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

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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. To facilitate risk assessments and identification authority, the key documents crops and origins where the present state of our knowledge does not allow identification to the species level.

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. Two pests of export concern to North American members of NAFTA (Canada, USA, Mexico) are *Helicoverpa zea* 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 may also be increasing (C. Brodel, pers. obsv.), this too is a cause for concern.

It is recommended that Heliothinae larvae submitted for identification include the hostplant family. Molecular methods and rearing immatures to adults both show promise as procedures to increase the accuracy of our PIN system.

Over the last four years, an analysis of the PIN database suggests that 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 *H. armigera* data appears 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).

Literature records of hosts for *Schinia chilensis* in Chile, and including *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) which have been intercepted by APHIS over 1400 times in the last four years alone (PIN database, 2000-2004). 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 (CAB 2000, Trowell et al. 2000), but they are not widely, if ever, used by APHIS. Hardwick (1965) published a detailed larval key to world Helicoverpa. From a practical standpoint, a long series of measurements is usually not possible at most PPQ ports, 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. Several new publications have appeared in recent years (Matthews 1991, 1999; Mitter et al. 1993), suggesting a review and update of identification authority in the Heliothinae is long overdue. This work presents a key to identify Heliothinae larvae to either subfamily, genus, or species depending on the state of the knowledge of the included taxa. Color photographs of the larvae, and typical damage to several crops, are also included for domestic surveys where screening is usually done with live larvae. 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 Heliothinae to aid in pest exclusion and risk assessments.

Selection of species. Every identification of a larva has a risk associated with the name. In a key such as this one, there is a tendency to be conservative because heliothine 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, 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 in 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 Heliothinae. 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 PIN dictionary was chosen as a starting point because it reflects reportable taxa that APHIS has intercepted. Three *Helicoverpa* are included in that database: *H. assulta, H. armigera,* and *H. gelotopoeon* (misspelled as *H. gelotopoen*). These were included in the key. There are also records for *Heliothis* sp., *Helicoverpa* sp. and species of Heliothinae. Non-reportable taxa (eg. *H. zea*) are absent from the PIN database. The status of other Heliothinae 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 the 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 (CAB, 2000). <u>A species name with square brackets indicates that APHIS has no documented interceptions of the species</u>.

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. *Helicoverpa zea* was also previously listed in the genus *Heliothis* under the name *Heliothis obsoleta* (eg., 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).

Early literature in North America also considered *H. virescens* and *H. 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. PPQ 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 (spms. in Passoa coll.). One example is *Agrotis* (=*Euxoa*) prob. *lutescens* (Noctuinae) from Chile on *Chicorium* (larva compared to Angulo 1973, Angulo and Weingert 1973). 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).

Besides the three subfamilies mentioned above, a spiny larval cuticle occurs in the Acronictinae, Cuculliinae, and Herminiinae (Mitter et al. 1993, Kitching and Rawlins 1999). 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 Passoa 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 1999).

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 1999).

Even when horizontal, the exact arrangement of the L setae is variable. An imaginary line connecting the two setae may be straight (180 degrees, see illustration) 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 record.

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.

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

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 individuals with pinacula and individuals with chalazae must be accounted for in each couplet.

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 illustrated as a first step in evaluating their usefulness.

Setal bar. Hardwick (1999) noted that some *Heliothis* larvae have a bar connecting the D setae of A1 and A2. A similar marking has been called a "saddle" in *Helicoverpa.* I have used this feature in the New World because I have seen a large series of specimens and because Hardwick (1999) has seen a wide range of taxa. More study is needed before accepting this feature in the Old World.

Mandibular retinaculum. The form of the retinaculum, or inner tooth (see Stehr 1987: 553, fig. 28, 29) is an important character to separate heliothine genera, especially in Europe (Beck 1999). However, the retinaculum can be worn away, therefore it was necessary to key *H. virescens* in several places to account for this variation. In regions where *H. virescens* is less common, other characters were added to the diagnosis instead of making the key longer and more complicated. Neunzig (1969) showed that as many as 17% of one hundred *H. virescens* larvae collected from tobacco seed capsules in North Carolina lacked a retinaculum on both mandibles. This variation should also be expected in PPQ samples.

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 *Heliothis* from *Helicoverpa.* This character has been widely used in the North American literature for many years (Crumb 1956, Peterson 1962, Neunzig 1969, Stehr

1987), and was considered to be an specialization (apomorphy) of the *Heliothis* *"virescens* group" by Poole et al. (1993). However, only three New World species (*H. virescens, H. sublflexa,* and *H. tergemina*) are known to have this modification. It is present in the Old World *Helicoverpa fletcheri* (Matthews 1991: fig. 740) and thus I have used this 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 exceptions are present.

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 not hairlike or do not cover the middle to upper portions of the setal base as is typical for members of the *H. virescens* group (Peterson 1962: L36).

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 based on hostplants, and this distinction is important to PPQ, I have not incorporated the wider host range in all couplets. Instead I limit the new hosts to *H. assulta* only in Australia pending other examples of this feeding habit from other parts of the world.

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. Recently, Ethiopa started to ship cut flowers to the Netherlands for distribution as well (OPIS update 2006). However, vegetables shipped from the Netherlands were probably grown in the Netherlands, therefore these imports can be treated as a known 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 PIN system or inaccurate reference specimens.

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).

