COMPARATIVE MORPHOLOGICAL STUDIES OF *HELIOTHIS* SPECIES (LEPIDOPTERA: NOCTUIDAE) IN QUEENSLAND

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SUMMARY

Studies of the external morphology of immature stages of the four *Heliothis* species present in Queensland have been made, and descriptions together with tables of important measurements are given. Some notes on adult morphology are also given. Similarities and differences among species are discussed, and keys to adults and immature stages are provided.

I. INTRODUCTION

Of the four *Heliothis* species in Queensland—*H. armigera* (Hubn.), *H. punctigera* Wallengr., *H. assulta* Gn. and *H. rubrescens* (Walk.)—the first three are pests attacking a wide range of crops, and quick recognition of all stages is therefore of some importance. These studies were carried out at Nambour during 1957-58.

II. GENERAL METHODS

Eggs, which are found on host surfaces, particularly on or near flowering parts (Figure 1), were examined *in situ*. Larvae were examined entire as suggested by Crumb (1956), after methods of mounting cuticles on slides as described by Balfour-Browne (1932) and Mukerji and Hukam Singh (1951) were found unsuitable owing to setal relations being disturbed by folds formed in the cuticle when pressed flat. Pupae, in a holder to prevent movement, were examined entire. Adults were killed with cyanide and set, while the genitalia were removed and mounted as described by Siverly (1947).

III. DESCRIPTIONS

(a) Eggs (Figure 1)

The following applies to the four species:—

Egg erect, nearly spherical, slightly flattened at summit and base, height and diameter equal. Chorion marked with 28-35 vertical ribs, most ribs entire, some branched. Micropyle in middle of summit surrounded by a smooth ribless area. Colour at oviposition pale or dark yellow. An irregular reddish-brown band encircling egg slightly above equator develops 2-3 days before larva emerges; entire colour changes to light-grey about 24 hr before larva emerges, with black head capsule of larva visible as a dark internal spot.

Additional data relating to the eggs of the four species are given in Table 1.

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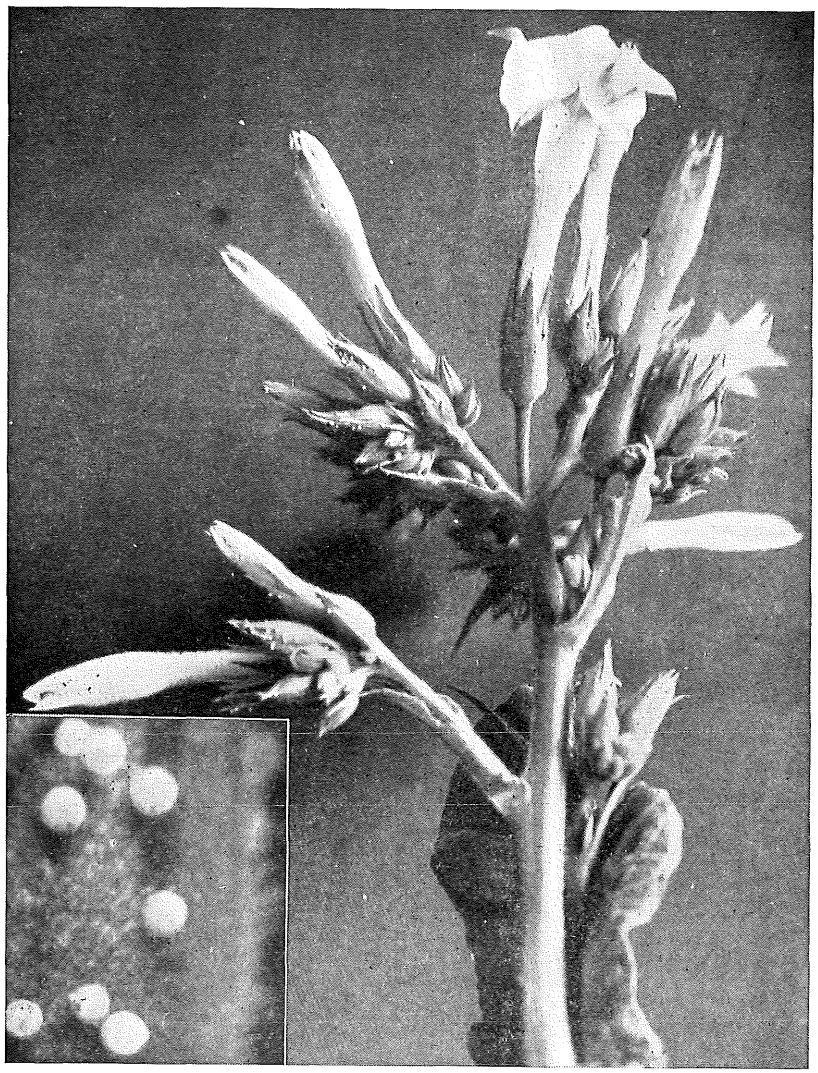


Fig. 1.—Eggs of *H. armigera* on tobacco inflorescence. (After W. A. Smith 1952.)

