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## 【Research report】

### 甜菜夜蛾 (*Spodoptera exigua*) 的生物學和生殖形態學之研究 【研究報告】

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## Abstract

### 摘要

甜菜夜蛾為熱帶與亞熱帶地區嚴重的多寄主食性害蟲，本文就其生物學和生殖形態學加予研究。描述了甜菜夜蛾雌雄成蟲的內、外生殖系統之形態學內生殖器官之不同分泌物的自然現象，精莖 (spermatophore) 在交配囊 (bursa copulatrix) 中的位置與結構，和交配囊在交尾前後改變的情形。並與夜蛾之已知種類加以比較。

### Key words:

關鍵詞:

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**THE BIOLOGY AND THE REPRODUCTIVE MORPHOLOGY OF  
BEET ARMY WORM *SPODOPTERA EXIGUA* (HÜBNER)  
(LEPIDOPTERA: NOCTUIDAE)**

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**ABSTRACT**

Biology and reproductive morphology of *Spodoptera exigua*, a serious polyphagous pest in the warmer regions of the world, have been studied. The morphology of internal and external reproductive system is described and illustrated for the adult male and female *Spodoptera exigua*. The nature of the different secretions of the internal reproductive organs, the structure and position of the spermatophore within the bursa copulatrix and the conditions of bursa before and after mating were described. Also the reproductive anatomy of *S. exigua* is compared with that of already known species of Noctuidae.

**INTRODUCTION**

The genus *Spodoptera* occurs throughout the warmer regions of the world (Mitchell, 1979). *Spodoptera exigua* persists in the tropical and subtropical climates. This pest appears native to southern Asia. *S. exigua* occurs commonly in Taiwan as it is in India attacking variety of food plants and wild plants. *S. exigua* is a serious pest of jute and tobacco in India and cotton in Egypt. This pest has traversed the entire United States of America from Oregon to Florida and extends itself into Mexico, South America and Island Nations of Carribean Sea (Todd, 1975). The hosts of this pest include vegetables, field crops, ornamental plants, turf grasses and weeds.

The literature available on the reproductive system of Lepidoptera is widely spread out. The reproductive anatomy of a number of species of Noctuidae has been thoroughly studied. (Siverly, 1947; Williams, 1948; Callahan, 1958; Callahan and Chapin, 1960; Etman and Hooper, 1979). All the above mentioned studies are on trifold type of Noctuidae and they are relatively advanced noctuids. Among quadrifid primitive type, only *Plathypena scabra* has been studied in detail (Buntin and Pedigo, 1982).

*Spodoptera exigua*, commonly known as beet army worm, is one of the important crop pests of the tropics. The host plants of this pest covers a wide range of crops such as corn, sorghum, melons, water melon, pea, peanut, soybean, tomato, cotton, potato, onion, garlic, asparagus, green bean, sunflower, common cabbage, cauliflower, carrot, radish, rose, tobacco etc. There has been no study made on the reproductive anatomy of *Spodoptera exigua*. The purpose of this study is to provide background information for further work on the reproductive physiology of *S. exigua* and indirectly to help integrated pest management of this polyphagous pest.

### MATERIALS AND METHODS

The voracious feeding larvae were collected from the vegetable fields of *Hsin Wu*, South West Town of Taipei area and reared in the laboratory in an artificial medium at  $28 \pm 1^\circ\text{C}$ , 12:12 light and dark environment in a growth chamber. The relative humidity was maintained at  $60 \pm 5\%$ . The artificial diet Bio Mix 9787 from New Jersey, U.S.A. was used. The adults were fed with 10% honey solution. Females oviposited on plastic towelling in 1 litre oviposition glass beaker cages. The eggs thus oviposited were cut out from the plastic towels and sterilised in 70% alcohol and placed them in an artificial food containing 30 cm $\times$ 20 cm sized and capped plastic containers. The hatched larvae started to find their food right away. When they were completing 4th instar, the larvae were transferred to above mentioned plastic containers half filled with wooden powder. Each plastic container held 60-75 larvae. The plastic containers contained artificial food in the Petri dishes. The grown up larvae went into the wooden powder and pupated and the pupae were collected. Sexes were separated. The pupae were sterilised once again in 70% alcohol. Sexed pupae were placed in cups of 3 cm<sup>2</sup> of plastic containers 33 cm $\times$ 18 cm measurements. The emerging adults from puparium were removed to smaller containers and fed with 10% honey solution dipped in cotton threads. Occurrence of *S. exigua* population was surveyed during the whole year under different seasons.