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 certainty 3

3. Feeds on non-agriculturally important grass (Poaceae) from arid regions of Australia and Africa (possibly *Heliocheilus* in part, *Helicoverpa*) [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

5. North American taxa (Canadian interceptions, USA exports and domestic surveys, Mexican interceptions) 6

5'. AQI interceptions from Latin America 12

6. Microspines present on the D setal bases of A1, 2, and 8 7

6'. Microspines absent on D setal bases of A1, 2, and 8 10

7. Mandible with a retinaculum most specimens of *Heliothis virescens*

7'. Mandible without a retinaculum 8

8. D chalazae of A1-8 strongly conical (as high as wide), or if poorly developed, then D setae of A1-8 inserted on flat unpigmented pinacula of equal size; head often marked with black; polyphagous feeder; distributed from southern Canada south to central Mexico [*Heliothis phloxiphaga* (in part)]

8'. D chalazae broadly conical (wider than high), or or if poorly developed, then D setae of A1-8 inserted on flat unpigmented pinacula of which are largest on A1, 2, and 8; head not strongly marked with black; feeding habits vary; distributed throughout North America 9

9. SD1 and L1 setal bases of A4 not connected to each other by a band of microspines and neither one is much larger than the diameter of the spiracle; polyphagous feeder rare specimens of *Heliothis virescens*

9'. SD1 and L1 setal bases of A4 connected to each other by a band of microspines (sometimes barely so) and both are much larger than the diameter of the spiracle; feeds primarily on *Physalis*, only rarely on *Solanum* *Heliothis subflexa*

10. Body setae lack pinacula; subdorsal stripe wide and obvious on living material; polyphagous, but usually recorded from flax; Manitoba south to Colorado and west through Canada [*Heliothis ononis*]

10'. Body setae, or at least SD1 of A1-8, inserted on a chaleza or large, sometimes unpigmented pinaculum; subdorsal stripe, if present, thin; polyphagous feeder; distributed throughout North America 11

11. D chalazae of A1-8 strongly conical (as high as wide), or if poorly developed, then D setae of A1-8 inserted on flat unpigmented pinacula of equal size; head often marked with black; the setal bases of the body often black; polyphagous feeder; distributed from southern Canada south to central Mexico [*Heliothis phloxiphaga* (in part)]

11'. 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 rarely marked with black; the setal bases of the body, if pigmented, light to medium brown, rarely black; polyphagous feeder; distributed throughout North America *Helicoverpa zea*

12. From Central America, Panama, or the West Indies 13

12'. From other regions of South America 15

13. Microspines present throughout the D pinacula of A1, 2, and 8; D setae of A1 and A2 may be connected to each other by a dark band 14

13'. Microspines absent on D pinacula of A8, or at most minute spines are present only at the base; D setae of A1 and A2 not connected to each other by a dark band *Helicoverpa zea*

14. Retinaculum usually present; if retinaculum absent, then SD1 and L1 setal bases of A4 not connected to each other by a band of microspines and neither one is much larger than the diameter of the spiracle; polyphagous feeder *Heliothis virescens*

14'. Retinaculum absent; SD1 and L1 setal bases of A4 connected to each other by a band of microspines and both are much larger than the diameter of the spiracle; feeds primarily on *Physalis*, only rarely on *Solanum* *Heliothis subflexa*

15. From northern South America (Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname, French Guiana, Trinidad and Tobago) 16

15'. From central or southern South America 21

16. Microspines absent on the D setal bases of A1, 2, and 8(*Helicoverpa*) 17

16'. Microspines present on the D setal bases of A1, 2, and 8 (*Heliothis*) 18

17. From Peru (*H. atacamae, H. bracteae, H. titicacae, H. zea*) [sp. of *Helicoverpa*]
17'. Not from Peru *Helicoverpa zea*

18. From Peru east to Venezuela 19
18'. From Guyana, Suriname, French Guiana 20

19. From Solanaceae (*H. tergemina, H. virescens, H. subflexa*) sp. of *Heliothis*
19. From non-solanaceous host *Heliothis virescens*

20. Retinaculum usually present; if retinaculum absent then SD1 and L1 setal bases of A4 not connected to each other by a band of microspines and neither one is much larger than the diameter of the spiracle; polyphagous feeder *Heliothis virescens*
20'. Retinaculum absent; SD1 and L1 setal bases of A4 connected to each other by a band of microspines and both are much larger than the diameter of the spiracle; feeds primarily on *Physalis*, only rarely on *Solanum* *Heliothis subflexa*

21. From **Chile** (*Schinia chilensis; Helicoverpa atacamae, H. gelotopoeon, H. zea; Heliothis virescens*) sp. of Heliothinae
21'. From other areas of central or southern South America (Brazil, Bolivia, Paraguay, Uruguay, Argentina) 22

22. Microspines absent on the D setal bases of A1, 2, and 8(*Helicoverpa*) 23
22'. Microspines present on the D setal bases of A1, 2, and 8 (five *Heliothis* spp. in Brazil; *H. molochitina* from Bolivia, Paraguay, Uruguay, and Argentina; *H. subflexa; H. virescens*) sp. of *Heliothis*

23. From Paraguay or Argentina (*H. bracteae, H. gelotopoeon, H. zea*) sp. of *Helicoverpa*
23'. From Brazil, Bolivia, or Uruguay 24

24. Prothoracic shield green; body setae white
(*H. gelotopoeon, H. zea*) sp. of *Helicoverpa*

24. Prothoracic shield black or dark brown; body setae dark brown *Helicoverpa zea*

OLD WORLD FAUNA

25. From Africa **26**

25'. From other Old World localities 32

26. Feeds on millet (*Pennisetum*) 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 [*Heliocheilus albipunctella*]

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 (*H. armigera*, [*H. fletcheri*]) sp. of *Helicoverpa*

28. From East Africa (Kenya, Tanzania, to South Africa) and Madagascar ([*H. toddi*], *H. assulta, H. armigera*) sp. of *Helicoverpa*

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 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 [*Heliothis peltigera*]

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 *Helicoverpa armigera*

31. From Solanaceae (*H. armigera, H. assulta*) sp. of *Helicoverpa*
31'. From other hosts *Helicoverpa armigera*

32. From the Atlantic and Pacific Islands (including Hawaii) 33
32'. From Europe, the Middle East, Asia, and Australia 38

