DOSSIERS ON *SESAMIA* SPECIES AS PESTS OF SUGARCANE

Sesamia **Guenée**
Sesamia Guenée 1852, 95.

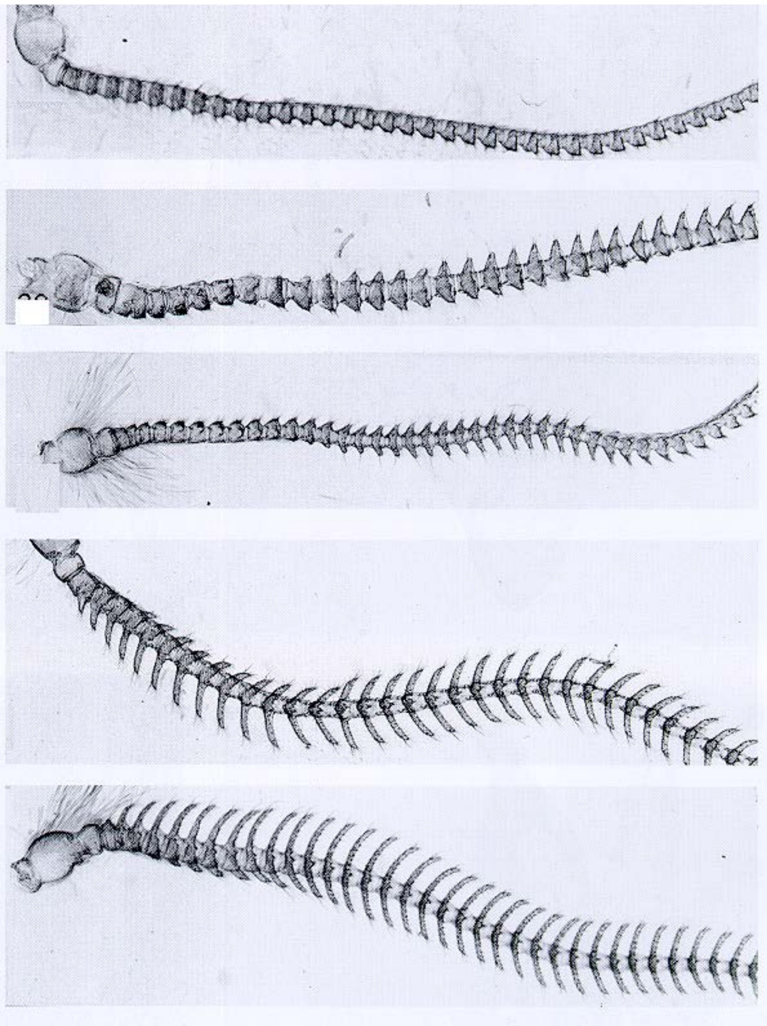
Type species: *Cossus nonagrioides* Lefebvre, by monotypy.

Adults
Tams and Bowden (1953) give extensive descriptions of both the male and female adults of the African species. The Oriental and New Guinea species do not appear to have been incorporated in any useful key.

Key to adults of *Sesamia* (African species based on Tams & Bowden 1953 and Holloway 1998)

1 Tympanal organ on first sternite of abdomen; proboscis scaled .... Pyraloidea (*Chilo, Diatraea, Eldana, Eoreumia, Scirpophaga*)
- Tympanal organ in metathorax; proboscis unscaled .... Noctuidae 2
2(1) *Bathyrichia*
- .... *Sesamia* 3
3(2) Antennae of male simple; male genitalia with the valve entire, juxta small, with a small medial process and the manica spinose; female genitalia with the ostium strongly transverse, bursa copulatrix pointed at apex, ductus bursae short and broad .... *cretica*
- Antennae of male bipectinate or serrate for more than half length of the antennal shaft; male genitalia with the sacculus and cucullus of valve separate, sacculus with an apical sclerotised process, juxta simple, manica usually membranous; female genitalia with the ostium not strongly transverse, bursa copulatrix broad and rounded, ductus bursae long and narrow 4
4(3) Males 5
- Females 9
5(4) Pectinations of the antennae longer than the width of the antennal shaft 6
- Pectinations of the antennae shorter than the width of the antennal club 8
6(5) Forewing not strongly speckled with dark brown and without a distinct dark brown longitudinal band along lower margin of the cell .... *nonagrioides nonagrioides*
- Forewing strongly speckled with dark brown and with a distinct longitudinal dark brown longitudinal band along lower margin of the cell 7
7(6) Genitalia with juxta short and broad, valve as broad as long, costal spine short, little curved and almost bifid at the apex .... *calamistis*
- Genitalia with the juxta flask-shaped with a long neck, valve longer than broad, costal spine long, curved and with a strong subapical tooth .... *nonagrioides botanephaga*
8(5) Forewing with considerable dark brown speckling; male genitalia with costal spine spatulate, irregular and finely spined; female genitalia with distal margin of pair of sclerotisations flanking the ostium irregular and somewhat bilobed, ostium narrow .... *penniseti*
- Forewing with very little dark brown speckling; male genitalia with costal spine apically bifid; female genitalia with distal margin of pair of sclerotisations flanking the ostium more or less straight, ostium wide .... *poephaga*
9(4) Genitalia with the last sternum strongly sclerotised, base of the ductus bursus strongly sclerotised in longitudinal strips 10
- Genitalia with the last sternum not strongly sclerotised, base of the ductus bursus strongly sclerotised, the sclerotised area obliquely cut off distally 12
10(9) Sclerotised area of last sternum consisting of two lateral, fairly narrow plates not produced posteriorly and not approximate in mid-ventral line .... *nonagrioides botanephaga*
- Sclerotised area of last sternum produced posteriorly and approximate in the mid-ventral line ... 11
11(10) Hindwing with veins 6 and 7 sessile .... *penniseti*
- Hindwing with veins 6 and 7 stalked .... *poephaga*

12(9) Sclerotised area of ductus not extended into the neck of the ductus; forewing usually more pale yellow with considerable dark brown suffusion and a well-developed dark-brown transverse band *calamistis*
Sclerotised area of ductus prolonged into the neck of the ductus; forewing more distinctly buff with reduced or obsolete dark-brown markings .... *nonagrioides nonagriodes*



Male antennae: from top to bottom: *Sesamia cretica cretica, S. poephaga, S. penniseti, S. nonagrioides botanephaga, S. calamistis* (Polaszek 1998a).

Larvae

All species of *Sesamia* examined by Meijerman and Ulenberg (1996, 1998) were characterised by having the distance between the setae D2 and D1, compared with the distance between D1 and MD1, smaller on abdominal segment 7 than on abdominal segment 3; occasionally there was no difference between the two segments.

Key to larvae of *Sesamia* [from Williams (1953) and Meijerman and Ulenberg (1996, 1998)]

1 Crochets on ventral prolegs in a circular row or mesal penellipse, triordinal or biordinal; six macroscopic setae on prothoracic shield; two lateral setae on prothorax; one dorsal microscopic seta on metathorax .... Pyraloidea (*Chilo*, *Diatraea*, *Eldana*, *Eoreumia*, *Scirpophaga*)

\- Crochets on ventral prolegs in mesoseries, uniordinal; five macroscopic setae on prothoracic shield; two dorsal microscopic setae on metathorax .... Noctuidae 2

2(1) .... *Bathyrichia*

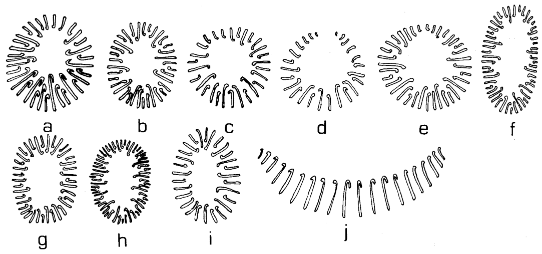
\- .... *Sesamia* 3

3(2) Abdominal segment 9 with angle between setae D2, D1 and SD1 usually less than 120°, MD1 anteroventral to D1; abdominal segment 8 with angle between setae MD1, D1 and D2 usually less than 150° .... *cretica cretica*

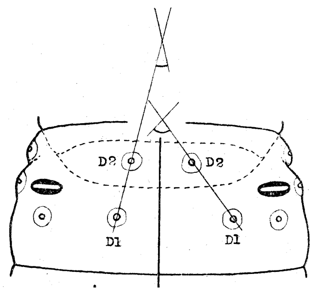
\- Abdominal segment 9 with angle between setae D2, D1 and SD1 usually more than 140°; abdominal segment 8 with angle between setae MD1, D1 and D2 usually more than 150° 4

4(3) Abdominal segment 8 with the angle formed by lines through setae D1 and D2 of both sides about 80° .... *inferens, uniformis*

Abdominal segment 8 with the angle formed by lines through setae D1 and D2 of both sides about 25° .... *calamistis, nonagrioides, penniseti, poephaga*



Arrangement of abdominal crochets: a-d, *Chilo* spp.; e, *Coniesta ignefusalis*; f, *Eldana saccharina*; g-h, *Maliarpha separatella*; i, *Scirpophaga* sp.; j, *Sesamia calamistis* (Meijerman & Ulenberg 1996, 1998).



Angle formed on segment 8 by dorsal setae of *S. calamistis* (left) and *S. inferens* (right) (Williams 1953).

Larvae of *S. calamistis* and *S. nonagrioides* can be separated under electrophoresis by differences in the migration distances for the loci encoding for *Est*, *Hbdh* and *Idh* (Meijerman *et al.* 1998). Electromorphs using *S. calamistis* as the standard and giving the relative difference in distance for *S. nonagrioides* are:

Locus	*S. calamistis*	*S. nonagrioides*
Est	100	108
Hbdh	100	106, 112
Idh	100	98, 104

***Sesamia arfaki* Bethune-Baker**

Types
Unknown

Common names
Pink stem borer

Distribution
Papua New Guinea (Popondetta) (Kuniata 1994; FitzGibbon *et al.* 1998).

Host Plants
Saccharum spp. hybrids (sugarcane), unspecified other grasses (Kuniata 1994).

Symptoms
Not described, but presumably similar to *S. grisescens* and *S. inferens*.

Economic Impact
Kuniata (1994) rated this species of minor importance in an area without commercial sugarcane, but presumably it could become of similar importance to other *Sesamia* spp. in commercial crops.

Morphology
Unknown.

Detection Methods
Presumably similar to those used for *S. grisescens*.

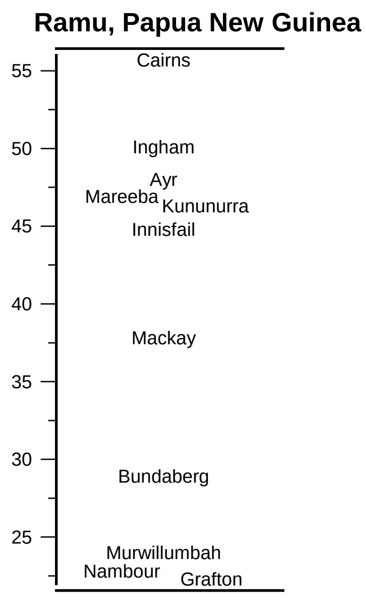
Biology and Ecology
Nothing known.

Natural Enemies
Nothing known.

Management
Nothing attempted; presumably strategies applied to *S. grisescens* would be useful.

Means of Movement
The most likely means of entry of *S. arfaki* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk to Australia
Entry potential: High - close to Australia, readily transmitted on infected planting material and adults carried by wind.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in northern Queensland, where entry is most likely (see Match Indexes for climate at Ramu and principal Australian areas below).


Ramu, Papua New Guinea
55
50
45
40
35
30
25
Cairns
Ingham
Ayr
Mareeba
Kununurra
Innisfail
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton

***Sesamia calamistis* Hampson**

Sesamia calamistis Hampson 1910, 325.
Sesamia mediastriga Bethune-Baker 1911, 518; Tams and Bowden 1953, 664 (syn.).

Notes on Taxonomy and Nomenclature
This species was consistently referred to in older literature as *S. vuteria* Stoll; this confusion was resolved by Tams and Bowden (1953).

Types
Cape Province, South Africa; in Natural History Museum, London.

Common names
Pink stalk borer, pink borer

Distribution
Tropical and southern Africa, Mauritius, Réunion

Angola, Benin, Botswana, Burkina Faso, Cameroon, Comoros, Congo, Congo (Democratic Republic), Ethiopia, Gambia, Ghana, Ivory Coast, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Niger, Nigeria, Réunion, Senegal, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe (Harris 1962; Rao & Nagaraja 1969; Williams 1978; Anon. 1981; Sithole *et al.* 1987; Moyal & Tran 1989; Leslie 1994; Meijerman & Ulenberg 1996; Bosque-Pérez & Schulthess 1998; FitzGibbon *et al.* 1998; Heinrichs 1998; Holloway 1998; Kfir 1998; Wale 1999; Nsami *et al.* 2001).

Common in savannah areas with a well-marked dry season (Tams & Bowden 1953).

Host Plants
Andropogon spp., *Beckeropsis uniseta*, *Cenchrus ciliaris* (buffel grass), *Cenchrus echinatus* Mossman River grass, *Chrysopogon aciculatus* (Mackie's pest), *Coix lacryma-jobi* (Job's tears), *Cyperus distans*, *Cyperus immensis*, *Cyperus papyrus*, *Echinocloa haploclada*, *Echinocloa pyramidalis* (antelope grass), *Eleusine coracana* (finger millet), *Hemarthria compressa* (matgrass), *Hyparrhenia filipendula* (Tambookie grass), *Hyparrhenia rufa* (thatchgrass), *Oryza sativa* (rice), *Panicum maximum* (green panic), *Paspalidium paniculatum*, *Paspalum conjugatum* (sourgrass), *Paspalum urvillei* (Vasey grass), *Pennisetum glaucum* (pearl millet), *Pennisetum purpureum* (elephant grass), *Pennisetum polystachion*, *Pennisetum subangustum*, *Pennisetum typhoides* (fountain grass), *Phalaris arundicacea* (reed canary grass) *Phragmites* spp., *Rottboellia exaltata*, *Saccharum* spp. hybrids (sugarcane), *Setaria barbata*, *Setaria sphacelata* (South African pigeon grass), *Setaria splendida*, *Sorghum arundinaceum*, *Sorghum bicolor* (sorghum), *Sorghum halpense* (Johnson grass), *Sorgum sudanense* (Sudan grass), *Sorghum versicolor, Sorghum verticilliflorum* (wild sorghum), *Tripsacum laxum*, *Triticum aestivum* (wheat), *Typha domingensis* (narrowleaf cumbungi, bulrush), *Vetiveria zizanioides* (vetiver), *Vossia cuspidata*, *Zea mays* (maize) (Tams & Bowden 1953; Harris 1962; Shanower *et al.* 1993; Leslie 1994; Meijerman & Ulenberg 1996, 1998; Bosque-Pérez & Schulthess 1998; Heinrichs 1998; Polaszek & Khan 1998).

Maize is the preferred host plant (Heinrichs 1998).

Symptoms
Larvae tend to bore in young shoots of sugarcane, causing typical 'dead-heart' symptoms (Anon. 1981; Leslie 1994).

Economic Impact
This species is frequently found on sugarcane in Africa, but is rarely of economic importance (Anon. 1981; Leslie 1994; Polaszek & Khan 1998). Both mature and young shoots are attacked, but it is much more common in the younger cane (Leslie 1994). Losses may be minimal under normal conditions, as the damage tends to be confined to young shoots and the plant can generally compensate by tillering (Anon.

1981; Leslie 1994). Williams (1978) attributed the more recent, lower importance of this insect in Mauritius to the parasitoids imported against it, especially *Cotesia sesamiae*.

Morphology

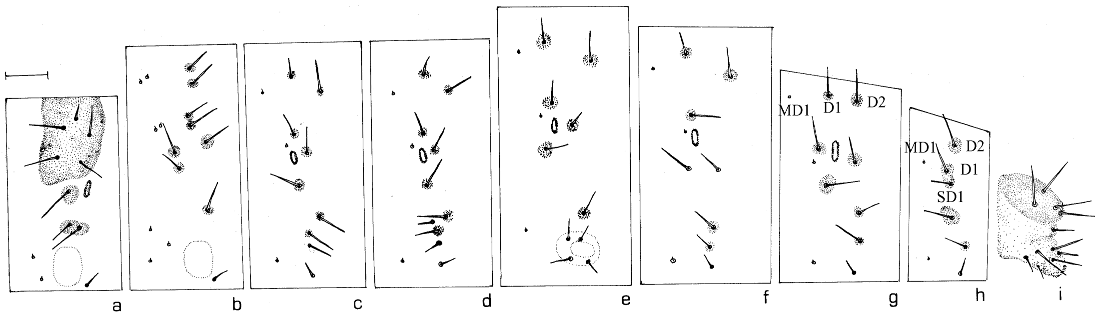
Eggs

Larvae

Williams (1953), Usua (1969, 1987), Moyal and Tran (1989), Heinrichs (1998) and Meijerman and Ulenberg (1996, 1998) provided descriptions of larvae.

Larva of *S. calamistis* (Polaszek 1998a).

Yellowish-pink coloured with small brown pinacula (chitinised areas). Spiracles black and oval-shaped, internal trachael system visible. Head capsule and prothoracic shield brown. Suranal plate yellow-brown. Angle formed by lines through D1 and D2 on each side of abdominal segment 8 averging 25° (12-45°). Angle between the setae D2, D1 and SD1 on abdominal segment 9 more than 140°. Crochets arranged in uniordinal mesoseries, can be curved to resemble penellipse.



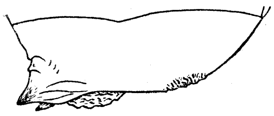
Setal map of *Sesamia calamistis*: a , prothorax; b, metathorax; c, abdominal segment 1; d, abdominal segment 2; e, abdominal segment 3 (=4,5,6); f, abdominal segment 7; g, abdominal segment 8; h, abdominal segment 9; I, abdominal segment 10; scale line = 1 mm (Mijerman & Ulenberg 1996, 1998).

Usua (1969) found *S. calamistis* to have two dorsal setae on a joined pinaculum on the mesothorax. This enabled him to separate this species from *S. nonagrioides botanephaga*, which has these setae arranged on separate pinacula. He also found that in *S. calamistis* SD1 is longer than SD2 on the meso- and metathorax, which enabled him to separate this species from both *S. penniseti* and *S. nonagrioides botanephaga*. Meijerman and Ulenberg (1996, 1998) found that both characters vary within a sample of *S. calamistis*, and, although most larvae matched Usua's descriptions, they considered the characters too variable to be reliable. No characters are known to separate larvae of *S. calamistis* from those of *S. poephaga* (Meijerman & Ulenberg 1996, 1998). Larvae of *S. calamistis* and *S. nonagrioides* can be separated under electrophoresis by differences in the migration distances for the loci encoding for *Est*, *Hbdh* and *Idh* (Meijerman *et al.* 1998).

Pupae

Pupa of *S. calamistis* (Polaszek 1998a).

Frontal tubercle with prominently raised cornicles. Abdominal pits on segments 4-7 dense near cephalic margin dorsally. Cremaster with two dorsal spines and a ventral tubercled protuberance (Williams 1953; Harris 1962).

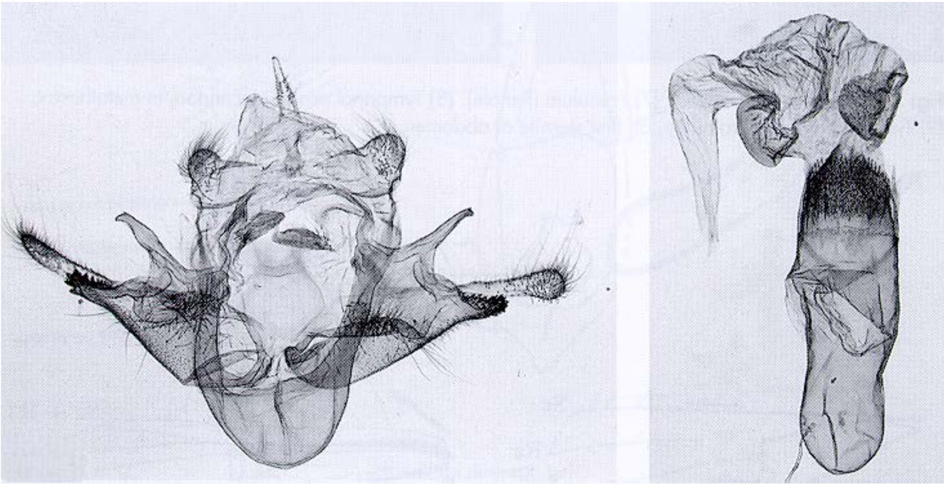


Cremaster of pupa of *S. calamistis* (Williams 1953).

