Observation and Results
IV. OBSERVATION AND RESULTS

PART - A. REPRODUCTIVE BIOLOGY AND BEHAVIOUR

1. INTRODUCTION

The Bihar hairy caterpillar, *Diacrisia (Spilosoma) obliqua* Walker (Lepidoptera : Arctiidae) is a notorious foliage feeder, widely distributed in the Oriental region. It is polyphagous in nature and is known to attack a wide variety of plant species including agricultural crops, weeds as well as some ornamental plants. In India, it is considered to be a serious pest of earheads of ragi (*Eleusina coracana* L.) in Karnataka and maize (*Zea mays* L.) in Bihar, Madhya Pradesh, Uttar Pradesh, Punjab and Rajasthan (Atwal and Dhaliwal, 1997). Damage of varying magnitude has been reported from crops like, sesame (*Sesamum indicum* L.), mash (*Phaseolus mungo*), mug (*Phaseolus aureus*), linseed (*Linum usitalissimum* L.), mustard (*Brassica* sp.), some vegetables, fruits, castor (*R. communis* L.), fodder crops, cotton (*Gossypium* sp.), sorghum (*Sorghum vulgare* Pers.), small millets, sugar-cane (*Saccharum officinarum*), paddy (*Oryza sativa*), wheat (*Triticum* sp.), jute (*Corchorum* sp.), sunhemp (*Crotolaria juncea* L.), potato (*Solanum tuberosum*), sweet-potato (*Ipomaca batatas* L.), cucurbitacea, barley (*Hordeum vulgari*), sugar-beat (*Beta vulgaris* L.), cow-pea (*Vigna unguiculata* Linn.), groundnut (*Arachis hypogaea* Linn.), sunflower (*Heliathus anuum* Linn.), lucerne (*Medicago sativa* Linn.), lobia (*Vigna catjung*) and bajra (*Pennisetum typhoidium*) (Mathur, 1962; Pant, 1964; Pandey *et al.*, 1968; Prasad & Premchand, 1980). Besides, it also attacks numerous species of forest, shrubs and trees including *Butea frondosa*, *Cedrela*
toona, Colebrookia oppositifolia, Lantana, Morus alba, M. indica, Tectona grandis, Vitex negundo (Beeson, 1941), Dalbergia sissoo and Shorea robusta (Prasad et al., 2000).

Being an irregular and sporadic in distribution, the pest appears during May–June and the maximum infestation occurs during July–August. The insect hibernates during December–February and aestivates from May–June. The adults emerge with the onset of monsoon. There are 5–7 generations in a year. The larvae feed on leaves and floral parts of the host plant. In many cases, the whole leaf is eaten away by the caterpillars. The moths are nocturnal in habit and get readily attracted to light. They are strong but short distance fliers. The female lays eggs on the lower side of leaves. The caterpillars feed gregariously during early stages but disperse as they grow and become voracious foliage feeder.

Insect behaviour as a separate sub-discipline is relatively of recent emergence and is expanding rapidly. As such it lacks a strong theoretical framework and is very unevenly investigated (Mathews and Mathews, 1978).

The present work was aimed to focus on some of the behavioural aspects of the biology of the moth such as eclosion, feeding and oviposition and reproductive biology as discrete variables, against the neem products, especially Multineem 8 EC and Achook 0.15 EC.

2. OBSERVATION & RESULTS

The life cycle is completed in 30–45 days depending upon the environmental conditions.
2.1. EGG (Plate-I, Fig. 1 & 2)

Eggs are laid usually at night or early morning, in prominent batches, on the under surface of leaves. A single female lays from 687 to 1474 eggs with average of $1094 \pm 83.44$ in its life span of two to three days. The eggs look-like clusters of poppy seeds conspicuous against the green foliage background on the lower side of leaves. Under laboratory conditions the eggs are laid on the paper strips provided for this purpose or on the inner wall of the jars or on the under surface of leaves when twigs were provided. Eggs are firmly glued to the surface of leaves or paper strips with sticky secretions from the accessory glands. The newly laid egg has a characteristic shine and is spherical in shape measuring $0.76$ mm (average) in diameter. Freshly laid eggs are light green in colour which undergo gradual change from green to pale, reddish brown and finally turning black at the time of eclosion. The outer covering of the egg becomes translucent few hours before hatching and the larva inside can easily be noticed from the exterior. The incubation period varies from $110.87 \pm 09.67$ to $131.92 \pm 12.35$ hours with an average of $123.45 \pm 02.11$ hours. Percent eclosion and eclosion period of eggs were found to be $91.08 \pm 01.12$ and $29.00 \pm 01.36$ minutes respectively (Table-1). The larvae hatch out simultaneously or in quick succession resulting in aggregation of large number of larvae at one place.

2.2. LARVA

The freshly hatched larvae feed on the lower epidermis of leaves and soon skeletonize the latter. They remain aggregated for a few days before dispersing to other leaves of the plant(s). Feeding activities of larva increase with age. It moults five times to attain maturity when it measures 40–48 mm in length. Body colour is light orange with terminal ends black. The whole body is densely covered with dark hairs. The larval period lasts for 20–25 days depending upon the environmental conditions.
2.2.1. First Instar Larvae  (Plate-I, Fig. 3)

A freshly hatched larva is uniformly pale yellow, which gradually turns greenish, when feeding commence on the tender leaves. Five pairs of prolegs are present from third to sixth abdominal segments and the last segment. Body is covered with setae and hairs; pre-spiracular wart of the prothorax with three setae, invisible to the naked eyes.

Full-grown first instar larva measures about 3–4 mm in length and the larval duration is 70.32 ± 02.59 hours (Table-2). The newly hatched larvae show wriggling movement and wander about in search of food. They feed on the mesophytic tissues of the leaves, leaving the vascular ones and thus act as skeletonizers. During scarcity of food the larvae consume the entire leaf and thus become defoliators. When disturbed they hang down with silken thread, which also help them in dispersal. The larvae are gregarious in habit.

2.2.2. Second Instar Larvae  (Plate-I, Fig. 4)

The second instar larva can easily be distinguished with its characteristic cylindrical body. The newly moulted ones remain sluggish and are light yellow in colour but the active feeding stages are bright yellow with slight orange tinge. Location and the number of setae on the pre-spiracular wart of the prothorax are similar to the first instar larvae except the setae are prominent because of acquiring black colour.