33. From St. Helena Island (south Atlantic Ocean) [*Helicoverpa helanae*]
33'. From Hawaii or another region 34

34. From any Atlantic or Pacific Island except Hawaii 35
34'. From Hawaii 36

35. From Solanaceae (*H. armigera, H. assulta*) sp. of *Helicoverpa*
35'. From other hosts *Helicoverpa armigera*

36. Microspines absent on the D setal bases of A1, 2, and 8(*Helicoverpa*) 37
36'. Microspines present on the D setal bases of A1, 2, and 8 *Heliothis virescens*

37. From corn *Helicoverpa zea*
37'. From another host ([*H. confusa, H. hawaiiensis, H. minuta, H. pallida, H. pacifica*], *H. zea*) sp. of *Helicoverpa*

38. From far eastern Russia to Japan and south to India and the Indo-Australian Region 39
38'. From Europe and western Russia to the Middle East 44

39. From Australia (*H. assulta, H. armigera, H. punctigera,* [*H. prepodes*]) sp. of *Helicoverpa*

39'. From another region of Asia 40

40. Larva green with pale 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 [*Heliothis peltigera*]

40'. 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 41

41. Spinneret spatulate, crochets bifurcate at their tip; from *Lablab* or *Hibiscus* [*Adisura atkinsoni*]

41'. Spinneret pointed, crochets simple at their tip; from other crops 42

42. From Solanaceae (*H. armigera, H. assulta*) sp. of *Helicoverpa*

42. From other hosts 43

43. From Tibet (*H. armigera, H. assulta,* [*H. tibetensis*]) sp. of *Helicoverpa*

43'. From another part of Asia *Helicoverpa armigera*

44. From the Netherlands 45

44'. From other areas of Europe to Russia or the Middle East 47

45. From Netherlands cut flowers 46

45'. From Netherlands vegetables 47

46. 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 *Helicoverpa* sp.

46'. 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

47. Mandible with a retinaculum 48

47'. Mandible lacks a retinaculum 49

48. 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 [*Pyrrhia* spp.]

48'. Larva green with pale flat pinacula, the cuticle with course white spines and white spots; mandible with a long thin inner tooth [*Heliothis peltigera*]

49. 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 mandible has a minute tooth on the inner rib *Helicoverpa armigera*

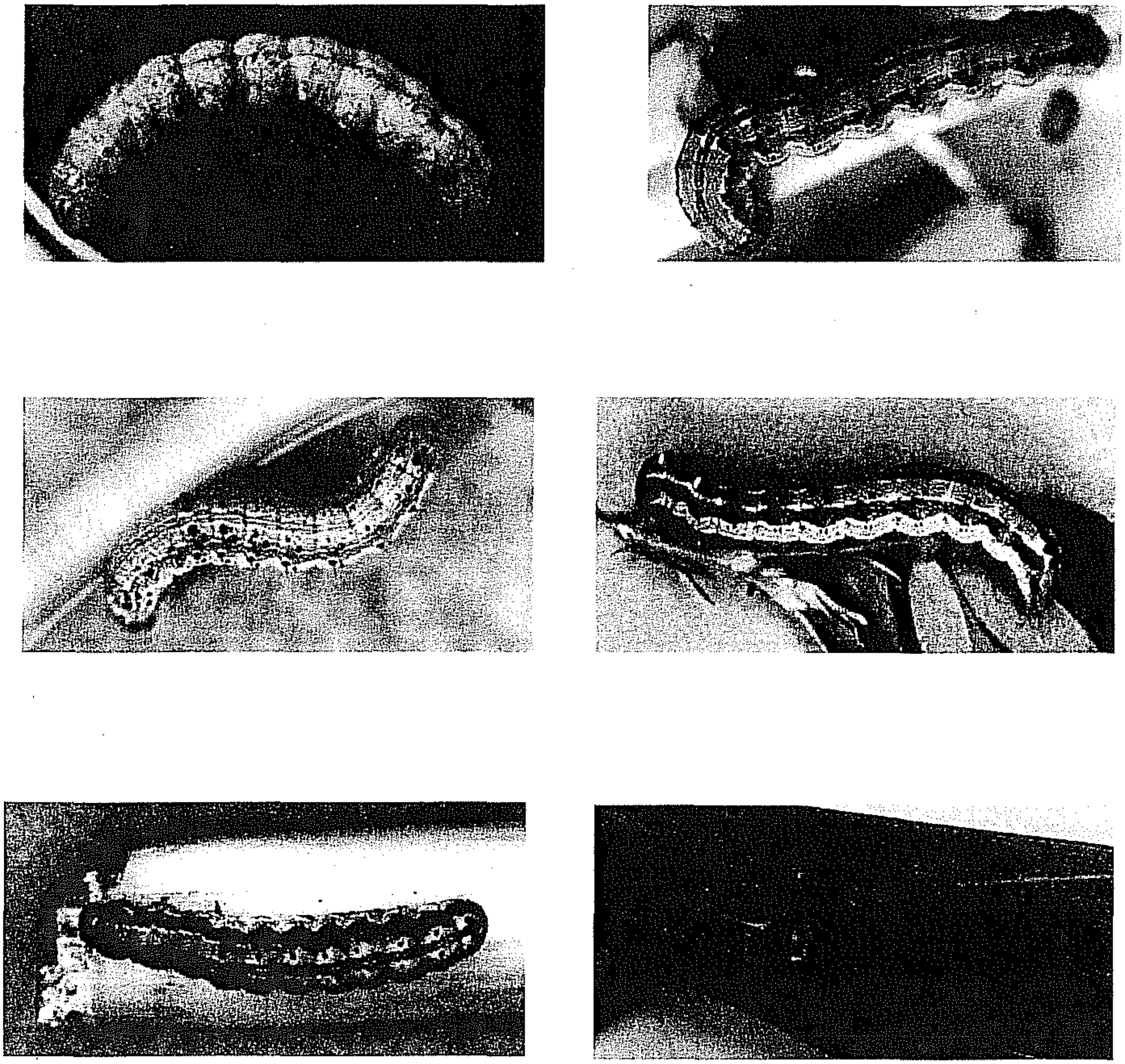
49'. D setae of A1-8 not inserted on large conical chalazae, those of A1, A2 or A8 often equal in size to the other setal bases; body color highly variable, but usually without lines and stripes and never with a black bar joining the D setae of A1 or A2; mandible lacks a minute tooth on the inner rib 50

