

IDENTIFICATION GUIDE TO LARVAL HELIOTHINAE (LEPIDOPTERA:  
NOCTUIDAE) OF QUARANTINE SIGNIFICANCE

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2014 (replaces previous versions)

## ABSTRACT

A preliminary key to Heliothinae larvae of quarantine significance is presented emphasizing morphology, hosts, and origins. The key includes commonly intercepted species and potential pests likely to be intercepted because of their broad host range or distribution. When the present state of our knowledge does not allow species level recognition, the key uses host and origin to give the best possible identification. This information is valuable for pest risk assessments and identification authority.

Pest species in the Heliothinae represent a serious threat to North American agriculture. APHIS needs to be concerned with the introduction of new pests to the United States as well as the exportation of our native species to other countries that could undermine trade agreements. Three pests of export concern from North America to other parts of the world are *Helicoverpa zea*, *Chloridea virescens* and *Heliothis phloxiphaga*. In recent years, *Heliocheilus albipunctella* has emerged as a pest of millet in central Africa. Millet is imported as bird feed in the pet trade so a potential pathway exists for introduction of this species. Interceptions of *Helicoverpa armigera* at United States ports were increasing in 2005 (C. Brodel, pers. obsv.), this too is a cause for concern.

Heliothinae larvae submitted for morphological identification must include at least the hostplant family. Molecular methods and rearing immatures to adults are two other procedures to increase the accuracy of our PestID system.

In 2005, the most recent analysis of the PestID database for Heliothinae, approximately 10% of the treatments for *Heliothis* were unnecessary (2 of 21 cases). *Helicoverpa* was intercepted over 1400 times in the same period, but no more than 100 of these samples were identified to two species (*H. armigera* and *H. assulta*). Most of the *H. armigera* data appeared biologically sound, but the few records for *H. assulta* are on atypical hosts (eg., Apiaceae). Unnecessary treatments for New World *Helicoverpa* (Mexico, West Indies, Central America) were present, but in low numbers (less than 100 times total).

Hosts for *Schinia chilensis* in Chile, and *Heliothis peltigera* as part of the North America fauna, need to be confirmed.

The subfamily Heliothinae includes many serious pests (Kogan et al. 1978, Mitter et al. 1993) that have been intercepted by APHIS over 1400 times from 2000-2004 alone (PestID database). At best, they are nearly impossible to identify because few morphological characters exist, and the few features that seem significant are often highly variable. This is especially a problem for quarantine inspectors who routinely examine a large series of specimens. Molecular identification kits are available for some species (Trowell et al. 2000, Specht et al. 2013), but they are not currently widely used by APHIS. Hardwick (1965) published a detailed larval key to world *Helicoverpa*. From a practical standpoint, using a long series of measurements is usually not possible at most APHIS ports and there are theoretical issues as well (see *H. armigera* fact sheet, section on setal bases below). Therefore, Hardwick's (1965) key was not fully utilized. Other problems with this key exist in Australia and there is no couplet for Central America making identifications from this region

difficult. New publications have appeared over the last two decades (Matthews 1991, 1999, Mitter et al. 1993, Beck 1999-2000, Gomez de Aizpurua 2002, Ahola and Silvonen 2005, Wagner et al. 2011), suggesting a review and update of identification authority in the Heliiothinae is long overdue. This work presents a key to identify Heliiothinae larvae to subfamily, genus, or species depending on the state of the knowledge of the included taxa. Practical and relatively rapid identification is stressed for each faunal region to an appropriate level for most quarantine decisions.

A second goal of this work is to present data on the distribution and biology of economically important Heliiothinae to aid in pest exclusion and risk assessments.

**Selection of species.** All larval identifications have a risk associated with the name. In a key such as this one, there is a tendency to be conservative because Heliiothinae immature stages are so poorly known. However, the mission of APHIS is to protect American agriculture, and to do this, we must have accurate identifications for pathway analysis, resource management, and risk assessments. I tried to balance these two positions by giving the key the maximum resolution possible while being as careful as possible. Ultimately, molecular diagnosis or rearing the immature stages is the only way we can be 100% sure of our identifications.

Previously, keys to species of quarantine Lepidoptera included the taxa most likely to be intercepted (Weisman 1986). Rare taxa were generally omitted. Now APHIS recognizes that our quarantine documents may be questioned and the emphasis is on accurate identifications we can defend using technical literature. Therefore, intercepted species, and the taxa most likely to be confused with them, need to be in this key. Above all, it is important to demonstrate an understanding of the systematics of the Heliiothinae. Only then will our critics have confidence in our reports. Identification of heliothine larvae is frustrating and complicated, but the stakes are high, as nearly all the pest taxa are a major threat to North American agriculture.

The PestID database and National Identification Service authority list were chosen as starting points because they reflect taxa that APHIS has intercepted. The status of other Heliiothinae taxa is unclear. Either APHIS does not intercept a diversity of genera, or perhaps they are entering the US but we fail to recognize them except for a subfamily identification. Unless the key is enlarged to include potential pests, it will be impossible to distinguish among these alternatives.