TABLE 1

EGGS OF HELIOTHIS SPECIES

Species	Colour at oviposition	Diameter (mm) = Height		Number Measured
		Mean	Range*	
H. armigera	Pale yellow ..	0·51±·005	0·46–0·53	23
H. assulta	Pale yellow ..	0·47±·003	0·43–0·52	55
H. punctigera	Pale yellow ..	0·53±·004	0·50–0·56	21
H. rubrescens	Dark yellow ..	0·44±·002	0·41–0·48	77

* The complete range has been recorded from eggs by individual females.

(b) Larvae

Thirty to 60 in each instar were examined. In these descriptions, nomenclature of the hypopharynx follows Gilbert (1939), of the setae Hinton (1946) and of colour areas Crumb (1956).

The following applies to the four species (except where indicated):—

(1) Head

Frons broadly triangular, slightly longer than wide, marked by several irregular transverse furrows, mandible (Figure 2) 4- or 5-toothed with ribs on oral surface extending from tooth bases to two-thirds mandible depth; hypopharynx (Figure 3) with lingula clothed with small erect spines, blade of maxillula with 8-12 serrations on free margin, spinneret length 4 times width at base.

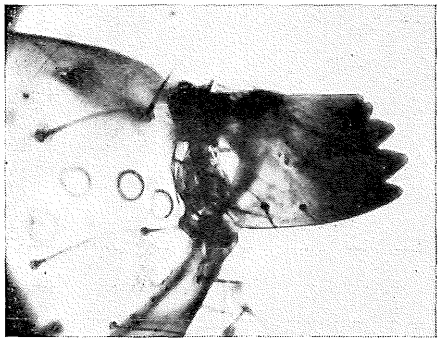


Fig. 2.—Mandible of *H. armigera* (× 72).

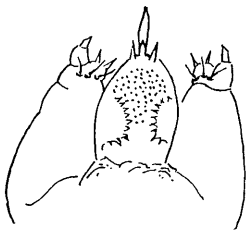
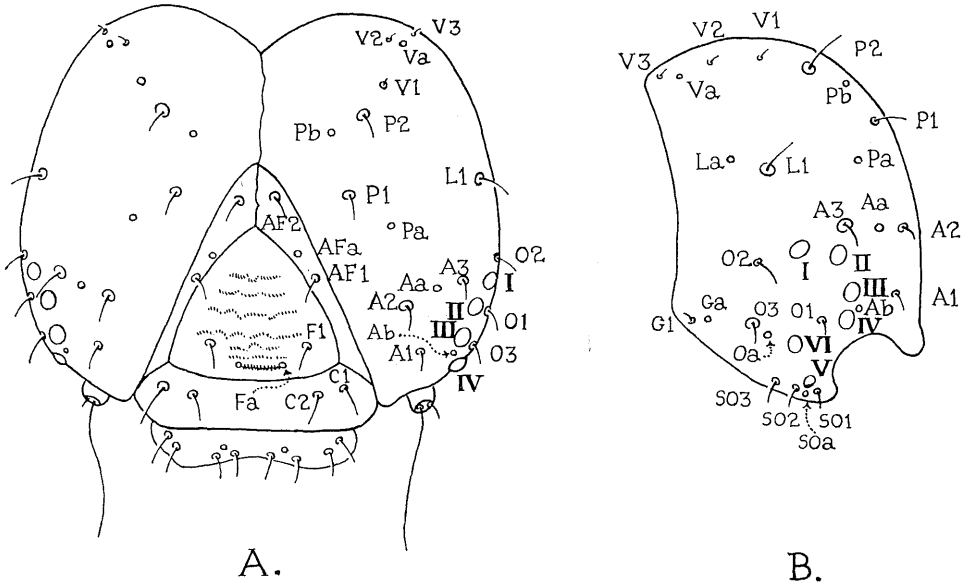


Fig. 3.—Hypopharynx of *H. armigera* (× 15).



A. B.

Fig 4.—Head of *H. armigera,* showing chaetotaxy (× 25). A, front view; B, lateral view. (Lettering after Hinton 1946).

Chaetotaxy (Figure 4) of general Noctuid pattern (see also Crumb 1929). Puncture *Afa* closer to seta *Af1* than to *Af2*. Punctures *Fa* joined across midline by pigmented furrow. Puncture *Va* nearly equidistant from microsetae *V2* and *V3*, on slightly lower level. *Pa* between *P1* and *A3*, twice as far from *A3* as from *P1*. *Aa* between and equidistant from *A2* and *A3*. *Ga* between *G1* and *O3*, much closer to *G1*. *SOa* between and equidistant from *SO2* and *SO1*. *Oa* between *O3* and ocellus *VI*, slightly closer to *O3*; ocellus *I* between and equidistant from *O2* and *A3*.

Colour of first instar black or dark-brown, of later instars light-brown to green, with a fairly constant pattern of darker spotting (Figure 5).