50. Mandible with three teeth, the second tooth much longer than the first or the third; ribs of mandible strongly diverging medially; polyphagous on cultivated plants [*Heliothis nubigera*]

50'. Mandible with five teeth, or if three teeth are present then ribs of mandible are parallel to each other at least medially 51

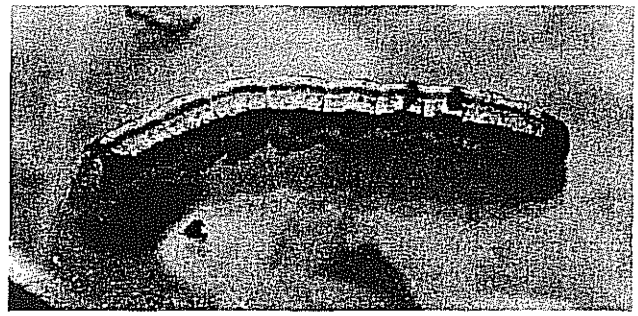
51. Medial spines of distal region of the hypopharangeal complex smaller than the lateral ones [*Heliothis viriplaca*]

51'. Medial spines of distal region of the hypopharangeal complex equal in length to the lateral ones [*Heliothis ononis*]

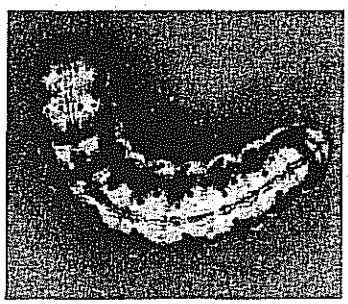


