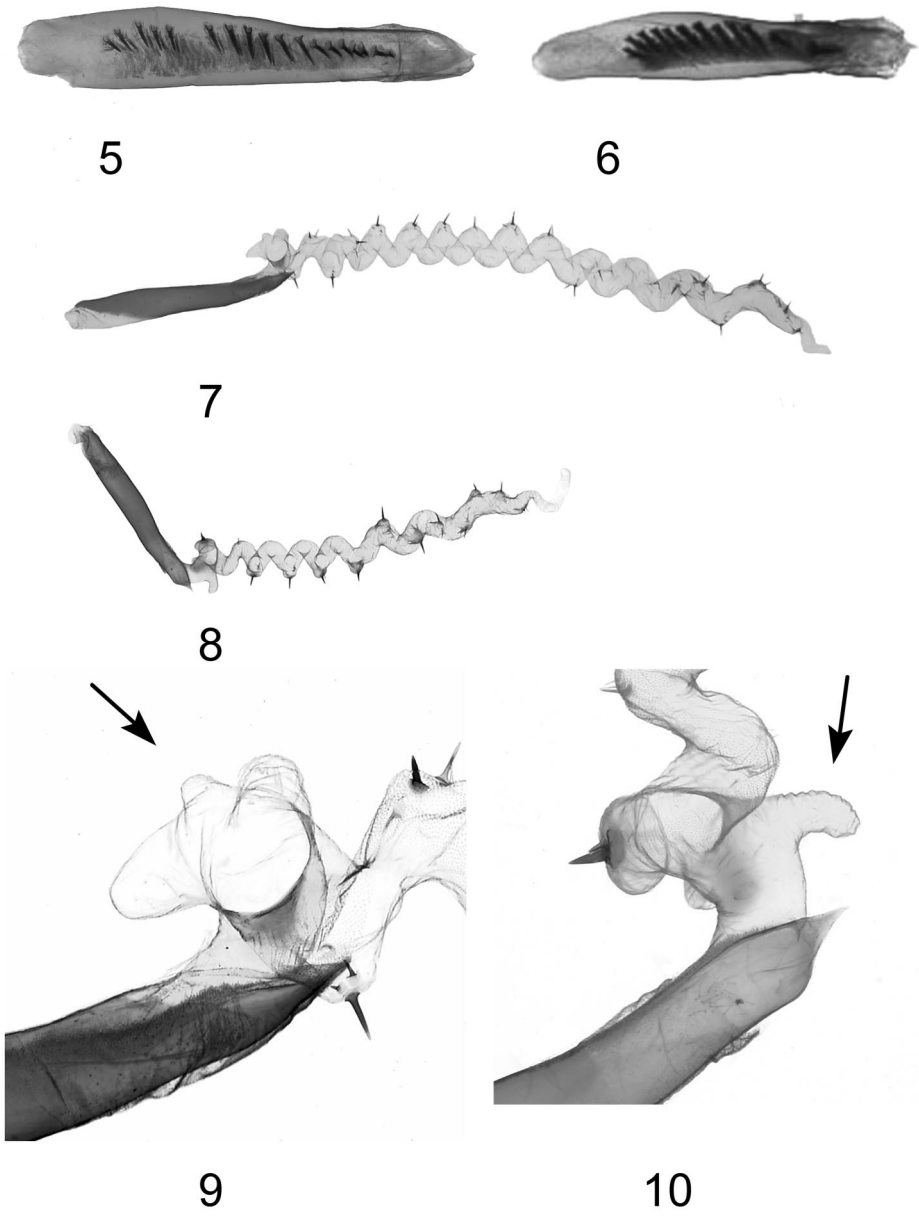


Figs. 1–4. (1) Eighth sternite of *H. zea.* (2) Eighth sternite of *H. armigera.* (3) Male genitalia of *H. zea.* (4) Male genitalia of *H. armigera.* da, distal apex; vm, ventral margin.

bacco, and grain sorghum (Parsons 1939, Pepper 1943, Johnson et al. 1975).

Both *H. zea* and *H. armigera* are phenotypically variable and cannot be identified reliably without genitalic dissection. In the comprehensive monograph of Hardwick (1965) on the genus *Helicoverpa*, the key to adults is based on male and female genitalic characters. Therefore, dissection is necessary to accurately identify adult males collected with pheromones. The purpose of this paper is to provide an efficient procedure for the differentiation of *H. zea* and *H. armigera* males using several diagnostic genitalic characters.