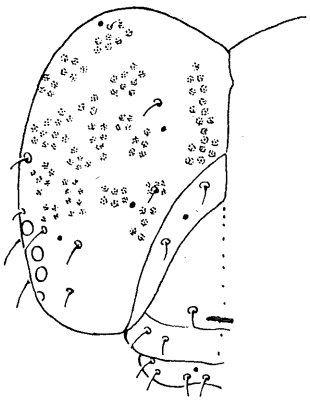


Fig. 5.—Head of *H. armigera* (× 20), showing pattern of dark spotting.

TABLE 2

HEAD WIDTHS (mm) OF *Heliothis* SPECIES

Instar	—	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
1 ..	Mean ..	0·27±·003	0·25±·003	0·24±·002	0·27±·003
	Range ..	0·25–0·31	0·23–0·31	0·22–0·26	0·24–0·29
2 ..	Mean ..	0·45±·005	0·46±·006	0·40±·005	0·44±·005
	Range ..	0·40–0·50	0·41–0·53	0·35–0·45	0·39–0·49
3 ..	Mean ..	0·73±·02	0·86±·01	0·65±·013	0·75±·011
	Range ..	0·60–0·85	0·75–0·95	0·61–0·78	0·70–0·85
4 ..	Mean ..	1·13±·02	1·56±·01	1·07±·025	1·39±·016
	Range ..	0·92–1·25	1·40–1·70	0·90–1·35	1·30–1·65
5 ..	Mean ..	1·80±·07	2·55±·022	1·61±·021	2·25±·03
	Range ..	1·55–1·95	2·20–2·60	1·45–1·75	1·90–2·40
6 ..	Mean ..	2·72±·02	..	2·45±·023	..
	Range ..	2·20–3·0		2·30–2·60	

Head widths are given in Table 2. Under the temperatures and humidities experienced at Nambour, *H. armigera* and *H. punctigera* had 6 instars, *H. assulta* and *H. rubrescens* 5. As the head widths of first and last instars of all species are similar, there are noticeable species differences in ratios according to Dyar's Law (see Table 3).

TABLE 3

RATIOS OF HEAD CAPSULE WIDTHS

Instar	—	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
1–2 ..	Mean ..	1·69	1·86	1·67	1·78
	Range ..	1·54–1·80	1·7–2·1	1·54–1·78	1·67–1·90
2–3 ..	Mean ..	1·53	1·80	1·6	1·71
	Range ..	1·4–1·82	1·7–1·93	1·43–1·75	1·63–1·78
3–4 ..	Mean ..	1·51	1·88	1·55	1·80
	Range ..	1·3–1·72	1·72–2·06	1·23–1·85	1·62–2·0
4–5 ..	Mean ..	1·51	1·67	1·60	1·64
	Range ..	1·40–1·62	1·5–1·82	1·25–1·76	1·58–1·77
5–6 ..	Mean ..	1·55	..	1·50	..
	Range ..	1·44–1·62		1·35–1·64	
Average for all instars		1·56	1·80	1·58	1·73

(2) Thorax and Abdomen

Length 10-12 times width. Spiracles conspicuous, present on prothorax and abdominal segments 1-8, height of spiracle approximately 1½ times width. Prolegs on abdominal segments 3, 4, 5, 6 and 10; crochets biordinal, in numbers varying from 11 to 19 on each proleg. Skin covered with minute spinules (Figure 6), a distinguishing feature of the genus.

Chaetotaxy (Figure 7) similar in all instars. On prothorax, setae XD1, XD2, D1, D2 and MXD1 located on prothoracic shield; setae SD1 and SD2 sometimes present, sometimes only SD1. Setae L1 and L2 anterior to spiracle, tubercles sometimes joined. Tubercles of setae SV1 and SV2 always joined. On meso- and meta-thorax, setae D1, D2, SD1 and SD2 in vertical row, MD1 directly anterior to D2. L1 directly above L2. MSD1 anterior to and slightly above MSD2. MV1 anterior to and in horizontal line with SV1. On abdominal segments, D2 below and posterior to D1, SD2 microscopic, anterior to and level with top of spiracle in segment 1, moving to a slightly lower position in successive segments until level with middle of spiracle in segment 8. L1 directly posterior to spiracle in all segments except 7, where it is just below line of spiracle. Microseta MV1 anterior to L3 in all segments.