Mitter et al. (1993) gave a list of polyphagous heliothine species. Their broad host range suggests they will be found on many agricultural crops. All six *Helicoverpa*, seven out of ten *Heliothis*, *Adisura atkinsoni*, and representatives of the genus *Pyrrhia* were added to this key. Several *Heliothis* were omitted because, even though they are polyphagous, their hosts seem not to include plants inspected by APHIS. *Pyrrhia* was added to the European fauna where it sometimes appears to be associated with economically important plants (Matthews 1991), although in other regions APHIS would unlikely to intercept many specimens. Additional species were evaluated using Hardwick (1965) and the Crop Protection Compendium Global Module (CABI, 2000). A species name in square brackets indicates that APHIS has no documented interceptions of the taxa.

**Nomenclature.** Hardwick (1996:17) suggested Heliothentinae is the correct spelling to replace Heliothidinae or Heliothinae. I follow Matthews (1991) who used Heliothinae. This is the most common spelling of the subfamily in the world literature.

Early literature in North America considered *H. zea* and *H. armigera* to be synonyms of a single widespread species (see King 1994). *Helicoverpa zea* was also previously listed in the genus *Heliothis* under the name *Heliothis obsoleta* (e.g., Forbes 1954). Following Hardwick (1965), *H. zea* is restricted to the New World and *H. armigera* is separated as a second Old World species. *Heliothis obsoleta* is now a synonym of the corn earworm, *H. zea*. Corn earworm, bollworm (of cotton), and tomato fruitworm are all common names for *H. zea*, one of the few insects to have three official Entomological Society of America common names associated with it (Bosik 1997).

Pogue (2013) resurrected *Chloridea* as the correct genus name for the *Heliothis virescens* species group. This is used for New World species but nomenclature of the Old World *Heliothis* is left unchanged pending further study.

Early literature in North America also considered *C. virescens* and *C. subflexa* to be a single species. I follow Poole et al. (1993) who consider the two taxa separate. Note that many of the endings were changed by Todd (1978) (*subflexa* versus *subflexus*) but I follow the spelling given by Matthews (1991), the most recent revision of the subfamily.

The history of the subfamily Heliothinae was reviewed by Kitching (1984).

## CHARACTERS

**Larval integument spiny.** APHIS has traditionally relied on this character to recognize heliothine larvae (Weisman 1986). As a result of this simplification, misidentifications can occur because scattered species in other subfamilies may also have a spiny cuticle, and a few of these are intercepted by APHIS (SPIC coll.). One example is the *Agrotis/Feltia/Euxoa* complex from Chile on *Chicorium* (larva compared to Angulo 1973, Angulo et al. 2006). Another is *Litoprosopus* (Catocalinae, see Dekle 1968 for illustration of *L. futilis*) from sabal palm and corn, the latter record being an atypical host. Even some loopers, for example *Rachiplusia ou* (Plusiinae) on various hosts from Mexico, have spiny skin (LaFontaine and Poole 1991). Therefore it is important to use a combination of characters when identifying heliothinae larvae instead of concentrating just on skin texture. No heliothine larva lacks spiny skin, but in some North American *Schinia* the spines are restricted to small areas of the posterior abdominal segments and anal shield (Hardwick 1999). See the Key to frequently named lepidopteran larvae intercepted, or potentially encountered, at U.S. ports (couplet 39) on the Keys page of LepIntercept for more information.

Besides the three subfamilies mentioned above, a spiny larval cuticle occurs in the Acronictinae, Cuculliinae, and Herminiinae (Mitter et al. 1993, Kitching and Rawlins 1998). I was unable to

confirm Garman's (1920) statement that the skin of *Alabama argillacea* is spiny, at 60x the skin appeared smooth in larvae from Honduras (spms. in SPIC coll.).

Most workers do not consider the spines of other noctuid larvae to be homologous with those of the Heliothinae (Garman 1920, Kitching and Rawlins 1998).

**Prothoracic L setae in a horizontal or slanted horizontal line.** This character is unique to the Heliothinae, but it only appears in the last instar. Early instars have the prothoracic L setae arranged vertically as is typical for most noctuids (Kitching and Rawlins 1998).

Even when horizontal, the exact arrangement of the L setae is variable. An imaginary line connecting the two setae may be straight (180 degrees) or slanted up to a 45 degree angle (Hardwick 1958, Matthews 1991). No comparative survey has been carried out on the world level to evaluate the position of the prothoracic L setae in non-heliothine noctuids. The horizontal arrangement probably occurs in other subfamilies, but this has not yet been recorded.

**Crochets biordinal.** Although sometimes difficult to evaluate (Matthews 1991), the crochets of the heliothine larvae included in this key are weakly biordinal (Hardwick 1965, Stehr 1987). Uniordinal crochets occur in some North American species of *Schinia* (Heliothinae) which are associated with Asteraceae (Crumb 1956, Hardwick 1958), but they are not pests of crops.

The Cuculliinae and Plusiinae also share biordinal crochets with the Heliothinae, in contrast to most other noctuid larvae where they are uniordinal (Crumb 1956).