The actively feeding second instar larva measures 5–8 mm in length. This stage lasts for 82.11 ± 02.24 hours (Table-2). The feeding pattern is more or less similar to the first instar. However, it feeds on the secondary and tertiary veins (cortical and vascular tissue) as well.
2.2.3. Third Instar Larvae  (Plate-II, Fig. 5)

The third instar larva is cylindrical, orange coloured with black spots on all thoracic and the last two abdominal segments. The number and position of the setae on the prespiracular wart is similar to the first and second instar larvae. Warts of each segment become prominent, because of thickening of the cuticle in that area. The hairs and setae are distinguishable in two types i.e. smooth and the spinose.

The third instar larva measures about 10-15 mm in length with instar duration lasting for 111.08 ± 04.34 hours (Table-2). These are gregarious and voracious feeders, causing serious damage to the crops. They consume entire leaf leaving only the midrib. When disturbed they try to drop themselves suspended with the silken thread, which soon breaks up because of significant increase in their body weight.

2.2.4. Fourth Instar Larvae  (Plate-II, Fig. 6)

Body is cylindrical, strong and stout, densely hairy and dark orange with very prominent black spots on thoracic and the last two abdominal segments.

It measures approximately 19-26 mm in length with larval period 121.16 ± 03.30 hours (Table-2). The feeding behaviour is much similar to that of third instar. When disturbed they try to escape from the area with their fast crawling movements.

2.2.5. Fifth Instar Larvae  (Plate-II, Fig. 7)

The fifth instar larva has tough and compact body, thickly pilose as compared to the fourth instar. The hairs are very long and tuft like on the warts. Single hair measures 6-10 mm in length. Body colour is yellowish orange with
similar black spots as in the previous instar except with a prominent black band in the inter-segmental area.

The full-grown, actively feeding fifth instar larva measures about 28-33 mm in length. This stage lasts for 128.33 ± 01.86 hours (Table-2). Feeding behaviour and pattern is almost similar to third and fourth instar but the amount and rate of food consumption is significantly high.

2.2.6. Sixth Instar Larvae (Plate-II, Fig. 8)

Body is slender, strong and stout, resembling very much with the fifth instar in colour, spots and the position of hairs; the latter being tufted, a clear mid-dorsal streak is present which is slightly pale in colour ventrally.

The sixth instar larva measures 32.12-34.87 mm in length. The larval period under controlled conditions varies from 108.25 ± 09.24 to 134.30 ± 04.13 hours. Average duration of the sixth instar alone is 122.69 ± 02.73 hours (Table-2). The feeding behaviour is similar to the earlier instar. It mostly feeds during night or in dim light, is voracious feeder and capable of devouring every soft part of the plant. The larva after attaining maximum size stops feeding and retires to pupate at a suitable site.

2.3. PRE-PUPAL STAGE

After selecting suitable site the larva becomes confined and the structural modifications start appearing. The size of the last larval instar is almost reduced to half; the inter-segmental grooves are deepened giving it an annular appearance. The hair and streaks almost fade out. The abdominal pro-legs are reduced. This stage lasts for 70.55 ± 02.90 hours (Table-3).
2.4. PUPAL STAGE  (Plate-III, Fig. 9 & 10)

The full-grown caterpillar sheds its hairs and pupates inside the soil, spinning a rough cocoon mainly composed of silky secretion interwoven with shed off hairs of last instar larva. It has also been found on the muslin cover or even on the sides of the glass jars in captivity. The pupa is of exarete type and about 20-25 mm in length. The newly formed pupa is pale yellow in colour but turns to leathery brown within 1-2 hours.

The mature sixth instar larva often pupates among dry leaves of host plant. A thick opaque, shelter-web in two layers transversely crossed at regular distances around the edges small oval holes are left along-with an emergence hole is provided at one end. Before pupation a thin lining of fine silk is added as a third layer inside, thereby increasing thickness and surface tension. The finished web measures 15-25 mm and is constructed in 2 to 3 hours. In regions with a winter climate, the pre-pupal stage is prolonged during the period of hibernation; when the host leaves fall at the end of the growing season, hibernating larvae remain hidden in their shelters constructed among the dry leaves on the ground.

There are 4-8 tubercles at the posterior extremity of the pupae in both the sexes. The average pupal duration is 255.14 ± 15.76 hours (Table-3). The abdominal segments start tanning first followed by the thoracic and cephalic segments. The female pupa is comparatively more tanned. The full-grown female pupa measures 19-20 mm in length the male pupa is comparatively smaller and measures 15-16 mm in length.

2.5. ADULT EMERGENCE

This is followed by distention of the abdomen that may be attributed to engulfing of air by the pupa. This causes rupture of the pupal case along the dorsal line of the thorax that provides a passage for adult to emerge out. Adult
emergence from pupa average 89.31 ± 01.98% (Table-3). The newly emerged adult rests for some time and later on ejects few drops of thick, reddish brown fluid from anus. The pad-like wings take about one and a half-hours to expand to their normal size thereby, enabling the adult to resort to active life. On average adult emergence from pupa takes 21.00 ± 01.34 minutes (Table-3).

2.6. ADULT (Plate-III, Fig. 11 & 12)

The adult is a pale buff-cloured moth of medium size with black spots on wings. The body is crimson and black-spotted. The eyes and antennae are black. Body robust and hairy, head small inconspicuous, proboscis well developed and palpi short. Abdomen bright orange, with mid-dorsal and lateral rows of black spots from second to sixth abdominal segments, terminal spots becoming more prominent. Wings are buff oranges with minute black spots on the fore-wing and very prominent spots on the lower margin of the hind wings. The moth measures 25-35 mm in length with wing expanse of 40-50 mm. Both males and females are almost similar but males are characterized by the presence of pectinate antennae. They are comparatively smaller than females and measure about 15-18 mm in length with 35-40 mm across wings. The females are bigger than males and measure 18-20 mm in length and 45-50 mm with wings expanse. The average longevity of adult mated male and female is 152.56 ± 07.50 and 172.71 ± 07.77 hours respectively, whereas for unmated male and female is 145.03 ± 04.64 and 163.56 ± 05.88 hours respectively (Table-4).

The adult is nocturnal in habit. During daytime the adult usually remains hidden inside the cracks and crevices; under dry leaves or grasses in the field and paper strips or castor leaves under laboratory conditions.
2.7. PRE-MATING

Pre-ovipositing adults of both sexes are swift. Pre-mating period varies on an average $17.36 \pm 0.91$ hours (Table-5).

2.8. PRE-OVIPOSITION

The male starts fluttering its wings and moves its abdominal tip up and down. These activities are continued for 40-60 minutes. The female reacts displaying two type of behaviour, some of them respond with fluttering of their wings with slight rhythmic movement (contraction & relaxation) in the anal area, while other start moving slowly. The female and male then bring their abdominal tips close to each other in end-to-end position and copulate.