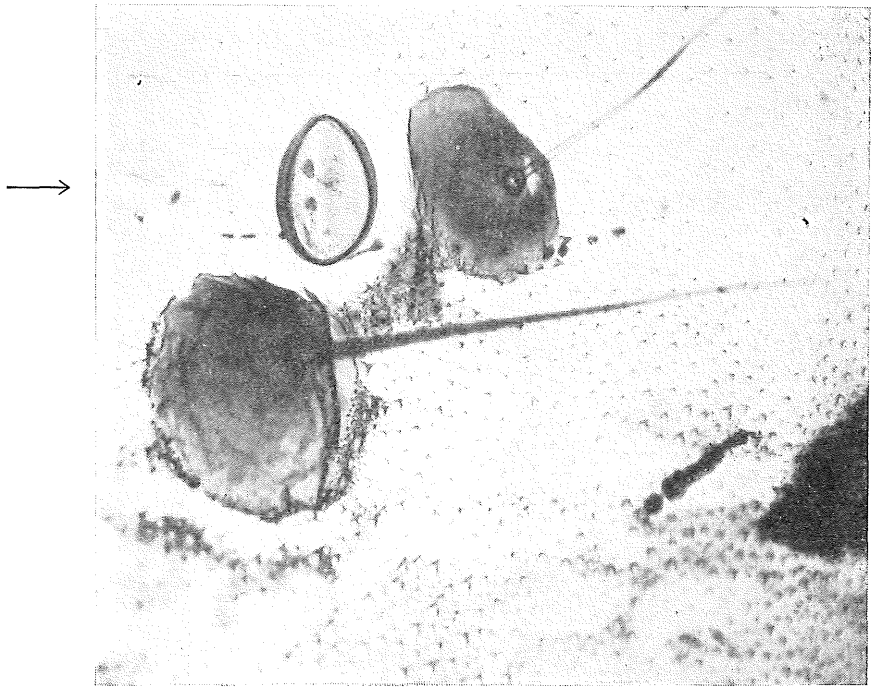


Fig. 6.—Photomicrograph of skin (abd. seg.1), showing minute spinules, spiracle and adjacent setae. Microseta opposite arrow (X 60).

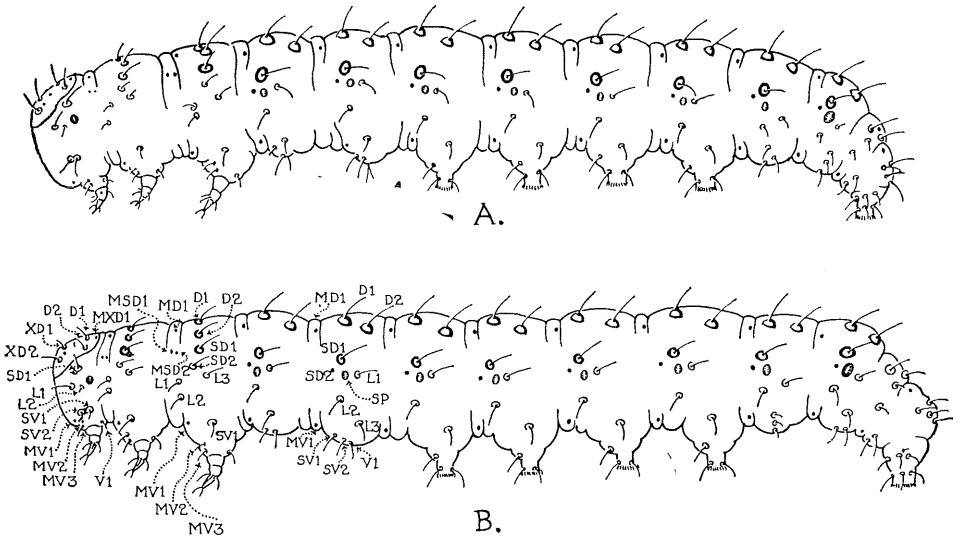


Fig. 7.—Larvae, showing chaetotaxy (× 3). Microsetae indicated by dots. A, *H rubrescens;* B, *H. armigera.* (Lettering after Hinton 1946).

Specific variation occurs in the size of the tubercles of the dorsal series of setae. This can be determined for any larva by finding the ratio of the vertical diameter of the tubercle of seta SD1 to the vertical diameter of the spiracle in the same segment. This ratio in abdominal segments 1 and 7 for the four species is given in Table 4.

TABLE 4

RATIO OF VERTICAL DIAMETER OF TUBERCLE SD1 TO VERTICAL DIAMETER OF SPIRACLE ON ABDOMINAL SEGMENTS 1 AND 7

Abdominal Segment	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
1	1·2 : 1–1·5 : 1	1·5 : 1–2·0 : 1	1·2 : 1–1·5 : 1	1·5 : 1–2·0 : 1
7	0·8 : 1–0·9 : 1	1·25 : 1–1·5 : 1	0·8 : 1–0·9 : 1	1·25 : 1–1·75 : 1

Some setal aberrations are common. On the prothorax seta SD1 is often missing, and seta XD2 is sometimes duplicated. On thoracic and abdominal segments D1 is often missing and D2 duplicated. Other less common aberrations involving loss or duplication of setae have been recorded.

Internal (background) colour of larvae greyish-white in first instar, varying from green to pinkish-brown in later instars. Dark-brown or black pigmentation present on prothoracic shield and setigerous tubercles in all instars, present over much of the body surface in all instars except the first in longitudinal anastamosing lines with intensity of pigmentation varying in the different body areas as follows: dorsal area extending from midline to just above seta D1 in all segments, heavily pigmented; subdorsal area lightly pigmented, extending from lower edge of dorsal area to seta SD1 on thoracic segments, to seta D1 in abdominal segments; supraspiracular area heavily pigmented, extending from lower edge of subdorsal area to just above spiracle on prothorax, to seta L3 on meso- and meta-thorax, to just above spiracle in abdominal segments with seta L1 included by an undulation in lower edge; subspiracular area a distinct white band with very light brown markings, sometimes with a pinkish suffusion at inter-segmental junction, extending from lower edge of supraspiracular area to midway between setae L1 and SV2 on prothorax, to seta L2 on other segments. Microseta SD2 on abdominal segments in subspiracular area usually marked by a dark spot.