All the moths used in this experiment were laboratory reared. The experimental moths were used to study the anatomy of 2 or 3 days old virgin males and females while the moths were used so as to study the structure of spermatophore of females that had been mated two days earlier. They were cold anesthetized for two minutes and dissected open in Weevers lepidopteran saline (Weevers, 1966). The male and female reproductive tracts and spermatophore were removed from the rest of the organs of the body and placed in separate, saline containing Petri dishes. They were then observed under a Nikon Z10 dissection microscope. Photographs were taken and diagrams were drawn by means of drawing tube. Culture of *S. exigua* in the laboratory is done to study the life span of egg, larva, pupa and adult. The ovulation, mating physiology,

spermatophore formation were also studied. Also the larvae were fed with natural food and studied their growth and development.

## RESULTS AND DISCUSSION

### 1. Biology of *S. exigua*

*Spodoptera exigua* is one of the serious pests of agriculture in the Republic of China and is found to occur throughout the year, although it is a much reduced population during winter. The egg, pupa and adult are all found to diapause. The area under study has very good rain fall and temperature is fulfilling such tropical conditions. The temperature is moderate to hot while the rain fall varies between months. These two conditions are ideally suitable for the *S. exigua* population. The winter months, October to January show a reduced rain fall and the chilly winter brings down the pest population.

Generally the adult appears grayish brown on the dorsal side. A tuft of hairs bears between head and thorax. Otherwise dark brown hair is present all over the body. Under the laboratory conditions, the females oviposited after mating within 1-4 days. The colour of the egg is greenish brown. The eggs are laid in clusters and the clusters are rather elongated unlike the *S. litura* which lays eggs in oval shaped cluster. The eggs are always covered by the hair of the body of the female as a protection from hostile environment. Lowerest number of eggs laid is 34 and the highest number of eggs laid is 965. The average eggs laid per female is 320. Incubation period of egg is 3-7 days while the larval period is 17-21 days and the pupal period is 8-10 days. The adult lived 5-16 days. The average life from egg to adult is 23 days.

Under the field conditions, there are 11 generations per year. To complete a successful generation, it took 21.28 to 79.13 days. The sexual ratio was 1:1. The eggs laid were about 300 per female. The percentage of hatchings were about 98%. The young larvae lived together when they were small but were separated when they were grown bigger and pupated in the soil. Onion, sorghum, peanut and corn were damaged a lot when they were attacked by larvae. Corn if attacked after 8th leaf grown, the damage was negligent and so insignificant. The larvae grew poorly when fed with tomato leaf while that with the common cabbage grew very well. The larvae were usually found 5 or 6 in one plant. The survival rate of the larvae in the field were 30 to 40%. The climatic condition always affected the growth and development of this pest in the field. The eggs were laid on the lower side of the leaf. Eggs were laid in the mornings and evenings.

The larvae ecdysed 4 times and exhibited 5 instar larvae. After ecdysis, they measured 1.8 cm to 2.0 cm long. The bigger larvae if they are not separated, exhibited cannibalism. The colour of larvae changed from light yellow green, dark brown, yellowish brown and finally to light reddish colour before they pupate. Towards the time of molting, it always exhibited black color. Just

before pupation, the grown up larvae measured 20 to 25 mm long. Sex ratio was found in the laboratory conditions were male: female 2:3 while in the field condition 1:1. The pupae were reddish in colour. If the pupae crossed beyond 12 days, they never emerged. The average weight of a female pupa is 0.07 g while