*Adisura atkinsoni* has the crochets bifurcate at the tip (Gardner 1946), this is an unusual modification.

Li et al. (2013) claimed *H. assulta* has uniordinal crochets and that separated it from *H. armigera*. I do not have enough material of either species to test this character.

**Setal bases.** I follow the terminology in Stehr (1987: 296). A pinaculum (plural: pinacula) is a sclerotized base with a seta. If the pinaculum is raised or elevated, it is called a chalaza (plural: chalazae).

The size of the setal base is used with caution in this key. Neunzig (1969:11) showed that the size of the setal base varies within an instar depending on how tight the skin is stretched. Therefore, variation in setal base size (individuals with pinacula and individuals with chalazae) must be accounted for in many species.

**Setal color.** Several authors have suggested that setal color or setal base color is a useful identification feature. My experience with the corn earworm indicates that setal color is highly variable and a larger series of specimens of related species would be needed before this character can be trusted for quarantine work. Nevertheless, dark and light setae are discussed as a first step in evaluating their usefulness. Setal color has also been suggested as a character for Australian *Helicoverpa* (see *H. armigera* Fact Sheet).

**Setal bar.** Hardwick (1999) noted that some *Chloridea* larvae have a bar connecting the D setae of A1 and A2. A similar marking has been called a “saddle” in Australian *Helicoverpa* (see *H. armigera* Fact Sheet). This character is mentioned in the Fact Sheets where appropriate but its use in identification is complicated because not all color forms of a given species show this feature. This variability was seen in both *C. virescens* and *H. armigera*. It has been used with caution in the key.

**Mandibular retinaculum.** The form of the retinaculum, also called the basal or inner tooth (see Stehr 1987: 553, fig. 28, 29) is an important character to separate heliothine genera in Europe (Beck 1999-2000) and species North America (e.g., Peterson 1962, Wagner et al. 2011). Neunzig (1969) showed that as many as 17% of one hundred *C. virescens* larvae collected from tobacco seed capsules in North Carolina lacked a retinaculum on both mandibles. This variation should also be expected in APHIS samples. Brazzel et al. (1953) photographed similar differences in *H. zea* and *C. subflexa* mandibles. *Helicoverpa zea* may or may not have a small ridge where the retinaculum would be located. *Chloridea subflexa* can have or lack a large retinaculum.

**Spines present on the top portion of the dorsal setal bases on A1, A2, and A8.** The key frequently uses the presence of spines on the setal bases of A1, 2, and 8 to separate *Chloridea* from *Helicoverpa*. This character has been widely used in the North American literature for many years (Crumb 1956, Peterson 1962, Neunzig 1969, Stehr 1987, Wagner et al. 2011), and was considered to be a specialization (apomorphy) of the *Chloridea* “*virescens* group” by Poole et al. (1993). However, larvae of only three New World species (*C. virescens*, *C. subflexa*, and *C. tergemina*) are well known and no information exists on the rest of the genus. Microspined chalazae are also present in *Helicoverpa fletcheri* (Matthews 1991: fig. 740) from the Old World and therefore this key uses the character only for the New World fauna. It is especially critical to study the dorsal setal bases of the poorly known South American species of *Helicoverpa* to see if any other exceptions are present.

Unless an exception is known, I follow Hardwick (1965: 28) who stated the D pinacula of A8 in *Helicoverpa* are “devoid of spicules except at the extreme periphery” even though I could not confirm this in the rarer species.

Some specimens of *H. phloxiphaga* have spines on the setal bases of A8 whereas other individuals lack these spines (Crumb 1956). Therefore, this species will key out in two locations. Neunzig (1969) mentioned that some individuals of *H. zea* have minute spines on the lower margin of the dorsal setal bases of A8, but they are small and do not cover the middle to upper portions of the setal base as is typical for *C. virescens* (Peterson 1962: L36). The spines of *C. virescens* tend to be longer than other species.

Peterson (1962), Stehr (1987) and Pogue (2013) considered the chalazae of *C. subflexa* to be spined. Wagner et al (2011: 345) considered them to be naked.

It is obvious that both the mandible and microspine pattern of North American Heliothinae are subject to great variation. The illustrations of A4 in Peterson (1962: L36), considered a standard reference, do not seem to separate all *C. virescens* from all *C. subflexa*. Still, his drawings and

Wagner et al. (2011)(see the color photos and comments on the SD2 pinacula and white spinules) may be helpful for doubtful cases. But there will always be some individuals that are difficult to name such as prepupa or forms with no chalazae and flat pinacula. For these cases, hosts can be important clues (see next section).

**Hosts.** Although Heliothinae are generally characterized as feeders on the reproductive parts of plants (seeds, flowers, and fruits), exceptions are common. There is a huge range of feeding habits in this taxon from extreme specialists to polyphagous generalists eating almost any green plant. Hardwick (1965) even recorded fruit trees and conifers as hosts of *Helicoverpa*.

Some Cucullinae, Stiriinae, and Hadeninae also feed on flowers (Matthews 1991), thus this habit is not unique to the Heliothinae.