Five common color forms of *Helicoverpa zea*
and damage to corn ear

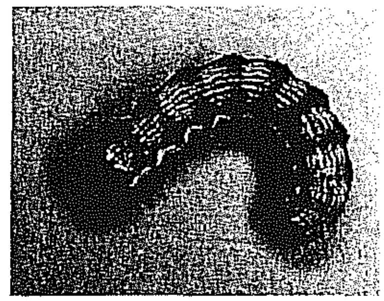
Helicoverpa gelotopoeon



Heliothus subflexa

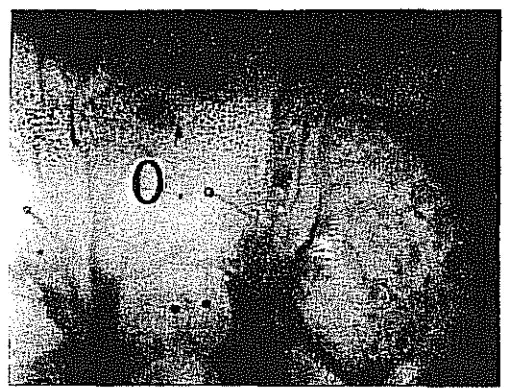


Heliothus virescens

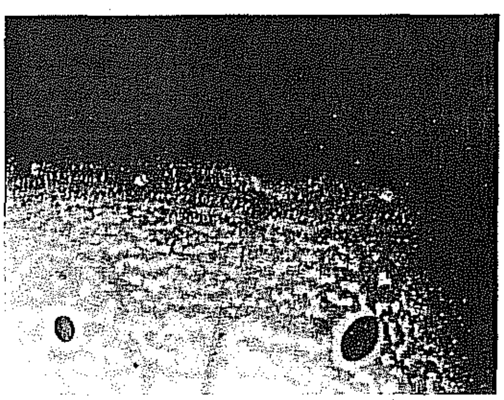


Heliothus virescens

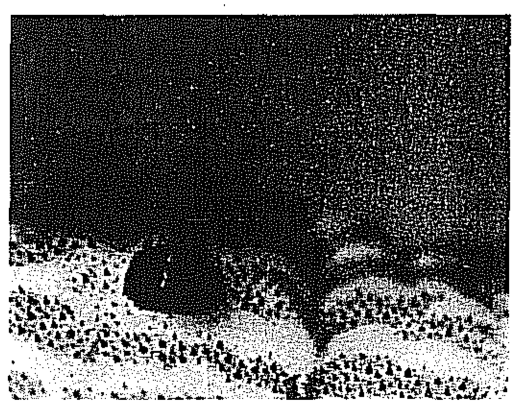
Heliothus virescens



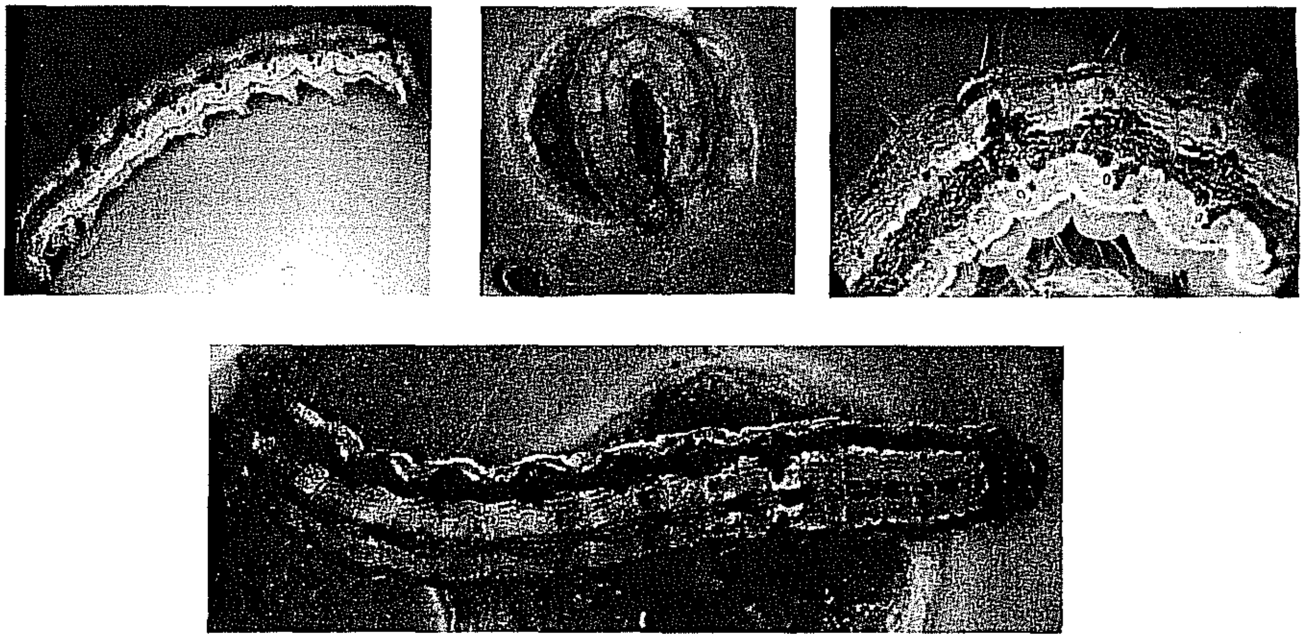
Horizontal arrangement of prothoracic L setae in Heliothinae



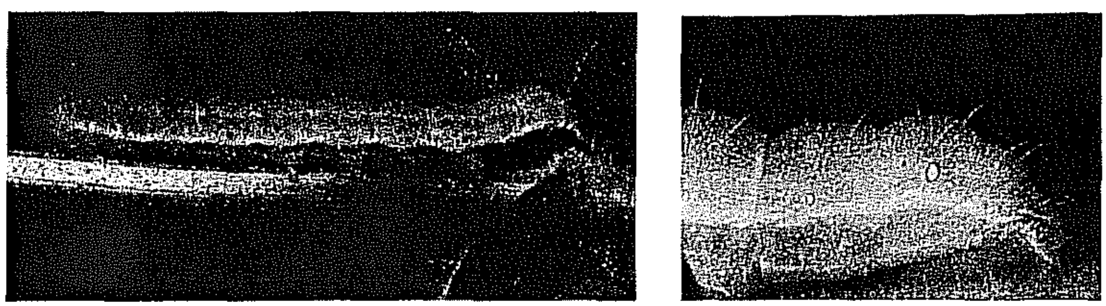
White dorsal abdominal setae



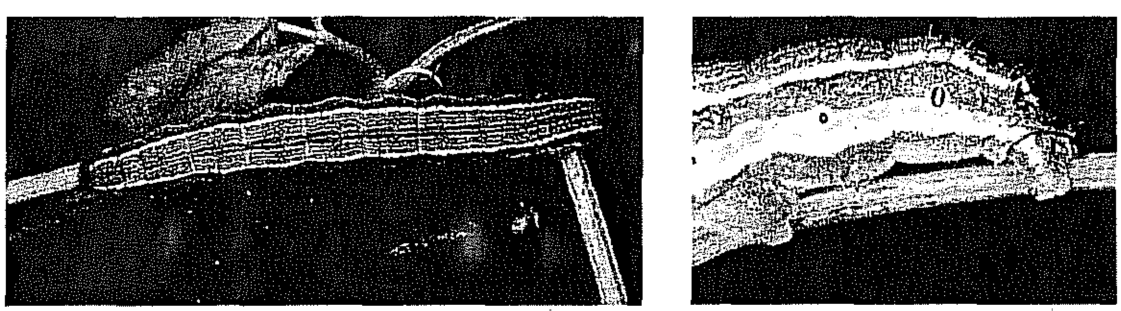
Black dorsal abdominal setae



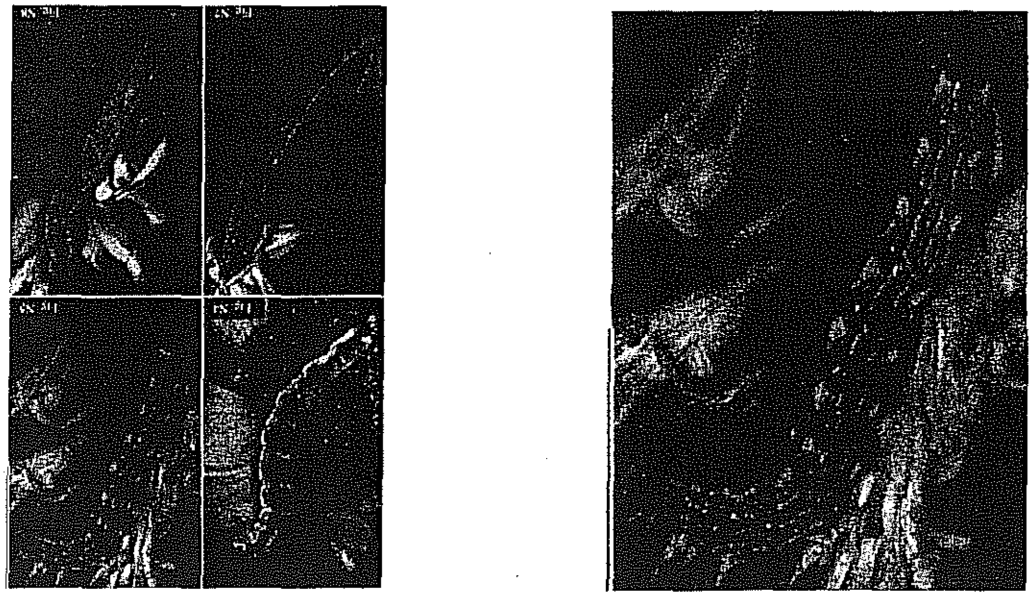
Helicoverpa armigiera (from Aizpurúa 1985)