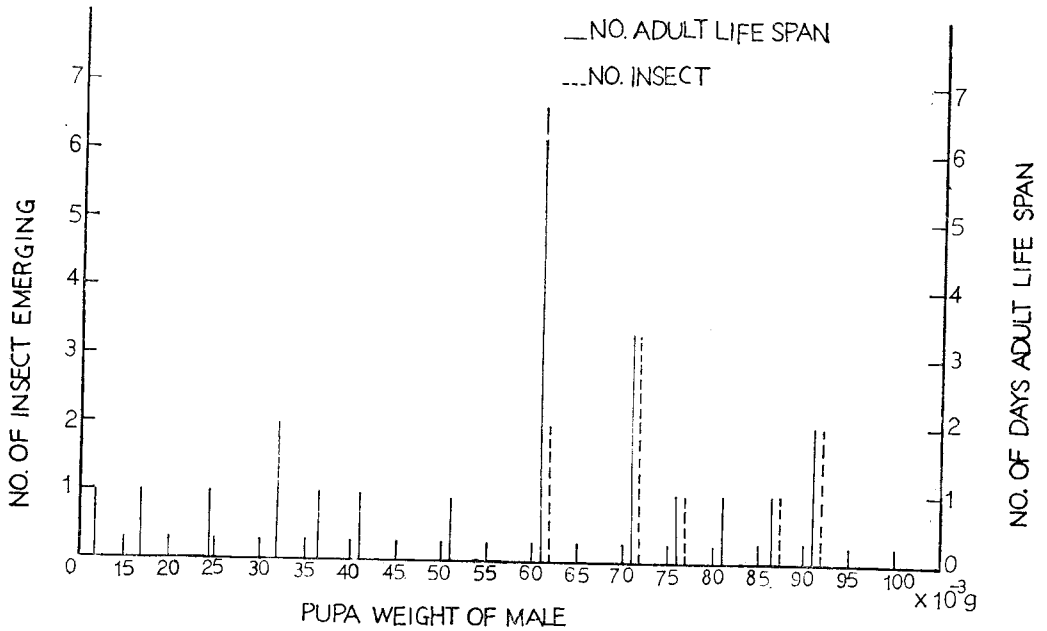


Fig. 1. Indicates the male pupal weight and its ability to emerge as an adult.

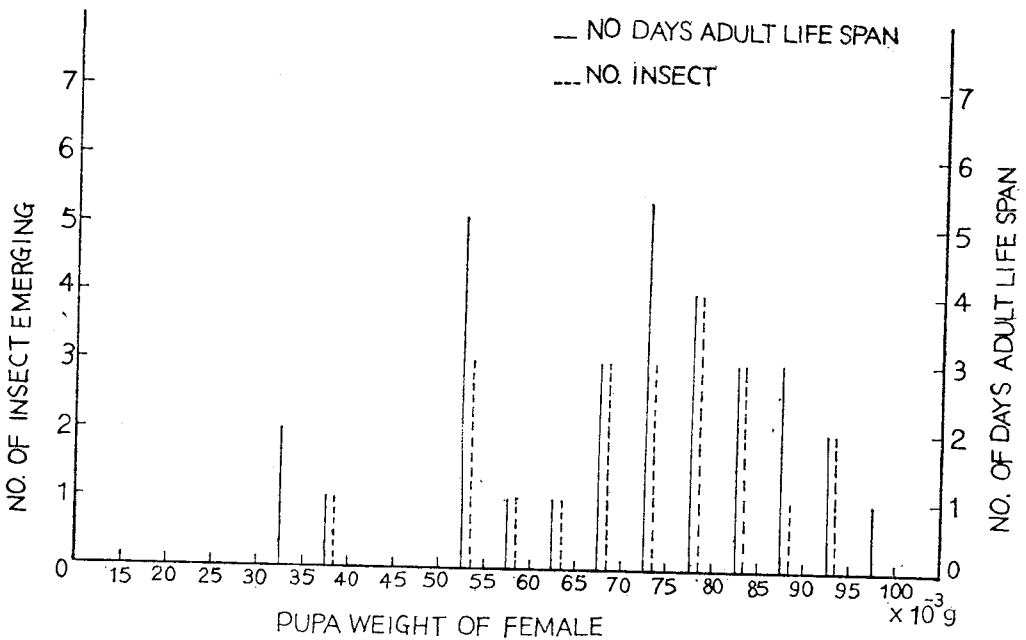


Fig. 2. Indicates the female pupal weight and its ability to emerge as an adult.

the weight of male pupa is 0.058 g. The optimum helpful weight of pupa of male for emergence is 40.91 g while that for female is 40.07 g (Figs. 1 and 2). The length of body of an adult is 8 to 11 mm while the wing expansion is 16-26 mm. The life span is ranged from 5 days to 16 days. Both the sexes were ready from the day of emergence for mating but optimum mating took place on the second night. Mating under laboratory conditions always occurred after midnight between 0