Adults

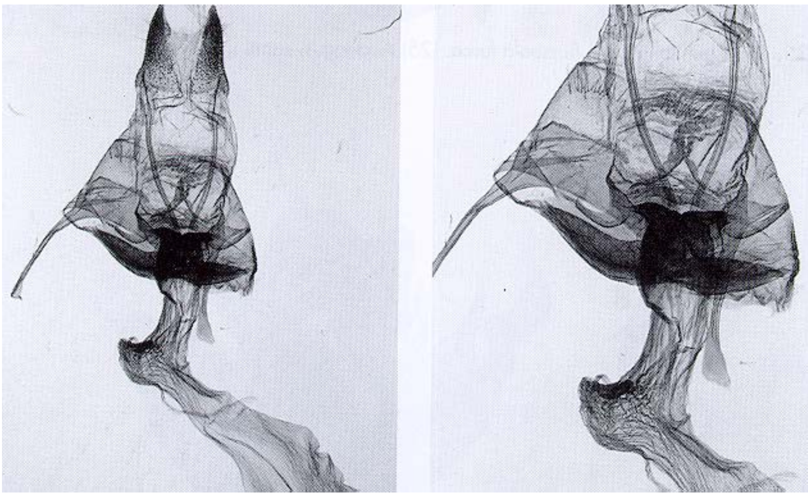
General. (Heinrichs 1998; Holloway 1998). The forewings are a streaked straw colour with the margin wide, whitish and partly smoky; the rest of the forewing is speckled with dark patches. The hind wings are pearly white with a yellowish margin. The male antennae are bipectinate, the pectinations longer than the width of the antennal shaft.

Male. (Tams &Bowden 1953). Palpus largely infuscate. Antenna moderately bipectinate, serrate at apex, cilia short, fasciculate. Head light ochraceous-buff, streaked with fuscous-brown. Thorax buff or light buff, variably suffused with ochraceous. Pectus buff, infuscate at base. Legs light buff, sometimes with ochraceous suffusion, the fore femur and tibia moderately, the mid and hind tibiae lightly, streaked with fuscous. Forewing cartridge-buff, variably irroate with fuscous and suffused with fuscous along termen; some fuscous to fuscous-black markings variable in extent and intensity; a longitudinal fuscous to fuscous-black fascia from base along lower margin of cell, partly within cell, partly without, extending to termen; a fuscous-black spot at apex of cell, a slightly dentate fuscous-black postmedial fascia, the point between veins 5 and 6 frequently prominent, sometimes separated into two rows of fuscous-black spots, the proximal row on the veins, the distal interneural, a narrow fuscous-black terminal line; fringe ochraceous-white, lightly infuscate at middle and tip; expanse 22-30 mm. Hindwing white. Underside of forewing white, costa suffused with light buff, costa and termen irroate with fuscous; a fuscous-black spot at apex of cell. Underside of hindwing white. Genitalia with tegumen with well-developed peniculi. Uncus small, narrow. Valve with sacculus and cucullus separate; costal spine short, straight, with a small tooth immediately before apex, sometimes almost bifid, sometimes without an apical tooth; extension of sacculus narrow, slightly curved inwards with several rows of stout short spines which may extend almost to costal spine; cucullus long, slightly spatulate at apex. Aedeagus short, dilated basally; manica scobinate dorsally, lateral lobes elongate, scobinate; vesica with apical flat cornutus. Juxta broad trapezoid. Vinculum with fairly deep ventral expansion.



Male genitalia of *S. calamistis* (Polaszek 1998a).

Female. Similar to male; expanse 24-36 mm. Genitalia with bursa copulatrix short and rounded, ductus bursae short and broad, ostium broad, anteostial pad as long or nearly as long as ostium, lateral plates of ostial segment reduced and lightly sclerotised.



Female genitalia of *S. calamistis* (Polaszek 1998a).

Geographic Variation. Specimens from West Africa and Mauritius and Réunion are generally smaller than those from southern Africa. There is also a great reduction in the fuscous-black wing markings, especially in southern and western forms, often combined in extreme western localities with a pronounced yellowish tinge or strong ochraceous suffusion (Tams & Bowden 1953). There is also variation in the shape of the costal spine of the male genitalia, with a reduction in size of the subapical tooth (Tams & Bowden 1953).

Detection Methods
In South Africa, both larval and adult populations are routinely monitored by means of field surveys and light traps, respectively (Leslie 1994).

Biology and Ecology
Based on Bosque-Pérez & Schulthess (1998) and Heinrichs (1998).

Moths are nocturnal and capable of flying long distances. Mating of adults takes place as early as the first night after emergence and oviposition begins the same night. In the field, the female lays up to 300 eggs, although more can be laid in the laboratory (Shanower *et al.* 1993). Eggs are thrust within the leaf sheath surrounding the upper internodes and hatch in 7-10 days. Larvae show a highly aggregated distribution (Schulthess *et al.* 1991). Larvae first feed within the tissues of the leaf sheath, and then enter the stem through a horizontal hole and move downward, sometimes through several internodes. The frass that fills the galleries is pushed out through openings in the leaf sheath. The larvae take 28-35 days to develop. The larva pupates within the base of the stem or in the folds of the withered leaf sheaths. The pupal period is 10-14 days.

On artificial diet, eggs needed 122 day-degrees above a threshold of 9.7°C, larvae required 383 day-degrees above 12.2°C, and pupae 204 day-degrees above 10.2°C (Shanower *et al.* 1993a). On artificial diet, larvae developed faster and had higher threshold temperatures than when developing on maize stem-cuttings. Adult females lived 5.7 days at 30°C and 10 days at 20°C, and produced 250-690 eggs per female

In wet, tropical areas the life cycle is practically continuous throughout the year. Drought or cold temperatures may slow development. Mature larvae become inactive from the start of the dry season and remain so until the rains begin. Under irrigation, development continues uninterrupted. There are five to six generations each year in most of West Africa to three in the drier Sahel region. In South Africa, light trap catches show an annual pattern in catches, with peaks in numbers during April-May and again in September-October (Carnegie & Leslie 1991).

Shanower *et al.* (1993a) give methods for rearing this species. Hamadoun and Strebler (1989) considered that cysteine is important for proper development. Shanower *et al.* (1993b) showed that larval survival of *S. calamistis* on five indigenous African grasses, *Andropogon* sp., *Panicum maximum*, *Pennisetum polystachion*, *P. purpureum* and *Sorghum arundinaceum*, was less than 10% compared to 95% on artificial diet and 30% on maize stems. While the larval period was similar on maize and all grasses, it was 50% faster on artificial diet. Pupal periods were similar for larvae reared on grasses, maize and artificial diet, with high pupal weights recorded from larvae reared on artificial diet, followed by maize and then grasses. One important feature of *S. calamistis* larvae is that they are cannibalistic, which explains the high rates of mortality recorded from laboratory and field observations as well as the difficulties encountered in laboratory rearing (Bosque-Perez & Dabrowski 1989; Sallam *et al* 1999).

Natural Enemies

***Bracon chinensis* Szépl. (*Myosoma chinensis*) (Hymenoptera: Braconidae).** Introduced to Mauritius from Sri Lanka in 1939 (Williams 1978), but not noted by Moutia and Courtois (1952). This parasitoid has been introduced by the Commonwealth Institute of Biological Control Indian Station, Bangalore, to Papua New Guinea in 1981. About 10,000 adults were liberated in the Ramu Valley but the parasitoid does not seem to have established (Li 1990). In Central Java, Indonesia, this species is reported to successfully parasitise the rice stemborer *Scirpophaga incertulas* (Mahrub & Pollet 1993).

***Cotesia chilonis* (Matsumura) (Hymenoptera: Braconidae).** Gregarious larval endoparasitoid, introduced from Japan into Kenya. Develops on a number of noctuid and pyralid stemborer hosts including *S. calamistis* (Okech & Overholt 1996, Hailemichael *et al* 1997).

***Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae).** Gregarious larval endoparasitoid that is morphologically and ecologically similar to *C. sesamiae*. Successfully established in East Africa following the introduction from Pakistan in 1993 (Overholt *et al* 1997).

***Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae).** Gregarious larval endoparasitoid. Introduced to Mauritius from Kenya in 1952 (Williams 1978) and the main parasitoid in Mauritius and South Africa (Leslie 1994).

***Dejeana bombylans*.** Mentioned by Leslie (1994).

***Descampsina sesamiae* (Diptera: Tachinidae).** Larval endoparasitoid, recorded from Ghana in sugarcane on *Sesamia calamistis*, *S. botanephaga* and *S. penniseti*. Rates of parasitism can be as high as 93.6% in sugarcane fields in Trom and Akorley. The relative abundance of the parasitoid appeared to vary with the pattern of rainfall occurring throughout the year and with the phenology of the sugarcane crop. Cultural practices such as the use of herbicides and burning may have a negative effect on the abundance of the parasitoid (Sampson & Kumar 1986).

***Enicospilus* sp. (Hymenoptera: Ichneumonidae).** A larval parasitoid in Mauritius (Williams 1978). parasitism rates reached 8% during late summer (Moutia & Courtois 1952).
***Envipio* sp. (Hymenoptera: Braconidae).** A solitary larval ectoparasitoid of stemborers. (Leslie 1994).

***Goniozus garouae* (Risbec) (Hymenoptera: Bethylidae).** This species is known from West Africa and is a gregarious larval ectoparasitoid, attacking concealed larvae. Oviposition follows temporary anesthesia of the host (Polaszek 1998b). It has a similar biology to *G. indicus* Ashmead, which parasitises pyralid stemborers. Polaszek (1998b) gives a brief description of the adult morphology.

***Ichneumon unicinctus* Brúlle (Hymenoptera: Ichneumonidae).** Recorded as a parasitoid in Mauritius (Williams 1978).

***Lathromeris ovicida* (Hymenoptera: Trichogrammatidae)**. Egg parasitoid from West Africa (Bosque Perez *et al* 1994; Chabi-Olaye *et al.* 2004).

***Mermis* sp. (Nematoda).** Found parasitising larvae in Mauritius during the wet months of March and April, attaining 20% infection (Moutia & Courtois 1952; Williams 1978).

***Pediobius furvus* Gahan (Hymenoptera: Eulophidae).** Mentioned by Leslie (1994).

***Platytelenomus ?hylas* Nixon (Hymenoptera: Scelionidae).** An egg paprasite, also reported from mainland Africa parasitising *S. cretica*. It has been referred to as *Prophanurus alecto* Crawford and *Telenomus* sp. In Mauritius it parasitises up to 32% of eggs during the winter when *S. calamistis* is scarce (Moutia & Courtois 1952).

***Telenomus busseolae* (Gahan) (Hymenoptera: Scelionidae).** Egg parasitoid recorded from West Africa. Regarded as one of the major factors influencing *S. calamistis* densities. Yield loss due to *S. calamistis* in maize decreased with increasing egg parasitism. (Bosque Perez *et al.* 1994, Setamou & Schulthess 1995).

***Telenous isis* (Hymenoptera: Scelionidae).** Egg parasitoid recorded from West Africa (Bosque Perez *et al.* 1994; Schulthess *et al.* 1997; Chabi- Olaye *et al.* 2001).

***Tetrastichus atriclavus* Waterston (Hymenoptera: Eulophidae).** A gregarious pupal parasitoid in Mauritius (Moutia & Courtois 1952; Williams 1978); <1% of pupae are parasitised.

***Trichogramma ?australicum* Girault (Hymenoptera: Trichogrammatidae).** An egg parasitoid in Mauritius (Moutia & Courtois 1952; Williams 1978). It parasitises a wide range of other Lepidoptera, although parasitism of *S. calamistis* eggs was 'rare' (Moutia & Courtois 1952).

***Trichogramma bournieri* Pintureau & Babault (Hymenoptera: Trichogrammatidae).** A polyphagous egg parasitoid that attacks *S. calamistis* eggs in East Africa (Bruce *et al.* 2006).

***Trichogramma* sp. nr *nana* Zehntner (Hymenoptera: Trichogrammatidae).** This second species of the egg-parasitic genus occurs in Mauritius (Williams 1978), and parasitises a small proportion of *S. calamistis*. eggs (Moutia & Courtois 1952).

***Trichogrammatoidea eldanae* (Hymenoptera: Trichogrammatidae).** Egg parasitoid from West Africa (Bosque Perez *et al* 1994).

***Trichospilus diatraeae* Cherian & Margabandhu (Hymenoptera: Eulophidae).** Gregarious pupal parasitoid. Introduced from India to Mauritius in 1963-4 (Williams 1978).

Xanthopimpla citrina **(Holmgren) (Hymenoptera: Ichneumonidae).** A solitary pupal parasitoid from Mauritius (Moutia & Courtois 1952; Williams 1978); parasitism of *S. calamistis* reaches about 5% during summer.

Xanthopimpla stemmator **Thunberg (Hymenoptera: Ichneumonidae).** Introduced from Sri Lanka, where it parasitises a wide range of stemborers, to Mauritius in 1939 and later from Mauritius to Reunion for the control of *C. sacchariphagus* in sugarcane (Caresche 1962; Williams 1978), and was later introduced to East Africa for the control of a complex of borers (Gitau *et al.* 2005). Parasitism reaches nearly 7% during summer. This parasitoid attacks a fairly wide range of stalk borers; hosts recorded are: *Sesamia inferens* (Walker), *Acigona steniella* (Hampson), *Scirpophaga nivella* (F.), *Chilo partellus* (Swinhoe), *Chilo infuscatellus* Snellen, *Ostrinia nubilalis* (Hübner) and *Ostrinia furnacalis* (Guenee). (Sonan 1929; Cartwright 1933; Takano 1934, Vinson 1942; Yunus & Hua 1969).

Pathogens
A nuclear polyhedral virus, a cytoplasmic polyhedral virus and a virus of the family Nodamuraviridae together were recorded to cause 40% larval mortality in sugarcane fields in Reunion (Jacquemard *et al.* 1985).

Management
Intercropping maize with cowpea reduced damage by *S. calamistis* and other stemborers in Kenya and significantly resulted in higher yields of maize (27-57%) (Skovgard & Pats 1997). Other work by Dissemond & Hindorf (1990) in Mbita, western Kenya, showed that intercropping sorghum, maize and cowpea reduced populations of *S. calamistis* and other major stemborers as well as weeds, though in an earlier study by Dissemond & Weltzien (1986), it was realised that intercropping sorghum with various other crops in the semi-arid area of Kenya appeared to have very little impact on stemborers infestation. Also in Kenya, Pats (1996) showed that stubble and old stems of maize and sorghum constitute an important reservoir for infestation. Therefore managing crop residues by exposing old stems to the sun and heat reduced carry over of infestation and proved suitable for both commercial and subsistence farmers because of the low input of labour and money.

Egg parasitoids can be responsible for up to 41.5–84.1% mortality (Bosque Perez *et al.* 1994, Setamou & Schulthess 1995).

In Benin, West Africa, Setamou *et al.* (1995) showed that though nitrogen fertilisation had a positive effect on plant growth in maize, it also increased the survival of *Sesamia calamistis* and *Eldana saccharina*, and thereby increased the incidence of dead hearts and stem tunnelling. Similar observations where made by Setamou *et al.* (1993) who reported that the application of 2.25 g N/plant increased larval survival from 18.7% to 37.3% and larval weight from 49.0 mg to 99.5 mg. Female fecundity was also increased from 77 eggs/female to 365/female at 1.69 g N/plant. Nitrogen increased adult longevity though it had no effect on larval and pupal durations. The intrinsic rate of increase and the net reproductive rate were positively related to leaf and stem Nitrogen, while generation time was negatively related, and a significant positive relationship was found between fecundity and female pupal weight.

Silica, on the other hand, had a negative effect on larval survival. Increasing the silica supply reduced larval survival from 26.0% in the control to 4.0% at 0.56 g Si/plant. However, larval developmental time, larval and pupal weight, pupal survival, female fecundity, egg viability and adult longevity were not affected by silica.

Pheromone attractants. Hexane extracts of adult female pheromone glands revealed the presence of five compounds that act as sex pheromones of *S. calamistis*. These are (Z)-11 hexadecenyl acetate (60%), (Z)-9 tetradecenyl acetate (14%), (Z)-11 hexadecen-1-ol (15%), (Z)-9-tetradecen-1-ol (9%) and tetradecanyl acetate (2%). A blend of the first two compounds was attractive to adult males. Armyworm adult males, *Mythimna loreyi*, were also attracted by the blend of (Z)-11 hexadecenyl acetate and (Z)-9 tetradecenyl acetate. Tests with this mixture confirmed its efficacy in maize, rice and sorghum fields in Mali (Zagatti *et al.* 1988).

Chemical control

In sub-Saharan Africa, recommended insecticidal treatments include spraying or granular applications of carbaryl at 100 g/ha, endosulfan at 500 g/ha, trichlorfon at 150 g/ha, carbofuran at 1 g/ha, diazinon at 150 g/ha or fenitrothion at 800 g/ha (Anon. 1985).

In Cote d'Ivoire, deltamethrin as an emulsifiable concentrate at 15 g a.i./ha and carbofuran as granules at 200 g a.i./ha gave economical control of *S. calamistis* and other stemborers in maize. However, none of the insecticides endosulfan, chlorpyrifos-ethyl (chlorpyrifos), phoxim, carbofuran, deltamethrin, cypermethrin and *Bacillus thuringiensis* controlled borers found in the ear (Moyal 1989).

In Nigeria, the application of carbofuran in granules at 2.5-4.5 kg/ha in maize at planting resulted in significant control of the pest (Atu & Duru 1990).

In Togo, whorl treatment of maize plants with pure neem kernel powder or a 50:50 mixture of neem and sawdust drastically reduced larval populations (Dreyer et al. 1987).

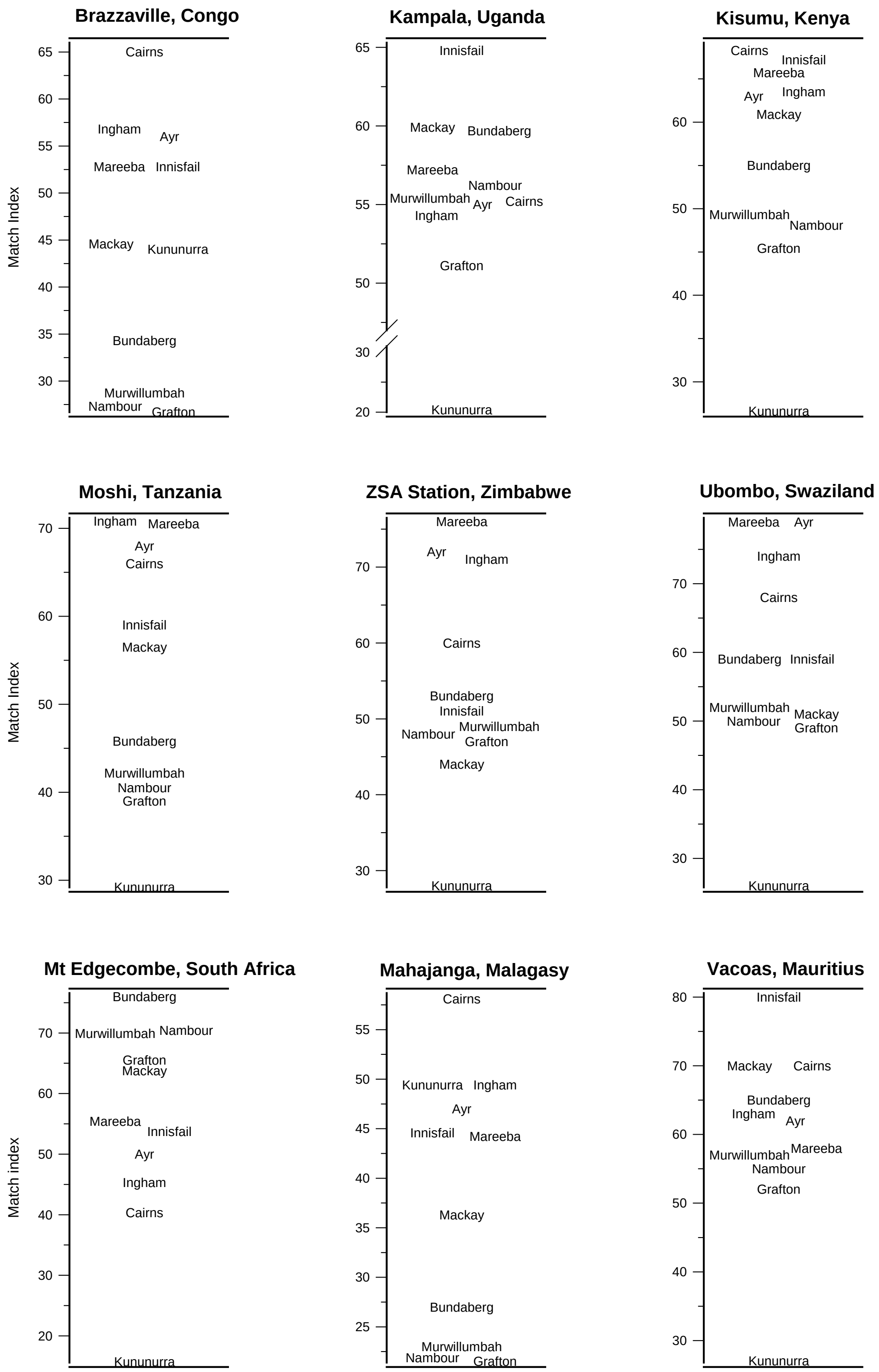
The aqueous extracts of the leaf and stem bark of the medicinal plant, *Alstonia boonei* De Wild (Apocyanaceae) significantly reduced larval survival and weight of *S. calamistis* in laboratory studies, and may be used as growth inhibitors against this species (Oigiangbe *et al.* 2007).

Means of Movement

The most likely means of entry of *S. calamistis* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths or eggs on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk

Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in northern Queensland (see Match Indexes for climate at selected African locations and principal Australian areas below).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Ingham
Ayr
Murwillumbah
Mareeba
Nambour
Grafton
Kununurra

***Sesamia cretica cretica* Lederer**

Sesamia cretica Lederer 1857, 225.
Sesamia pecki Tams 1938, 9; Tams and Bowden 1953, 671 (syn.).
Sesamia cretica striata Staudinger.