In the experiment, isolated pairs were kept from the time of emergence and when the males completed mating with females the former were kept with other virgin females. The old males were found to mate again with the virgin females. Thus it was concluded that a male could mate with more than one female. The newly emerged moth mates on subsequent nights. The pre-oviposition period lasts for $26.12 \pm 0.94$ hours (Table-5).

2.9. OVIPOSITION

The egg laying does not occur just after the cessation of mating. It takes about 2-3 hours for the females to get ready for oviposition. Before performing the actual act of oviposition, the females show a series of behavioural responses. They become very active, start fluttering their wings, show rhythmic movements in the anal area and move fast all around the container till they are apparently exhausted. After a pause of 20-30 minutes a suitable oviposition site is selected by touching the substratum by means of slightly protruded anal area. After the selection of the oviposite, the female shows peristaltic movement in the
abdominal region before egg laying. For the deposition of the egg, the female brings abdominal tip close to the substratum and discharges an egg out, then the abdomen is retracted with a slight jerk and the wings are slightly raised. The eggs get adhered to the substratum because of a sticky coating. After laying an egg the female moves its abdomen on either side and lays the next egg. In this way the eggs are laid in an organized fashion in several rows. The average oviposition period in the mated female is 91.71 ± 05.67 hours (Table-5).

In the case of virgin females the mechanism of oviposition is the same but the pattern is different. In most of them the eggs are laid scattered or in heaps which is an abnormal characteristic for this species. Further, most of the virgins do not have the urge for oviposition.

2.10. POST-OVIPOSITION

The post-oviposition period is the duration between the cessation of egg laying and mortality of the adults. This is short period and average 34.19 ± 02.96 hours (Table-5).

2.11. LONGEVITY AND SEX RATIO

The longevity of adult moth of *S. obliqua* was observed in three replicates of experiments under laboratory conditions. In the first, ten pairs of adults were kept in ten rearing jars and allowed to feed and copulate. The longevity of males and females fed and allowed copulation varied from 4-7 and 6-10 days respectively. In second experiment, ten males and ten females were kept separately in ten rearing jars. Each was fed regularly but not allowed to copulate. The longevity of males and females in such cases varied from 7-12 and 6-14 days respectively. In the third experiment, ten males and ten females were captivated separately and no food was given to them. The longevity of both sexes in such cases is 2-3 and 3-4 days respectively.
Females usually predominate in wild populations and are often twice as numerous as males. The female-dominant strain of *S. obliqua* when artificially breed in the B.O.D. under controlled conditions for several generations results into more females. Neither artificial environment nor breeding is the reason for this tendency as the time, space and nutrient status are main limiting factors governing sex ratio.
3. DISCUSSION

The female moths of *Spilosoma obliqua* normally lay eggs during later part of night. The nocturnal ovipositional behaviour has been reported in *Phyllocnistiis citrella* (Pandey & Pandey, 1964), *Cnaphalocrosis medinalis* (Velusany and Subramaniam, 1974), *Hemithea tritonaria* (Mehra & Shah, 1966), *Nephoplexy leucocephala* (Shah & Mehra, 1966), *Thiacidas postica* (Mehra & Shah, 1970), *Andraca bipunctata* (Banerjee, 1971), *Lamprosema indicata* (Kapoor et al., 1972), *Halitosis armigera* (Singh & Singh, 1975). Female of *Chilo zonellus*, however, is reported to deposit eggs in the evening only (Trehan & Bhutani, 1949), whereas females of *Polymatus boeticus* oviposit in the bright daylight (Pandey et al., 1978). The moths generally lay their eggs in clusters or patches or singly with a few showing all the patterns. The recognition and orientation of the host plant by the insect, followed by the section of specific sites and finally the deposition of eggs are known to be governed by a number of factors both physical and chemical (Beak, 1965). The females of *S. obliqua* have been found to lay their eggs in large prominent batches as also reported in some other species, *A. bipunctata* (Banerjee, 1971), *C. zonellus* (Trehan & Bhutani, 1949), *T. postica* (Mehra & Shah, 1970). On the other hand the females of *Parnara mathias* (Teotia & Nand, 1966) and *H. armigera* (Singh & Singh, 1975) lay their eggs singly. Both the patterns have been reported in the females of *P. citrella* (Pandey & Pandey, 1964) and *P. boeticus* (Pandey et al., 1978).

Fecundity of female of *S. obliqua* under controlled conditions was found to vary from 687 to 1474 with an average of 1094 ± 83.44 eggs. There is record of considerable variation in the fecundity of moths for example 15 to 45 eggs in *Polytela gloriosae* (Sachan & Srivastava, 1965), 64 ± 4.70 eggs in *P. gloriosae* (Yadava, 1972), Ewing et al., (1947), Christids & Harrison (1955), and Hsu et al., (1960), recorded 1,000 egg in *H. armigera*, Patel et al. (1968) reported 1142.3 ± 360.6 eggs in *H. armigera* (Singh & Singh, 1975), 400 eggs in *A. bipunctata*...
(Banerjee, 1971) and the females of *Anomis flava* laid on average of 370 eggs when caged with a single male and 407 eggs when caged with two males (Rao & Patel, 1973).

In the present study it has been noticed that the eggs are originally light green which later turn green to pale, reddish brown and finally black at the time of hatching as also reported in *A. flava* (Rao & Patel, 1973), *Pericallia ricini* (Ghosh & Gonchaudhuri, 1996). The incubation period in *S. obliqua* varied between $110.87 \pm 0.91$ to $131.92 \pm 12.35$ hours with an average of $123.45 \pm 0.21$ hours. These figures are in broad agreement with those (2 to 5 day) reported by Srivastva & Saxena (1958); Hsu *et al.* (1960); Mathur (1962); Reed (1965) and 2.6 to 3.6 days Singh & Singh (1975) in *H. armigera*. However, Wilcox *et al.* (1956) reported in *H. armigera* the incubation period as 5 to 10 days. Further 2 to 6 days incubation period was reported by Khan (1956); Puttarudriah & Maheswariah (1956); Srivastava & Bhatnagar (1963) and Rao & Patel (1973) and 33 hours in *Spodoptera mauritia* (Murad, 1969).

In the recent investigations the percentage of eclosion was found varying from $82.81 \pm 0.37$ to $96.12 \pm 0.21$% with an average $91.08 \pm 0.12$%. The hatching percentage has been recorded towards higher side in *A. flava* of 94.53% (Rao & Patel, 1973) and in *P. ricini* a high of 98% (Ghosh & Gonchaudhuri, 1996) was recorded.