In some aberrant forms of later instars, the body completely lacks dark pigmentation; in others, prothoracic shield and setigerous tubercles only are darkly pigmented.

(c) **Pupae** (Figures 8 and 9)

The following applies to all species:—

Epicranial suture absent; labial palp one-quarter to one-fifth length of maxilla; maxilla length of forewing; femur of prothoracic leg visible between

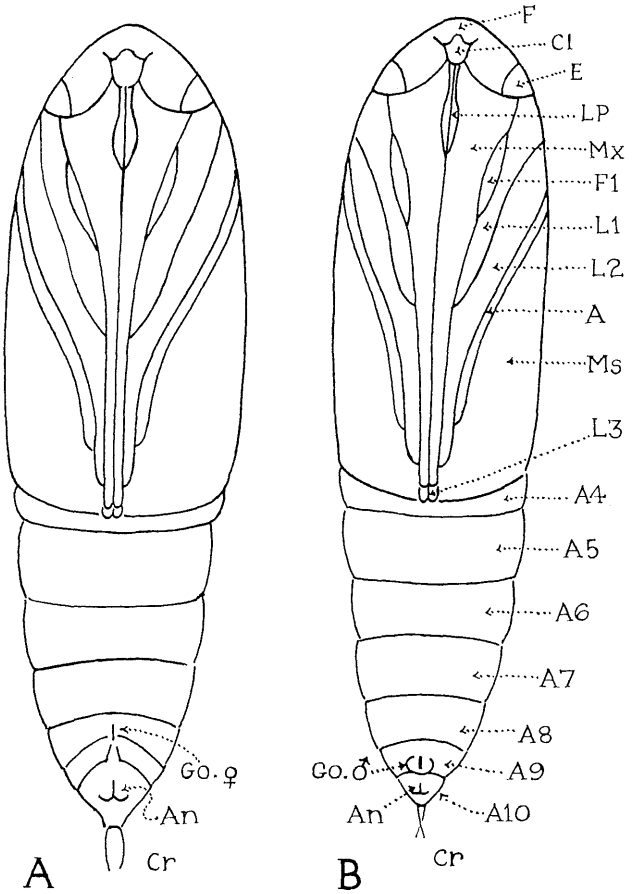


Fig. 8.—Ventral views of pupae (× 5). A, *H. armigera* ♀; B. *H. punctigera* ♂. A, antennae; A4–10, abdominal segments 4–10; An, anus; Cl, clypeus; Cr, cremaster; E, eye; F, frons; F1, femur of prothoracic leg; Go ♂, male gonopore; Go ♀, female gonopore; L 1–3, pro-, meso-, and meta- thoracic legs; LP, labial palp; MS, mesothoracic wing; Mx, maxilla.

maxilla and tibia-tarsus of prothoracic leg, which is half length of maxilla; mesothoracic legs almost length of maxilla; tip of metathoracic leg just protruding below maxilla; antenna six-sevenths length of maxilla. Metathoracic wing covered by mesothoracic wing on ventral surface. Cremaster with 2 spines, tips usually crossed, rarely 1 or no spines present. Anus slit-like, on abdominal segment 10. Male gonopore small, on segment 9, edged by lateral swellings. Female gonopore small, midway between segments 8 and 9. A slight sex difference in profile of terminal abdominal segments (Figure 9). Cuticle of movable abdominal segments pitted above spiracles, smooth below.

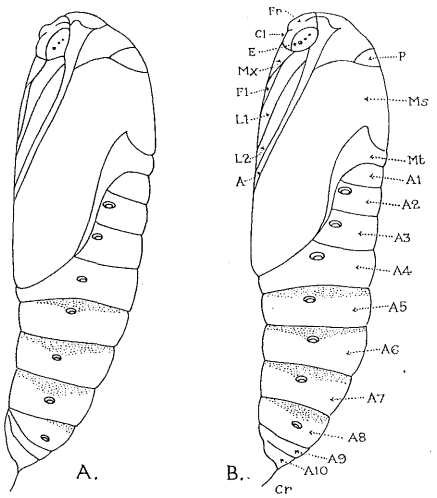


Fig. 9.—Lateral views of pupae (× 5·5). A, *H. armigera* ♀; B, *H. punctigera* ♂. (Lettering as in Fig. 8.) A 1–4, abdominal segments 1–4; Mt, metathoracic wing.

Colour at first translucent green, slowly changing to dark-brown as cuticle hardens. Tips of cremaster spines transparent. Several days after pupation three dark spots appear in an oblique line in eye. Colour pattern of adult visible through pupal cuticle several days before emergence.

The distance between the outer edges of the cremaster spines at the junction with cremaster differs among species (Figure 10) and is given in Table 5.