Notes on Taxonomy and Nomenclature
FitzGibbon *et al.* (1998) gives *S. cyrnaea* as a synonym. Holloway (1998) gives *S. uniformis* Dudgeon and *S. griselda* Warren as possible synonyms. *Sesamia c. striata* is recorded from Tadjikistan (Rao & Nagaraja 1969), but little is known of it.

Types
cretica: Unknown.
pecki: holotype male and allotype female, Burao, Somalia; both in Natural History Museum, London.

Common names
Durra stem borer, corn stem borer, pink borer, pink stalk borer, greater sugar cane borer.

Distribution
Northern Africa and southern Europe east through Arabia and Iraq to India and Sri Lanka, and perhaps Thailand (doubtful).

Algeria, Egypt, Croatia, Ethiopia, France (Corsica), Greece, India, Iraq, Iran, Italy, northern Kenya, Morocco, northern Nigeria, Saudi Arabia, Somalia, Sri Lanka, Sudan, Syria, Tadjikistan, Thailand, Yemen (Tams & Bowden 1953; Rao & Nagaraja 1969; El-Amin 1984; Shchetkin 1989; Leslie 1994; Shojai *et al* 1995; Meijerman & Ulenberg 1996; Moharram *et al* 1996; FitzGibbon *et al.* 1998; Holloway 1998).

Host Plants
Avena sativa (oats), *Hordeum vulgare* (barley), *Oryza sativa* (rice), *Pennisetum typhoideum* (bullrush millet), *Saccharum* spp. hybrids (sugarcane), *Sorghum bicolor* (sorghum), *Sorghum halpense* (Johnson grass), *Triticum aestivum* (wheat), *Zea mays* (maize), tomato, unidentified bamboo, unidentified bullrush, unidentified palms (Tams & Bowden 1953; Rao & Nagaraja 1969; Leslie 1994; Meijerman & Ulenberg 1996, 1998; Zaki *et al* 1997; Heinrichs 1998; Polaszek & Khan 1998).

Symptoms
Damage to sugarcane usually results in typical dead shoots as produced by other *Sesamia* spp. (Leslie 1994), although larvae can infest mature stalks. Larvae also feed on the leaves, stems and ears of maize (El-Amin 1984; Shojai *et al* 1995).

S. cretica is considered to be the most damaging of the maize and sugarcane stemborers in Egypt. Larvae attack plants shortly after emergence. Early-instar larvae devour the whorl leaves resulting in the death of the growing point and causing dead hearts. Later-instar larvae damage older plants by excavating tunnels into the stem, ears and/or cobs. (Soliman & Miham 1997).

Economic Impact
On sugarcane, this species has characteristically been thought of as a shoot borer (Temerak & Negm 1979), but it can damage more mature stalks (El-Amin 1974). There are no records of crop-loss estimates (Leslie 1994). However in Iran, *S. cretica* is reported to cause an average annual damage of about 20-30% in maize and could be up to 70% during population outbreaks (Shojai et al 1995). In Egypt, adult females lay their eggs during March, and in cases of high infestation, may cause complete death of small maize plants by April-May (Soliman & Miham 1997). Infestation was reported by Semeda (1998) to result in about 40-45% reduction in maize yield. Other studies in Khuzestan, Iran, estimated sugar losses to be 0.11 t/ha for every 1% bored stalk (Seraj 2001).

In Egypt, the economic threshold was determined as 8 egg masses/100 plants in maize (Ismail 1989).

El Halafawy & Aziz (1991) isolated *Aspergillus flavus*, *A. ochraceus* and *F. moniliforme* from the adult gut which indicate that *S. cretica* may play an important role as vector of plant moulds and mycotoxins.

Morphology

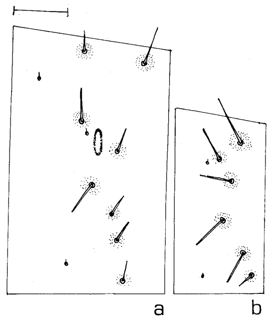
Sesamia cretica and *S. nonagrioides* have largely overlapping distribution ranges and are difficult to distinguish morphologically even in the adult stage. Laboratory studies in Italy on the microstructure of the eggs of the two species revealed differences in the shape of the lumps and depressions on the chorion (circular in *S. cretica,* elongated in *S. nonagrioides*) that were of value for identification. In addition, the diameter of the eggs and the number of micropyles and primary patterns on the chorion could be used to distinguish the two species (Pucci & Forcina 1984).

Larvae

Meijerman and Ulenberg (1996, 1998) provided a description of the larva.

Crochets and colour of cuticle and panicula similar to those in *S. calamistis*, but can be paler. Mesothorax and usually metathorax with SD1 longer than SD2. Distance between setae D2 and D1 divided by the distance between D1 and MD1 smaller on abdominal segment 7 than on abdominal segment 3. Angle between setae MD1, D1 and D2 on abdominal segment 8 less than 150°. Angle between setae D2, D1 and SD1 on abdominal segment 9 less than 120°.

S. crecita is distinguished from all other African species on sugarcane by the angle between the setae D2, D1 and SD1 on abdominal segment 9; less than 120° in *S. cretica* and almost in a line in the other species (Meijerman & Ulenberg 1996, 1998). In addition, the angle between MD1, D1 and D2 on abdominal segment 8 is less than 150° in *S. cretica*, while it is more than this in the other *Sesamia* spp.



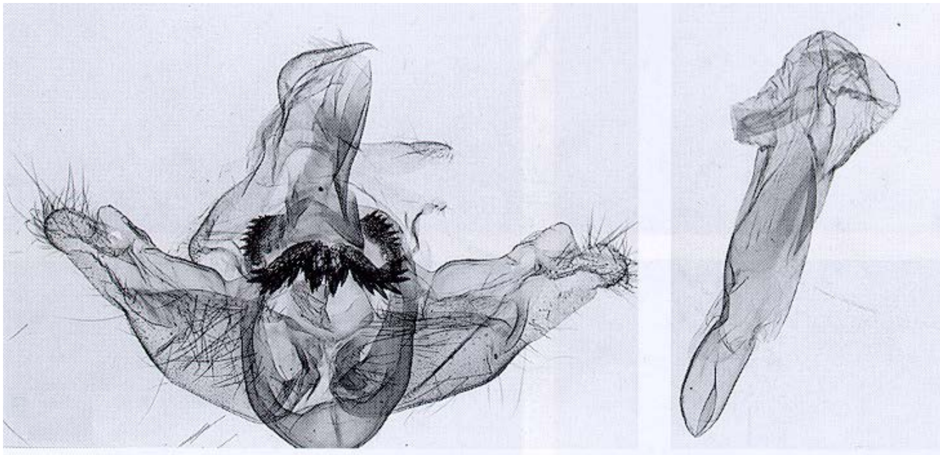
Setal map of *Sesamia cretica*: a, abdominal segment 8; b, abdominal segment 9; scale line = 1 mm (Meijerman & Ulenberg 1996, 1998).

Adults

General. (Holloway 1998). The adult moth has the forewings a more uniform pinkish straw than in *S. calamistis* and the hind wings are pure white, as in *S. calamistis*, rather than the bone-white as in *S. nonagrioides botaneophaga*, *S. poephaga* or *S. penniseti*. The male antennae are simple, filiform and ciliate, rather than bipectinate.

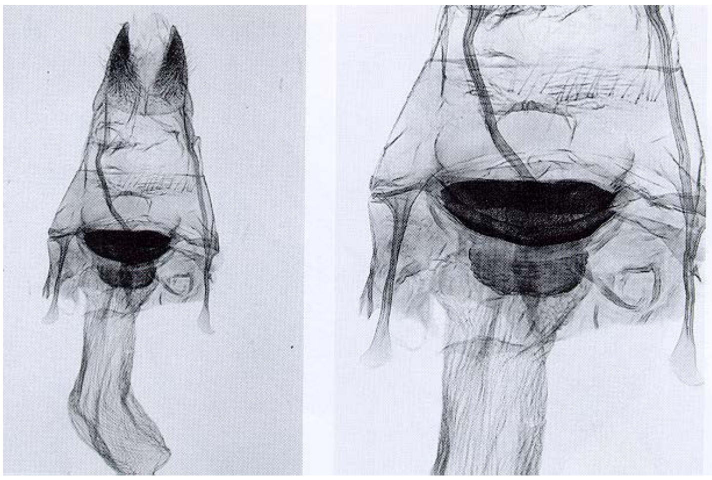
Adult of *S. cretica cretica* (Polaszek 1998a).

Male. (Tams & Bowden 1953). Palpus cartridge-buff or largely cartridge buff, sometimes irroate with fuscous. Antenna serrate, cilia short, fasciculate. Head buff to very pale buff, frons sometimes infuscate. Thorax buff to very pale buff with a buff suffusion anteriorly in pale specimens. Pectus buff to cartridge. Legs buff or cartridge-buff with the fore tibia sometimes infuscate. Forewing ochraceous-buff to very pale buff, with some fuscous to fuscous-black markings, varying in extent and intensity; a sub-basal patch below the cell, followed by a similar but smaller antemedial spot; a longitudinal fuscous fascia along the lower margin of the cell, partly within the cell and partly without, extending beyond the end of the cell to a postmedial series of spots or sometimes to termen; a prominent fuscous-black spot at the lower angle of the cell, a smaller one above it at the middle of discocellulars; a curved postmedial fascia of fuscous-black spots, consisting of two rows, the proximal row interneural, the distal on the veins; a fine fuscous-black terminal line, slightly widened interneurally; fringe irroate with fuscous*;* expanse 26-32 mm. Hindwing white, termen and inner margin tinged with cartridge-buff. Underside of forewing cartridge-buff to light ochraceous-buff, tinged sometimes with ochraceous-buff. Underside of hindwing similar, with very pale buff suffusion along costa and termen. Genitalia with tegumen with very small peniculi. Uncus curved, simple. Valve with sacculus and cucullus fused; costal margin broadly sclerotised, spine broad, rather triangular at apex, sacculus with an oblique sclerotised bar at apex, cucullus broadly rounded. Aedeagus short and slender; manica strongly spinose. Juxta with a small, laterally compressed, medial projection, rounded at apex. Vinculum with ventral expansion indented on lower margin.



Male genitalia of *S. c. cretica* (Polaszek 1998a).

Female. Similar to male; expanse 29-40 mm. Genitalia with bursa copulatrix short and broad, rather pointed at apex, ductus bursae very short. Anteostial pad moderately large, almost quadrate. Ostium strongly transverse, the anterior lip sclerotised. Ostial segment with a lightly sclerotised band immediately posterior to ostium.



Female genitalia of *Sesamia c. cretica* (Polaszek 1998a).

Geographic Variation. This species shows variation in colour with three main local races (Tams & Bowden 1953): an ochraceous to ochraceous-buff form from the Balkans; a very pale yellowish-buff form from Morocco and southwestern Mediterranean; a light cartridge-buff form with well-developed fuscous markings from Saudi Arabia, Ethiopia and Somalia.

Detection Methods
Light traps were used by Hanne and Atries (1970) to monitor seasonal populations.

Biology and Ecology
Egg masses are deposited on the inner surfaces of leaf sheaths and the newly hatched larvae feed on the epidermal tissues. After 3-4 days, they bore into the stalk. The third-instar larvae move to the lower part of the stalk near soil level. In July, larvae start to hibernate in the tunnels where they pupate the following January (Hafez *et al.* 1970). In Egyptian sugarcane Kira and El-Sherif (1974) showed that egg masses predominated from late March to April (early spring) and again in June, indicating two generations per year. However, counts of larvae indicated three overlapping generations. Farag *et al* (1992) also showed that *S. cretica* was highly abundant in maize during May and between late June and early August.

In Assiut, upper Egypt, adults were found to emerge from early March. An average accumulation of 166.66, 433.33 and 601.66 day-degrees C, based on 11°C as a development threshold, is necessary for the emergence of 10, 50 and 90%, respectively, of the total overwintering population (Abdel Wahab *et al* 1987).

Ismail 1989 reported that adult females begin to lay eggs when maize plants reach 20 cm in height in Egypt. Females continue laying eggs until plants reach 1 m in height, with plants about 40 cm in hight being preferred. Light-trap catches in sorghum and sugarcane plantations in the Sudan showed that highest flight activity to be during the winter months (November-February) and is negatively correlated with average minimum temperature. Late-sown fodder grass (*Sorghum bicolor* var. Abu Sabein) and some grain sorghum varieties were preferred hosts in comparison to sugarcane. Early sowing in July and early harvesting in late October almost eliminate infestation. Sorghum stalks left after harvest serve as a reservoir for the larvae in November-January and provide a source for peak infestation of sugarcane (Elamin 1988).

Studies by Ahmed 1984 in the El Serw region of Egypt showed that *Panicum repens*, followed by maize, are the most suitable food plant for *S. cretica*. Therefore, removal of *P. repens* during winter may reduce infestation in the following spring and summer.

In the Giza district of Egypt, larvae were shown to be able to disperse for up to 30 m in all directions within 9 days and then stabilise after about 2 weeks within a range of 15-30 m (El Sherif & Mostafa 1987).

Larvae in diapause apparently possess sufficient supercooling ability to avoid dying at low temperatures over their normal environmental temperature ranges, however, larvae in diapause do not survive freezing (Grubor *et al* 1992).

There are 6-8 larval instars, depending on temperature (Hafez *et al.* 1970). In Assiut, Egypt, Mannaa (1999) reported that maize planted either early (1 May) or late (1 July) suffered more infestation than that planted in mid-season (between 15 May and 15 June). In Lebanon, where *S. cretica* infests maize simultaneously with *Helicoverpa armigera,* Atiyeh *et al* (1996) showed that although ear infestation was highest in early planted sweet corn, and decreased with the delay in planting from early May to early June, the maximum yield, however, was obtained from early planting and decreased as planting delayed.

S. cretica is reported to infest maize plants at all growth stages in Abu-Graib, Iraq. Thirty-day-old seedlings can sustain severe economic losses if infested with more than two second-instar larvae/plant. The pest appears in maize fields in late March and is continually present until November with a noticeable peak in spring. The pest has 5 overlapping generations a year. The duration of the larval, pre-pupal and pupal stages average 11, 3.66 and 9.53 days, respectively, and the adult lifespan average 3.65 days (Younis et al 1984).

Salama and Tolba (1971) refer to rearing in the laboratory, but no details of the method used are given.

Natural Enemies
Parasitoids
***Bracon brevicornis* (Hymenoptera: Braconidae).** Larval ectoparasitoid reported from Egypt. This species attacks a range of noctuid pests of maize and sugarcane. Zaki *et al* (1998) showed that spraying a 10% molasses solution on maize stalks before releasing the parasitoid increased the rate of parasitism from 7.74 to 28.21%. Similar rates of parasitism are reported by Temerak *et al* 1984, who also refer to the impact of a hyperparasitoid (*Pediobius bruchicida* Eulophidae: Hymenoptera) on rates of parasitism by *B. brevicornis*.

***Habrobracon hebetor* L.** (Hymenoptera: Braconidae). Larval parasitoid.
Both species are reported from Iran as key parasitoids with a wide distribution in the north, central and south parts of the Iranian plateau (Shojai *et al* 1995).

***Meteorus rubens* (Hymenoptera: Braconidae).** Larval parasitoid reported from Egypt. Release of females of at a rate of 10 females/m^2 after spraying molasses and kairomone gave a significant increase in the rate of parasitism of larvae Zaki *et al* 1997.

***Platytelenomus hylas* Nixon (Hymenoptera: Scelionidae).** Reported as an egg parasitoid from Egypt by Temerak and Negm (1979) and Hafez *et al.* (1977). It was considered to be the key mortality factor of eggs with an average parasitism of about 74%. Only one parasitoid develops in each host egg, and each female parasitoid lays 41 eggs.

***Platytelenomus busseolae* Gahan.** (Hymenoptera: Scelionidae). Egg parasitoid.

Pathogens
In a field experiment in maize in Egypt, a single spray with a nematode suspension of 1000 infective juveniles/ml of a locally isolated nematode (*Heterorhabditis taysearae*) and another imported isolate (*Heterorhabditis bacteriophora*) resulted in 67.86 and 40.62% larval mortality within one week of application (Saleh *et al.* 2000). Generally, larvae were more vulnerable to nematode infection than pupae (Saleh *et al* 2000).

ScGV. Granulosis virus isolated from larvae infesting maize in Kafr El-Sheikh, Egypt. The viral insecticide is a highly purified suspension of granules in water plus 10% molasses as a sticker as well as a feeding stimulant additive. The preparation contains 0.1 g of granules/litre (1.48 x 1010 polyhedral inclusion bodies/mL). Application at the rate of 1.25 and 2.51/0.01 feddan (1 feddan = 4200 m^2) at 2-week intervals using a portable knapsack sprayer and starting 3 weeks after sowing noticeably reduced numbers of larvae and increased maize yield (Fediere *et al* 1997).

RNA-virus. Isolated from larvae collected from maize in Egypt. The virus capsid contained 3 major proteins with molecular weights of 60 000, 54 000 and 28 000, and a minor protein with molecular weight of 58 000 daltons. The viral genome is composed of one single strand RNA, molecular weight 9.4 Kb. The presence of non-enveloped isometric viral particles, 30 nm in diameter, was observed. The virus caused 96% mortality in 8 days following oral infection by last-instar larvae (Fediere *et al* 1994).

Predators
Ants and coccinellids have been found near egg masses and probably predate on them (Temerak & Negm 1979) with about 2% mortality. Predators were considered the key mortality factors of neonate larvae (Temerak & Negm 1979), of which the 'true' spiders (probably lycosids and salticids; Leslie 1994) were the most significant.

Management
Cultural Controls. In Egypt, early season control by rouging dead hearts (Ezzat & Atries 1969) has been used. Hassanien and El-Naggar (1972) showed that autumn plantings were more severely damaged than

spring plantings and that damage declined with age of ratoons. Similar planting-time effects were found in Sudan (El-Amin 1988). Sorghum can act as a reservoir host and provide a source to infest sugarcane (El-Amin 1988).

Awadallah *et al* 1993 showed that onion plants have a repelling effect on *S. cretica* adult females. Onion planted in the surroundings of maize crops reduced infestation.
Nawar et al (1992) showed that increasing nitrogen fertilization of maize plants increased infestation.

Growing a mixture of maize cultivars in Abu Gharib, Iraq, reduced infestation in comparison to growing these cultivars separately (Al Adil & Al Jassany 1992).

In Tadjikistan, *S. cretica* shows three generations in low irrigated valleys and two generations on wild sugarcane and larvae overwinter in stems and ears. Control measures include the destruction of large gramineous weeds and the complete processing of stems and ears, leaving no remains in winter (Shchetkin 1989).

Biological Control. Egg parasitoids and larval predators are effective in reducing numbers (see above).

Host-Plant Resistance. Considerable variation in resistance exists between cultivars (Temerak & Negm 1979; Mesbah *et al.* 1976; El-Amin 1984) with higher mortality of neonate larvae on the resistant cultivars. In Egypt, susceptibility was best correlated with sucrose content and poorly correlated with plant height, weight, number of internodes and stem thickness (Mesbah *et al.* 1976). However, a cultivar's susceptibility may change with maturity; PR1000 was most susceptible at the tiller stage, but most resistant at maturity (El-Amin 1984).

Chemical Control. Awadallah *et al.* (1980) tested carbofuran granules at about 3 kg ai/ha, but they did not have any effect on growth or infestation level.

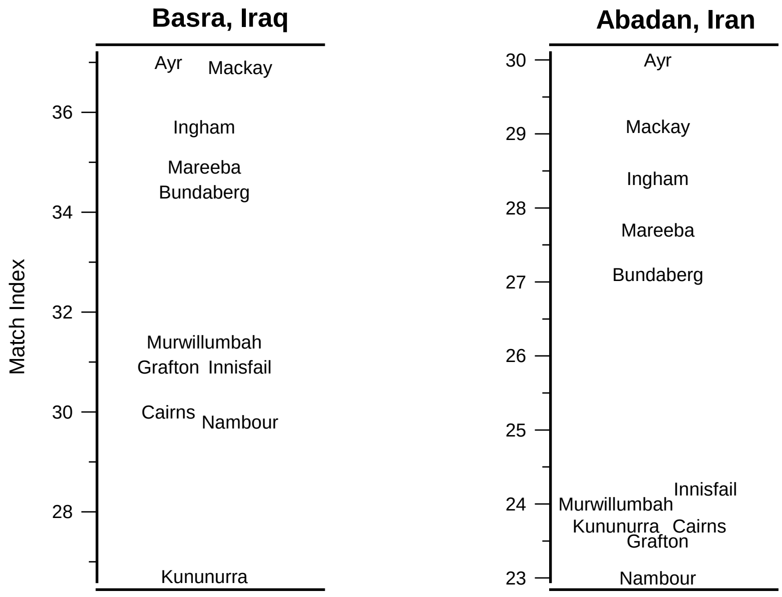
In Egypt, routine treatments of Sevin 85% WP (carbaryl), Gardona 70% WP (tetrachlorvinphos) and Malathion 57% have been used to control the pest effectively (Semeda *et al* 1993). Methomyl and monocrotophos are the currently used pesticides in Egypt (Fediere *et al* 1997).