The larval period is subject to great variation in the lepidoptera depending on various parameters, like the atmospheric conditions, quality and quantity of food and the population density. Marked variations in the duration of larval developmental period was recorded when rearing was done on different food plants as reported in *Prodenia litura* by Moussa *et al.* (1960), Ratan & Nayak (1963), and in *D. obliqua* by Pandey *et al.* (1968) and Prasad & Premchand (1980). In the present work larval longevity was recorded as $70.32 \pm 0.59$, $82.11 \pm 0.25$, $111.08 \pm 0.34$, $121.16 \pm 0.34$, $128.33 \pm 0.86$ and $122.69 \pm$
02.73 hours for 1\textsuperscript{st} to 6\textsuperscript{th} instar respectively. In other reported species it was 2.68 ± 0.18, 3.42 ± 0.28, 4.78 ± 034, 2.76 ± 0.20 & 5.45 ± 0.33 day in 1\textsuperscript{st} to 5\textsuperscript{th} instars larvae of *P. gloriosae* (Yadava, 1972) and 5, 3, 3, 3 & 4 days in respective 1\textsuperscript{st} to 5\textsuperscript{th} instar larvae of *P. gloriosae* (Yadava, 1972) and 5, 3, 3, 3 & 4 days in respective 1\textsuperscript{st} to 5\textsuperscript{th} instar in *P. ricini* (Ghosh & Gonchaudhuri, 1996).

The total average larval period as 624.42 ± 16.23 hours (26 days) was recorded in the present study when the population density was 20 larvae per jar with abundance of food (castor leave). Whereas the average larval period was 19.5 - days when fed on Maize and Urd, 26.5 - days on Sannhemp, 17.0 – days on Castor, 20.5 – days on Cotton, 19.0 - days on Jute and Groundnut, 17.5 - days on Til, 21.5 - days on Dhainch, and 18.0 - days on Lobia in *D. obliqua* (Pandey et al., 1968). Pandey and Srivastava (1967 and Rathore & Sachan (1978) obtained almost similar results with *C. zonellus* and *Prodenia litura* respectively. Total larval period was to 12.70 ± 0.084 days in *H. armigera* (Rao & Patel, 1973), 33.7 - days in *D. obliqua* (Singh & Gangrade, 1974), 19.9 - days on *Chenopodium album* and 32.1 days in *Brassica rugosa* in *D. obliqua*. In *S. mauritia* the average larval duration was reported as 351 hours (Murad, 1969). Total larval duration was further recorded as 21-28 days on Maize (Srivastava & Saxena, 1958), 21.8 to 33.6 days and Sunflower (Coaker, 1959), 20-21 days (Hsu et al., 1960 and Reed, 1965) and 10.8 ± 0.75 days (Singh & Singh, 1975) in *H. armigera* and 15-21 days in *H. virescens* (Martinez et al., 1986). Total larval period of *Hyblaea puera* on young, mature & senescent leaves of *Tectona grandis* was 15.90 ± 0.8309, 18.02 ± 0.5638 & 20.15 ± 0.8530 days respectively (Murugan & Kumar, 1996).

The size of larvae in *S. obliqua* varies from 3-4 mm in 1\textsuperscript{st} instar, 5-8 mm in 2\textsuperscript{nd} instar, 10-15 mm in 3\textsuperscript{rd} instar, 19-26 mm in 4\textsuperscript{th} instar, 28-33 mm in 5\textsuperscript{th} instar and 32.12-34.87 mm in 6\textsuperscript{th} instar. In *A. gloriosae* (Yadava, 1972) and *A. flava* (Rao & Patel, 1973) variable size of larvae has been recorded. Generally, mature last instar larvae are gregarious in feeding habit and are also voracious.
feeder, a view shared with *P. gloriosae* (Yadava, 1972) and *H. puera* (Ananthakrishnan et al., 1985 and Murugan & Kumar, 1996).

The pre-pupal and pupal duration last 70.55 ± 0.29 hours (3 days) and 255.14 ± 15.76 hours (11 days) respectively. Pre-pupal period is highly variable for example 12 hours in *S. mauritia* (Murad, 1969), 1-2 days in *H. armigera* (Singh & Singh, 1975), 1.5-1.8 days in *D. obliqua* (Rathore & Sachan, 1978), 2-3 days in *H. virescens* (Martinez et al., 1986). The food of the larvae also plays considerable role in determining the pre-pupal period, for example 1.58 ± 0.3681 days, 1.75 ± 0.3012 days and 2.95 ± 0.5540 days on young, mature and senescent leaves of *T. grandis* in *H. puera* respectively (Murugan & Kumar, 1996). Similarly, pupal period is also determined by food, for example 9 days on Maize, Till and Groundnut, 10 days on Sannhemp, 8 days on Urd, Castor, Jute, Dhainch & Lobia, 7.75 days on Cotton, in *D. obliqua* (Pandey et al., 1968), 10.40 ± 0.62 days in *P. gloriosae* (Yadava, 1972). Similarly, average pupal period was also found variable as 25.4 days on Cowpea, 12.0 days on Groundnut, 14 days on Sunflower, 18.1 days on Kalai, 15.1 days on Cotton in *D. obliqua* (Prasad and Premchand, 1980). However quite variable pupal period in *D. obliqua* was reported by different authors which vary from 8.8-9.6 days (Rathore & Sachan, 1978). Similarly, in some related species it was recorded as 11.72 ± 0.8248 days, 13.99 ± 1.0153 days and 15.04 ± 0.8497 days on young, mature and senescent leave of *T. grandis* respectively in *H. puera* (Murugan and Kumar, 1996), 164 hours in *S. mauritia* (Murad, 1969), 5.8 days in *H. armigera* (Singh and Singh, 1975) and 9-17 days in *H. virescens* (Martinez et al., 1986).

The present studies show that the average adult emergence is 89.31 ± 0.198 percent. Whereas the percentage of adult emergence was 77.7 on Maize, 60.0 on Sannhemp, 70.5 on Urd, 87.5 on Castor, 88.2 on Cotton, 91.6 on Jute, 92.1 on Til, 64.2 on Dhainch, 75.0 on Groundnut and 67.6 on Lobia (Pandey et al., 1968), 100 on Cowpea and Groundnut, 66.6 on Sunflower, 87.5 on Kalai,
87.5 on cotton and 85.8 on Lucerne (Prasad and Premchand, 1980). The adults of *S. obliqua* generally emerge during night, a finding shared with Siddiqi (1985).