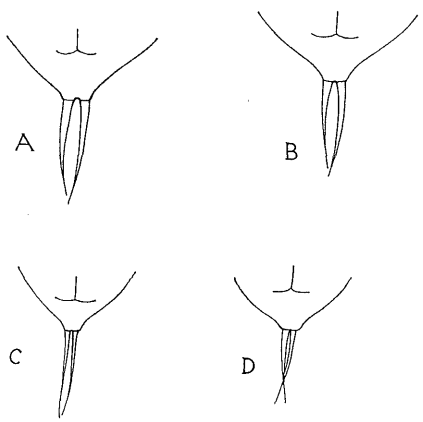


Fig. 10.—Pupal cremaster spines (× 26). A, *H. armigera;* B, *H. assulta;* C, *H. punctigera;* D, *H. rubrescens.*

TABLE 5

DISTANCE BETWEEN OUTER EDGES OF CREMASTER SPINES AT JUNCTION WITH CREMASTER

Measurement (mm)	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
Mean	0·28 ± ·003	0·22 ± ·002	0·17 ± ·002	0·10 ± ·008
Range	0·22 to 0·39	0·18 to 0·28	0·14 to 0·20	0·12 to 0·20

(d) Adults

The four species have been redescribed by Common (1953); the following are additional notes from bred material.

(1) H. armigera

Wings.—Male and female (Figure 11A): Subterminal line usually distinct, strongly angled outwards on vein R5, M3, Cu1a and Cu1b to form three well-defined dentations as in *H. assulta.*

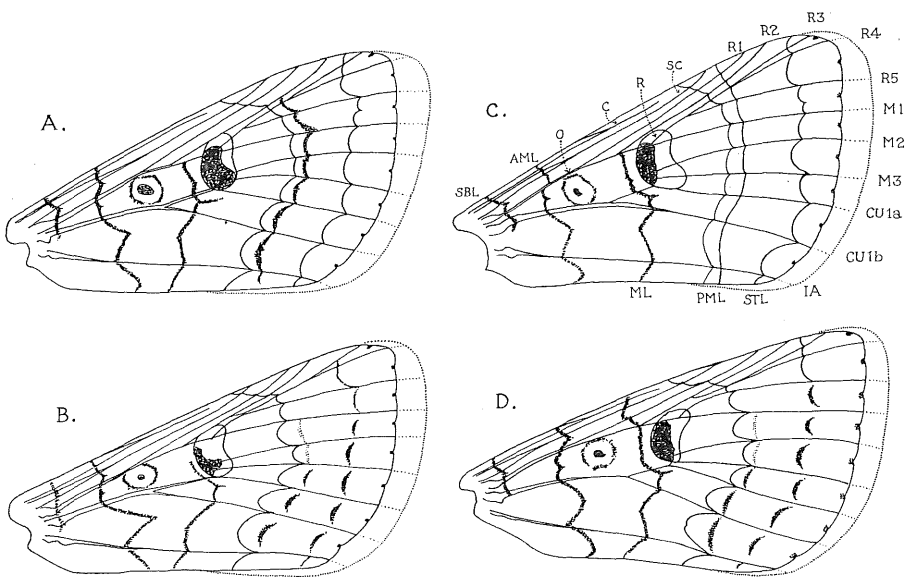
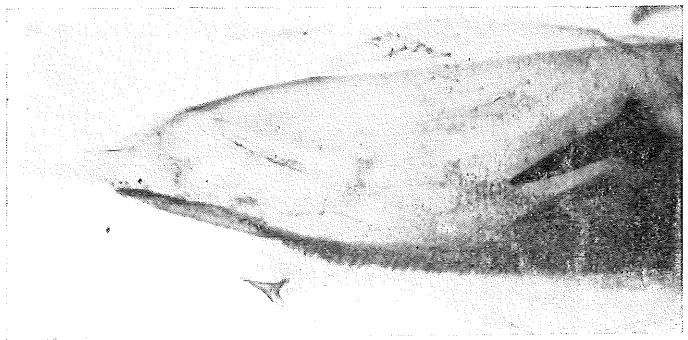


Fig. 11.—Forewings, showing venation and main markings (× 6·5). A, *H, armigera;* B, *H. punctigera;* C, *H. assulta;* D, *H. rubrescens.* 1A, C, Cula, Cu1b, M1, M2, M3, R1, R2, R3, R4, 55, Sc, veins; AML, antemedial line; ML, medial line; O, orbicular; PML, postmedial lines; R, reniform; SBL, sub-basal line; STL, subterminal line.

Genitalia.—Male (Figure 12B): Short backwardly directed thorn in distal orifice of adeagus variable in size and amount of sclerotization, often difficult to find. Thorn sometimes double (Figure 13). *Female:* Some variation in extent of spinulation of inner surface of bursa seminalis, some specimens very lightly spined.