Heliothus peltigera (from Matthews 1991, Aizpurúa 1985)

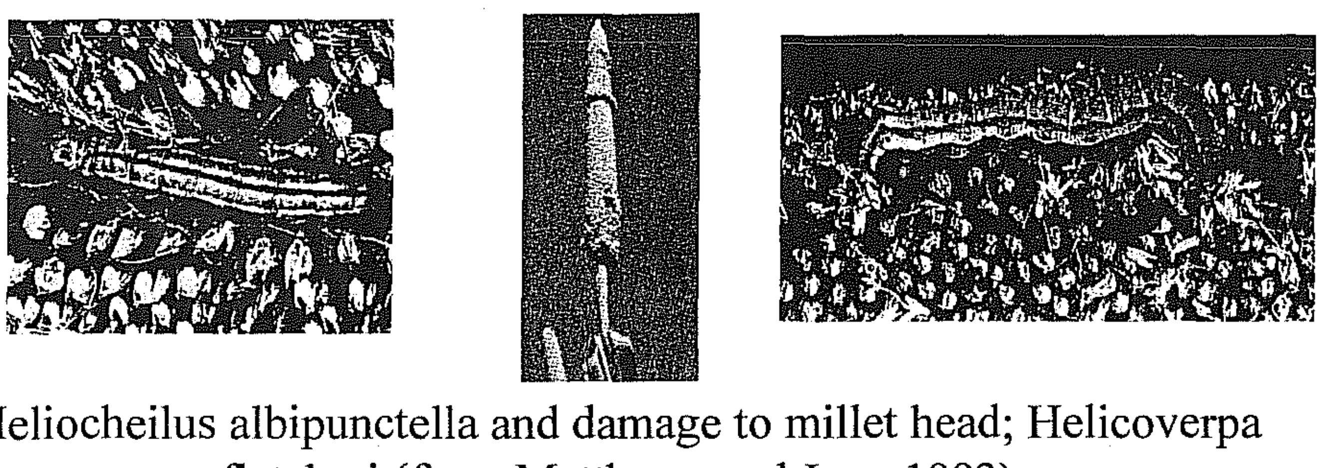


Helicoverpa viriplaca (from Aizpurúa 1987)

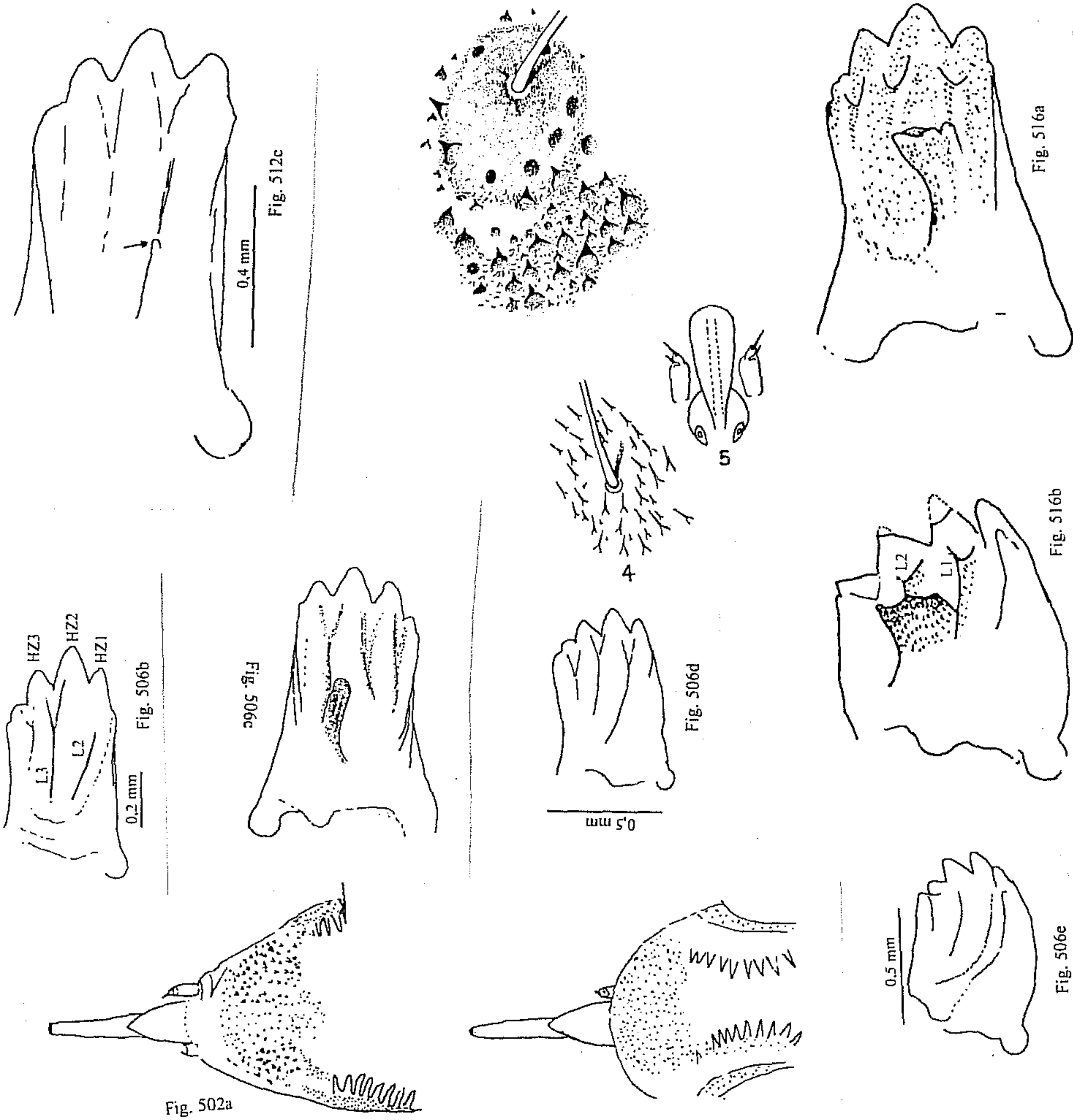


Heliothus phloxiphaga (from Hardwick 1996)