Pre-mating period varies between 7.92 ± 02.74 to 25.35 ± 03.26 hours and average 17.36 ± 01.91 hours in the present study which is comparable with 18 hours as suggested by Siddiqi (1985). The moths of *A. bipunctata* however, are reported mating immediately after emergence (Banerjee, 1971), while the same period was 14-24 hours in *P. citrella* (Pandey and Pandey, 1964), one day after emergence in *Lambroserma indicata* (Kapoor *et al.*, 1972) and average pre-mating period 32 hours-36 minute in *H. armigera* (Singh and Singh, 1975). It takes 1-2.5 hours for the adults of *Hyphantria cunea* to become ready for mating (Arai and Mahuchi, 1979).

In most lepidoptera diurnal changes in activity and rhythmic behaviour have been correlated with changes in light intensity (Larsen, 1943 and Edwards, 1964). *S. obliqua* generally mate at night or at dark i.e. their mating time coincides with the emergence time. Siddiqi (1985) have reported similar findings in *D. obliqua*. In the majority of moths, mating generally occurs during night as in *P. citrella* (Pandey & Pandey, 1974), *C. medinalis* (Velusany & Subramaniam, 1964), *A. bipunctata* (Banerjee, 1971) and *Lamproserma indicata* (Kapoor *et al.*, 1972). The *Euxco bilitura* always prefers to mate and oviposit during day (Ripa, 1980). Both the male and females show the activities of excitement. Only the recognition of the presence of the female in the vicinity excites the male and the behaviour is reflected by its activities. In *S. obliqua* the fast movement and fluttering of wings occurs before mating. Similar, responses have also been recorded by Arai & Mubuchi (1979) and Siddiqi (1985) in *D. obliqua*. While females are expected to minimise risks and energy expenditure during mating, males generally attempt to maximize their number of copulation (Emlen & Oring, 1977; Thornhill & Alcock, 1983). The mating occurs in end to end position in *S. obliqua*. Similar, observations have been made in *P. gloriosae* (Sachan and...

Present study show that the mating in S. obliqua occurs only once in its lifetime which takes place prior to the laying of eggs. Siddiqi (1985) made similar observations. Single mating in the whole life was also reported in P. citrella (Pandey & Pandey, 1964) and H. armigera (Singh and Singh, 1975) but the moths of L. indicata mated more than once during their life time (Kapoor et al., 1972).

The adult male of S. obliqua measures 25-35 mm in length with wing expanse of 40-50 mm. In certain other related species length from tip to tip and wingspan is 10.23 ± 0.45 mm (n=10) and 31.84 ± 0.03 mm (n=10) in P. gloriosae (Yadava, 1972), and 14.72 mm in length with wing expanse of 30.15 mm in A. flava (Rao & Patel, 1973).

The data of present investigation shows average longevity of the mated male as 152.56 ± 07.50 hours, female as 72.71 ± 07.77 hours, unmated male as 145.03 ± 04.64 hours and female as 163.56 ± 05.88 hours. Whereas in A. flava the average longevity was 10.68 ± 1.07 days (1:1) and 11.70 ± 1.15 days (2:1) in male and 9.75 ± 1.89 (0:1), 10.37 ± 0.83 (1:1), 11.60 ± 1.12 (2:1) in female (Rao & Patel, 1973). The longevity of laboratory reared males and females was 3.13 ± 0.78 and 6.63± 0.85 days in H. armigera (Singh & Singh, 1975), and the adult longevity on young, mature and senescent leaf of T. grandis was 7.32 ± 0.7372 days, 5.92 ± 0.8016 days, 4.86 ± 0.8611 days in male and 8.69 ± 0.6366 day, 6.86 ± 0.7567 days, 5.68 ± 1.022 days in female of H. puera respectively (Murugan & Kumar, 1996).

In the majority of lepidopterans, pre-oviposition, and post-oviposition period is generally quite short. In the present study, the pre-oviposition period varied from 18.82 ± 04.17 to 35.73 ± 07.36 hours with an average of 26.12 ± 01.94 hours. In other studies pre-oviposition period is shown to last for 1-2 days
as in *T. postica* (Mehra & Shah, 1970) 1-3 days in *N. leucocephela* (Shah & Mehra, 1966) and 54 hours in *S. mauritia* (Murad, 1969). Similarly, the pre-oviposition period was recorded 1-4 days in *H. armigera* (Singh & Singh, 1975).

In the present investigation the oviposition period is found to vary between 71.20 ± 08.08 to 122.48 ± 05.84 hours with an average of 91.71 ± 05.67 hours. The oviposition duration of a single batch was recorded as 20.30 minutes. The oviposition period in moths is subject to great variation. It was 1-3 days in *C. zonellus* (Trehan & Bhutani, 1949), 1-11 days in *H. tritonaria* (Mehra & Shah, 1966), 4-6 days in *T. postica* (Mehra & Shah, 1970), 20-24 hours in *A. bipunctata* (Banerjee, 1971), 2-14 days in *A. flava* (Rao & Patel, 1973) and *C. medinalis* (Velusany & Subramaniam, 1974), 2-5 days in *H. armigera* (Singh & Singh, 1975) and *P. boetius* (Pandey et al., 1978), 1-2 days in *P. ricini* (Ghosh & Gonchaudhuri, 1996), and 11.72 ± 0.8248 days, 13.99 ± 1.0153 days and 15.04 ± 0.8497 days on young, mature and senescent leaves of *T. grandis* in *H. puera* respectively (Murugan and Kumar, 1996).

On the basis of present finding it could be suggested that the post-oviposition period in *S. obliqua* range from 23.58 ± 05.56 to 51.20 ± 03.51 hours with an average of 34.19 ± 02.96 hours. The findings in *H. armigera* (Rao and Patel, 1973; Singh and Singh, 1975) are in line with the results in the present study.
4. SUMMARY

1. The Bihar hairy caterpillar, Diacrisia (Spirosoma) obliqua Walker (Lepidoptera : Arctiidae) was selected for present study as it is an important foliage feeder, widely distributed in the Oriental region. It is polyphagous in nature and known to attack a wide variety of plant species including agricultural crops, weeds as well as some ornamental plants.

2. The life cycle is completed in 30-45 days depending upon the environmental conditions.

3. A single female lays from 687 to 1474 eggs with average of $1094 \pm 83.44$ in its life span. The incubation period varies between $110.87 \pm 09.61$ to $131.92 \pm 12.35$ hours with an average of $123.45 \pm 02.11$ hours. Percent eclosion of eggs was found to be $91.08 \pm 01.12$.