Economically important plants are defined as those plants which have a cash value. For the purposes of this key, most are crops or cut flowers.

The host records given in the key are literature records. Matthews (1999) noted that *H. assulta* has been reared from several non-solanaceous hosts in Australia. Because the ability to distinguish *H. armigera* from *H. armigera* is partially based on hostplants, and this distinction is important to APHIS, I have not incorporated the wider host range in all couplets. Instead I limit the new hosts only to the population of *H. assulta* in Australia pending confirmation of this feeding habit from the African subspecies of *H. assulta* described by Hardwick (1965). Related to this discrepancy, Sannino et al. (1993: fig. 5) illustrated the spine pattern of *H. assulta* from Europe differently from Bejakovich and Dugdale (1998) in New Zealand. This may reflect the age of the larva or a further subspecies characteristic. These morphological differences were also kept separate by regions, the illustration by Sannino (1995) was used except for the couplet on New Zealand.

As a general rule, for North and Central America, *C. virescens* does not eat corn (Crumb 1956) and it common on legumes. Do not identify *C. subflexa* from anything except *Physalis* or *Solanum*. More often than not, *H. zea* is the species in corn ears (but see the *H. zea* Fact Sheet for South American interceptions).

According to Pogue (2013), *C. tergema* is considered to be oligophagous on Solanaceae. Hostplants for *Schinia chilensis* are based on Jana-Saenz and Angulo (1985) (cited by Matthews 1991). Jana-Saenz and Angulo (1985) only implied *S. chilensis* was associated with a complex of economically important heliothine species attacking crops. Their material examined gave no hosts and thus the biology of this species needs confirmation.

**Origin.** Geographical distribution is an important clue when trying to identify larval Heliothinae, therefore the keys are arranged by geographical region. The distribution records given in the key are literature records. I consider cutflowers from the Netherlands to be an unknown origin because flowers are often shipped through the Netherlands from the Middle East or Asia, perhaps even South America or Africa. However, vegetables shipped from the Netherlands were probably

grown in the Netherlands, therefore these imports can be treated as a known European origin (J. Brusch, pers. comm.).

*Heliothis peltigera* is rarely listed as part of the North America fauna (Gomez de Aizpurua 2002:150), this need to be confirmed.

I cannot stress the importance of accurate data when trying to identify Heliothinae larvae. Fruits from multiple origins mixed in a single heap will surely lead to errors in our PestID system or inaccurate reference specimens.

**Miscellaneous comments.** This key is intended for middle to late instar larvae over 10 mm long. Early instar larvae should not be identified past subfamily (species of Heliothinae)(see Fact Sheet on *Helicoverpa* sp.)

References are given to published illustrations in many couplets. This does not signify the authors agreed with the characters in the couplet, nor that they were the source of all the characters. Some of these pests have been illustrated hundreds of times, for this key, only an example or two was selected. Consult the reference list of LepIntercept for other publications that may contain addition illustrations.

If a couplet does not lead to a species name because a larva is unknown or not studied, the taxa that fall out in that portion of the key are listed, often with a reference giving further information. Generally, getting preserved specimens would be required to improve the key at these points.

As with any of these difficult highly variable noctuid taxa (Heliothinae, *Spodoptera*), all the characters of a given couplet may not exactly fit the unknown specimen. In these situations, select the choice that fits the best. Many species of Heliothinae are not covered by this key. Identify only to subfamily if needed.



1. Prothoracic L setae arranged in a horizontal or slanted horizontal line, if vertically arranged (early instars) then cuticle is spiny and crochets weakly biordinal; prolegs of A3-6 equal in size; feeds on flowers, fruits, and seeds of the host, only rarely on foliage; cosmopolitan (Heliothinae).....	2
1'. Prothoracic L setae arranged vertically; cuticle smooth or granular, rarely spiny; crochets usually uniordinal, rarely biordinal; prolegs of A3-6 sometimes unequal in size; feeds on leaves or in stems of the host, only rarely on flowers, fruits or seeds; cosmopolitan.....	sp. of Noctuidae
2. Either origin unknown or host unknown or less than 10 mm .....	sp. of Heliothinae
2'. Origin and host known with <u>certainty</u> and larva greater than 10 mm .....	3
3. Feeds on non-agriculturally important grass (Poaceae) from arid regions of Australia and Africa (possibly <i>Heliocheilus</i> in part, <i>Helicoverpa</i> ) .....	[sp. of Heliothinae]
3'. Feeds on agriculturally important Poaceae (corn, rice, sorghum, millet, etc.) or other plant families .....	4
4. New world taxa .....	5
4'. Old world taxa.....	25
<b>5. North American taxa (Canadian interceptions, USA exports and domestic surveys, Mexican interceptions) .....</b>	<b>6</b>
5'. AQI interceptions from Latin America .....	11
6. Microspines present on at least the bottom third to the top of the D setal bases on A1, A2, and A8; mandible may have a large retinaculum .....	7
6'. Microspines absent, or only a few are scattered around the edge, of the D setal bases on A1, A2, and A8; mandible always lacks a large retinaculum but may have a small tooth or ridge .....	9