The insect growth regulator Match [lufenuron] was also tested in Iraq. Lufenuron at 200 ppm decreased egg hatch ability to 40 and 64% of 1- and 4-day-old eggs. Larvae that emerged from treated eggs died after hatching. Treatment of newly hatched larvae with 200 ppm resulted in 100% mortality compared to only 14% when late instar larvae were treated with the same concentration. Lufenuron treatment produced malformed larvae, small pupae with low body weight and short adult life span with low fecundity. Adults fed on a lufenuron-sugar solution formulation had reduced life span and fertility compared with normal adults. Maize plants treated with lufenuron at 100 ppm maintained good protection against larval development and further insect infestation (Tariq *et al* 1999).

Ammar *et al* (1986) reported a reduction in infestation after the application of the plant growth regulators gibberellic acid at 250, 500, 750 and 1000 ppm and chlorocholine chloride (chlormequat) at 1000, 2000, 4000 and 6000 ppm to sugarcane. However, gibberellic acid increased infestation by the mealybug *Saccharicoccus sacchari* while chlormequat reduced their numbers. Both compounds induced a noticeable yield increase.

Means of Movement
Most likely in infested plant material of sugarcane or other grass host.

Phytosanitary Risk
Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in the Burdekin (see Match Indexes for climate at Basra and Adadan and principal Australian areas below).


Basra, Iraq
Match Index
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Mareeba
Bundaberg
Murwillumbah
Grafton
Innisfail
Cairns
Nambour
Kununurra
Abadan, Iran
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Bundaberg
Innisfail
Murwillumbah
Kununurra
Cairns
Grafton
Nambour

***Sesamia grisescens* Warren**

Sesamia grisescens Warren 1911, 148.

Notes on Taxonomy and Nomenclature

The species name has often been incorrectly attributed to Walker (eg Young & Kuniata 1992, 1995; Kuniata 1994, 1998; Kuniata & Sweet 1994; Eastwood *et al.* 1998; Kuniata *et al.* 1998; Lloyd & Kuniata 2000).

Types

Holotype male and paratype females and males, Upper Setekwa River, Snow Mountains, West Papua; paratype male and female, Haidana, Collingwood Bay, Papua New Guinea; all presumably in Natural History Museum, London (ex Tring Museum).

Common Names

Ramu shoot borer, Pink stalk borer, Sugarcane borer, Shoot borer.

Distribution

New Guinea

Papua New Guinea, Indonesia (West Papua) (Warren 1911; Szent-Ivany and Ardley 1963; Rao and Nagaraja 1969; Kuniata 1994; FitzGibbon *et al.* 1998; Lloyd & Kuniata 2000).

In Papua New Guinea the species ranges from near sea level to as high as 1675 m above sea level and occurs in the Eastern Highlands, Morobe Province, Markham-Ramu Valleys and New Britain (Szent-Ivany & Ardley 1963).

Host Plants

Oryza sativa (rice), *Panicum maximum* (Guinea grass), *Pennisetum purpureum* (elephant grass), *Saccharum* spp. hybrids (sugarcane), *Saccharum edule* (pit pit), *Saccharum robustum* (wild pit pit), *S. spontaneum* (Rao & Nagaraja 1969; Young & Kuniata 1992; Lloyd & Kuniata 2000).

Symptoms

Young and Kuniata (1992) and Lloyd and Kuniata (2000) give descriptions of the symptoms. Moths readily oviposit on cane 2-6 months old. Mature cane is less attractive, although side shoots can become favourable oviposition sites (Kuniata 1994).

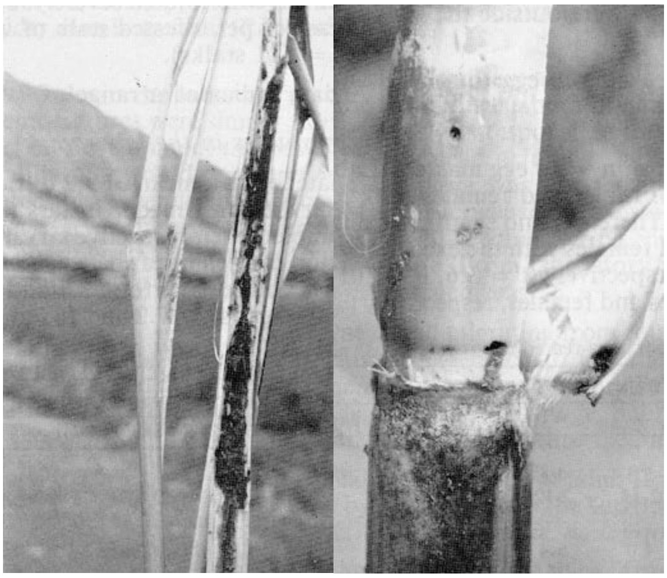
The first-instar larvae bore through the epidermis on the inner surface of the leaf sheath and feed gregariously on the mesophyll tissue. After about 2 days, they exit through the rotting epidermis and bore into the soft internode tissue of the meristem of the upper three internodes of the stalk. The apical meristem is killed either as a result of direct feeding or through massive destruction of vascular tissues. This is the damage to the primary stalk. The first field symptom of this damage is the development of a greyish tint to the spindle leaf, 4-6 days after the larvae hatch. Subsequently, the spindle leaf yellows, becomes brown, and finally shrivels by 11 days after hatching; this is termed a dead heart.

Damage to secondary stalks occurs when fourth- or fifth-instar larvae migrate from the primary stalk and tunnel through the leaf sheath into the upper internodes of adjacent healthy stalks. Here tunnels are large and extensive, but the meristem is rarely destroyed. There are usually not more than 3 larvae in a secondarily invaded stalk.

Prior to pupation the final-instar larva tunnels downwards and cuts an exit hole through the stalk rind at the node. It plugs the hole with frass.

Usually the lower portions of stalks are not bored by *S. grisescens* larvae, but may become favoured sites for stalk rots and sugarcane weevil borer larvae [*Rhabdoscelus obscurus* (Boisduval)] to cause further damage (Kuniata 1998, 2000).

Sideshooting and wind breakage can occur following damage (Kuniata 1994; Lloyd & Kuniata 2000).



Damage to stalks by *Sesamia grisescens* (left) and emergence holes (right) (Young & Kuniata 1992).

Economic Impact

Damage by *S. grisescens* reduces cane yield and adversely affects the quality of cane juice, which results in lower recovery of sucrose in the mill (Kuniata 1998, 2000; Lloyd & Kuniata 2000). At Ramu, estimated losses are 0.82 tonnes of cane per hectare, 0.13 tonnes of sugar per hectare and 0.15% pol for every 1% of bored and rotting stalks (Eastwood *et al.* 1998; Kuniata 1998). More recent studies recrded up to 31 tons/ha of cane (Kuniata *et al.* 2001). For cost-effective extraction of sucrose, damage must be well below 20% bored and rotting stalks (Kuniata 2000). Larval feeding results in increased fibre, glucose, fructose and raffinose contents and reduces the glucose/fructose ratio. Processing of this low-quality cane results in higher production of molasses and a consequent need for extra storage facilities (Eastwood *et al.* 1998).

Bored cane also increases harvesting costs (Kuniata 1998, 2000). There is a linear relationship between cost of harvesting and proportion of bored stalks, with 55% extra cost to harvest cane with more than 75% bored stalks (Kuniata 2000).

Subsequent damage by sugarcane weevil borer and rots will further lower cane and sugar yields and in extreme situations will cause poorer ratooning of subsequent crops (Kuniata 1998).

Infestation at 2-3 months of age when the crop is actively tillering has little effect on final yield as any shoots lost are readily replaced by new shoots. Greatest production losses occur in cane attacked between 5-9 months after planting or ratooning (Lloyd & Kuniata 2000). There is then insufficient time before harvest for stalks to be replaced, but ample time for maximum stalk rotting and sideshooting with consequential losses in cane and juice quality.

Morphology

Eggs

Eggs are white to cream coloured, barrel shaped with longitudinal striations, and 0.97 mm (range 0.90-1.11 mm) long and 0.56 mm (0.42-0.69 mm) wide (Young & Kuniata 1992). They are laid in masses of about 120 eggs (range 22-309).

Larvae

No comprehensive description of the larvae exists. Chaetotaxy is likely to be useful in distinguishing larvae from those in other genera, but within *Sesamia* identification of particular species on morphological bases is very difficult or impossible (Meijerman & Ulenberg 1996, 1998).

Newly hatched larvae are up to 2.5 mm long. The head capsule is brown and the cuticle varies from dull pink to a cream colour. Final instars are up to 48 mm long. The head capsule is a deep-brown colour, while the thoracic shield is lighter brown and the cuticle smooth, pink to violet on the dorsal surface and creamy white underneath. There are two rows of lateral tubercles on each side of the abdomen.

There are seven larval instars with head capsules widths (mm) (range) of: first, 0.47 (0.42-0.50); second, 0.69 (0.53-0.74); third, 0.97 (0.77-1.09); fourth, 1.85 (1.17-2.24); fifth, 2.42 (2.30-2.55); sixth, 2.77 (2.59-2.94); seventh, 3.10 (2.95-3.25) (Young & Kuniata 1992).

Pupae

Pupae have a mean length of 22.0 mm (range 18-26 mm) and a mean width across the metathorax of 5.6 mm (4-7 mm) (Young & Kuniata 1992). They are a light-tan colour initially, becoming brown with age and almost black just before adult emergence.

Adults

No comprehensive description of the adult exists; the original description by Warren (1911) provides few useful characters and is:

> "*Forewing:* dull cinerous dusted with dark atoms; the two folds and the inner margin dull flesh-coloured ochreous, the streaks reaching subterminal line; inner line marked only by a dark spot on submedian fold; outer line lunulate-dentate, very obscure, the tooth on submedian fold marked by a dark spot; a blackish spot on discocellular and another beyond cell; fringe concolorous.
> *Hindwing:* dirty whitish, grey-tinged towards apex and termen; fringe whitish.
> Underside slightly glossy, uniform dull grey, the hindwing somewhat paler.
> Head, thorax, and abdomen dull grey; palpi externally darker.
> Expanse of wings: male 26-32 mm; female 32 mm.
> The species comes nearest to *S. calamistis* Hmps. from S. Africa."

Young and Kuniata (1992) describe adults as: "stout bodied, up to 20 mm in length with a wing span up to 39 mm for males and 47 mm for females. In both sexes the fore wing is light grey to dark brown in colour with a darker longitudinal streak and a small orbicular spot. The hind wings are greyish white without colour patterns."

Detection Methods

The presence of dead hearts on primary infected stalks and boring within stalks are primary signs of infestations. Holes made for emergence of pupae suggest previous infestation.

Adults are caught in light traps, but these traps are ineffective in monitoring numbers (Young & Kuniata 1995). They can also be sampled with pheromone traps containing a 3:2 blend of (*Z*)-11-hexadecenyl acetate and (*Z*)-11-hexadecenol (Whittle *et al.* 1995). In Papua New Guinea, pheromone traps have also caught *S. inferens*, *Mythimna* sp., *Chilo terenellus* and *Hydrilloides* sp., whilst in Australia they have caught the noctuid *Athenis reclusa* and the geometrid *Petelia medardaria* (Whittle *et al.* 1995).

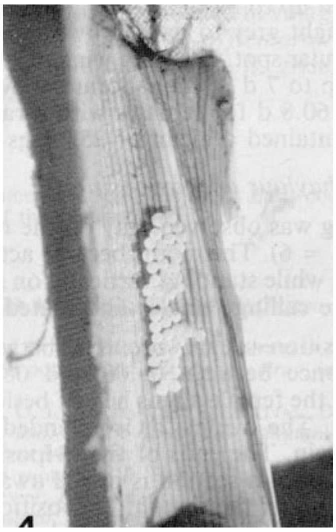
Boring within stalks can be sampled by collecting stalks and slicing them longitudinally. At Ramu, populations are monitored 2-7 months-old cane at 3-4 week intervals (Kuniata 1994; Kuniata & Sweet 1994). Since infestations usually start from field edges, the first 60-100 m from headlands is sampled. Twenty cane rows are selected at random and, from each row starting 5 m from the headland and at every 20 paces, a stalk is sampled (gives a total of 200 stalks per field). The sampled stalks are cut, leaf sheaths examined for egg masses, and the stalks are split open and the number of larvae and pupae counted. An average of eight pupae per 200 stalks or 20% damaged stalks is used as a critical level. Similar sampling has been used in population studies (Young & Kuniata 1995) and insecticide trials (Kuniata 2000).

Cane quality parameters were studied by Eastwood *et al.* (1998) by selecting 1000-4000 stalks of each cultivar and separating them into those with no external signs of borer damage and those with borer entry holes. These were then sectioned into four parts, joints 1-5 (oldest), 6-10, 11-15 and 16-20 and these were then split longitudinally to rate damage. The stalk samples were analysed for pol values and fibre content by the press juice method. Juice samples were also analysed for pH, ash, reducing sugars, glucose and fructose content and total nitrogen.

Biology and Ecology

The biology of *S. grisescens* at Ramu is reported by Young and Kuniata (1992, 1995) and summarised by Lloyd and Kuniata (2000).

Eggs are laid in egg clusters of 22-309 eggs (mean 120) under green leaf sheaths 4-10 (taking the unfurling spindle as leaf 1), with each female laying 2-3 egg masses. 62% of the egg masses are in sheaths 6 and 7 and 94% are in sheaths 5-8. Eggs take about 8-9 days (range 6-11 days) to hatch.



Egg mass of *Sesamia grisescens* (Young & Kuniata 1992).

Upon hatching, first instars eat the egg remnants and then bore through the epidermis on the inner surface of the leaf sheath and begin to feed gregariously on the mesophyll tissue. Larvae feed and mine in the mesophyll for 2-3 days, then exit through the rotting inner epidermis and bore into the soft internode tissue below the apical meristem of the stalk. Up to 300 larvae can feed in the upper three internodes of a single stalk. These larvae feed for 8-15 d and then most of them migrate as fourth instars (10% fifth instars) to infest nearby unbored stalks. By the onset of the prepupal stage, there are usually not more than three larvae in a secondarily invaded stalk. Before pupation, the mature larva cuts an exit hole and retreats 40-100 mm into the tunnel to pupate leaving a plug of frass between it and the exit hole. Some may pupate outside the stalk in the leaf sheaths when populations are very high and the stalk has deteriorated.

The pupal period is 8-21 d (mean 16-17 days), with females developing slightly faster than males.

Pupa in stalk (Young & Kuniata 1992).

Adults emerge between 1930 hr and 2100 hr, with most emerging in the first half hour. In the laboratory, moths live for up to 7 days and moths hide in the cane trash during the day. Female moths use a sex pheromone to attract male moths for mating (Whittle *et al.* 1995). Mating occurs only on the night after emergence, between 0530 hr and 0615 hr. The moths become active 1 hour before sunrise, the females fluttering their wings while standing vertically on stalks and leaves. Males then fly or walk towards the calling females and mate.

Oviposition usually occurs between 2100 hr and 2300 hr, but can occur in the morning under overcast weather. Prior to oviposition, the female aligns herself beside and parallel to the margin of the enfolding leaf sheath. The ovipositor is extended and the abdomen is flexed towards the leaf-sheath margin. The ends of the ovipositor valves are moved up and down against the margin until a section is prised away from the stalk allowing the ovipositor to be inserted under the sheath. Oviposition continues for up to 1 hour, with the egg mass adhering to the leaf sheath. Females may raise a leaf sheath, but not oviposit and then abandon that section of the margin and proceed to raise another section. Usually a female's complement of eggs is laid in 2-3 batches.

The lifecycle takes about 60-70 d from egg to adult. Under Ramu conditions, populations are highly discrete with larval and pupal peaks every 6-8 weeks; there are 5½ generations annually starting to increase with the onset of the monsoon. Highest numbers of larvae occur in April-May, inflicting the most damage to the crop.

Young and Kuniata (1992) give duration of larval and pupal stages 22-30°C as (mean and range, days):

Sex	Stage								
	L1	L2	L3	L4	L5	L6	L7	Prepupa	Pupa
Female	4.4 2-11	4.9 2-10	3.6 2-7	4.8 1-13	5.3 2-15	4.6 2-12	5.2 1-10	2.1 1-4	16.7 13-21
Male	3.9 2-7	4.6 2-12	4.0 2-15	5.7 1-13	4.0 2-11	5.4 1-11	3.1 1-9	2.4 1-4	17.2 13-23

A semi-artificial diet for rearing larvae was given by Kuniata (1999).

Natural Enemies
Kuniata and Sweet (1994) surveyed parasitoids and predators of *S. grisescens* at Ramu and Kuniata (2000) discussed the augmentative releases of *Cotesia flavipes*.

***Bracon chinensis* Szépl. (Hymenoptera: Braconidae).** This species was released at Ramu against *Chilo terrenellus* Pagenstecher but apparently failed to establish (Lloyd & Kuniata 2000).

***Carcelia* sp. (Diptera: Tachinidae).** Parasitises up to 4% of larvae in the field, but has not been mass reared (Kuniata & Sweet 1994).

***Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae).** This is the main parasitoid species at Ramu. It attacks semimature to mature larvae and emerges from the late larva. The migration of borer larvae at the fourth instar makes them particularly susceptible to parasitisation; nonaugmentative parasitism stands at about 30% (Kuniata 2000), more recent results recorded parasitism levels of up to 80% (Kuniata & Korowi 2005).

The strain at Ramu (dark coloured) appears to be of local origin, despite Indian material being released in the early 1980s (Kuniata 1999). It also parasitises *Chilo terenellus*. Parasitoid emergence takes place in the late morning and the females require a preoviposition period of 12-24 hours. A female takes 10-20 seconds to parasitise a host larva; those attacking near to the head are more successful. Egg and larval stages take about 14 days in the laboratory. Once the larvae are fully grown, they emerge from the host larva and each parasitoid larva spins a cocoon and pupates inside. This process takes 2-6 hours. Pupation takes about 10 days and with honey provided the adults can live for up to 8 days. Each host larva produces many parasitoid larvae; mean of 42, with 17% producing >70.

Kuniata (1999) describes the mass-rearing procedure using semi-artificial diet to rear host larvae. He also describes the augmentative release program that forms part of the IPM system at Ramu (Kuniata 1999, 2000).

***Enicosphilus terebrus* Gauld (Hymenoptera: Ichneumonidae).** This species parasitises fully grown larvae and up to 19% of larvae have been parasitised at Ramu (Kuniata & Sweet 1994; Kuniata & Korowi 2005). It has not been mass reared.

***Pediobius furvus* Gahan (Hymenoptera: Eulophidae).** This species is indigenous to Africa south of the Sahara and occurs there on a wide variety of pyralid and noctuid borers of grasses (Mohyuddin 1968). It was introduced to Ramu in 1991 (Lloyd & Kuniata 2000). Nonaugmentative parasitism stands at less than 10% (Kuniata 2000), however, more recent results recorded up to 50% field parasitism (Kuniata & Korowi 2005). In the laboratory, females readily parasitise 1-2 day old *S. grisescens* pupae. The duration of the egg and larval stages is 17-24 days and they pupate within the host pupa. Each host pupa produces many adult parasitoids; mean of 316 and range of 5-1069. Kuniata (1999, 2000) describes the massrearing and attempts at an augmentative release program.

***Telenomus* sp. (Hymenoptera: Scelionidae).** This species occurs at Ramu and parasitises up to 10% of egg masses (Kuniata & Sweet 1994). It has been used as part of the augmentative release program.

Predators. At Ramu (Kuniata & Sweet 1994) the general predatory earwig *Chelisoches morio* (F.) (Dermaptera: Chelisochidae) preys on egg masses and young larvae, and the anthocorid bug *Blaptostethoides* sp. can cause >10% predation of eggs. The ants *Phediole* sp. and *Iridomyrmex* spp. also prey on larvae and pupae, but it is difficult to determine their impact on borer populations. Trash blanketing might help conserve these predators.

Pathogens. Both *Beauvaria* sp. and *Metarhizium anisopliae* have been recorded (Kuniata & Sweet 1994; Young & Kuniata 1995), but nothing has been done to use these augmentatively. An unidentified virus kills up to 40% of field-collected larvae and infections appear to be highest where *Cotesia* has been released (Kuniata & Sweet 1994).

Management

Cultural Controls. Damage from *S. grisescens* peaks towards the end of the wet season at Ramu (Kuniata & Sweet 1994; Kuniata 2000). Early planted cane (March-May into declining soil moisture) is usually exposed to declining populations of the borer and damage occurs during the tillering stage. This damage does not result in heavy yield loss, perhaps due to compensatory growth in the following wet season. In contrast, the tillering of late-planted cane (September-November) is exposed to high borer populations, the plants can not compensate and high yield losses are sustained. Susceptible, but otherwise attractive, cultivars are planted and ratooned early season, and, if late planting is unavoidable, then resistant cultivars are used.

Rouging of primarily infested stalks, identified by dead hearts, has been practiced at Ramu, but is highly labour intensive and the gaps left encourage weed growth (Kuniata & Sweet 1994).

Preharvest burning of cane kills >98% of larvae, but also kills predatory earwigs and probably other parasitoids and predators (Kuniata & Sweet 1994). Green-cane trash-blanketing reduces infestations by 15%, probably through the conservation of natural enemies.

Virtually all irrigated crops at Ramu have been devastated by *S. grisescens* (Lloyd & Kuniata 2000). Lush, active growth during the otherwise dry season, when *S. grisescens* levels normally fall, attracts moths, and as well as suffering considerable damage, acts as a source of infestation for other crops.