4. The freshly hatched larvae feed on the lower epidermis of leaves and soon skeletonize the latter. Feeding activities of larva increase with age. The whole body is densely covered with dark hairs. The total larval period lasts for 20-25 days.

5. Full-grown first instar larva measure about 3-4 mm in length and the first instar larval period lasts for $70.32 \pm 02.59$ hours.

6. The actively feeding second instar larvae measure 5-8 mm in length. This stage lasts for $82.11 \pm 02.24$ hours. The feeding pattern is more or less similar to the first instar larvae.

7. The third instar larva is cylindrical, orange coloured with black spots on all thoracic and the last two abdominal segments. Its measures about 10-15 mm in length with instar duration lasting for $111.08 \pm 04.34$ hours. These are gregarious and voracious feeders, causing serious damage to the crops.
8. The fourth instar larva measures approximately 19-26 mm in length with larval period 121.16 ± 03.34 hours. The feeding behaviour is much similar to that of the third instar.

9. The fully-grown, actively feeding fifth instar larva measures about 28-33 mm in length. This stage lasts for 128.33 ± 01.86 hours. Feeding behaviour and pattern is almost similar to third and fourth instar. But the amount and rate of food consumption is significantly high.

10. The sixth instar larva measures 32.12-34.87 mm in length. The larval period under control conditions varies from 108.25 ± 09.24 to 134.30 ± 04.13 hours. Average duration of the sixth instar alone is 122.69 ± 02.73 hours. The feeding behaviour is similar to the earlier instar.

11. The pre-pupal and pupal stage last 70.55 ± 02.90 and 255.14 ± 15.76 hours respectively. The full-formed female pupa measures 19.8 mm in length, the male pupa is comparatively smaller and measures 15.2 mm in length. The newly formed pupa is pale yellow in colour but turns to leathery brown within 1-2 hours.

12. The rupture of the pupal ease along the dorsal line of the thorax that provides a passage for adult to emerge out. Adult emergence from pupa an average 89.31 ± 01.98%. The newly emerged adult has pad-like wings take about one and half-hours to expand to their normal size.

13. The average longevity of adult mated male and female is 152.56 ± 07.50 and 172.71 ± 07.77 hours respectively, whereas for unmated male and female are 145.03 ± 04.64 and 163.56 ± 05.88 hours respectively.

14. The newly emerged moth mates during nights. The observation also reveals that the females mate only once in their lifetime, whereas the males can mate more than once. The pre-oviposition period lasts for 26.12 ± 01.94 hours.

15. The average oviposition period in the mated female is 91.71 ± 05.67 hours.

16. The average post-oviposition period is very short i.e., 34.19 ± 02.96 hours.
Table: 1. Showing the number of eggs laid by single female (Fecundity), Incubation period, Eggs Eclosion (Fertility) % and Eclosion period of larvae of S. obliqua.

<table>
<thead>
<tr>
<th>Number of eggs (Fecundity)</th>
<th>Incubation of eggs (hrs.) (Mean ± S.E.)</th>
<th>Eggs Eclosion (Fertility) % (Mean ± S.E.)</th>
<th>Time of first movement inside the egg</th>
<th>Time of exit of the larva from the egg shell</th>
<th>Eclosion period (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1026</td>
<td>110.87±09.61</td>
<td>91.45±03.78</td>
<td>4:15 pm</td>
<td>4:44 pm</td>
<td>29.00</td>
</tr>
<tr>
<td>918</td>
<td>120.48±10.78</td>
<td>96.12±02.18</td>
<td>4:24 pm</td>
<td>4:55 pm</td>
<td>31.00</td>
</tr>
<tr>
<td>867</td>
<td>119.92±09.16</td>
<td>90.37±02.77</td>
<td>4:30 pm</td>
<td>4:57 pm</td>
<td>27.00</td>
</tr>
<tr>
<td>1228</td>
<td>128.35±06.95</td>
<td>93.69±02.29</td>
<td>4:35 pm</td>
<td>5:01 pm</td>
<td>26.00</td>
</tr>
<tr>
<td>1474</td>
<td>129.63±05.18</td>
<td>92.44±02.04</td>
<td>4:38 pm</td>
<td>5:12 pm</td>
<td>34.00</td>
</tr>
<tr>
<td>687</td>
<td>124.92±16.57</td>
<td>88.95±03.21</td>
<td>4:45 pm</td>
<td>5:17 pm</td>
<td>32.00</td>
</tr>
<tr>
<td>858</td>
<td>123.58±06.40</td>
<td>82.81±03.74</td>
<td>4:50 pm</td>
<td>5:26 pm</td>
<td>36.00</td>
</tr>
<tr>
<td>1417</td>
<td>115.92±06.65</td>
<td>91.05±01.06</td>
<td>4:56 pm</td>
<td>5:24 pm</td>
<td>28.00</td>
</tr>
<tr>
<td>1135</td>
<td>128.87±14.49</td>
<td>90.83±04.06</td>
<td>5:05 pm</td>
<td>5:27 pm</td>
<td>22.00</td>
</tr>
<tr>
<td>1320</td>
<td>131.92±12.35</td>
<td>93.12±03.17</td>
<td>5:20 pm</td>
<td>5:45 pm</td>
<td>25.00</td>
</tr>
<tr>
<td>1094±83.44</td>
<td>123.45±02.11</td>
<td>91.08±01.12</td>
<td>-----</td>
<td>-----</td>
<td>29.00±01.36</td>
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</tbody>
</table>
Table 2. Showing the larval longevity (Duration) of *S. obliqua*.

<table>
<thead>
<tr>
<th>Instar</th>
<th>Larval longevity (Duration) hrs. (Mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>62.88±07.66</td>
</tr>
<tr>
<td>II</td>
<td>76.63±07.63</td>
</tr>
<tr>
<td>III</td>
<td>82.63±05.92</td>
</tr>
<tr>
<td>IV</td>
<td>70.25±05.47</td>
</tr>
<tr>
<td>V</td>
<td>75.30±04.97</td>
</tr>
<tr>
<td>VI</td>
<td>69.97±08.36</td>
</tr>
<tr>
<td>Total</td>
<td>62.68±04.95</td>
</tr>
<tr>
<td></td>
<td>80.25±06.78</td>
</tr>
<tr>
<td></td>
<td>63.68±06.25</td>
</tr>
<tr>
<td></td>
<td>58.97±03.34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instar</th>
<th>Larval longevity (Duration) hrs. (Mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>70.32±02.59</td>
</tr>
<tr>
<td>II</td>
<td>82.11±02.24</td>
</tr>
<tr>
<td>III</td>
<td>111.08±04.34</td>
</tr>
<tr>
<td>IV</td>
<td>121.16±03.34</td>
</tr>
<tr>
<td>V</td>
<td>128.33±01.86</td>
</tr>
<tr>
<td>VI</td>
<td>122.69±02.73</td>
</tr>
<tr>
<td>Total</td>
<td>624.42±16.23</td>
</tr>
</tbody>
</table>
Table: 3. Showing the Pupal duration, Adult emergence % and Emergence period of adult of *S. obliqua*.