Heliothus ononis (from McDonald 1947)



Heliocheilus albipunctella and damage to millet head; Helicoverpa fletcheri (from Matthews and Jago 1993)



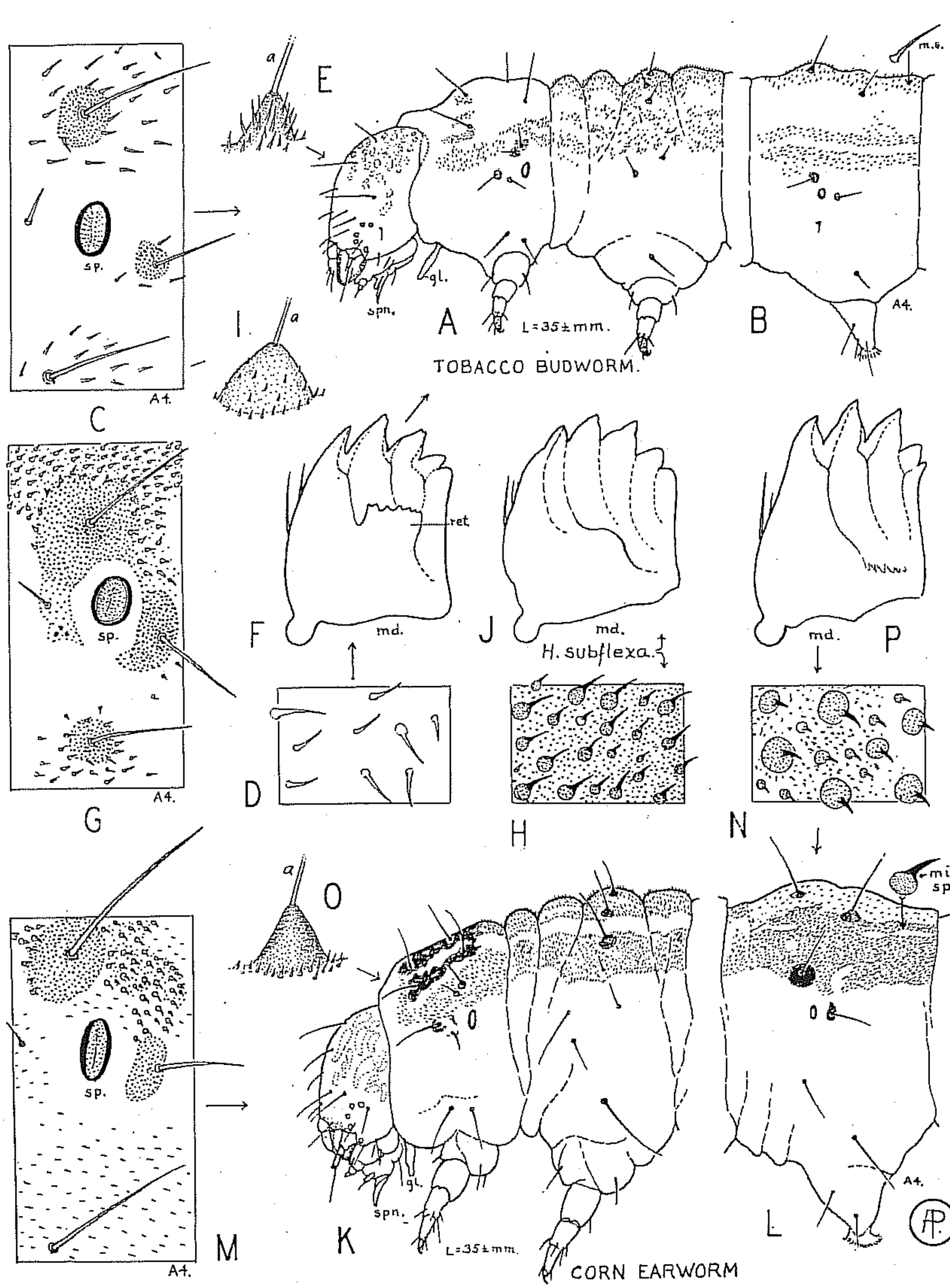
Heliothinae mandibles, mouthparts and cuticle (from Beck 1999, Gardner 1946)

Top row: *H. armigera* mandible (512c), *Pyrrhia* cuticle, *Pyrrhia exprimens* mandible (516a), *Adisura atkinsoni* spinneret and skin (figs 4,5).

Second row: *H. nubigera* mandible (506b), *H. peltigera* mandible (506c), *H. ononis* mandible (506d), *Pyrrhia umbra* mandible (516b).

Third row: *H. viriplaca* hypopharyngeal complex (502a), *H. ononis* hypopharyngeal complex, *H. viriplaca* mandible (506e).