7. The D, and often the SD1, chalazae of A1-8 strongly conical (as high as wide); if the D and SD1 setal bases on A1-8 are flat and unpigmented, then they are of equal size; head unmarked or sometimes with dark spots forming an arc; mandible without a retinaculum; body pinacula sometimes minutely ringed with white; polyphagous feeder, but not expected on *Physalis* (Hardwick 1999: plate N, Wagner et al. 2011: 347) .....*Heliothis phloxiphaga* (in part)
- 7'. Strongly conical (as high as wide) chalazae, if present, are only on A1, A2 and A8; SD1 seta of A1-8 never on conical chalazae; if the D and SD1 setal bases on A1-8 are flat and unpigmented, then they are largest on A1, A2 or A8; head with various patterns, but without dark spots forming an arc; mandible often has a retinaculum; body pinacula not minutely ringed with white; polyphagous feeder often on *Physalis* .....8
8. Most microspines on A1, A2 and A8 wider than the diameter of the corresponding seta (Peterson 1962: L36) and often covering the whole setal base; SD2 pinaculum of A1-8 normally unpigmented; body may have white spinules; polyphagous feeder, often on legumes, rarely on *Physalis* (Hardwick 1999: plate M, Wagner et al. 2011: 346, LepIntercept Fact Sheet) ..... *Chloridea virescens*
- 8'. Microspines on A1, A2 and A8 as large or smaller than the diameter of the corresponding seta (Peterson 1962: L36) and normally only covering the bottom half the setal base; SD2 pinaculum of A1-8 normally pigmented; body without white spinules; feeds primarily on *Physalis*, only rarely on *Solanum*, and not on other hosts (Wagner et al. 2011: 347) ..... *Chloridea subflexa*
9. Body setae lack pinacula; subdorsal stripe wide and obvious on living material; polyphagous, but often recorded from flax; Manitoba south to Colorado and west through Canada, absent from Mexico (Peterson 1962: L37, Ahola and Silvonen 2005: Plate 49D, E) .....[*Heliothis ononis*]
- 9'. Body setae, or at least D1 of A1-8, inserted on a chalaza or large, sometimes unpigmented pinacula; subdorsal stripe, if present, thin; polyphagous feeder; distributed throughout North America to Mexico .....10

10. The D, and often the SD1, chalazae of A1-8 strongly conical (as high as wide); if the D and SD1 setal bases on A1-8 are flat and unpigmented, then they are of equal size; head unmarked or sometimes with dark spots forming an arc; body pinacula sometimes minutely ringed with white; polyphagous feeder, but not expected on corn (Hardwick 1999: plate N, Wagner et al. 2011: 347) .....*Heliothis phloxiphaga* (in part)
- 10'. D chalazae broadly conical (wider than high), or if poorly developed, then D setae of A1-8 inserted on flat unpigmented pinacula which are largest on A1, 2, and 8; head not marked with dark arcs; body pinacula not minutely ringed with white; polyphagous feeder, common in corn ears; distributed throughout the New World (Hardwick 1999: plate N, Wagner et al. 2011: 347, LepIntercept Fact Sheet) ... *Helicoverpa zea*
- 11. From Central America, Panama, or the West Indies.....12**
- 11'. From other regions of South America.....14
12. Microspines present on at least the bottom third to the top of the D setal bases on A1, A2, and A8; mandible may have a large retinaculum if not worn off; polyphagous feeder, not expected in in corn ears .....13
- 12'. Microspines absent, or only a few are scattered around the edge, of the D setal bases on A1, A2, and A8; mandible always lacks a large retinaculum but may have a small tooth or ridge; polyphagous feeder, common in corn ears (Hardwick 1999: plate N, Wagner et al. 2011: 347, LepIntercept Fact Sheet) ..... *Helicoverpa zea*

13. Most microspines on A1, A2 and A8 wider than the diameter of the corresponding seta (Peterson 1962: L36) and often covering the whole setal base; SD2 pinaculum of A1-8 normally unpigmented; body may have white spinules; polyphagous feeder, often on legumes, rarely on *Physalis* (Hardwick 1999: plate M, Wagner et al. 2011: 346, LepIntercept Fact Sheet) ..... *Chloridea virescens*
- 13'. Microspines on A1, A2 and A8 as large or smaller than the diameter of the corresponding seta (Peterson 1962: L36) and normally only covering the bottom half the setal base; SD2 pinaculum of A1-8 normally pigmented; body without white spinules; feeds primarily on *Physalis*, only rarely on *Solanum*, and not on other hosts (Wagner et al. 2011: 347) ..... *Chloridea subflexa*
- 14. From northern South America (Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname, French Guiana, Trinidad and Tobago) .....15**
- 14'. From central or southern South America .....20
15. Microspines absent, or only a few are scattered around the edge, of the D setal bases on A1, A2, and A8; mandible without a large retinaculum, but a ridge or tooth may be present in species examined (*Helicoverpa*) .....16
- 15'. Microspines present on at least the bottom third to the top of the D setal bases on A1, A2, and A8; mandible may have a large retinaculum if not worn off .....17
16. From Peru (LepIntercept Fact Sheet on *H. zea*, [*H. titicacae* (SPIC coll.), neither *H. atacamae* or *H. bractea*] were studied) ..... sp. of *Helicoverpa*
- 16'. Not from Peru (LepIntercept Fact Sheet) ..... *Helicoverpa zea*
17. From Peru east to Venezuela .....18
- 17'. From Guyana, Suriname, French Guiana .....19