<table>
<thead>
<tr>
<th>Pupal duration (hrs.)</th>
<th>Adult emergence Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-pupa (Mean ± S.E.)</td>
<td>Pupal stage (Mean ± S.E.)</td>
</tr>
<tr>
<td>71.53±06.02</td>
<td>285.58±10.33</td>
</tr>
<tr>
<td>75.58±07.31</td>
<td>334.25±11.71</td>
</tr>
<tr>
<td>67.92±05.55</td>
<td>132.97±11.10</td>
</tr>
<tr>
<td>65.87±04.23</td>
<td>219.53±12.40</td>
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<td>77.87±07.88</td>
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<td>65.63±05.28</td>
<td>181.25±05.30</td>
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<td>80.68±03.97</td>
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<tr>
<td>59.25±05.57</td>
<td>240.25±10.74</td>
</tr>
<tr>
<td>56.58±03.40</td>
<td>197.53±11.77</td>
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<tr>
<td>84.58±05.40</td>
<td>317.07±11.62</td>
</tr>
<tr>
<td>70.55±02.90</td>
<td>255.14±15.76</td>
</tr>
</tbody>
</table>
Table 4. Showing the Longevity of Mated and Unmated adult of *S. obliqua*

<table>
<thead>
<tr>
<th>Adult Mated Longevity (hrs.)</th>
<th>Adult Unmated Longevity (hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male</strong> (Mean ± S.E.)</td>
<td><strong>Male</strong> (Mean ± S.E.)</td>
</tr>
<tr>
<td>149.87±16.56</td>
<td>182.48±16.45</td>
</tr>
<tr>
<td>171.30±15.13</td>
<td>136.97±12.08</td>
</tr>
<tr>
<td>141.87±17.57</td>
<td>155.53±19.68</td>
</tr>
<tr>
<td>161.68±15.26</td>
<td>175.63±19.34</td>
</tr>
<tr>
<td>175.48±12.79</td>
<td>209.53±16.13</td>
</tr>
<tr>
<td>125.40±09.31</td>
<td>195.25±17.31</td>
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<tr>
<td>135.58±11.84</td>
<td>167.87±16.36</td>
</tr>
<tr>
<td>114.58±11.17</td>
<td>151.58±16.31</td>
</tr>
<tr>
<td>158.82±10.59</td>
<td>202.58±17.25</td>
</tr>
<tr>
<td>191.02±14.10</td>
<td>149.63±19.04</td>
</tr>
<tr>
<td><strong>152.56±07.50</strong></td>
<td><strong>172.71±07.77</strong></td>
</tr>
</tbody>
</table>
Table: 5. Showing the Pre-mating, Pre-oviposition, Oviposition and Post-oviposition period of adult female of S. obliqua.

<table>
<thead>
<tr>
<th>Pre-mating period (hrs.) (Mean ± S.E.)</th>
<th>Pre-oviposition period (hrs.) (Mean ± S.E.)</th>
<th>Oviposition period (hrs.) (Mean ± S.E.)</th>
<th>Post-oviposition period (hrs.) (Mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.53±03.30</td>
<td>22.53±05.20</td>
<td>87.63±04.99</td>
<td>26.53±05.47</td>
</tr>
<tr>
<td>16.58±03.91</td>
<td>24.68±05.28</td>
<td>88.25±06.44</td>
<td>35.48±06.44</td>
</tr>
<tr>
<td>23.87±04.24</td>
<td>26.63±07.01</td>
<td>78.53±04.36</td>
<td>51.20±03.51</td>
</tr>
<tr>
<td>13.02±03.31</td>
<td>20.30±03.16</td>
<td>77.92±09.33</td>
<td>46.40±07.93</td>
</tr>
<tr>
<td>19.53±03.55</td>
<td>35.73±07.36</td>
<td>109.02±09.86</td>
<td>25.25±04.06</td>
</tr>
<tr>
<td>07.92±02.74</td>
<td>18.82±04.17</td>
<td>73.48±06.45</td>
<td>23.58±05.56</td>
</tr>
<tr>
<td>24.92±04.74</td>
<td>35.35±05.30</td>
<td>122.48±05.84</td>
<td>27.73±05.82</td>
</tr>
<tr>
<td>16.68±02.86</td>
<td>20.30±03.84</td>
<td>71.20±08.08</td>
<td>30.63±05.50</td>
</tr>
<tr>
<td>15.10±05.59</td>
<td>25.87±04.82</td>
<td>94.53±09.66</td>
<td>40.82±07.18</td>
</tr>
<tr>
<td>25.35±03.26</td>
<td>31.02±07.52</td>
<td>114.02±05.93</td>
<td>34.25±05.16</td>
</tr>
<tr>
<td>17.36±01.91</td>
<td>26.12±01.94</td>
<td>91.71±05.67</td>
<td>34.19±02.96</td>
</tr>
</tbody>
</table>
PART - B. EFFECT OF MULTINEEM 8 EC AND ACHOOK 0.15 EC ON REPRODUCTIVE BIOLOGY AND BEHAVIOUR

1. INTRODUCTION

Two commercial neem products (Multineem 8 EC and Achook 0.15 EC) were evaluated by spraying method with different concentrations on castor leaves for their biological activities against polyphagous lepidopterous pest, *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae). While multineem was found quite toxic on fifth and sixth instar larvae, achook proved to be more effective in comparison to multineem. Observations on the reproductive potential, mortality and abnormality in larval, pupal and adult forms were made. Similarly, the fecundity and fertility and longevity of adults were also observed and compared with the control. In larvae treated with multineem and achook, the mortality, reproductive period, rate of reproduction and longevity was considerably reduced.