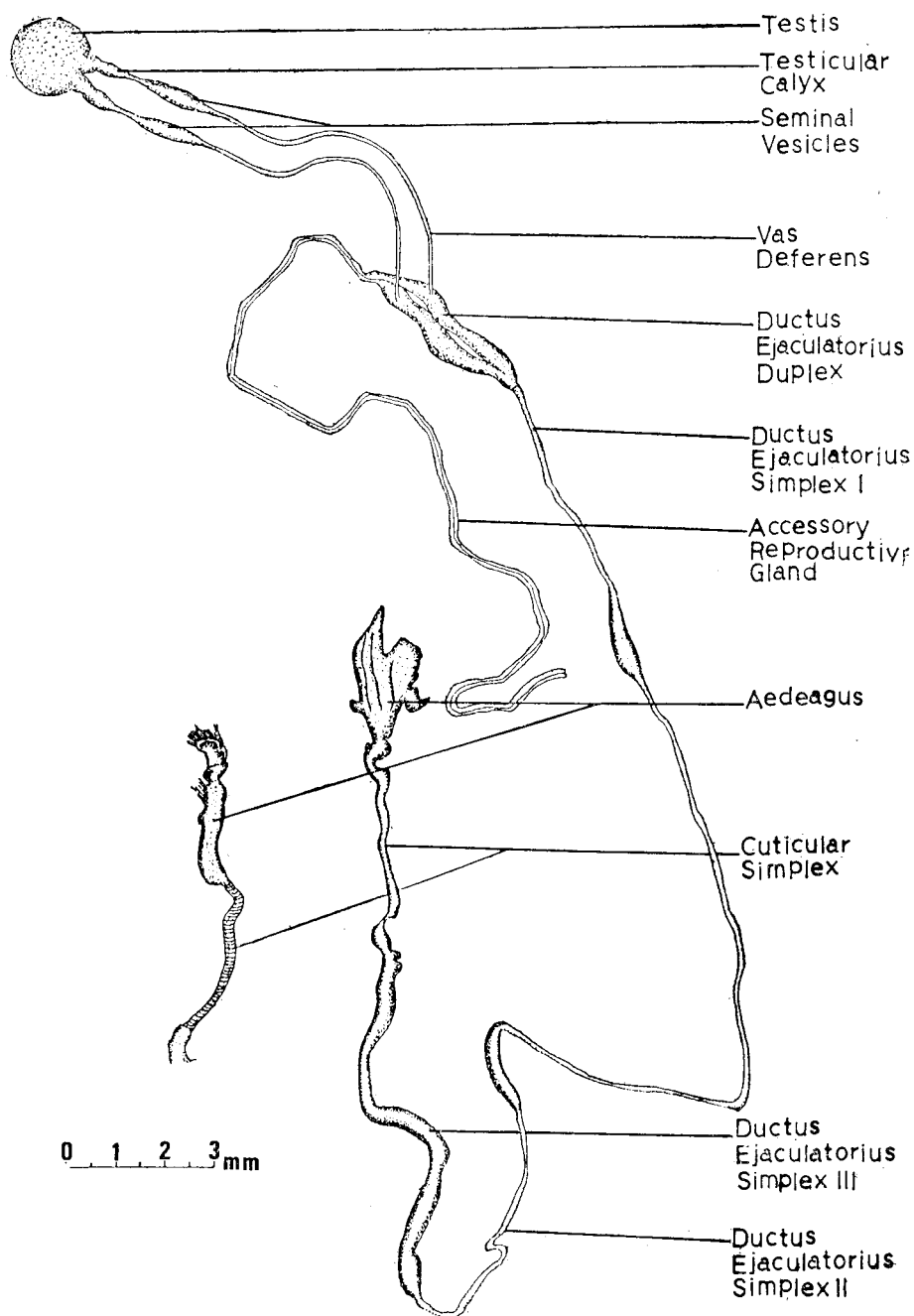
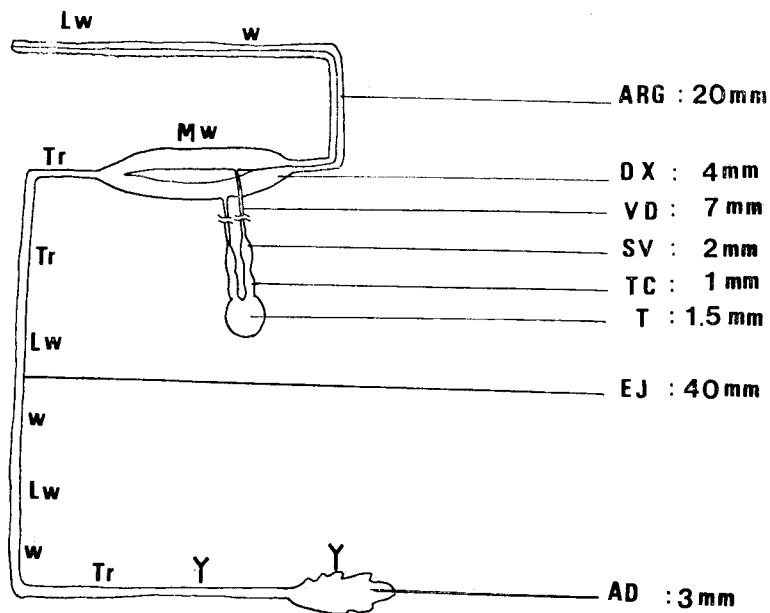


Fig. 3. *Spodoptera exigua* reproductive system of adult male.

hour to 4 AM. The average period of copulation is about 1 hr and 29 min.