Use of borer-free planting material will reduce spread of the pest.

Biological Control. The braconid *Cotesia flavipes* and the eulophid *Pediobius furvus* are key parasitoids and their numbers increased steadily at Ramu through the 1990s (Kuniata 1999). Both have been used in augmentative releases, but the high degree of synchronisation of populations of *S. grisescens* in the field makes it difficult to establish sufficient numbers of parasitoids at the beginning of the wet season. Kuniata (1999, 2000) describes the augmentative strategy used.

Host-Plant Resistance. There is wide variation in susceptibility to *S. grisescens* damage between cultivars and Kuniata (2000) has devised a rating system and tested a range of cultivars. This screening program is on-going at Ramu. Cultivar H56-752 was the most resistant. Resistant cultivars showed lower damage and also yielded fewer pupae; the latter is an important factor in determining the size of the subsequent pest generation. Cultivars H56-752, BT65152, B72177, RQ117 and Co997 were identified as having one or both of these attributes. At the other end of the scale were Q135 and Cadmus, which were not only susceptible to borer damage but also yielded many pupae. The intermediate cultivars were Q136, BJ6732, Co6519 and Q127, which have variable reactions. The resistance observed in these cultivars was more apparent when canes were more than 6-months old (>13-15 internodes long). Younger cane, regardless of cultivar, was usually severely damaged.

Resistant cultivars, such as H56-752, BT65152 and B72177, usually produced a constriction in the internode below the bored internode. This constriction does not allow stalk rotting to extend below the damaged section of the stalk. In susceptible cultivars such as Cadmus and Q135, this rotting is usually extensive and also becomes a favoured breeding site for sugarcane weevil borer.

Recent studies in Papua New Guinea showed that the following sugarcane varieties were susceptible to *Sesamia grisescens*: Q234, Q182, MQ239, Q135, Q213 and Q208. Varieties Q209, Q203 and Cadmus were found to be intermediate while Q241, Q200 and Q235 were found to be resistant. A detailed list of ratings is available in the final report of Project BSS331 and in the SRA SPIDNet database.

Chemical Control. Attempts to control stemborer populations with insecticides are usually ineffective, because of extreme overlapping of generations and little effect on the target life stages. Two factors improve the efficacy of insecticides against *S. grisescens*: the highly synchronised generations, and the migration of fourth instar larvae from the primary to secondary stalk. However, more frequent spraying is needed on susceptible cultivars (Kuniata & Sweet 1994; Kuniata 2000).

Carbufuran (Furadan® granules) was trialed in the late 1980s, but provided poor and eratic control (Kuniata & Sweet 1994). A side effect of treatment was an increase in cicada populations in treated fields.

Acephate (Orthene®) and monocrotophos (Azodrin®, Nuvacron®) have been used successfully; the former is used because of its residual and translamina activity and as an alternative to pyrethroids in an insecticide-resistance-management program (Kuniata *et al*. 1998; Kuniata 2000). No data on the efficacy of either of these insecticides have been published.

Lamda-cyhalothrin (Karate®) was trialed as a boom application from high-clearance tractors by Kuniata (1999, 2000). Application at 25 g ai ha^{-1} of the 2.5 EC formulation reduced numbers of bored stalks and numbers of larvae and pupae, and increased cane yields by 57%.

Permethrin (Ambush®) was also trialed by Kuniata (1999, 2000). At 250 g ai ha^{-1} applied from ground rigs, there were reductions in *S. grisescens*-bored internodes and stalks of up to 57% and 48%, respectively, a 20% increase in the number of internodes per stalk, increases in cane yields of 65%, and the cane juice was of superior quality compared to unsprayed plots. Estimated sugar yield was 91% higher, and there was a lower fibre content in sprayed cane compared to unsprayed plots.

Terbufenozide (Match®) stops treated larvae feeding after 2-3 days and these start dying after 4 days (Kuniata 1999). In a field trial, rates as low as about 10 g ai ha^{-1} gave significant mortality 10 days after application. However, its high cost means that at Ramu it is used only in plant nurseries, where the chemical's low mammalian toxicity is an asset.

Bacillus thuringiensis var. *kurstaki*, seotype 3a,3b (Delfin®) was trialed in the field at Ramu, but gave variable and low (<20%) mortality despite giving good (>80%) mortality in bioassays (Kuniata 2000).

Pheromonal Control. Two pheromonal attractants have been identified (Whittle *et al.* 1995), (*Z*)-11-hexadecenyl acetate and (*Z*)-11-hexadecenol, and trapping trials indicated that a blend of 3:2 as the most effective bait. Wing and delta traps are more efficient than Hara traps. In addition to *S. grisescens*, the traps caught a few pyralids and other noctuids. The pheromones have not been tested in mating disruption trials.

Integrated Pest Management. Management of *S. grisescens* at Ramu uses a combination of cultural, biological, insecticidal and plant-resistance approaches, with decisions on use based on population monitoring and risk assessment based on site features. High-risk sites are located close to the river and/or blocks of wild cane. Kuniata (1999, 2000) details these and they are summarised as:

Site risk	Season*	Cultivar resistance†	Planting or ratooning windows	Borer management strategies	
				Major	Others
High	Low	1-3	March-August	Insecticides + Parasitoid release	Harvesting infested cane
	High	1-3	March-August	Insecticides	Harvesting infested cane
Moderate	Low	4-5	April-October	Parasitoid release	Insecticides + Harvesting infested cane
	High	4-5	May-October	Insecticides + Parasitoid release	Harvesting infested cane
Low	Low	6-8	April-September	Parasitoid release	Roguing infested cane
	High	6-8	May-July	Parasitoid release	Roguing infested cane + Insecticides

*Seasonal factors are low (severe dry season) or high risk (soft dry season).

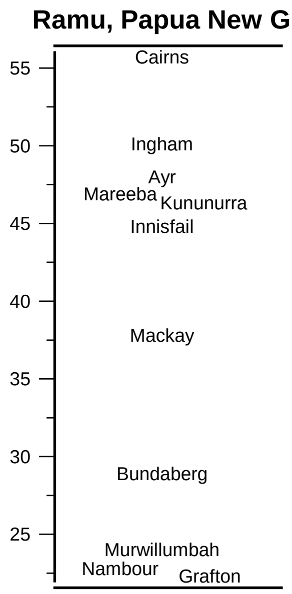
†Cultivars with low scores are the most resistant.

Means of Movement

The most likely means of entry of *S. grisescens* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant.

Within an area, the use and distribution of borer-free planting material will reduce spread of the pest.

Phytosanitary Risk to Australia
Entry potential: High - close to Australia, readily transmitted on infected planting material and adults carried by wind.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in northern Queensland, where entry is most likely (see Match Indexes for climate at Ramu and principal Australian areas below).



***Sesamia inferens* (Walker)**

Leucania inferens Walker 1856
Nonagria inferens

Types
Unknown.

Common names
Purple stemborer, ragi stemborer; pink stem borer; shoot borer; top borer; pink rice borer; violet stem borer; pink borer; pink graminaceous borer.

Distribution
Pakistan through the Indian subcontinent and south-east Asia to Solomon Islands and north to Japan and Korea

Bangladesh, Burma, Cambodia, China, India, Indonesia, Japan, Korea, Laos, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka, Solomon Islands, Taiwan, Thailand, Vietnam (CIE 1967; Rao and Nagaraja 1969; Kalshoven 1981; David *et al.* 1991; Cheng 1994; Kuniata 1994; FitzGibbon *et al.* 1998; Morris and Waterhouse 2001).

Records in Mauritius are of *S. calamistis* and a record in Guam is probably incorrect (CIE 1967). Brunei and East Timor are well within the general range given by CIE (1967).

Host Plants
Andropogon nardus, Andropogon schaenathus (lemon grass), *Avena sativa* (oats), *Beckmannia syzigachne* (American sloughgrass), *Calamagrostis epigejos*, *Coelorachis glandulosa*, *Cyperus japonicus*, *Cyperus rotundus* (nutgrass), *Echinochloa crus-galli*, *Echinochloa frumentacea* (barnyard millet), *Echinochloa stagnina*, *Echinochloa villosa, Elaeis guineensis* (oil palm), *Eleusine coracana* (finger millet), *Eleusine*

spp., *Eragrostis major*, *Erianthus arundinaceus*, *Eriochloa annulata*, *Eriochloa villosa*, *Hordeum vulgare* (barley), *Hymenache* sp., *Ischaemum rugosum*, *Miscanthus sacchariflorus* (reed), *Miscanthus sinensis* (eulalia), *Musa paradisiaca* (banana), *Oryza latifolia*, *Oryza sativa* (rice), *Panicum maximum* (Guinea grass), *Paspalum scrobiculatum* (scrobic), *Paspalum thunbergii*, *Phragmites karka* (narkat, tropical reed) *Phragmites communis* (*P. australis*), *Rottboellia compressa* (jove grass), *Rumex crispus* (curled dock), *Saccharum spontaneum*, *Saccharum* spp. hybrids (sugarcane), *Sacciolepis* sp., *Scirpus affinis* (sedge), *Scirpus grossus* (sedge), *Setaria italica* (foxtail millet), *Setaria rubiginosa*, *Sorghum halpense* (Johnson grass), *Sorghum sudanensis* (Sudan grass), *Teosinte* sp., *Triticum aestivum* L. (wheat), *Zea mays* (maize), other wild and cultivated grasses (Azuma & Oshiro 1969; Rao & Nagaraja 1969; Kalshoven 1981; Hasan & Cervancia 1986; Shah & Garg 1986; Garg 1988; David *et al.* 1991; Jacob 1995, Li 1993).

Jacob & Kochu (1995) recorded *S. inferens* damaging 8 to 10 month old seedlings of oil palm in Karnataka, India, which is the first report on oil palms in India.

Symptoms
This species causes 'dead hearts' in young plants and dead leafsheaths and boring in older plants (Kalshoven 1981; David *et al.* 1991; Kuniata 1994). Several larvae may enter a tiller and then disperse after the third instar (Cheng 1994).

Economic Impact
Maize and upland rice are favoured hosts; development on sugarcane is slower than on those species (Kalshoven 1981). In India, maximum survival of *S. inferens* was recorded to be on maize (48%), followed by sorghum (41%) and wild sorghum (39%). However all larvae died before pupation when fed on sugarcane, which may explain the low economic importance of this species in cane crops in India. Moreover, weight gain by the larvae was greatest on maize and lowest on sugarcane and both larval and pupal periods were longer on wild sorghum. Maximum adult emergence was recorded on maize (40.8%) followed by sorghum (33%) and wild sorghum (24.6%). The mean number of days required to complete one generation was 44.4 on maize, 45.9 on sorghum and 55.3 on wild sorghum (Tyagi & Sharma 1989). Other studies on food preference in Uttar Pradesh, India, showed that transplanted irrigated rice was the most susceptible plant to the pest, followed by barnyard millet (*Echinochloa frumentacea*). Winter crops (wheat and barley) were also infested during later growth stages, mainly in late April-May (Garg 1988). However, more recent work in Hoshangabad, Madhya Pradesh, India recorded infestation levels of up to 19.0% in sugarcane, where damage by *S. inferens* reduced cane weight and brix by 57.31 and 36.45% respectively (Choudhary & Shrivastava 2007).

In Taiwan, 23.6% of dead hearts in young cane in autumn were caused by this species, although only 0.5% internode infestation of millable cane was recorded (Cheng 1994).

In Bangladesh, *S. inferens* is a minor pest of rice and wheat but populations can increase in rice fields from November up to May, possibly because the availability of wheat (Husain & Begum 1985). In recent studies modelling the behaviour of *S. inferens* and another pest, *Scirpophaga incertulas*, Shahjahan and Talukder (1995) showed that these two pests had the greatest negative impact on rice yield in Bangladesh. In Bihar, India, Alam *et al* (1992b) showed that *Sesamia inferens* was the dominant species in deepwater rice at the seedling stage then *Scirpophaga incertulas* became dominant at a later growth stage in lowland. While *Scirpophaga incertulas* was the dominant species throughout the season in medium land. On the other hand, *Sesamia inferens* was the dominant borer in deepwater rice during the pre-flooding period while *Scirpophaga incertulas* was dominant during the flooding and post-flooding periods (Alam *et al* 1992a). Similar life histories were recorded from Bangladesh in 1977-80 and Thailand in 1981-82 on the incidence of stemborers in deepwater rice. *Scirpophaga incertulas* usually comprised more than 90% of the borer population and was almost exclusively present during the main flooding period, while *Chilo polychrysus* comprised 11% and *S. inferens* 6% of the population in the pre-flood and ripening stages (Catling et al 1984).

S. inferens is also endemic to rice growing areas of Almora, Uttar Pradesh, India where infestation peaks in September-October (Garg 1984). The pest is also recorded by (Thakur 1984) in the Sikkim Hills, India, to cause 7.2-19.5% infestation in rice. In West Bengal, India, a survey by Dutt and Kundu (1983) in 1975-

1977 showed that *Scirpophaga incertulas* and *Sesamia inferens* were the most abundant species in rice fields. The proportions of *S. inferens* and *Scirpophaga incertulas* on the variety Jaya increased considerably during the rabi (cool) season, while the proportion of *Chilo* spp. decreased during this period. The proportion of *S. incertulas* was much higher in the complex of varieties IR-579, IR-25 and Jaya than in pankaj and Patnai-23, while that of *Sesamia inferens* was higher in the last two than in the first three varieties. Dormancy in the form of overwintering larvae in dry stubble was recorded only for *Scirpophaga incertulas* but not for *Sesamia inferens*.

In the states of Punjab and Haryana, India, rice-wheat rotation is practiced in a 2.4 million ha area and is blamed to have created a number of problems such as salinity, untimely raising of crops and a gradual yield decline. Moreover, the possibility of the wheat crop serving as a host for the survival of mainly *Sesamia inferens* as well as other borers during non-rice growing months (November-April) may be the cause for the increase in the pest population above the economic threshold level (Nagarajan 1989).

Morphology

Eggs

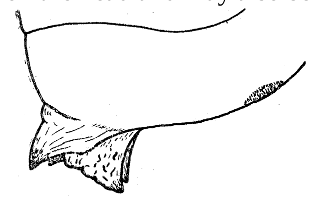
Eggs are milky-yellow in colour, bead-like and 0.66-0.69 mm in diameter and 0.33 mm thick (Cheng 1994). They are laid in rows within the leafsheath with 30 to more than 100 eggs in a batch (Kalshoven 1981; Cheng 1994).

Larvae

The larva was described by Gardner (1948) and Cheng (1994), but the characters given do not distinguish this species from other *Sesamia* spp. The larva is purple or pink dorsally and white ventrally; the head capsule is orange-red and the spiracles are dark (Kalshoven 1981; David *et al.* 1991; Cheng 1994; Kuniata 1994). Larvae are up to 30-35 mm long.

Pupae

The pupa is brown with a bluish tinge on the head and may also bear white powder (Kuniata 1994).



Cremaster of pupa of *S. inferens* (Williams 1953).

Adults

Adults are 7-14 mm long with the head, thorax and forewing light yellowish-brown. The hind wing and abdomen are yellowish-white (Cheng 1994).

Detection Methods

Young larvae feed in the spindle of sugarcane and cause characteristic shot-holing. Older larvae bore in the top section of stalks.

Biology and Ecology

Eggs are laid in batches of 30-100 in rows under the leafsheath. Each female lays about 300 eggs in 5-6 batches and lives for 5-6 days in summer and 10-20 days in winter. Eggs hatch in about 5-7 days in summer and 10-20 days in winter. The young larvae initially feed on the leafsheath before boring into the stem. When the available food is consumed, larvae migrate to other plants. In the lowlands of Indonesia and summer in Taiwan, development takes about 3-4 weeks; in winter in Taiwan it takes about 8-9 weeks. When mature, the larva chews an oval exit hole in the stem, sometimes sealing this with frass, and pupates in the tunnel without forming a cocoon. Mating and oviposition take place soon after emergence and the adults are short lived. Taken from Kalshoven (1981), Cheng (1994) and Kuniata (1994)

In Uttar Pradesh, India, Garg (1988) recorded that larvae remain dormant in winter, overwintering in rice stubble from the end of October to March. Only older larvae overwintered while younger ones died.

Overwintered larvae entered the pupal stage in late March-early April with the onset of warmer weather, with a high mortality rate of the overwintering larvae due to low winter temperatures (often below 0°C). Adults generally emerged from mid April. High infestations are mainly caused by second-generation larvae resulting from mass oviposition during July-August.

In Taiwan there are 5-6 generations per year (Cheng 1994), although 6-7 generations have been reported from Okinawa (Azuma & Oshiro 1969). Moderate temperatures and high humidities are suitable for build up of this species; intercropping with wheat will also increase populations (David *et al.* 1991).

In Zhejiang Province, China, where the incidence of *S. inferens* increasing with the increased cultivation of hybrid rice in the area since the late seventies, Lu and Tan (1981) recorded four overlapping generations a year with the fourth being incomplete. The first, second and third generations attacked rice while the fourth attacked maize. The larval stage lasted for 21.9-28.3 days and larvae overwintered in the stalks. Adult lifespan was 4.55-6.5 days.

On Hainan Island, China, a study by Zhou & Chen (1985) showed that the pest had 7 incomplete generations a year. Adult emergence peaked at 19.00-20.00 h, with a 1:1.2-1.4 female: male ratio. Females lay between 8 and 656 eggs. Fifth and sixth instars consume far more food than earlier instars, with rice forming 60% of the total plants infested. Larva hibernated on rice plants. In hilly areas, fields were ploughed and submerged in winter, and *Miscanthus sinensis* became the main host with *S. inferens* accounting for 98.6% of the insect population. No hibernation was recorded since the lowest mean monthly temperature in this region is >17°C.

In Sichuan, China, a study by Jing (1985) showed that the temperature required for initial development of the egg, larva, pupa, adult and for the whole life cycle was 12.2, 7.5, 9.1, 13.6 and 8.7°C, respectively, and the total effective temperature (in day-degrees C) was 85.1, 448.7, 172.5, 50.0 and 757.9, respectively. Duration of each stage and the whole life cycle decreased with an increase in mean temperature and the whole life cycle of one generation lasted for 64 days at 19.8°C and 41 days at 26.4°C.

On Okinawa Island, Japan, Abdul-Mannan & Iwahashi (1999) recorded two peaks of infestation per year, with the first peak being in April/May (20.5 to 29.3%) and the second one is later in August (22.2 to 29.5%).

A synthetic diet has been developed, but no details are given (Kalshoven 1981). Irradiation to sterilise males is possible (Kalshoven 1981), but, because females mate more than once, is not an effective field control. . Siddiqui et al 1983 showed that *S. inferens* was most successfully reared on a medium based on a grain powder of green gram (*Vigna radiata*), dried maize leaf and whorl powder and sucrose. Further ingredients added are wheat powder, ascorbic acid, methyl paraben (methyl 4-hydroxybenzoate), sorbic acid, vitamin E, yeast powder, formaldehyde, agar powder and distilled water). The addition of a small amount of vitamin E was necessary to increase egg production. In addition, Senthilkumar & Siddiqui (1998) showed that synthetic diets containing 0.2, 0.4, 0.6 or 0.8 g cysteine had detrimental effects on the development showing as a prolonged period of larval development, a low percentage of adult emergence, and a lower percentage of viable eggs.

In a study by Sun *et al* (1993), adult flightability of *Scirpophaga incertulas*, *Chilo suppressalis* and *Sesamia inferens* were determined with a flight mill and computer system. Results showed that adults of *S. inferens* had the strongest flight capability among the three species and the flight distance of female and male moths was >32 and 50 km, respectively. Normal flight could occur during the first 6 days of adult life and the pre-reproductive period lasted 2-3 days. Adults in the second phase of ovarian development made the longest flights and their flight capability declined with the development of the ovaries. As for *S. incertulas* and *C. suppressalis*, the cumulative flight distance of a female was found to be over 32 km, therefore *S. inferens* may have the potential for long distance dispersal as well as the physiological and behavioural bases of migration flight.

In Mianyang Prefecture, Sichuan, China, where *S. inferens* is a major pest of maize, a study by Jing *et al* (1987) showed that the spatial distribution pattern of eggs was near the positive binomial type, while that of the larvae was the common assembly type. The distribution of individuals in groups was random. The average density of eggs was 0.47 clusters/plant and the density of larvae was 0.51/plant.