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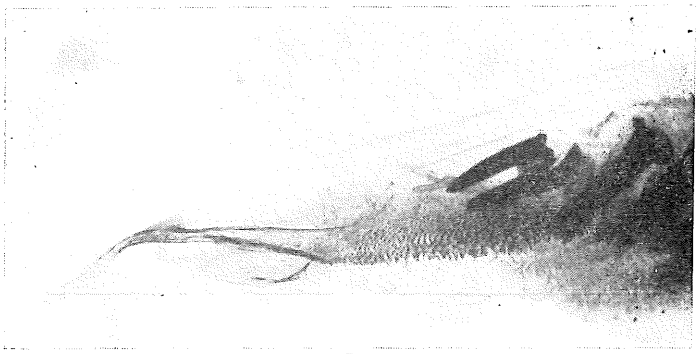

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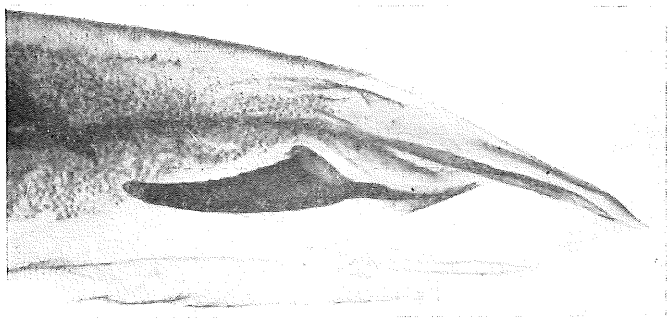

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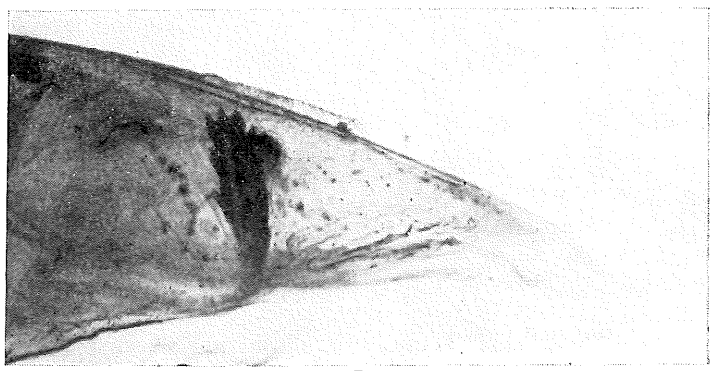

D

Fig. 12.—Tips of adeagi, showing sclerotized processes. A, *H. armigera* (× 90); B, *H. assulta* (× 90); C., *H. punctigera* (× 80); D, *H. rubrescens* (× 80).

Fig. 13.—Double "thorn" in tip of adeages of *H. armigera* (× 400).

(2) H. assulta

Wings.—Male and female (Figure 11B): Subterminal fascia on underside of forewing identical with that of *H. armigera,* covered from vein M1 to costa by a reddish suffusion. This suffusion may be abraded in old specimens. *Male:* Ground colour of forewings ocherous grey with a yellowish tinge. *Female:* Ground colour of forewings orange-brown to reddish-brown.

(Common (1953) apparently based his redescription on abraded or faded specimens of both sexes.)

Genitalia.—Male: Definite area of sclerotization in distal orifice of adeagus, produced into a thorn as in *H. armigera* (Figure 12B), but relatively smaller and sometimes difficult to find.

(3) H. punctigera

Wings.—Male and female (Figure 11C): Post-medial lines usually present but indistinct, inner line angled sharply on veins R5, M1, M2, M3, Cu 1 a, Cu 1 b and 1A; outer line barely distinguishable. *Female:* Colour of forewing varies from reddish-brown to light-brown.

(4) H. rubrescens

The "pink form" described by Common (1953) is one extreme of a wide range of colour variation within the species.

IV. DISCUSSION

Species show a remarkable similarity in the immature stages and separation of all species in any one of these stages is not possible.

The only specific difference at any time in the eggs is that those of *H. rubrescens* are dark-yellow at oviposition (Table 1).

The larvae of *H. armigera* and *H. punctigera* can be separated from those of *H. assulta* and *H. rubrescens* by the size of the dorsal series of setigerous tubercles (Table 4), other important differences being in normal instar number and ratios of head capsule widths (Tables 2 and 3). *H. rubrescens* larvae, which have black tubercles, may be distinguished from *H. assulta* larvae, which have dark-brown tubercles, but larvae of *H. armigera* and *H. punctigera* are identical in all characters examined.

The pupae differ specifically in the spacing of the cremaster spines (Table 5), but the differences can be used for species separation only if the larva from which a pupa developed is known, in which case only *H. armigera* and *H. punctigera* need be separated. The pupae of *H. armigera* have widely spaced spines, with the distance between their outer edges at junction with the cremaster always greater than 0·22 mm, while pupae of *H. punctigera* have closely spaced spines with the corresponding measurement less than 0·20 mm.

In contrast to the immature stages, the adults are readily separable on many characters, as discussed by Common (1953). Many basic similarities are evident, however, and care is needed if incorrect identifications are to be avoided. Forewing colours are similarly variable in all species: those of females vary from pink to shades of brown, those of males are shades of grey. In *H. punctigera* the distinction in forewing colour between sexes is least marked, many females being pale brown while males tend to fawn rather than grey.