## 2. Male reproductive system

The terminology used in this paper is basically from Callahan (1958) except the term "testicular calyx" from Brits (1978). On dissecting open the two days old male *Spodoptera exigua*, the most conspicuous organs are the paired bright yellow colored testes. The paired testes are so closely apposed that they appear as a single round organ (Fig. 3). The testes are enclosed in a common scrotum. Carefully using the fine forceps, this scrotum is removed and it appears thin, structureless membrane. The testes are 1.75 mm in diameter (Fig. 4). Immediately below attached to the ventral surface of the testes are paired elongated inflated testicular calyces (TC). The testicular calyces are 1 mm long and are externally covered by fatbody. The seminal vesicles (SV) arise as swollen portions of the vasa deferentia (VD) immediately below the testicular calyces. Seminal vesicles are 2 mm long and appear white in color due to the presence of spermatozoa within. The testicular calyces (TC) and seminal vesicles are divided by means of the short tubular region. The vasa deferentia (VD) are paired, narrow tubes of 7 mm long and they join posteriorly the two arms of ductus ejaculatoris duplex



- |                                   |                 |
|-----------------------------------|-----------------|
| ARG: Accessory reproductive gland | AD: Aedeagus    |
| DX: Duplex                        | LW: Light white |
| VD: Vas deferens                  | MW: Milky white |
| SV: Seminal vesicles              | Tr: Transparent |
| TC: Testicular Calyx              | W: White        |
| T: Testis                         | Y: Yellow       |
| EJ: Ejaculatory duct              |                 |

Fig. 4. Diagrammatic representation of male reproductive tract.

(Duplex) on one third of the distance from accessory reproductive glands (ARG). The VD are highly extensible ducts. Each arm of the duplex is 4 mm long, the duplex glands are paired glandular reservoir for secretions coming from ARG, VD and spermatozoa from VD. There is a sharp bend at the junctions of paired duplex and paired VD. The duplex ducts are easily ruptured at old age. The ARG are uniform and contiguous throughout most of their length. The other end of ARG is blind. The proximal part of ARG are white in color while the distal part is blue in color. Each accessory gland measures 20 mm in length. The paired accessory glands are bound together by means of tracheae. The ductus ejaculatoris (Simplex) is the only unpaired organ in the male reproductive tract. The simplex displays morphologically three regions: Simplex I, is the transparent and proximal region to the duplex; Simplex II, is the middle portion of the ejaculatory duct and it is white in color and at the end of which is a small milky white segment; and Simplex III, is the distal region which is initially yellow transparent in color and later granular yellow. The ejaculatory duct or the simplex measures 40 mm long, which is the longest duct among the male reproductive organs. Simplex I and II can be termed as primary simplex and it is non cuticular region while Simplex III is the cuticular region and highly expanded duct. The secondary simplex has obvious striated musculature. The aedeagus is the intromittent organ which is muscular and measures 3 mm long. A sclerotized caecum extends from the aedeagus into the body cavity. Cuticular simplex is continuous with eversible endophalus. This has 14 pairs of sclerotized spines.

### 3. Female reproductive system

In the female (Figs. 5 and 6) the conspicuous organs are the ovaries and bursa copulatrix (BC). The BC of *S. exigua* is heavily sclerotized and this sclerotization extends to the ventral side of ostium bursae (OB), the ductus bursae (DB) and the proximal corpus bursae (PCB). The dorsal side of the ostium and the distal corpus bursae are membranous. The distal corpus bursae (DCB) bears