Hardwick (1965) resolved the present taxonomy of *H. zea* and *H. armigera* when he established *Helicoverpa* as a new genus. Before his study, both species were included in *Heliothis* Oschenheimer. These species were considered conspecific by early workers (e.g., Grote 1862) as *Heliothis armigera.* Later, Aurivillius (1897) and Hampson (1903) used the name *Heliothis obsoleta* (Fabricius) as the correct name based on priority. *Bombyx obsoleta* Fabricius was described in 1793 and *Noctua armigera* Hübner in 1809. *Heliothis obsoleta* was then used, particularly in North America. Heinrich (1939) determined that the name *obsoleta* of Fabricius was unavailable for the corn earworm, because it was a junior primary homonym of *Bombyx obsoleta* of Fabricius, 1775, a species now in Lymantriidae. The name *H. armigera* again became more widely used, but not exclusively. Common (1953) recognized that the New World species was different from the Old World *armigera* and suggested that Grote's name *umbrosus* be used. Forbes (1954) also recognized that the Old and New World species were different, but he used *H. obsoleta* for the New World species. Forbes also rec-



Figs. 5–10. (5) Aedoeagus of *H. zea*, vesica uninflated. (6) Aedoeagus of *H. armigera*, vesica uninflated. (7) Aedoeagus of *H. zea*, vesica fully inflated. (8) Aedoeagus of *H. armigera*, vesica fully inflated. (9) Three lobes at base of vesica in *H. zea*. (10) Single lobe at base of vesica in *H. armigera*.

ognized that *obsoleta* was invalid but proposed that it be a *nomen conservandum*. Todd (1955) determined by genitalic characters that there were two economically important species in South America, *Helicoverpa gelotopoeon* (Dyar) and *H. zea*. He noted that the name *H. zea* (1850) had priority over *H. umbrosus* (1862). Thus, the older literature on the corn earworm must be interpreted with caution because the names *armigera*, *obsoleta*, and *umbrosus* can be referred to as *zea* if the origin is in the New World, and the Old World bollworm can be referred to as either *armigera* or *obsoleta*.

Okumura and Bauer (1969) described *Heliothis stombleri*. This species was indistinguishable from *H. zea* except that the genitalia of both sexes differed dramatically from *H. zea*. Hardwick (1970) suggested that *H. stombleri* is a genitalic aberration of *H. zea*. The vesica is barely perceptible in *H. stombleri*, and the female genitalia are greatly reduced as well. He mentioned that these reductions would render *H. stombleri* either infertile or at least incapable of copulation. *H. stombleri* has been collected throughout California, Oregon, southern Washington, central Missouri, and

central Texas. In a series of specimens reared from a single female from the Waianae Mountains, Oahu, HI, Hardwick obtained 5.6% male and 2.5% female *H. stombleri.* In populations of *H. zea* from Argentina and Brazil, the occurrence of *H. stombleri* was 3.6% and 15.2%, respectively.

Materials and Methods

Two samples of adult *Helicoverpa*, each containing 23 specimens, were submitted to the U.S. Department of Agriculture, Systematic Entomology Laboratory for identification by the Texas Department of Agriculture. Each sample was placed in a jar of 10% KOH and left overnight. The genitalia were dissected from the abdomen, and the aedoeagus was removed. The aedoeagus was inflated using a syringe fitted with a size 30 needle filled with 99% isopropyl alcohol.

Results

Several characters are useful in separating males of *H. zea* from *H. armigera.* In both species, the eighth sternite is moderately forked at both margins. However, *H. zea* has rounded distal apices and the proximal margin is U-shaped (Fig. 1), whereas *H. armigera* has more pointed distal apices, and the proximal margin is V-shaped with the apex of the "V" flattened, not pointed (Fig. 2). The valve is also longer in *H. zea* (length, 4.65–5.40 mm; mean, 4.98 ± 0.21 mm; median, 4.95; $n = 15$; Fig. 3) than in *H. armigera* (length, 4.10–4.85 mm; mean, 4.48 ± 0.07 mm; median, 4.5; $n = 12$; Fig. 4). The vesica in both species is an eversible sac within the aedoeagus that is an elongate spiral with numerous spines or cornuti. These cornuti are visible on the uninflated vesica within the aedoeagus. There are more cornuti in the vesica of *H. zea* (Fig. 5) than in *H. armigera* (Fig. 6). The vesica in *H. zea* has 8.0–11.0 coils (Fig. 7), and in *H. armigera*, 6.5–8.5 coils (Fig. 8). This character is difficult to use because the vesica must be fully inflated. A better vesica character to use, because full inflation is not necessary, is the number of small lobes or diverticula at the base of the vesica near the apex of the aedoeagus. In *H. zea*, there are three lobes (Fig. 9), and in *H. armigera*, there is a single lobe (Fig. 10).

The occurrence of *H. stombleri* in specimens from Texas dissected by the author was 9.1% ($n = 46$). The evidence given by Hardwick (1970) and the recent dissections from Texas clearly indicates that *H. stombleri* is nothing more than an aberration; therefore, I propose *Heliothis stombleri* as a new synonym of *Helicoverpa zea.*

Discussion

The goal of examining large numbers of samples is efficiency in determining which specimens need further dissection. Specimens collected from pheromone traps are usually in poor condition, with missing legs and tattered and torn wings. To speed identification, the entire specimen can be placed in KOH.

After dissection, the valve is measured. If it is ≥4.9 mm, it is identified as *H. zea.* If it is <4.9 mm, it is kept for observing the number of cornuti in the aedoeagus or vesica inflation. *H. zea* has more cornuti than *H. armigera*, and this can be seen within the aedoeagus (Figs. 5 and 6). It is not necessary to fully inflate the vesica, but just enough to determine the number of basal diverticula; there is one in *H. zea*, and there are three in *H. armigera* (Figs. 9 and 10). The shape of the eighth sternite (Figs. 1 and 2) is diagnostic, and after some experience, these differences should be easily recognizable, making further dissection unnecessary.

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