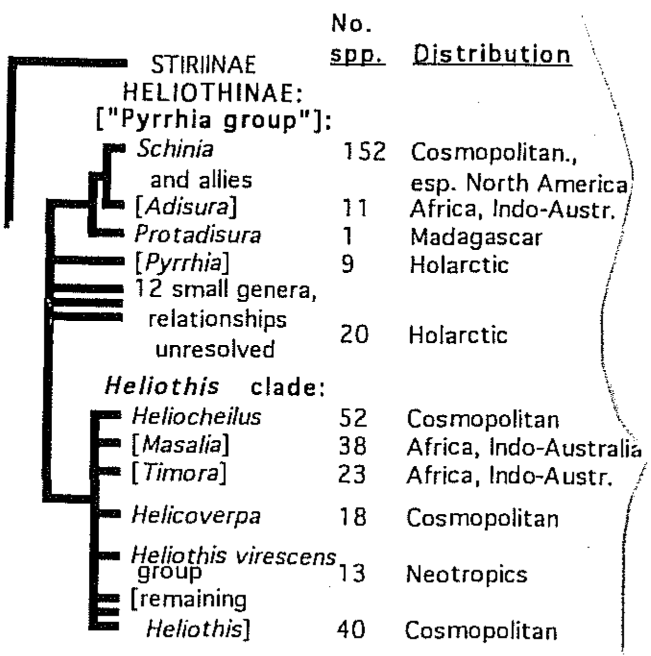
LEPIDOPTERA, PHALAENIDAE, HELIOTHIS FIGURE L36

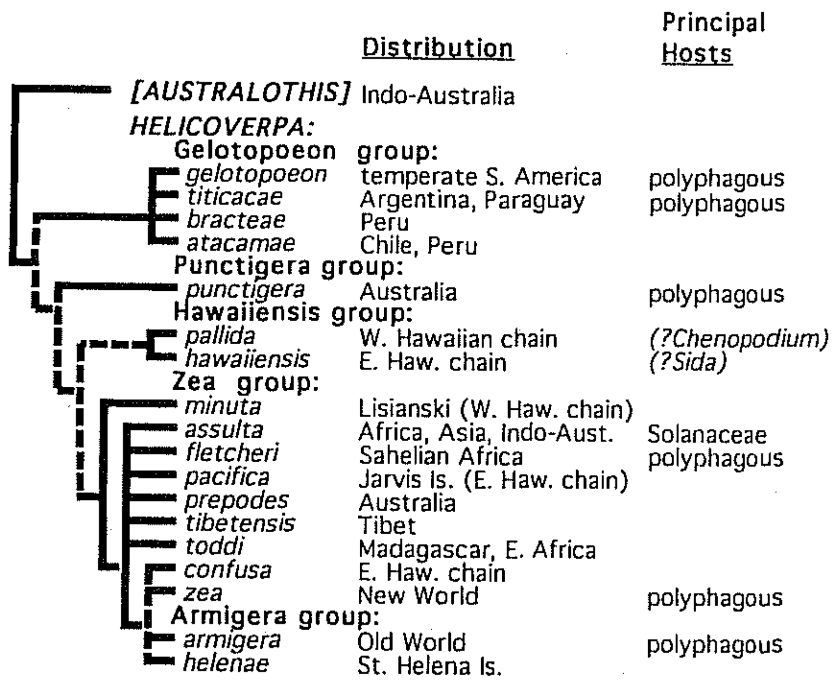


Heliothis Interceptions 1/1/96-12/31/00

PEST	ORIGIN	HOST	TOTAL
HELIOTHIS SP.	COLOMBIA	CHRYSANTHEMUM SP. (STEM)	1
HELIOTHIS SP.	HAWAII	OCIMUM BASILICUM (LEAF)	1
HELIOTHIS SP.	HAWAII	OCIMUM SP. (LEAF)	1
HELIOTHIS SP.	INDIA	ROSA SP. (FLOWER)	1
HELIOTHIS SP.	INDIA	TAGETES SP.	1
HELIOTHIS SP.	INDONESIA	DIANTHUS SP. (FLOWER)	1
HELIOTHIS SP.	ISRAEL	ANETHUM GRAVEOLENS	1
HELIOTHIS SP.	ISRAEL	MENTHA ARVENSIS	1
HELIOTHIS SP.	ISRAEL	ROSMARINUS OFFICINALIS	1
HELIOTHIS SP.	ISRAEL	RUMEX SP.	1
HELIOTHIS SP.	ITALY	CALENDULA SP.	1
HELIOTHIS SP.	KOREA	BRASSICA SP.	1
HELIOTHIS SP.	MOROCCO	MENTHA SP. (LEAF)	1
HELIOTHIS SP.	NETHERLANDS	CALENDULA SP.	1
HELIOTHIS SP.	NETHERLANDS	CARTHAMUS SP.	1
HELIOTHIS SP.	NETHERLANDS	DELPHINIUM SP. (FLOWER)	1
HELIOTHIS SP.	NETHERLANDS	DELPHINIUM SP.	1
HELIOTHIS SP.	REPUBLIC OF CHI	DIANTHUS SP. (FLOWER)	1
HELIOTHIS SP.	SAUDI ARABIA	THYMUS VULGARIS	1
HELIOTHIS SP.	SOUTH KOREA	CAPSICUM SP. (FRUIT)	1
HELIOTHIS SP.	THAILAND	GARDENIA SP.	2
sum			22

21 rows selected.





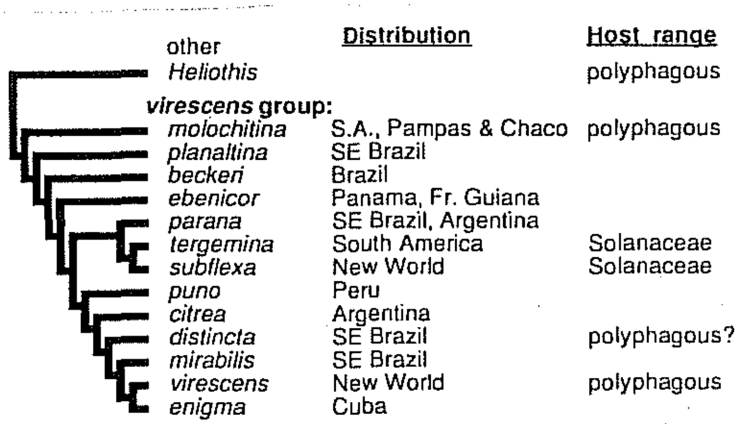


Figure 4 Estimate of relationships among species in the *Heliothis virescens* group, based on phylogenetic analysis of adult morphological characters (54).