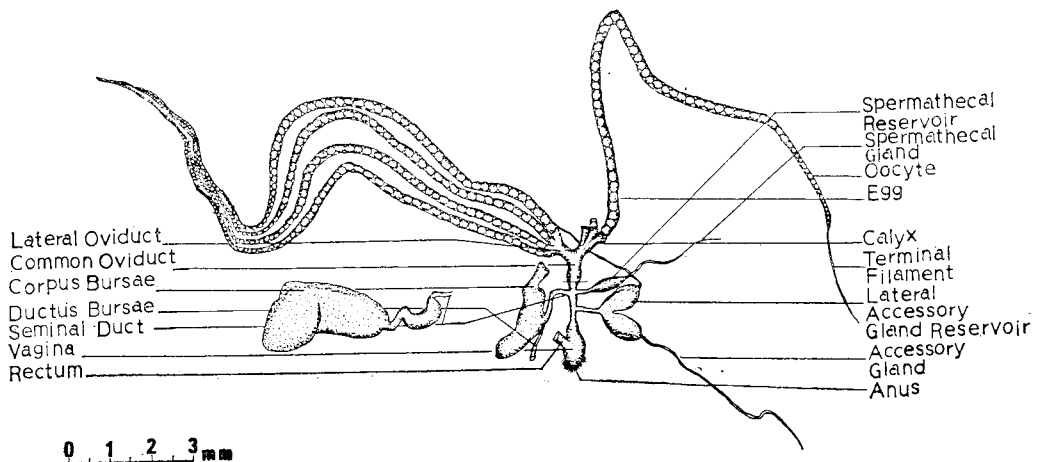


Fig. 5. *Spodoptera exigua* reproductive system of adult female.



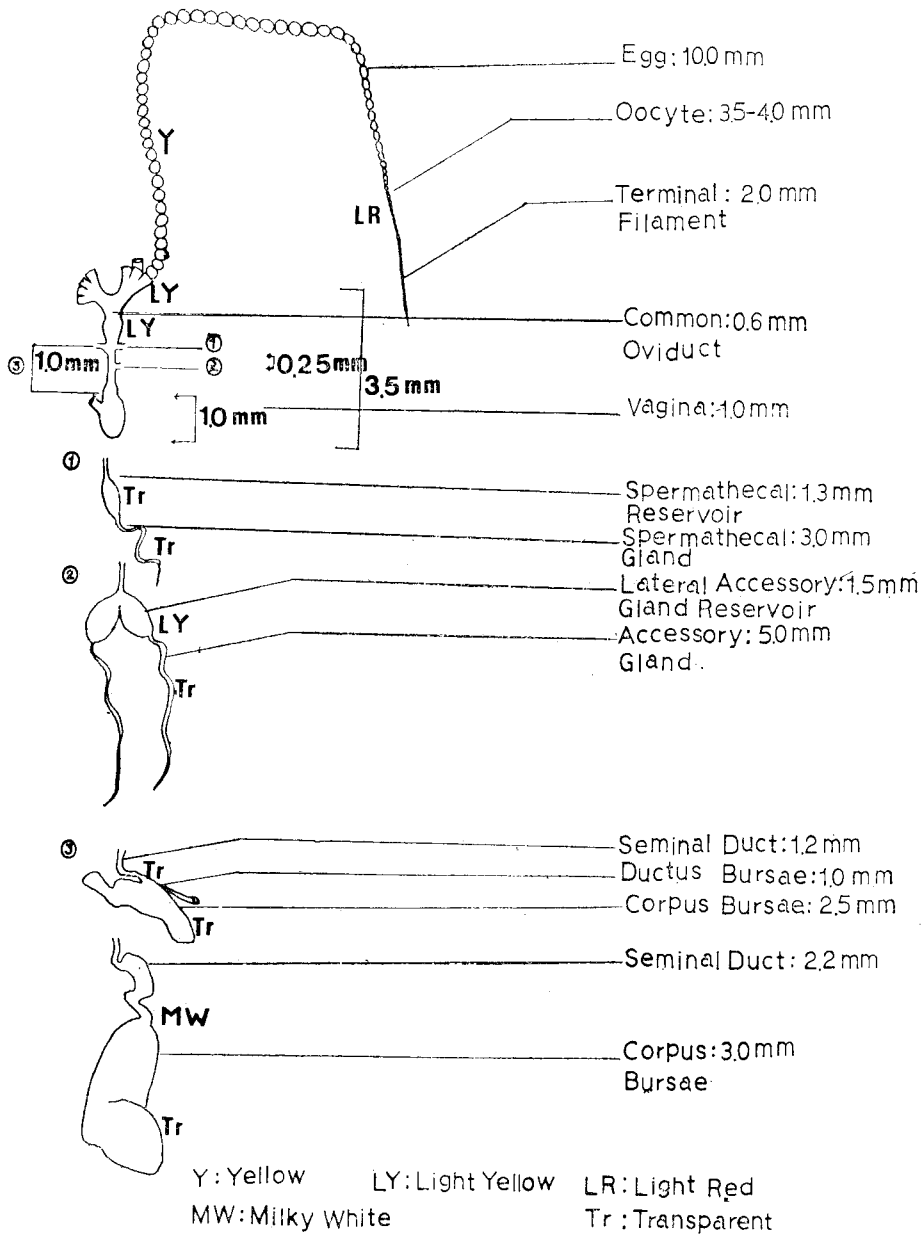


Fig. 6. Diagrammatic representation of female reproductive tract.