18. From Solanaceae (*C. tergemina* Matthews 1991: Figs: 696, 711, 733, LepIntercept Fact Sheets on *C. virescens* and *C. subflexa*) ..... sp. of *Chloridea*
- 18'. From non-solanaceous host (LepIntercept Fact Sheet) ..... *Chloridea virescens*
19. Most microspines on A1, A2 and A8 wider than the diameter of the corresponding seta (Peterson 1962: L36) and often covering the whole setal base; SD2 pinaculum of A1-8 normally unpigmented; body may have white spinules; polyphagous feeder, often on legumes, rarely on *Physalis* (Hardwick 1999: plate M, Wagner et al. 2011: 346, LepIntercept Fact Sheet) ..... *Chloridea virescens*
- 19'. Microspines on A1, A2 and A8 as large or smaller than the diameter of the corresponding seta (Peterson 1962: L36) and normally only covering the bottom half the setal base; SD2 pinaculum of A1-8 normally pigmented; body without white spinules; feeds primarily on *Physalis*, only rarely on *Solanum*, and not on other hosts (Wagner et al. 2011: 347) ..... *Chloridea subflexa*
- 20. From Chile** (LepIntercept Fact Sheets on *H. zea* and *Heliothis virescens*, neither *Schinia chilensis*, *Helicoverpa atacamae* or *H. gelotopoeon* were studied) ..... sp. of Heliothinae
- 20'. From other areas of central or southern South America (Brazil, Bolivia, Paraguay, Uruguay, Argentina) .....21**
21. Microspines absent, or only a few are scattered around the edge, of the D setal bases on A1, A2, and A8; mandible without a large retinaculum, but a ridge or tooth may be present (LepIntercept Fact Sheet on *H. zea*, neither *H. bracteae*, *H. gelotopoeon* or were studied) (*Helicoverpa*) .....22
- 21'. Microspines present on at least the bottom third to the top of the D setal bases on A1, A2, and A8; mandible may have a large retinaculum if not worn off (LepIntercept Fact Sheets on *C. subflexa* and *C. virescens*, but five *Chloridea* spp. in Brazil and *C. molochitina* from Bolivia, Paraguay, Uruguay, and Argentina all not studied) ..... sp. of *Chloridea*

22. From Paraguay or Argentina (LepIntercept Fact Sheet on <i>H. zea</i> , neither <i>H. bracteae</i> or <i>H. gelotopoeon</i> were studied) .....	sp. of <i>Helicoverpa</i>
22'. From Brazil, Bolivia, or Uruguay .....	23
23. Prothoracic shield green; body setae white (LepIntercept Fact Sheet on <i>H. zea</i> , <i>H. gelotopoeon</i> not studied) .....	sp. of <i>Helicoverpa</i>
23'. Prothoracic shield black or dark brown; body setae dark brown .....	24
24. From Bolivia or Uruguay (LepIntercept Fact Sheet) .....	<i>Helicoverpa zea</i>
24'. From Brazil (LepIntercept Fact Sheets on <i>H. zea</i> , <i>H. armigera</i> ) .....	sp. of <i>Helicoverpa</i>

## OLD WORLD FAUNA

<b>25. From Africa</b> .....	<b>26</b>
25'. From other Old World localities .....	32
26. Feeds on millet ( <i>Pennisetum</i> ) from southeastern to central Africa (Mauritania and Senegal to the Sudan) .....	27
26'. From any host except millet .....	28
27. Dorsum with three solid longitudinal stripes, no white spots, and small inconspicuous setal bases lacking microspines (Matthews and Jago 1993, Matthews 1991: Figs 699, 715, 716, 736) .....	[ <i>Heliocheilus albipunctella</i> ]
27'. Subdorsal or spiracular stripe well developed, but dorsum lacks longitudinal stripes except for a weak, broken middorsal line; dorsal white spots and striations present; and setal bases usually enlarged to form chalazae sometime with microspines ( <i>H. armigera</i> , [ <i>H. fletcheri</i> ] Matthews and Jago 1993: 67, Matthews 1991: Figs 737, 740, LepIntercept Fact Sheet on <i>H. armigera</i> ) .....	sp. of <i>Helicoverpa</i>
28. From East Africa (Kenya, Tanzania, to South Africa) and Madagascar ( <i>H. assulta</i> or <i>H. armigera</i> but [ <i>H. toddi</i> ] not studied) .....	sp. of <i>Helicoverpa</i>
28'. From other parts of Africa .....	29