Hindwing colours provide the most consistent differences among species. The basal colour in *H. armigera* and *H. punctigera* is white with a greyish brown suffusion, while in *H. assulta* and *H. rubrescens* the colour is yellow or yellowish orange. A pale spot of variable extent is present in the black terminal fascia of *H. assulta* and *H. armigera,* but no such spot occurs in *H. punctigera* and *H. rubrescens.*

Forewing markings are basically similar in all species (Figure 11), with extensive intraspecific variation in shape and clarity of outline. The subterminal line in *H. punctigera* and *H. rubrescens* is distinguishable only as some darker shading, but in *H. assulta* and *H. armigera* is well marked, being angled to form well-defined dentations on veins R5, M2, Cu1a and Cu1b, but the depths of the dentations vary considerably in *H. armigera.* The post-medial line is distinctly double in all species, but in *H. punctigera* and *H. rubrescens* the outer line is reduced to a light shading. The inner line is angled in all species to form dentations on veins R5, M1, M2, M3, Cu1a, Cu1b and 1A, the dentations being deep in *H. rubrescens* and *H. punctigera,* less deep in *H. armigera* and shallow in *H. assulta.* Other transverse lines, orbicular and reniform markings are variable in all species, and are least distinct in *H. punctigera.*

The patterns of the under-surfaces of the wings are similar, but the suffusion covering the costal margins of the subterminal fasciae of both wings is only faintly pink in *H. punctigera.*

Differences in the genitalia are consistent, and serve to identify species with certainty. In the males the shape of the sclerotized process in the distal orifice of the adeagus (Figure 12) immediately distinguishes *H. punctigera* and *H. rubrescens,* while *H. assulta* and *H. armigera,* which have similarly shaped processes, may be distinguished by the cornuti, which are smaller and more numerous in *H. assulta* than in *H. armigera.* In the female genitalia, the spines on the inner surface of the bursa seminalis distinguish *H. armigera* and *H. punctigera* from *H. assulta* and *H. rubrescens,* which lack spines, the cup-shaped genital plate of *H. armigera* is distinct from the parallel-sided plate of *H. punctigera,* while the lack of spiral coiling of the bursa seminalis of *H. rubrescens* distinguishes this species from *H. assulta.*

V. KEYS

(*a*) Eggs

1. Eggs pale yellow at oviposition . . . . . *H. armigera, H. assulta, H. punctigera*
   Eggs dark yellow at oviposition . . . . . *H. rubrescens*

(*b*) Larvae

1. Vertical diameter of tubercle of seta SD1 on abdominal segment 7 much greater than that of spiracle in same segment 2
   Vertical diameter of tubercle of seta SD1 in abdominal segment 7 less than, rarely the same as, that of spiracle in same segment . . *H. armigera* and *H. punctigera*
2. Tubercle pigment black . . . . . *H. rubrescens*
   Tubercle pigment brown (sometimes dark brown) . . . . . *H. assulta*

(*c*) Pupae of *H. armigera* and *H. punctigera*

1. Distance between outer edges of cremaster spines at junction with cremaster greater than 0·22 mm . . . . . *H. armigera*
   Distance as measured above less than 0·20 mm . . . . . *H. punctigera*

(*d*) Adults

Males

1. Basal area of hindwing yellow or orange, without greyish suffusion . . 2
   Basal area of hindwing whitish, suffused with grey or greyish brown 3

2. (1) Subterminal line indistinct, no pale marginal spot in terminal fascia of hindwing; adeagus with distinct spiny process in distal orifice of adeagus; cornuti of adeagus small and poorly developed . . *H. rubrescens*

Subterminal line of forewing forming 3 well defined dentations on veins M3, Cu1a, Cu1b; pale marginal spot in terminal fascia of hindwing; adeagus with small thorn in distal orifice; cornuti of adeagus large . . . . . *H. assulta*

3. (1) Forewings with indistinct transverse lines, no pale marginal spot in terminal fascia of hindwing; adeagus with long backwardly-directed spine in distal orifice . . . . . *H. punctigera*

Forewings with distinct transverse lines, pale marginal spot in terminal fascia of hindwing; adeagus with small thorn in distal orifice . . . . . *H. armigera*

Females

1. Basal area of hindwing ochreous yellow or orange, without greyish suffusion; inner surface of bursa seminalis without clothing of minute spines 2

Basal area of hindwing whitish, suffused with grey or greyish brown; bursa seminalis clothed internally with minute spines 3

2. Subterminal line of forewing indistinct, no pale marginal spot in terminal fascia of hindwings; bursa seminalis not spirally coiled . . *H. rubrescens*

Subterminal line of forewing distinct with well defined dentations on veins M3, Cu1b, terminal fascia of hindwing with pale marginal spot; bursa seminalis spirally coiled . . . . . *H. assulta*

3. (1) Transverse lines on forewing indistinct, terminal fascia of hindwing without pale marginal spot; genital plate with parallel sides . . . . . *H. punctigera*

Transverse lines on forewing distinct, terminal fascia of hindwing with pale marginal spot; genital plate cup-shaped with sloping sides . . . . . *H. armigera*

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