Natural Enemies

Allorhogas pyralophagus **Marsh (Hymenoptera: Braconidae).** A gregarious larval ectoparasitoid from Mexico that was introduced to India. Varma et al (1987) stated that it accepted *Chilo auricilius*, *C. partellus*, *C. sacchariphagus indicus*, *C. tumidicostalis*, *Emmalocera depressella* and *Acigona steniellus* (*Bissetia steniella*) as hosts in the laboratory. However, *Sesamia inferens***,** *Scirpophaga excerptalis* and *Corcyra cephalonica* were rejected. The authors also state that a total of 3580 and 2651 parasitoids were released in sugarcane fields in India in 1982-83 and 1983-84 and cocoons were subsequently recovered from the release area. On the other hand, Easwaramoorthy *et al.* (1992) included *S. inferens* in the list of suitable laboratory hosts for parasitism (*Chilo infuscatellus*, *C. sacchariphagus indicus*, *C. partellus*, *Scirpophaga excerptalis*, *Corcyra cephalonica* and *Galleria mellonella*), of which *S. excerptalis* was the most suitable. Moreover, Ballal and Kumar (1989) stated that *C. partellus*, *C. infuscatellus*, *C. auricilius* and *S. inferens* were equally accepted by the parasitoid.
Contrary to previously sited results, Easwaramoorthy *et al.* (1992) refer to another attempt to establish *A. pyralophagus* in sugarcane fields in Tamil Nadu, India, whereby a total of 11754 and 15651 mated females were released in a 0.4 ha sugarcane field during 1988 and 1989, respectively. The parasitoid however was not recovered from the release area therefore considered to have failed to establish.
Additionally, Jayanth and Nagarkatti (1985) refer to laboratory rearing of a species of *Allorhogas* from Mexico, which the authors state that it was capable of parasitising larvae of *Chilo auricilius*, *C. infuscatellus*, *C. sacchariphagus indicus*, *Acigona steniellus*, *Scirpophaga incertulas*, *Sesamia inferens* and *Corcyra cephalonica*.

Amyotea **(*Asopus*)** ***malabarica*** **(Fabricius) (Hemiptera: Pentatomidae).** This predator is recorded to feed on a wide range of rice pests. Nymphs and adults were observed predating upon larval instars in rice fields in Orissa, India. Under laboratory conditions at 25-29°C, female predator laid 64-236 eggs in clusters of 7-45 eggs generally on the upper surface of the rice leaf. There were five nymphal instars with the period of nymphal development ranging from 22 to 24 days. Life span of adults ranged from 11 to 25 days. Nymphs and adults became cannibalistic during food shortage.

Apanteles **(*Cotesia*)** ***ruficrus*** Haliday (Hymenoptera: Braconidae). Larval parasitoid recorded in Zhejiang, China. Zhang (1986) refers to 17% parasitism achieved in the laboratory. This parasitoid however gave good control of other noctuid and hesperiid pests in rice fields in China. This species is highly hyperparasitised by *Eupteromalus parnarae* (*Trichomalopsisi apanteloctena*) (Hymenoptera: Pteromalidae).

Cotesia flavipes **(Cameron) (Hymenoptera: Braconidae).** Larval parasitoid (Kuniata 1994). Also recorded from Okinawa Island, Japan, where it can be responsible for up to 80.1% parasitism of larvae. Variable progeny production is recorded during the year and attributed to seasonal changes of temperature (Abdul-Mannan & Iwahashi 1999). In Taiwan, it parasitizes a wide range of stemborers including *S. inferens* in autumn sugarcane fields. It is however recorded to be hyperparasitised by *Aphanogmus fiijiensis*, *Catolaccus* sp. and *Eurytoma* sp. (Cheng *et al* 1987).

Euborellia stali **(Dermaptera)**. Recorded as an active predator of larvae in rice fields in the Philippines (Barrion et al 1987).

Euborellia stali **(*Euborellia annulata*) (Fabricius) (Dermaptera: Carcinophoridae)**. An earwig predator found preying on larvae of *S inferens* on rice in the Philippines. Also recorded preying on *Ostrinia nubilalis* in maize. Cage studies showed that each adult female could consume 20-30 young larvae of *S. inferens*/day (Barrion et al 1987).

Pediobius furvus **Gahan (Hymenoptera: Eulophidae).** *S. inferens* is used as a factitious host for mass rearing this species in Papua New Guinea (Kuniata 1994).

***Platytelenomus* sp. (Hymenoptera: Scelionidae).** This species is an egg parasitoid in Indonesia (Kalshoven 1981).

Sturmiopsis inferens (Diptera: Tachinidae). Larval parasitoid, attacks a wide range of pyralid and noctuid stemborers of which *S. inferens* is a key host. *S. inferens* is used as a laboratory host for mass breeding of this parasitoid (Easwaramoorthy *et al.* 1991). In Uttar Pradesh, India, parasitism ranged from 12.50 to 25.00% during the monsoon (July-August) and from 26.47 to 43.48% in the post monsoon period (September-November) following periodical releases of the parasitoid (Rai *et al* 1999). Varma (1989) recorded the hyperparasitism of *Nesolynx thymus* (Hymenoptera: Eulophidae) on the pupal stage of this species.

***Tetrastichus israeli* (M. & K.) (Hymenoptera: Eulophidae).** Recorded as a pupal parasitoid in Indonesia (Kalshoven 1981).

***Trichogramma chilonis* and *Trichogramma japonicum* (Hymenoptera: Trichogrammatidae).** Egg parasitoids, mass released in Haringar, West Champaran, Bihar, India, for the management of *S. inferens* and other borers in sugarcane (Misra *et al* 1986). Misra & Pawar (1987) refer to the release of the two species in April 1985 and 1986 at a rate of 20 000 parasitoids/acre per week, resulting in a significant reduction in borer damage to sugarcane in North Bihar. In Guangdong, China, *T. chilonis* (*T. confusum*) was mass released at the egg stage 5-7 times a year at a rate of 90,000–150,000 individuals/ha in sugarcane fields. This was one of a number of IPM practices that took place during 1981-1990, in which very good management of sugarcane borers including *S. inferens* was achieved (Liu *et al* 1985; Liu *et al* 1996).

Unidentified braconid (Hymenoptera: Braconidae). Braconid wasps have been reared from the larvae in Indonesia (Kalshoven 1981).

Hippasa greenalliae, Cyrtophora cicatrosa* and *Oxyopes shweta are predatory spiders recorded to predate upon larval instars in sugar cane fields in India (Easwaramoorthy *et al* 1996).

Pathogens

***Bacillus thuringiensis* (Bacterium).** The species is quite tolerant to strains of this disease (Kalshoven 1981).

Nuclear polyhedrosis virus was reported to result in slow death of larvae in 3-5 days in rice in India (Godse DB & Nayak P 1983). In Korea, a NPV from *S. inferens* was also pathogenic to the common armyworm *Mythimna separata* (So & Okada 1989).

Steinernema glaseri, S. feltiae* and *Heterorhabditis indicus are entomopathogenic nematodes that attack larval stages of a number of pyralid and noctuid pests. However *Sesamia inferens* shows very low susceptibility to infection by any of the three species (Karunakar *et al* 1999).

***Parasitorhabditis* sp.** An entomopathogenic nematode. Originally isolated from larvae of *S. inferens* and was afterwards found to be pathogenic to other lepidopterous pests of rice (Nayak *et al* 1983).

Entomopathogenic fungi. Varma & Tandan (1996) showed that the fungi *Beauveria bassiana*, *Fusarium oxysporum* and *Metarhizium anisopliae* var. *anisopliae* were pathogenic to the larvae in the laboratory. Also, Varma *et al* 1988 isolated *Beauveria bassiana* (Balsamo) *Vuillemin* from the sugar cane defoliator *Phytoscaphus* sp. (Coleoptera: Curculionidae) and found it to be pathogenic to *S. inferens* larvae. In addition, isolated strains of *Beauveria amorpha* and *Paecilomyces tenuipes* from Taiwan proved pathogenic to *S. inferens* larvae in the laboratory (Wang 1996), while Sivasankaran *et al* 1990 stated that a strain of *Beauveria* nr. *bassiana* was not infective to the parasitoid *Sturmiopsis inferens*.

Li (1992) refers to the use of *Isaria farinosa* (*Paecilomyces farinosus*) as an important fungal pathogen.

Management

Since this borer is a relatively minor pest in sugarcane, few control strategies have been developed specifically for cane. Biological control normally keeps the pest in check (Kuniata 1994).

In Bangladesh, the application of granules of cartap (Padan) at 3-kg ai/ha in July and August gave satisfactory control of the borer in sugarcane (Miah *et al.* 1983). Also, Ul-Haq and Inayatullah (1990) tested granular chlorpyrifos (5%), carbofuran (3%) and diazinon (10%) at 25 kg/ha and a spray of chlorpyrifos at 2.5 liters/ha against overwintering larvae in no-tillage and conventional-tillage wheat after rice in Pakistan. All treatments resulted in high mortality. Average larval mortality was higher in conventional-tillage plots than in no-tillage plots because of increased larval contact with the insecticide due to the breaking of the stubble.

In Manipur, India, The use of 0.02% chlorfenvinphos (root dip) or carbofuran granules at 0.75 kg/ha proved effective against stemborer complex of paddy rice (Ram & Pathak 1986).

In the Punjab, India, two granular compounds, chlorpyrifos and cartap hydrochloride (with carbofuran as a standard), were evaluated together with foliar sprays of chlorpyrifos, phosalone and a mixture of deltamethrin and buprofezin against *Scirpophaga incertulas*, *Scirpophaga innotata* and *Sesamia inferens* on rice. Of the granular insecticides, cartap hydrochloride was the most effective, with average whitehead incidence 3.8% compared with 25.4% for carbofuran and 26.4% for chlorpyrifos. The lowest incidence of whiteheads in the foliar spray treatments was 20.2% for chlorpyrifos. The highest yield was obtained with cartap hydrochloride (Sukhija *et al* 1988).

In Uttar Pradesh, two applications of phosphamidon, monocrotophos or quinalphos at 250 g a.i./ha or endosulfan at 0.5 g a.i. immediately the pest appeared and 15 days later minimized pest infestations in wheat crops. Yields were highest after treatment with phosphamidon followed by monocrotophos, cypermethrin, quinalphos and endosulfan (Singh *et al* 1990). Also, four applications of chlorpyrifos in foliar sprays at 0.5 liter toxicant/ha gave the best results in rice fields of Uttar Pradesh (Garg 1985).

Root-zone applications of systemic insecticides in southern China controlled nearly all potential insect pests of rice (*Scirpophaga incertulas, Chilo suppressalis, Sesamia inferens, Cnaphalocrocis medinalis, Orseolia oryzae, Nilaparvata lugens, Nephotettix* spp., *Baliothrips biformis* (*Stenchaetothrips biformis*) and *Echinocnemus squameus*). Applications of carbofuran mixed with thiocyclam or Padan (cartap) were the most effective (Chiu 1985).

Sukhani 1986 stated that proper disposal of the previous season's stubble reduces infestation in sorghum in India. In Pakistan, almost 100% destruction of stubble and elimination of all overwintering larvae could be obtained in rototilled fields, while larval infestation was highest in the stubble of zero-tilled/direct drilled fields (Zafar & Razzaq 1988).

Gyawali 1986 showed that intercropping maize with soybeans gave almost a 13% reduction in *Chilo partellus* and *S. inferens* and a 9.2% increase in grain weight per plant, with a 24% increase in yields per unit area of land. However on rice, intercropping caused a considerable increase in dead-hearts and white heads caused by *C. suppressalis*, *S. inferens*, *Scirpophaga incertulas* and *S. innotata*.

Pheromones: In China, three components were identified to attract *S. inferens* adults; (Z)-11-hexadecenyl acetate, (Z)-11-hexadecen-1-ol and (Z)-11-hexadecenal (4:1:0.1 blend ratio) (Zhu et al 1987). In addition, in rice-growing areas of southern China, pheromone traps could be used to forecast the incidence of the pest in rice, maize, sorghum and sugarcane crops. Traps baited with (Z)-11-hexadecenyl acetate and (Z)-11-hexadecen-1-ol in a ratio of 4:1 caught comparable numbers to those recorded from ultraviolet-light traps, with a good correlation between trap counts and the pest population in the field (Chen *et al* 1987).

In Japan, a mixture of (Z)-11-hexadecenyl acetate and (Z)-11-hexadecen-1-ol was developed to attract male armyworms, *Mythimna separata* (Wlk.) (*Pseudaletia separata*), in rice. The mixture also attracted males of *S. inferens* (Takahashi 1983).

Means of Movement

The most likely means of entry of *S. inferens* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant. There is a low chance of adults dispersing from Papua New Guinea through the Torres Strait Islands.

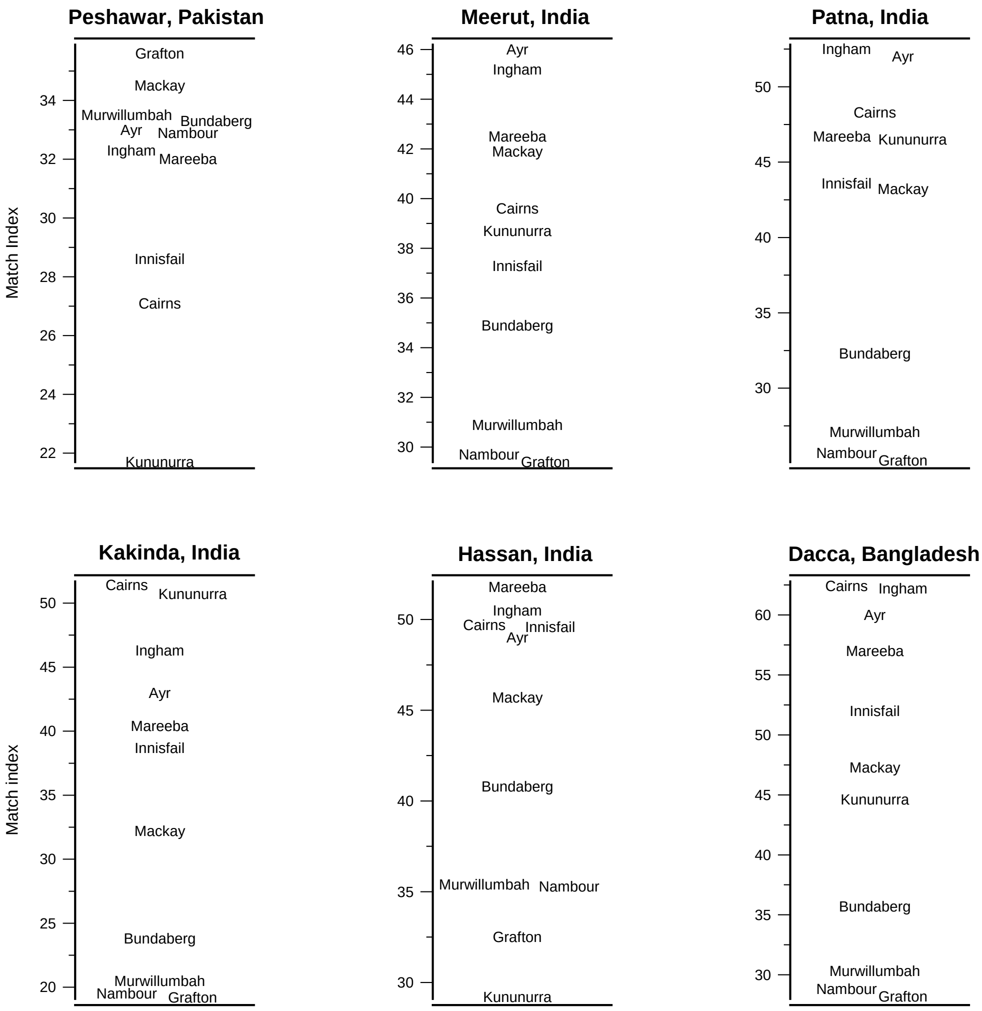
Phytosanitary Risk to Australia

Entry potential: High - close to Australia, readily transmitted on infected planting material and adults carried by wind.

Colonisation potential: High in all sugarcane-growing areas.

Spread potential: High, unless strict controls imposed over movement of infested material.

Establishment potential: Highest in northern Queensland, where entry is most likely (see Match Indexes for climate at selected locations and principal Australian areas below). Strains from cooler areas, such as Pakistan and China, will establish well in southern areas.

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Colombo, Sri Lanka
Cairns
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Iloilo, Philippines
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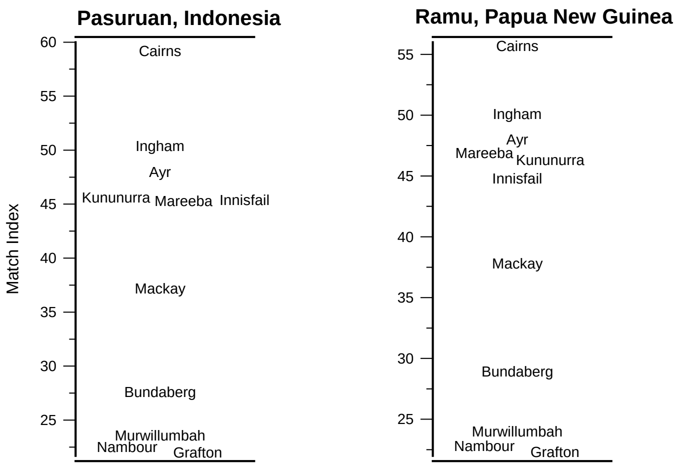
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Ramu, Papua New Guinea
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Mareeba
Innisfail
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton

***Sesamia nonagrioides nonagrioides* (Lefebvre)**

Cossus nonagrioides Lefebvre 1827
Sesamia nonagrioides: Guenée 1852, 95.
Nonagria hesperica Rambur 1839, plate 18.
Nonagria sacchari Wollaston 1858, 117.
Tapinostola gracilis Rebel 1898, 365.

Notes on Taxonomy and Nomenclature
Often referred to in older literature as *S. vuteria* Stoll.

Types
nonagrioides: Unknown.
hesperica: Unknown.
sacchari: Unknown.
gracilis: Unknown.

Common names
Moth borer; corn stalk borer.

Distribution
Mediterranean area east to western Turkey and southwestern Iran

Azores, Canary Islands, France, Greece, Iran, Israel, Italy, Spain, Portugal, Turkey (Tams & Bowden 1953; Rao & Nagaraja 1969; Meijerman & Ulenberg 1996; FitzGibbon *et al.* 1998; Holloway 1998; Fantinou & Kagkou 2000; González-Núñez *et al.* 2000).

Host Plants
Avena sativa (oats), *Oryza sativa* (rice), *Saccharum* spp. hybrids (sugarcane), *Sorghum bicolor* (sorghum), *Triticum aestivum* (wheat), *Zea mays* (maize), unidentified millet, unidentified vines (Tams & Bowden 1953; Rao & Nagaraja 1969). The pest has also been found on other non-gramineous hosts; larvae were found damaging fruits of persimmon var. Triumph in Bizzaron, Israel where *S. nonagrioides* is considered to be a significant pest of maize and other gramineous plants, and probably migrated to the orchard from maize fields (Wysoki 1986). Other hosts include the ornamental plant *Strelitzia reginae* in the Azores, leaves and flowers of *Strelitzia reginae* in Puglia, Italy, and bananas in South Anatolia, Turkey (Wysoki 1986, Uygun & Kayapinar 1993, Porcelli & Parenzan 1993). In South Anatolia, Turkey, almost 59% of banana plantations were heavily infested during the early 1990s. The pest population reached high densities by September-November and the damage caused by larvae was higher on suckers than on full-grown plants. Population density and infestation of *S. nonagrioides* in banana plantations were closely related with the presence of maize plants being the main host of *S. nonagrioides* (Uygun & Kayapinar 1993).

Symptoms
Larvae tend to bore in young shoots of sugarcane, causing typical 'dead-heart' symptoms.

Economic Impact
In Morocco, feeding by *Sesamia nonagrioides* results in reduced saccharose (sucrose) and increased dextran (glucose) content of the juice (Hilal 1985). However, sugarcane does not seem to be a preferred host to this pest in Morocco; larvae feeding on maize ears or maize stems have the highest rate of development and weight gain and lowest larval mortality. Larvae feeding on wheat and especially sugarcane shows a slow development rate and high mortality (10-25%), which may explain the comparatively low larval density found on sugarcane in the field (1 larva/plant), as compared to almost 10 larvae/plant on maize in Morocco (Hilal 1984).

Morphology

Adults

General. (Holloway 1998). Forewing with a submarginal row of brown flecks. Male antennae with long pectinations. Very similar to *S. n. botanephaga*, *S. pennisiti* and *S. poephaga*; the four taxa are best separated on genitalic characters.

Male. (Tams & Bowden 1953). Palpus cartridge-buff slightly irrorate with fuscous. Head buff. Thorax cartridge-buff, anteriorly suffused with buff. Pectus pale cartridge-buff. Legs cartridge-buff, fore tibia infuscate on inner surface, mid femur infuscate on inner surface. Forewing buff suffused with light ochraceous; some fuscous markings variable in extent and intensity; a very indistinct longitudinal fuscous fascia from base along lower margin of cell; a fuscous patch about middle of discocellulars; a curved postmedial fuscous fascia of one row of spots on the veins; termen suffused pale fuscous; a narrow fuscous terminal line; fringe white, suffused with pale buff; expanse 32-34 mm. Hindwing white with pale buff suffusion at apex; fringe white suffused with pale buff along termen. Underside of forewing pale cartridge-buff suffused with ochraceous-buff along costa and termen. Underside of hindwing white, suffused with pale buff along costa, with some fuscous irroration along costa and at apex. Genitalia small; tegumen with well-developed peniculi. Uncus small, narrowing rather sharply at about halfway. Valve with sacculus and cucullus separate; costal spine small with a small tooth some way before apex and sometimes slightly dentate at base; apical extension of sacculus slightly broadened with several rows of short stout spines; cucullus narrow, rather broadened at apex. Aedeagus long, slightly dilate at basally; manica scobinate, the lateral lobes less so; vesica with a small irregularly shaped subapical cornutus. Juxta rather rounded-conical, the base slightly produced to a blunt point. Vinculum with ventral expansion deep, without indentation.