29. From North Africa bordering the Mediterranean Sea.....	30
29'. From central and southern Africa .....	31
30. Larva green with pale white to dark flat pinacula, the D setae of A1 never connected to each other by a dark bar; cuticle with course white spines and white spots; mandible with a long thin inner tooth; spiracle of A8 about three times the height of the spiracle on A7 (Gomez de Aizpurua 2002:150, Ahola and Silvonen 2005: Fig.1092, Plate 49F, G, H) .....	[ <i>Heliothis peltigera</i> ]
30'. Larva usually darkly marked with conical black chalazae, the D setae of A1 often connected to each other by a dark bar; cuticle with minute dark spines and white markings that give the larva a striped instead of spotted appearance; if larva is pale green with pale pinacula, then mandible lacks a long thin inner tooth; and spiracle of A8 is only about twice the height of the spiracle on A7 (Yamaskaki et al. 2009, LepIntercept Data Sheet and Key for <i>H. armigera</i> ) .....	<i>Helicoverpa armigera</i>
31. From Solanaceae, dorsal and subdorsal areas of A1-8 with fine spines evenly distributed (Sannino et al. 1993: Fig. 5) .....	<i>Helicoverpa assulta</i>
31'. From other hosts, including Solanaceae; dorsal and subdorsal areas of A1- 8 with spines in sinuate longitudinal bands (Bejakovich and Dugdale 1998: Fig. 34, Yamaskaki et al. 2009, LepIntercept Data Sheet and Key on <i>H. armigera</i> ) .....	<i>Helicoverpa armigera</i>
<b>32. From the Atlantic and Pacific Islands (including Hawaii).....</b>	<b>33</b>
32'. From Europe, the Middle East, Asia, and Australia .....	38
33. From St. Helena Island (south Atlantic Ocean)(Hardwick 1965).....	[ <i>Helicoverpa helanae</i> ]
33'. From Hawaii or another region .....	34
34. From any Atlantic or Pacific Island except Hawaii .....	35
34'. From Hawaii.....	36

35. From Solanaceae, dorsal and subdorsal areas of A1-8 with fine spines evenly distributed (Sannino et al. 1993: Fig. 5) .....	<i>Helicoverpa assulta</i>
35'. From other hosts, including Solanaceae; dorsal and subdorsal areas of A1-8 with spines in sinuate longitudinal bands (Bejakovich and Dugdale 1998: Fig. 34, Yamaskaki et al. 2009, LepIntercept Data Sheet and Key on <i>H. armigera</i> )	<i>Helicoverpa armigera</i>
36. Microspines absent, or only a few are scattered around the edge, of the D setal bases on A1, A2, and A8; mandible without a large retinaculum at least in <i>H. zea</i> although a small ridge or tooth may be present, mandible of other species listed in couplet 37 not studied ( <i>Helicoverpa</i> ) .....	37
36'. Microspines present on at least the bottom third to the top of the D setal bases on A1, A2, and A8; mandible may have a large retinaculum if not worn off (LepIntercept Fact Sheet) .....	<i>Chloridea virescens</i>
37. From corn (LepIntercept Fact Sheet on <i>H. zea</i> ).....	<i>Helicoverpa zea</i>
37'. From another host ([ <i>H. confusa</i> , <i>H. hawaiiensis</i> , <i>H. minuta</i> , <i>H. pallida</i> , <i>H. pacifica</i> ], Hardwick 1965, LepIntercept Fact Sheet on <i>H. zea</i> ) .....	sp. of <i>Helicoverpa</i>
<b>38. From far eastern Russia to Japan and south to India and the Indo-Australian Region .....</b>	<b>39</b>
<b>38'. From Europe and western Russia to the Middle East .....</b>	<b>47</b>
<b>39. From New Zealand.....</b>	<b>40</b>
<b>39'. From another part of Asia.....</b>	<b>42</b>
40. Segments A1-A7 with SD1 and L2 pinacula large and closely spaced; microspines in irregular patches around D, SD and L pinacula (Bejakovich and Dugdale 1998) .....	<i>Helicoverpa assulta</i>
40'. Segments A1-A7 with SD1 and L2 pinacula not closely spaced; microspines in three wide longitudinal bands on dorsal midline, between setae D2 and L2, and between setae L1 and L3 (Bejakovich and Dugdale 1998).....	41