the bulb of the spermatophore while the collum bursae (CB) bears the collum of the spermatophore. The BC of the newly emerged virgin female is very small and looks insignificant in comparison with a four or five days old virgin female, where BC shows significant changes. The BC looks bulged and its entire length is 3.5 mm. The PCB is filled with transparent secretion while the DCB appears white and has many tracheae on its outer surface. In between the PCB and DCB the secretion appears milky white. The secretion of the DB is light yellow in color. The DCB measures 0.6 mm long. The bursae of *S. exigua* consists of OB,

DB, PCB, CB and DCB bursae. The BC of a mated female reveals the formation of spermatophore within and the distribution of the secretion within. The entire length of the BC has increased to 4.5 mm. Near the OB it measures 0.7 mm wide and the DCB doubles its length 1.2 mm. The spermatophore formation has started with development of corpus and later the collum. The corpus contains milky white secretion apparently evident from the presence of spermatozoa inside. The lower part of the collum carries the yellow secretion and the mid region of the collum is still transparent. The spermatophore of *S. exigua* like other Noctuidae has three distinct parts; a bulbus corpus, a long tubular collum and a terminal aperture (Fig. 7). There is no frenum present. The yellow secretion is later found in the corpus region. The spermatozoa are stored in the corpus. The lower part of the collum still shows a little yellow secretion. The region in between the collum is still transparent. The entire length of the spermatophore is 3.5 mm. The terminal aperture measures 0.5 mm long. The corpus measures 1.45 mm long and 1.2 mm broad. Most of the mated females contained only a single spermatophore in the BC. The ductus seminals (seminal duct) measuring 2 mm long arises

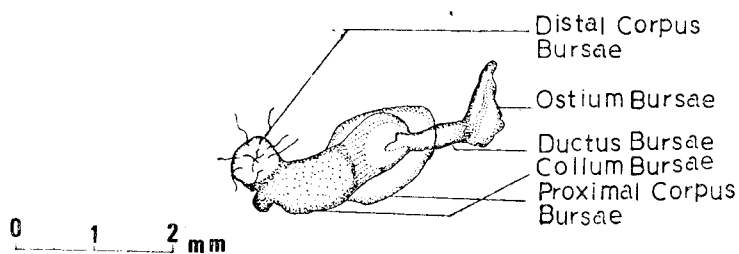


Fig. 7a. Bursae copulatrix of 4 days old virgin female.

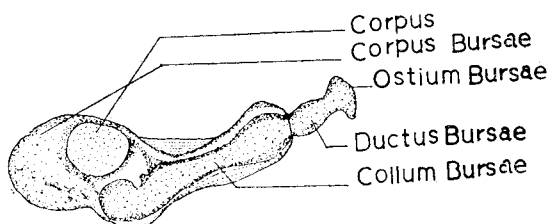


Fig. 7b. Spermatophore formation within the bursae copulatrix of a mated female.

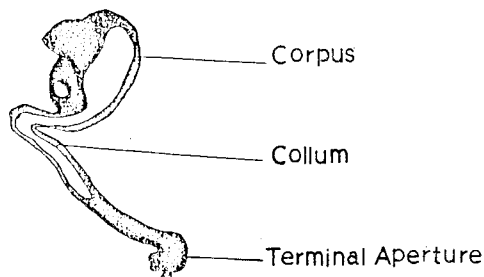


Fig. 7c. Spermatophore forms bursae copulatrix of a laboratory reared moth.