Female. (Tams & Bowden 1953). Similar to male, somewhat larger and frequently with much stronger buff suffusion; expanse 32-40 mm. Genitalia with bursa copulatrix large; ductus bursae long and narrow, with a basal sclerotised area obliquely cut off but with a lateral extension into neck of ductus. Ostial segment with weakly sclerotised, rather rectangular, lateral plates.

Geographic Variation. This taxa is of variable coloration, ranging from light buff to ochraceous buff with frequently reduced or obsolete fuscous markings; the genitalic characters are constant (Tams & Bowden 1953).

Detection Methods

Young larvae feed in the spindle and shoots of sugarcane and cause characteristic shot-holing. Older larvae bore in the top section of stalks.

Biology and Ecology

In southern France, this species generally has two generations in a year on maize, the periods of damage being from May to July and from August to October. The larvae of the second generation remain at the base of the stalks until spring (Delagado de Torres 1930; Feytaud 1931). Larvae overwintering in the leftover plant stumps have a better chance of surviving the winter than those residing in the stem, therefore plant stump removal may be an effective control method (Anglade & Vible 1999). The spring generation is reported to have a lower mating rate (41%) than the summer (63%) or the autumn generation (49%), with average oviposition rates of 265±(44), 452±(40) and 392±(53) eggs for these generations. The oviposition periods last for about 2.2 - 3.4 days and females lifespan range from 6.5 to 8.2 days (Al Salti et al 1986). After a succession of mild winters, *S. nonagrioides* tends to become the main pest of maize in southern France and insecticides do not seem to result in a reasonable control (Frerot et al 1997, Naibo et al 1996).

In Greece, there are 3-4 generations per year with the first adults appearing in early March to early May (Fantinou & Kagkou 2000) with the population reaching its peak during August-September (Tsitsipis et al 1984); larvae overwinter and their diapause is induced by short daylengths.

In the Izmir district of Turkey, mature larvae were recorded to overwinter in maize stems as well as stems of *Typha latifolia* and *Arundo donax* growing along the banks of streams. About 75% of overwintering larvae are able to resume activity at 14°C. Whereas activity declines if temperature falls to 3°C, with high mortality of overwintering larvae below -4°C. Eggs are laid on the inner surface of the leaf sheaths of maize, and larvae penetrate the stem 48 h after hatching. Adults emerge over a period of 30-40 days, and the pest shows a 3 generations/year pattern. *Gladiolus horthulans* was shown to be an alternative food plant along with other grasses, which enables earlier populations emerging from overwintering larvae to survive when maize is not yet available in a susceptible stage (Kavut 1987).

In northwest Spain, *Sesamia nonagrioides* attacks maize plants simultaneously with *Ostrinia nubilalis*, and the collective impact of the two species may result in 100% crop damage. In maize, *S. nonagrioides* has of two generations with the first one flying in May and the second one in July-August. Larvae of the first generation of both species rarely attack maize and seem to exploit alternative plant hosts. Later in the autumn, most plants become colonized by *S. nonagrioides* and, to a lesser degree, by *O. nubilalis* larvae. Larvae of both species overwinter inside dead maize plants, which are usually left in the field after harvesting. Given the mild winter temperatures of the South Atlantic coast, most of the population is able to survive until the following spring. Cultural methods (e.g. destruction of plant stems) and the use of resistant maize genotypes could improve the management of maize borers, diminishing economic damage (Cordero et al 1998).

Natural Enemies

***Lydella thompsoni* (Diptera: Tachinidae).** A solitary endo-parasitoid that attacks larvae of *S. nonagrioides* along with other noctuid and pyralid stemborers. Recorded from maize, sorghum and reed fields in France, between April and October, and in maize in Spain. This parasitoid attacks a wide range of borers and was introduced to North America for the control of *Ostrinia nubilalis* in maize fields. This species is the main parasitoid of *S. nonagrioides* in Portugal throughout the 2nd and 3rd generation, though does not seem to have any impact on the first generation of the pest due to temporal desynchronization between the parasitoid's 1st generation and that of the host (Figueiredo & Araujo 1996). *L. thompsoni* requires the abundance of alternative borer hosts to be able to survive all through the year (Galichet et al 1985, Galichet 1986, Eizaguirre et al 1990).

***Platytelenomus busseolae* (Hymenoptera: Scelionidae)**. Egg parasitoid. Recorded from egg masses in maize fields in Istiaea, central Greece. Parasitized eggs were found during July to mid-October. The parasitoid was responsible for up to 76.2% parasitism rate of egg masses (Alexandri & Tsitsipis 1990). Also reported from Cukurova, Turkey to be the most effective natural enemy of *Sesamia nonagrioides* in maize, with up to 49.4% parasitism. Highest activity of the parasitoid is recorded from May until November (Sertkaya & Kornosor 1994).

***Pseudoperichaeta nigrolineata* (Diptera: Tachinidae).** In Portugal, reported to parasitize a low proportion of the 1st generation (Figueiredo & Araujo 1996).

Management

Control of first generation is crucial because once maize crops are affected they are unable to recover. In southern France, maize stump removal and debris grinding contribute to the management of the pest population (Anglade & Vible 1999, Guery & Naibo 1999).

Insecticides. In France, good control of the 1st generation during the 1980s could be obtained with diflubenzuron (as 0.7 kg dimilin/ha) or through the use of pyrethroids. Control of the 2nd generation is more difficult as pyrethroids were reported to provoke outbreaks of aphids and reduce natural parasitism of another borer (*Ostrinia nubilalis*) by a tachinid. Diflubenzuron was reported to have had little or no adverse effects on beneficial insects (Naibo 1984). Mechanical control against the overwintering larvae is practiced in southern France by crushing the plant residues in autumn with or without a desiccant. Since *S. nonagrioides* attacks maize plants soon after sowing, regardless of the sowing date, seed treatments with imidacloprid can reduce the number of applications and quantities of insecticide applied. Control of the 2nd generation is sometimes practiced in very infested and windy areas (Naibo et al 1996, Naibo et al 1999).

The residual effect of 1% aqueous neem (*Azadirachta indica*) seed kernel extract significantly reduces pupation of larvae (Melamed et al 1989).

Larvae are susceptible to Cry1Ab toxins produced by *Bacillus thuringiensis* (González-Núñez *et al.* 2000).

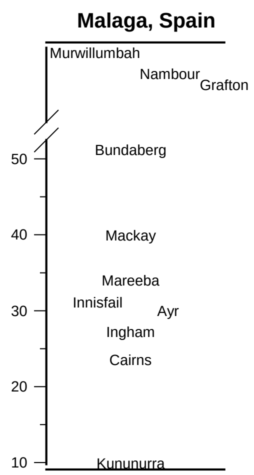
Pheromone attractants. Minor components of the sex pheromone were identified in Greece as (Z)-11-Hexadecenyl acetate, dodecyl acetate, (Z)-11-hexadecenal and (Z)-11-hexadecen-1-ol, with (Z)-11-hexadecenyl acetate being the main component. The blend of 4 synthetic components in the ratio 69:15:8:8 was highly attractive to males, with 200 µg/trap being the most effective concentration in the field (Mazomenos 1989).

Means of Movement

The most likely means of entry of *S. nonagrioides* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk to Australia

Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in northern New South Wales and southern Queensland (see Match Indexes for climate at selected locations and principal Australian areas below).



***Sesamia nonagrioides botanephaga* Tams and Bowden**

Sesamia botanephaga Tams and Bowden 1953, 662.
Sesamia nonagrioides botanephaga: Nye 1960; Rao and Nagaraja 1969, 210; Leslie 1994, 61; Holloway 1998, 84.

Types
Holotype male, Ilesha, southern Nigeria; allotype female, Kumasi, Ghana; both in Natural History Museum, London.

Common names
Moth borer

Distribution
Central west and east Africa

Cape Verde, Ghana, Ivory Coast, Kenya, Nigeria, Togo, Sudan, Uganda (Tams & Bowden 1953; Rao & Nagaraja 1969; Meijerman & Ulenberg 1996; Bosque-Pérez & Schulthess 1998; FitzGibbon *et al.* 1998; Holloway 1998).

Dominant in forest and fringing-forest areas where there is >2000 mm of rain well distributed through the year (Tams & Bowden 1953).

Host Plants
Chasmopodium afzelii, *Cyperus distans*, *Cyperus papyrus*, *Echinochloa pyramidis*, *Eleusine coracana* (finger millet), *Oryza sativa* (rice), *Pennisetum purpureum* (elephant grass), *Rottobellis compressa*, *Rottboellia exaltata*, *Saccharum* spp. hybrids (sugarcane), *Setaria chevalieri*, *Sorghum arundinaceum*, *Sorghum bicolor* (sorghum), *Sorghum rigidifolium*, *Sorghum verticilliflorum*, *Typha australis*, *Vossia cuspidata*, *Zea mays* (maize) (Tams & Bowden 1953; Rao & Nagaraja 1969; Meijerman & Ulenberg 1996, 1998; Bosque-Pérez & Schulthess 1998; Heinrichs 1998; Polaszek & Khan 1998).

Symptoms
Larvae tend to bore in young shoots of sugarcane, causing typical 'dead-heart' symptoms.

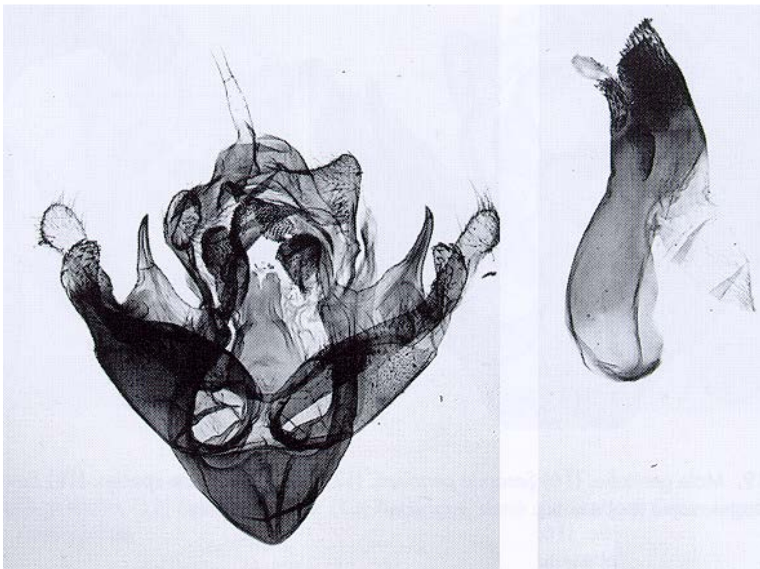
Economic Impact
A significant pest of maize, causing almost complete crop loss in late-planted crops (Tams & Bowden 1953). Minor species on sugarcane.

The accuracy of the following account is difficult to assess as S. n. botanephaga is not recorded from Iran in previous literature. *Sesamia n. botanephaga* [*S. botanephaga*] is an important pest of sugarcane in the Haft-Tappeh and of rice in the Fars regions of Iran (Daniali 1986, Fazeli 1992). It is also recorded on maize in Khuzestan, Iran (Gemsi & Kamali 1992). In the Haft-Tappeh region, where the climate permits cultivation of sugarcane from mid-March to mid-October, the pest is reported to have 4-5 generations a year. Females oviposit on the leaf sheath of the young shoots of sugarcane plants. Adult females do not seem to be attracted to plants taller than 100 cm for oviposition, but taller plants become infested later by migrating larvae. Cultural practices such as irrigation, fertilization and the timing and duration of harvest can reduce borer populations if completed during the winter months. Late harvesting may result in a reduction of sugar yield and juice quality as well as ratooning ability and eventually lead to heavier infestation by the pest (Daniali 1986). In the Fars province, *S. nonagrioides botanephaga* is recorded to be a major pest of rice where it has 3-4 generations per year and overwinters as an advanced larval stage in rice roots. Cultural control methods followed for the management of this pest include cutting rice stems near the soil surface and removing them from the field, winter flooding in January, deep-ploughing in March and the control of *Typha* plant on which early generations develop before they attack rice. Experiments with chemical control methods showed 3 applications of diazinon at 2 litres a.i./ha to be satisfactory (Fazeli 1992).

Morphology
Larvae
No reliable characters were found by Meijerman and Ulenberg (1996, 1998) to separate this species from *S. calamistis*, *S. poephaga* and *S. penniseti*. Tran (1981) separated this species from *S. calamistis* by the colour of the cuticle, but Meijerman and Ulenberg (1996, 1998) found this unreliable. Usua (1969) found SD1 longer than SD2 on the metathorax and shorter on the mesothorax in *S. n. botanephaga*, while in *S. penniseti* SD1 is the shorter seta on the metathorax and the longer on the mesothorax. Meijerman and Ulenberg (1996, 1998) found that these differences were no consistnet and could not be relied upon for identification.

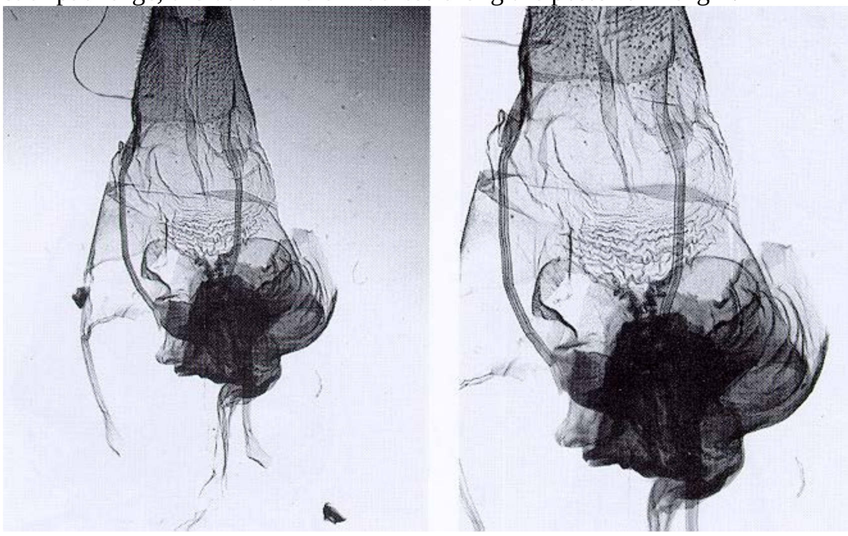
Adults
General. (Holloway 1998). Forewing with a submarginal row of brown flecks. Male antennae with long pectinations. Male genitalia are needed to distinguish this species from *S. n. nonagrioides*, *S. penniseti* and *S. poephaga*.

Male. Palpus light cartridge-buff, lightly to moderately infuscate. Antenna short-bipectiate, serrate at apex, cilia short, fasciculate. Head light cartride-buff, sometimes suffused with light ochraceous, lightly to moderatley streaked with fuscous. Thorax light cartridge-buff, sometimes suffused with light ochraceous, sometimes almost white streaked with fuscous. Pectus white, infuscate at base. Legs light cartridge-buff, streaked with fuscous, fore femur infuscate on inner surface, fore tibiae suffused with ochraceous on inner surface. Abdomen white, suffused with light buff and variably irrorate with fuscous. Anal tuft white, suffused with light buff and streaked with fuscous. Forewing light cartridge-buff, sometimes suffused with ochraceous, with considerable fuscous-buff to fuscous irroration, particularly along termen; some fuscous to fuscous-black markings, variable in extent and intensity; an antemedial fuscous-black spot below cell; a longitudinal fuscous-black fascia from base along lower margin of cell, partly within, partly without cell, extending to wing margin; a curved dentate postmedial fascia, extending from about vein 10 to vein 2, sometimes split into two postmedial rows of spots, the proximal on the veins, the distal interneural, a fuscous-black spot at the end of vein 1 on inner margin; a narrow fuscous-black terminal line; fringe with a narrow basal ochraceous-white line, infuscate medially and fuscous-white at tips; expanse 22-30 mm. Hindwing white, veins sometimes with small fuscous-black stripes and apex sometimes irrorate with fuscous. Underside of forewing white, costa suffused buff, apex and terminal area suffused and heavily irrorate with fuscous to fuscous-black. Underside of hindwing white, costa and apex, termen sometimes, lightly irrorate with fuscous. Genitalia very similar to *S. n. nonagrioides* but larger and stouter. Valve with costal spine large and curved with a prominanet tooth before apex, sometimes dentate beneath apex and at base; extension of sacculus larger, more heavily spinose, sometimes almost to costal spine. Aedeagus similar to *S. n. nonagrioides* but vesica broadly sclerotised at base and without a distinct cornutus. Juxta larger and broader.



Male genitalia of *S. n. botanephaga* (Polaszek 1998a).

Female. (Tams & Bowden 1953). Similar to male; expanse 30-42 mm. Genitalia with bursa copulatrix large, ductus bursae long and narrow. Ostial segment with two broad sclerotised lateral plates before ostium. Anteostial pad large, the ventral fold indented along the posterior margin.



Female genitalia of *S. n. botanephaga* (Polaszek 1998a).

Geographic Variation. *S. n. botanephaga* is a variable taxon, with two main colour variants (Tams & Bowden 1953): a very pale form, almost white in ground colour and with correspondingly pale wing markings, most frequently seen towards the end of the wet season or during the dry season; a very dark form with considerable fuscous-black of fuscous irroration, prevalent at the beginning of the rains. Variation in the male genitalia largely concerns the costal spine.

Detection Methods

Young larvae feed in the spindle and shoots of sugarcane and cause characteristic shot-holing. Older larvae bore in the top section of stalks.

Biology and Ecology

Not recorded in detail.

Natural Enemies

None recorded.

Management

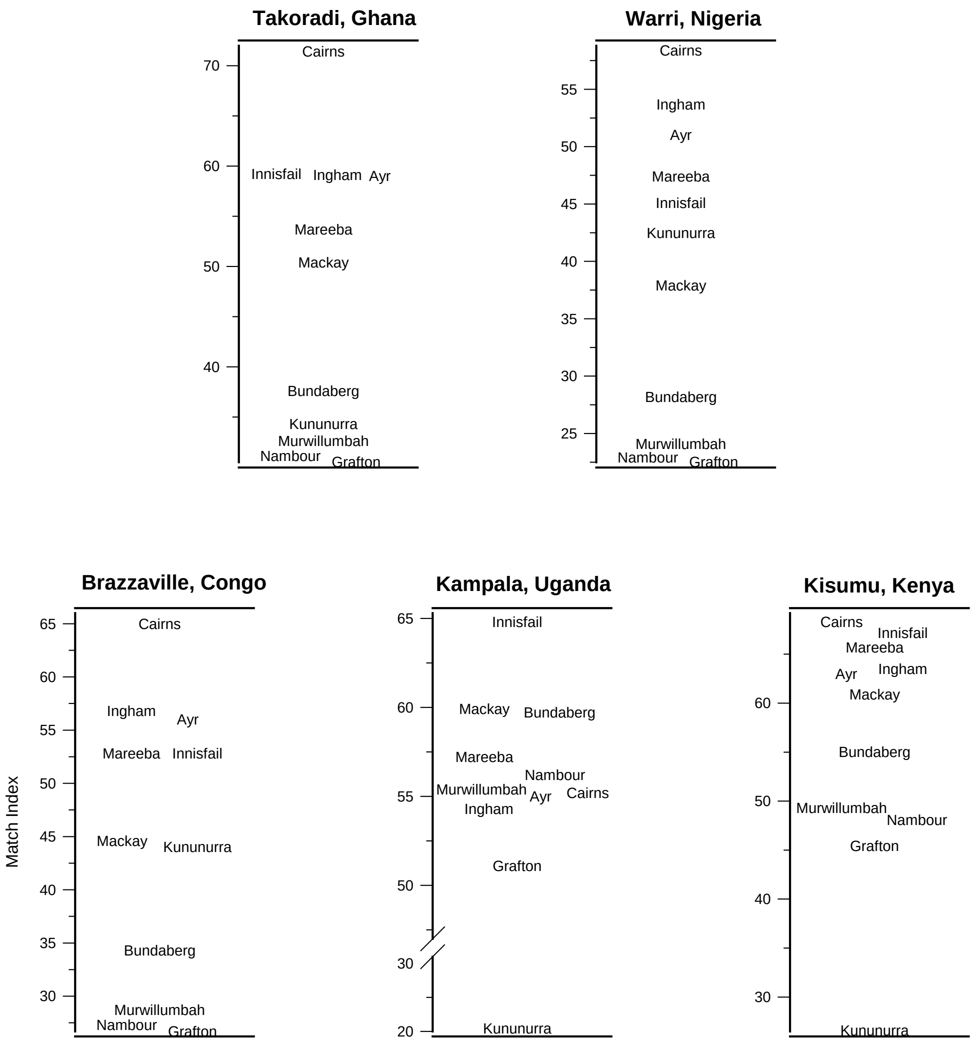
Not considered a species worth controlling.

Means of Movement

The most likely means of entry of *S. n. botanephaga* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk to Australia

Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in northern Queensland (see Match Indexes for climate at selected locations and principal Australian areas below).


Takoradi, Ghana
70
60
50
40
Cairns
Innisfail Ingham Ayr
Mareeba
Mackay
Bundaberg
Kununurra
Murwillumbah
Nambour Grafton
Warri, Nigeria
55
50
45
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35
30
25
Cairns
Ingham
Ayr
Mareeba
Innisfail
Kununurra
Mackay
Bundaberg
Murwillumbah
Nambour Grafton
Brazzaville, Congo
Match Index
65
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Cairns
Ingham Ayr
Mareeba Innisfail
Mackay Kununurra
Bundaberg
Murwillumbah
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Nambour
Murwillumbah Ayr Cairns
Ingham
Grafton
Kununurra
Kisumu, Kenya
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Cairns
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Mareeba
Ayr Ingham
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton
Kununurra

Sesamia penniseti Tams and Bowden

Sesamia penniseti Tams and Bowden 1953, 669.