41. XD and SD1 setae on prothorax dark; saddle between the D setae on A1 and A2  
absent; peritreme of spiracles usually pale brown in late instars; microspines  
absent below ventral margin of seta SD1 on segments A1-A6; platelets between  
microspines sparse (Bejakovich and Dugdale 1998, Matthews 1999)..... *Helicoverpa punctigera*
- 41'. XD and SD1 setae on prothorax pale; saddle between the D setae on A1 and A2  
often present; peritreme of spiracles usually black in all instars; microspines  
present below ventral margin of seta SD1 on segments A1-A6; platelets between  
microspines dense (Bejakovich and Dugdale 1998, Matthews 1999, LepIntercept  
Fact Sheet on *H. armigera*) .....*Helicoverpa armigera*
42. From Australia (*H. assulta*, *H. armigera*, *H. punctigera*, [*H. prepodes*] not  
studied) (Matthews 1999).....sp. of *Helicoverpa*
- 42'. From another region of Asia .....43
43. Spinneret spatulate, crochets bifurcate at their tip; from *Lablab* or *Hibiscus*  
(Gardner 1946) .....[*Adisura atkinsoni*]
- 43'. Spinneret pointed, crochets simple at their tip; from other crops .....44
44. Larva green with pale white to dark flat pinacula, the D setae of A1 never  
connected to each other by a dark bar; cuticle with course white spines and white  
spots; mandible with a long thin inner tooth; spiracle of A8 about three times the  
height of the spiracle on A7 (Gomez de Aizpurua 2002:150, Ahola and Silvonen  
2005: Figs. 1092, Plate 49F, G, H).....[*Heliothis peltigera*]
- 44'. Larva variable in color, either with conical chalazae or flat pinacula, the D setae of  
A1 often connected to each other by a dark bar; cuticle usually lacks course white  
spines and white spots; mandible lacks a long thin inner tooth; spiracle of A8 not  
three times the height of the spiracle on A7 .....45
45. From Tibet (*H. armigera*, *H. assulta*, [*H. tibetensis*] not studied) .....sp. of *Helicoverpa*
- 45'. From another part of Asia .....46

46. From Solanaceae, dorsal and subdorsal areas of A1-8 with fine spines evenly distributed (Sannino et al. 1993: Fig. 5) .....	<i>Helicoverpa assulta</i>
46'. From other hosts, including Solanaceae; dorsal and subdorsal areas of A1-8 with spines in sinuate longitudinal bands (Bejakovich and Dugdale 1998: Fig. 34, Yamaskaki et al. 2009, LepIntercept Data Sheet and Key on <i>H. armigera</i> ).....	<i>Helicoverpa armigera</i>
47. From Netherlands cut flowers .....	48
47'. From Netherlands vegetables or other areas of Europe to Russia and the Middle East .....	49
48. Larva usually darkly marked with conical black chalazae, the D setae of A1 often connected to each other by a dark bar; cuticle with minute dark spines and white markings that give the larva a striped instead of spotted appearance ; if larva is pale green with pale pinacula, then mandible lacks a long thin inner tooth.....	<i>Helicoverpa</i> sp.
48'. Larva lacks conical black chalazae, the D setae of A1 never connected to each other by a dark bar; cuticle without a striped appearance (unknown origin) sp. of Heliothinae	
49. Mandible with a retinaculum .....	50
49'. Mandible lacks a retinaculum .....	51
50. Mandible with a large broad retinaculum; larval pinacula not pale green with course white spines and spots; occasionally feeds on trees, ornamental flowers and crucifers (Ahola and Silvonen 2005: Figs. 1111, 1112, plate 50, Wagner et al. 2011: 344).....	[ <i>Pyrrhia</i> spp.]
50'. Mandible with a long thin inner tooth; larva green with pale white to dark flat pinacula, the cuticle with course white spines and white spots; (Beck 1999-2000 Fig. 506c, Gomez de Aizpurua 2002:150, Ahola and Silvonen 2005: Figs. 1092, Plate 49F, G, H).....	[ <i>Heliothis peltigera</i> ]

51. D setae of A1-8 inserted on large conical chalazae, those of A1, A2 or A8 often larger than the rest; body color highly variable, but usually with lines and stripes and sometimes a black bar joining the D setae of A1 or A2; if the setal bases are small, then the spinneret is about 5 times longer than the basal segment of the labial palpus (Bejakovich and Dugdale 1998: Fig. 34, Yamaskaki et al. 2009, LepIntercept Data Sheet and Key on *H. armigera*).....*Helicoverpa armigera*
- 51'. D setae of A1-8 not inserted on large conical chalazae, those of A1, A2 or A8 often equal in size to the other setal bases; body color highly variable, but usually without lines and stripes and never with a black bar joining the D setae of A1 or A2; if lines and stripes are present then the spinneret is about 3 times longer than the basal segment of the labial palpus .....52
52. Mandible with three teeth to five teeth; spinneret about 3 times as long as the basal segment of the labial palpus; no contrasting subdorsal stripes; polyphagous on cultivated plants(Beck 1999-2000 Fig. 506b, B206; Ahola and Silvonen 2005: Figs. 1101, 1109, Plate 49I, J).....[*Heliothis nubigera*]
- 52'. Mandible with five teeth; spinneret about 5 times as long as the basal segment of the labial palpus; subdorsal stripes contrasting .....53
53. Medial spines of distal region of the hypopharangeal complex are larger than the medial spines between the blades (Gomez de Aizpurua 2002:149, Ahola and Silvonen 2005: Fig. 1085, Plate 48G, H, I, J) .....[*Heliothis virescens*]
- 53'. Medial spines of distal region of the hypopharangeal complex are subequal to the medial spines between the blades (Beck 1999-2000 B205, Ahola and Silvonen 2005: Fig. 1087, Plate 49D, E).....[*Heliothis ononis*]

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