from the anterior end of DB. The seminal duct connects the BC with the vagina on the antero-dorsal surface of the vagina. This linking to the vagina is almost continuous with the point of attachment of the spermatheca on the dorsal surface of the vagina. The spermatheca arises from the antero-dorsal surface of the vagina but a little below the attachment of the seminal duct. The spermatheca consists of a proximal duct of 1.3 mm long and a distal spermathecal gland of 3 mm long. The spermathecal gland is thin tubular while spermathecal reservoir is enlarged and its tapering end coils before it attaches to the surface of the vagina. Above the spermatheca and seminal duct points of attachments is the common oviduct which is 0.6 mm long and then the common oviduct branches anteriorly into two lateral oviducts, about 0.4 mm long. The lateral oviducts extend into the base of the ovaries called calyx. Each ovary consists of four polytrophic ovarioles. The dorsally located ovaries loop back and forth within the abdomen. Three distinct regions can be found on the ovarioles, the first area consists of mature eggs; the second area consists of maturing oocytes and the third area called germarium where oogonia are produced from follicular cells. Finally the ovarioles fuse together to form a single thin filament. The female accessory glands are paired and attached to the dorsal surface of the vagina below the spermatheca by a common duct. Each accessory gland had two parts, an enlarged reservoir and a tubular gland. Both accessory glands have filamentous ends attached to the ovaries one to each ovary. The distance between the attachments of the spermatheca and accessory glands is 0.25 mm. Each accessory gland is 5 mm long and the accessory gland reservoir together with common duct measures 1.5 mm long. The ovipore is located below the anus. Both orifices are enclosed by a pair of sclerites, papillae anales. The whole length from ovipore to the oviduct measures 3.5 mm long.

The male reproductive system of *S. exigua* resembles that of other advanced species of Noctuidae. Callahan (1958) and Etman and Hooper (1979) have distinguished ductus ejaculatoris simplex into two parts, whereas in *S. exigua* there are morphologically three distinct regions. Possibly the secretions of three different regions have definite functions. The yellow granular secretion of the distal part of the ejaculatory duct later appears in the spermatophore and probably plays some role in the spermatophore. Immediately follows this region is the muscular area and the region of frenum formation as in *S. litura* (Etman and Hooper, 1979) and as in *Heliothis zea* (Callahan, 1958), is absent. Secondary segment of the simplex is cuticular and has transversed striated musculature as in *S. litura* (Etman and Hooper, 1979). In contrast to *Peridroma saucia* (Hübner) and *Pseudoletia unipuncta* (Hawarth) in which the aedeagus is approximately 1 mm long (Callahan and Chaplin, 1960), the aedeagus of *S. exigua* is 3 mm long and Etman and Hooper (1979) reported the presence of 5 mm long aedeagus in *S. litura*. Callahan and Casio (1963) and Etman and Hooper (1979) have found that the seminal vesicles in *H. zea* and *S. litura* function as a storage site for sperm bundles. Seminal

vesicles of *S. exigua* may have a similar function. Because the enclosed portion below the testis are the continuation of non-cellular layer of the testes, they are termed as testicular calyces as in *Phthorimaea operculella* (Brits, 1978). Callahan (1958) and Buntin and Pedigo (1983) found that the caecum of *H. zea* and *Plathypena scabra* reveals as a site for storage of endophalus to retract. *S. exigua* may have a similar function for the caecum. The seminal duct is simple in the female as in *P. scabra* (Buntin and Pedigo, 1983) and has no pouch-like structures and this probably serves in transport of sperm from the BC to the spermatheca. As in *S. litura* (Etman and Hooper, 1979), *S. exigua* also has the seminal duct attached 0.16 mm anterior to spermatheca on dorsal surface of the vagina. This is similar to the situation in *P. unipuncta* and *S. litura* but it is different from that in *Peridroma saucia*. The spermatheca is simple as in the case of *P. scabra* having a proximal spermathecal coiled duct, a mid reservoir and a distal spermathecal gland. The situation is very different in *S. litura* where it is reported the spermatheca is bilobed. The division of ovariole is very similar to the *H. zea* (Callahan, 1958). The interesting point is the accumulation of secretions in the corpus bursa of four days old virgin female. Of course, after mating, the bursa copulatrix is enlarged and conspicuous due to the lodging of spermatophore within.

#### ACKNOWLEDGMENTS

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## 甜菜夜蛾 (*Spodoptera exigua*) 的生物學 和生殖形態學之研究

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輔仁大學生物系

甜菜夜蛾為熱帶與亞熱帶地區嚴重的多寄主食性害蟲，本文就其生物學和生殖形態學加予研究。描述了甜菜夜蛾雌雄成蟲的內、外生殖系統之形態學內生殖器官之不同分泌物的自然現象，精莢 (spermatophore) 在交配囊 (bursa copulatrix) 中的位置與結構，和交配囊在交尾前後改變的情形。並與夜蛾科之已知種類加以比較。