Notes on Taxonomy and Nomenclature
May be conspecific with *S. poebora* Tams and Bowden from Uganda (Holloway 1998).

Types
Holotype male, Owabi, Ghana; allotype and paratypes, Ghana; all in Natural History Museum, London.

Common names
Moth borer

Distribution
West Africa

Ghana, Nigeria, possibly Uganda (Tams & Bowden 1953; Rao & Nagaraja 1969; FitzGibbon *et al.* 1998; Holloway 1998).

More frequent in forest localities than *S. poephaga* (Tams & Bowden 1953; Holloway 1998).

Host Plants
Oryza sativa (rice), *Panicum maximum* (Guinea grass), *Pennisetum glaucum* (pearl millet), *Pennisetum purpureum* (elephant grass), *Saccharum* spp. hybrids (sugarcane), *Setaria splendida*, *Sorghum bicolor* (sorghum), *Zea mays* (maize) (Harris 1962; Rao & Nagaraja 1969; Meijerman & Ulenberg 1996, 1998; Heinrichs 1998).

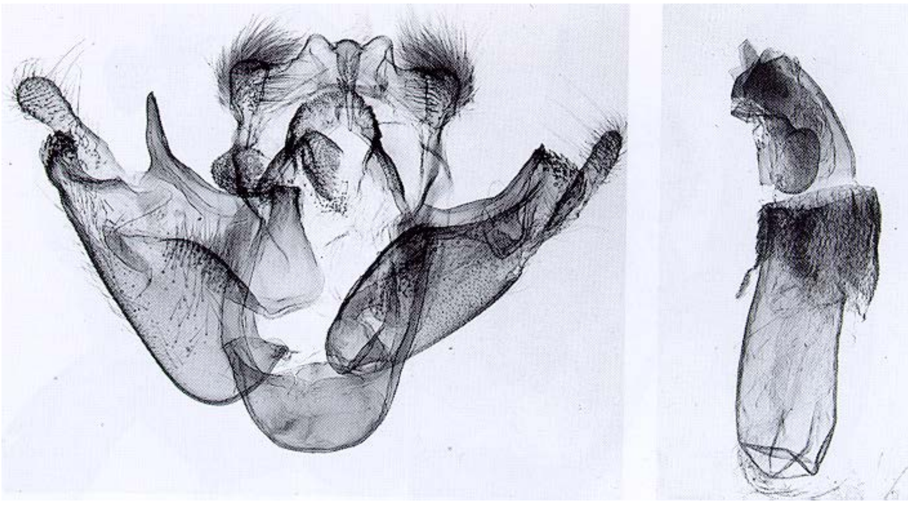
Symptoms
Larvae tend to bore in young shoots of sugarcane, causing typical 'dead-heart' symptoms.

Economic Impact
Frequent and common in *Pennisetum puprpureum*, and is of little economic importance in maize and sugarcane (Tams & Bowden 1953).

Morphology
Larvae
Larvae are indistinguishable from those of *S. calamistis, S. nonagrioides* and *S. poephaga* (Usua 1969; Meijerman & Ulenberg 1996, 1998). Usua (1969) found a small difference in the chaetotaxy of the head capsule, which Meijerman and Ulenberg (1996, 1998) did not find in comparing *S. poephaga* (a species closely related to *S. penniseti*) with *S. calamistis* and *S. nonagrioides.*

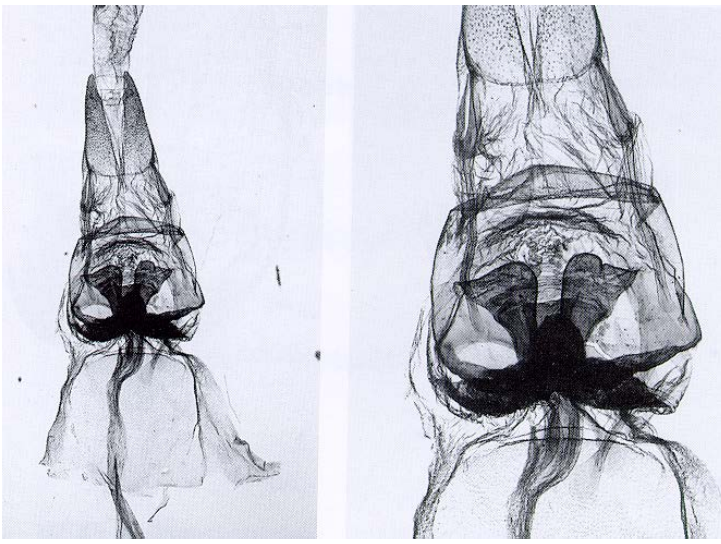
Adults
General. (Holloway 1998). Fore wings are straw coloured and the antennal pectinations of the male are shorter than the width of the antennal shaft. This species is very similar to *S. nonagrioides* and *S. poephaga* and genitalic characters are needed for positive identification. The venation character used by Tams and Bowden (1953) to distinguish *S. penniseti* and *S. poephaga* is unreliable and should not be used (Holloway 1998).

Male. (Tams & Bowden 1953). Palpus fuscous, streaked white or pale cartridge-buff. Antenna shortly bipectinate, cilia short, fasciculate. Head pale cartridge-buff, fairly heavily streaked with fuscous, particularly anteriorly, thorax thus appearing rather fuscous-buff. Pectus fuscous-buff to buff-white, infuscate at apex, fuscous medially. Legs pale cartridge-buff to buff-white, variably irrorate with fuscous, fore femur infuscate. Abdomen cartridge-buff, white laterally at base, suffused and irrorate with fuscous-buff, anal tuft cartridge-buff streaked with fuscous. Venter more ochraceous-buff, straked with fuscous-buff. Forewing cartridge-buff with considerable ochraceous-buff, fuscous-buff or rather pale fuscous suffusion; some fuscous to fuscous-black markings varying in extent and intensity; an antemedial fuscous-black spot below the cell; a longitudinal fuscous fascia, almost a smudge, along lower margin of cell, rather narrow along this margin, partly within the cell, partly without, extending through the sell, where it broadens, to the discocellulars or even to the termen; a post medial curved fascia of two rows of fuscous-black spots, the proximal row of two to three spots at the discocellulars, the distal row more extended, and on the veins the lower spots of the distal row connecting with the corresponding spots of the proximal row, thus producing a scalloped effect; a fuscous-black terminal line; variable fuscous-black irroration; fringe basally buff-white, infuscate at tips; expanse 28-30 mm. Hindwing white, lightly irrorate with fuscous at the apex, with a fine terminal line; fringe infuscate at apex. Underside of forewing white suffused with buff, and irrorate with fuscous along costa, with a fairly heavy fuscous suffusion from base of cell to termen, more confined to veins near termen; a terminal fascia of interneural fuscous-black spots. Underside of hindwing white, suffused with buff and irrorate with fuscous along costa; fringe infuscate, particularly at apex. Genitalia with tegumen with prominent peniculus. Costal spine of valve bent outwards, with a single recurved apical hook; extension of sacculus very broad and heavily spinose. Ventral edge of vinculum curved outwards, not indented.



Male genitalia of *S. penniseti* (Polaszek 1998a).

Female. Similar to male, but forewings frequently distinctly brownish-buff with the fuscous markings reduced or obsolete; expanse 28-37 mm. Genitalia similar to *poephaga*, but bursa copulatrix smaller, ductus bursae less heavily sclerotised; anteostial pad more conical; plates of ostial segment more rounded-quadrate; ovipositor lobes relatively shorter and broader.



Female genitalia of *S. penniseti* (Polaszek 1998a).

Detection Methods

Young larvae feed in the spindle and shoots of sugarcane and cause characteristic shot-holing. Older larvae bore in the top section of stalks.

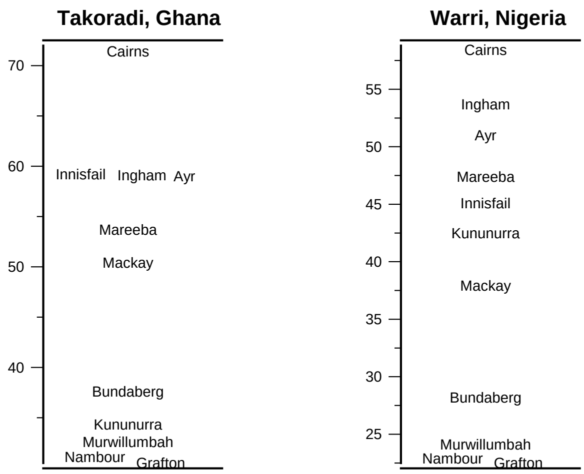
Biology and Ecology
Not well understood.

Natural Enemies
Not recorded.

Management
Not considered a species worth controlling in sugarcane.

Means of Movement
The most likely means of entry of *S. penniseti* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk to Australia
Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in northern Queensland (see Match Indexes for climate at selected locations and principal Australian areas below).



Sesamia peophaga Tams and Bowden

Sesamia peophaga Tams and Bowden 1953, 668.

Notes on taxonomy and Nomenclature
May be conspecific with *S. epunctifera* Hampson from eastern and southern Africa (Holloway 1998).

Types
Holotype male, Ketekrachi, Ghana; paratypes from Comoros, Ivory Coast, Kenya, Malawi, Nigeria, Sudan, Tanzania, Togo, Uganda, Zimbabwe; all in Natural History Museum, London.

Common names
Moth borer

Distribution
Western, central, eastern and mid-southern Africa

Comoros, Ghana, Ivory Coast, Kenya, Malawi, Madagascar, Nigeria, southern Sudan, Tanzania, Togo, Uganda, Zimbabwe (Tams & Bowden 1953; Rao & Nagaraja 1969; Meijerman & Ulenberg 1996; Holloway 1998).

More frequent in savannah localities than *S. penniseti* (Tams & Bowden 1953; Holloway 1998).

Host Plants
Oryza sativa (rice), *Sorghum bicolor* (sorghum), *Panicum maximum* (green panic), *Pennisetum purpureum* (elephant grass), *Saccharum* spp. hybrids (sugarcane), *Setaria splendida*, *Sorghum rigidifolium*, *Sorghum verticilliflorum*, *Vossia cuspidata*, *Zea mays* (maize), unidentified millet (Harris 1962; Rao & Nagaraja 1969; Meijerman &Ulenberg 1996, 1998; Heinrichs 1998).

Pennisetum purpureum is the usual food plant (Tams & Bowden 1953).

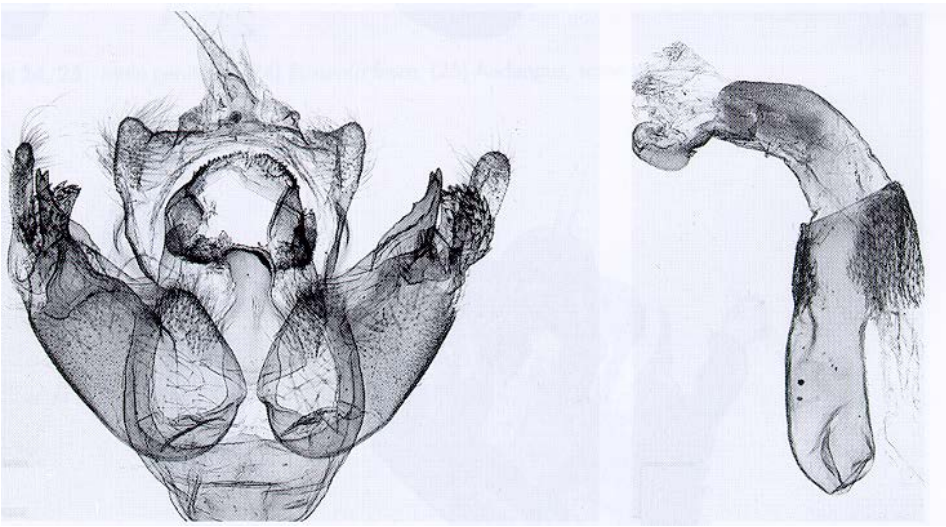
Symptoms
Larvae tend to bore in young shoots of sugarcane, causing typical 'dead-heart' symptoms.

Economic Impact
A significant pest of maize and sorghum (Tams & Bowden 1953). Minor species on sugarcane.

Morphology
Larvae
No reliable characters are found by Meijerman and Ulenberg (1996, 1998) to separate larvae of this species from those of *S. calamistis*, *S. nonagrioides* and *S. penniseti*. On abdominal segment 9, Meijerman and Ulenberg (1996, 1998) found the majority of larvae to have the microscopic MD1 seta anteroventral to D1, while in the three other *Sesamia* spp., this seta is situated anterodorsal to D1 in most individuals. Since both variations occur in all *Sesamia* spp., with the exception of *S. cretica* in which it is always anteroventral, this character can not be used for identification.

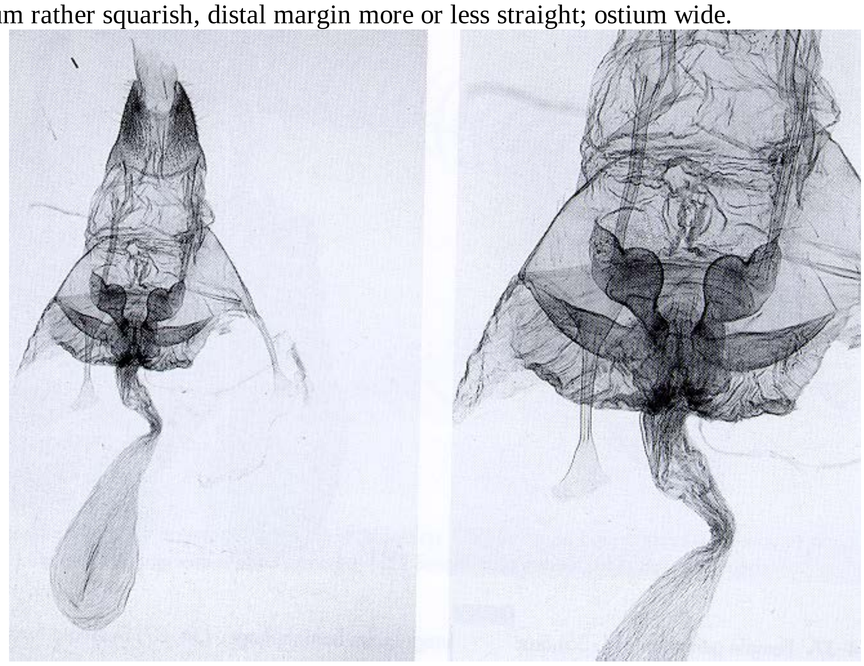
Adults
General. (Holloway 1998). Fore wings are straw coloured and the antennal pectinations of the male are shorter than the width of the antennal shaft. This species is very similar to *S. nonagrioides* and *S. poephaga* and genitalic characters are needed for positive identification. The venation character used by Tams and Bowden (1953) to distinguish *S. penniseti* and *S. poephaga* is unreliable and should not be used (Holloway 1998).

Male. (Tams & Bowden 1953). Palpus cartridge-buff, infuscate. Antenna shortly bipectinate, cilia short, fasciculate. Head pale cartridge-buff, streaked with fuscous. Thorax pale cartridge-buff, anteriorly streaked with fuscous. Pectus pale cartridge-buff, infuscate basally. Legs pale cartridge-buff, fore femur infuscate, fore tibia streaked with fuscous. Abdomen white suffused with pale buff, anal tuft white suffused with pale fuscous and lightly streaked with fuscous. Forewing light yellowish-buff, suffused with light fuscous-buff at apex and along termen; some fuscous to fuscous-black markings; an indistinct fuscous-black patch along upper margin of cell and within it; an indistinct fuscous-black patch along lower margin of cell and within it; medial fuscous-black patch below cell; curved postmedial fascia of fuscous-black spots consisting of two rows, proximal row interneural, distal on veins, both rows connected, thus producing a scalloped effect, spot on second vein connected to medial patch below cell, spot on first vein isolated; fuscous-black terminal line interrupted at veins; some scattered fuscous irroration, particularly at base; fringe lightly infuscate; expanse 30 mm. Hindwing white. Underside of forewing cartridge-buff, with broad medial pale-fuscous suffusion extending above and below cell; some pale-fuscous irroration. Underside of hindwing white, suffused with buff and irrorate with fuscous along costa. Genitalia with costal spine of valve stouter and bifid at apex, apical extension of sacculus broader and heavily spinose, cucullus broad, juxta narrowly conical with sharp apical point.



Male genitalia of *S. poephaga* (Polaszek 1998a)

Female. (Holloway 1998). Similar to male. Gentalia similar to *S. pennisiti*; pair of sclerotisations flanking ostium rather squarish, distal margin more or less straight; ostium wide.



Female genitalia of *S. poephaga* (Polaszek 1998a).

Detection Methods

Young larvae feed in the spindle and shoots of sugarcane and cause characteristic shot-holing. Older larvae bore in the top section of stalks.

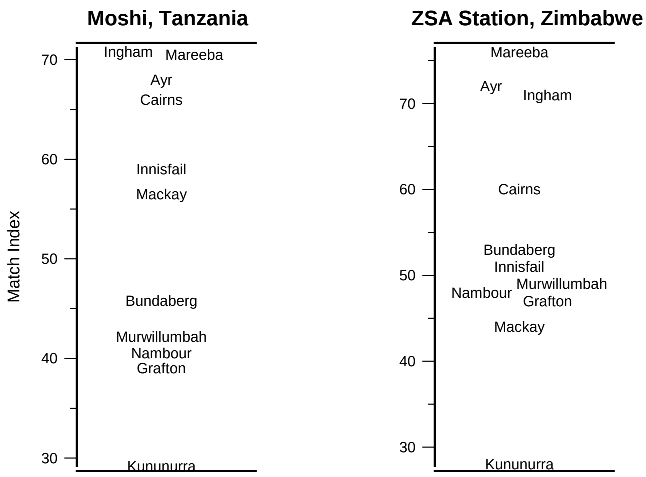
Biology and Ecology
Not well understood.

Natural Enemies
Not recorded.

Management
Not considered a species worth controlling in sugarcane.

Means of Movement
The most likely means of entry of *S. poephaga* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk to Australia
Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in northern Queensland, especially in the drier areas (see Match Indexes for climate at selected locations and principal Australian areas below).



***Sesamia uniformis* (Dudgeon)**

Nonagria uniformis Dudgeon 1905, 402.
Sesamia uniformis

Types
Unknown, possible Natural History Museum, London.

Common names
Shoot borer

Distribution
Northern India, Pakistan, Philippines (Rao & Nagaraja 1969); the record of Philippines appears doubtful.

Host Plants
Oryza sativa (rice), *Erianthus arundinaceus, Saccharum spontaneum*, *Saccharum* spp. hybrids (sugarcane), *Sorghum bicolor* (sorghum), *Triticum aestivum* (wheat), *Zea mays* (maize) (Rao & Nagaraja 1969).

Symptoms
Larvae tend to bore in young shoots of sugarcane, causing typical 'dead-heart' symptoms.

Economic Impact
Minor pest of sugarcane

Morphology
No useful descriptions recorded.

Detection Methods
Young larvae feed in the spindle and shoots of sugarcane and cause characteristic shot-holing. Older larvae bore in the top section of stalks.

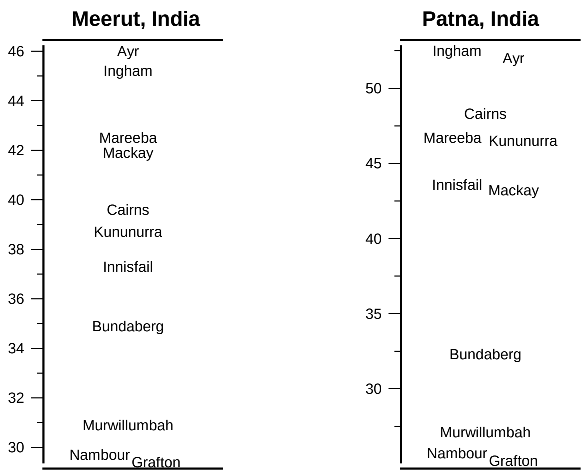
Biology and Ecology
Not well understood.

Natural Enemies
Not recorded.

Management
Not considered a species worth controlling in sugarcane.

Means of Movement
The most likely means of entry of *S. uniformis* into Australia would be by the introduction of infested planting material. The chance of the introduction of moths on aircraft, in luggage, or on people is much smaller, though still significant.

Phytosanitary Risk to Australia
Entry potential: Medium - isolated from Australia, but readily transmitted on infected planting material.
Colonisation potential: High in all sugarcane-growing areas.
Spread potential: High, unless strict controls imposed over movement of infested material.
Establishment potential: Highest in the drier areas of northern Queensland (see Match Indexes for climate at selected locations and principal Australian areas below).


Meerut, India
46
44
42
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36
34
32
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Ayr
Ingham
Mareeba
Mackay
Cairns
Kununurra
Innisfail
Bundaberg
Murwillumbah
Nambour
Grafton
Patna, India
50
45
40
35
30
Ingham
Ayr
Cairns
Mareeba
Kununurra
Innisfail
Mackay
Bundaberg
Murwillumbah
Nambour
Grafton

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