The effects of sub-lethal doses of multineem and achook were studied on *S. obliqua* in the laboratory. Different concentrations of multineem & achook i.e. 0.01%, 0.025%, 0.05% & 0.08% and 0.001%, 0.002%, 0.004% & 0.006% respectively were applied on the castor leaves and provided to two days old fifth instar larvae in three replicates. Each replicate consisting of 20 larvae was subjected to application by spraying method on castor leaves which were subsequently offered to fifth and sixth instar larvae. On a parallel basis three replicates of same stage and age untreated larvae were maintained as control. The results obtained on mortality, longevity of larvae, emergence and longevity of adults, fertility and fecundity, pupal and adult malformations and unhatched pupa, pre-oviposition, oviposition and post-oviposition period of treated *S. obliqua* are presented.
2. OBSERVATION & RESULTS (Treated with Multineem)

Application of different doses viz., 0.01%, 0.025%, 0.05% and 0.08% multineem through spray as well as feeding method was made. Their effect on mortality, longevity of larvae, adult emergence, longevity of adult, fertility, fecundity, malformation and unhatched pupa, pre-oviposition, oviposition and post-oviposition period of *S. obliqua* was recorded. The effect of neem extract on larval behaviour were visually observed and studied under laboratory conditions. It was visualized that multineem has significant effect on larval stages understudy (fifth & sixth instar).

The moulting behaviour of the fifth and sixth instar larvae of *S. obliqua* with different concentrations of multineem was studied. Twenty newly moulted fifth instar larvae were kept individually in separate rearing glass jars having above-mentioned concentrations of multineem to test the feeding efficiency and preference if any. It was observed that the treatment caused the larva to stop feeding, become sluggish and dark in colour before moulting. The excuviae were observed having shrunken outer exoskeleton consisting of chitinous covering of hairy skin of the larvae. The total number of moults that the larva undergoes during post-embryonic development and the duration of fifth and sixth instar varied considerably with different concentrations. The results indicate that the number of instar is generally not affected by low concentrations of multineem. However, slight change in the duration of larval instar has been noticed with 0.05 & 0.08% multineem where duration of instar was extended of even shortened. These changes were however not found significant.
2.1. EFFECT ON MORTALITY OF FIFTH & SIXTH INSTAR LARVAE

2.1.1. Fifth Instar larvae  (Table-6, Fig. 119)

Different concentrations of 0.01%, 0.025%, 0.05% and 0.08% multineem were used against two days old fifth instar larvae with castor leaves. The average mortality of fifth instar larvae of *S. obliqua* was 14.66 ± 03.57%, 23.33 ± 04.24%, 26.28 ± 04.86% and 32.42 ± 04.53% against respective concentrations. The results obtained by 0.08% concentration was quite significant (*t*=02.963, *P>*0.05). 0.01% concentration show no significant effect (*t*=01.997, *P>*0.05) and other two treatments of 0.025 & 0.05% gave good results (*t*=02.511, *P>*0.05) & (*t*=02.550, *P>*0.05) when compared with the control (03.97 ± 01.08).

2.1.2. Sixth Instar larvae  (Table 6, Fig. 119)

Above mentioned concentrations were applied and continued on same replicate up to full mature sixth instar larvae. The average mortality of sixth instar larvae was obtained as 10.82 ± 02.20%, 17.60 ± 03.25%, 27.43 ± 03.57% and 29.01± 02.73% against respective concentration. High mortality (29.01 ± 02.73%) was recorded by 0.08% concentration which was quite significant (*t*=03.446, *P>*0.05). First two treatment 0.01 & 0.025%, presented no significant results (*t*=02.028, *P>*0.05) and (*t*=02.416, *P>*0.05) but 0.05% concentration was significant (*t*=03.017, *P>*0.05) when compared with the control (03.13 ± 01.05).

Results presented in Table-6, Fig. 119 showed that the average total mortality of fifth and sixth instar larvae up to pupal stage was 25.48%, 40.93%, 53.71% and 61.43% against respective concentrations, the last two concentrations (0.05 & 0.08%) were more effective than the first two doses (0.01 & 0.02%). Thus, it could be concluded that higher concentration of multineem (0.08%) gives higher mortality when compared with the control (07.10)
2.2. EFFECT ON LONGEVITY OF FIFTH & SIXTH INSTAR LARVAE

2.2.1. Fifth Instar larvae  (Table-6, Fig. 121)

The effect of different doses of 0.01%, 0.025%, 0.05% and 0.08% multineem were recorded on the larval longevity during fifth instar. Reduced longevity as 116.15 ± 04.11 hours, 97.20 ± 04.88 hours, 89.07 ± 06.13 hours and 76.20 ± 06.40 hours were obtained against respective concentrations. Longevity was greatly shortened (76.20 ± 06.40 hours) by 0.08%. 0.01% concentration proved insignificant (t=01.911, P<0.05) but the other three higher concentrations (0.025, 0.05 & 0.08%) showed significant results (t=02.492, P>0.05), (t=02.588, P>0.05) and (t=02.870, P>0.05) against respective doses when compared with the control (139.30 ± 06.86).

2.2.2. Sixth Instar larvae  (Table-6, Fig. 121)

The concentrations, which were applied on castor leaves and provided to the fifth instar larvae, were continued on the sixth instar larvae up to pupal stage. The higher concentration proved highly effective and the larval longevity was adversely affected being 111.35 ± 05.05 hours, 94.53 ± 06.26 hours, 88.30± 05.92 hours and 73.40 ± 07.36 hours against respective applications. However, the 0.01% concentration proved to be insignificant (t=01.966, P<0.05), whereas 0.025%, 0.05% and 0.08% concentrations were found significant (t=02.497, P>0.05), (t=02.744, P>0.05) and (t=02.974, P>0.05) when compared with the control (131.68 ± 04.06).

2.3. EFFECT ON MATED & UNMATED ADULT LONGEVITY

Newly emerged adults were reared normally. The treated & untreated adults were observed for longevity, fecundity and fertility.
2.3.1. Mated Male  (Table-8, Fig. 123)

The effect on the longevity of mated males following the application of different concentrations of multineem viz., 0.01%, 0.025%, 0.05% and 0.08% have been noted. While 0.01% dose was slightly reduced as 145.92 ± 04.66 and insignificant (t= 01.911, P<0.05). Other three higher concentrations (0.025, 0.05 and 0.08%) greatly reduced their longevity as 127.92 ± 03.80 hours, 123.73 ± 06.04 hours and 110.87 ± 04.32 hours with respective concentrations which was found statistically significant (t=02.586, P>0.05), (t=02.472, P>0.05) & (t=02.981, P>0.05) when compared with the control (171.58 ± 07.51).

2.3.2. Mated Female  (Table-8, Fig. 123)

Following the applications of 0.01%, 0.025%, 0.05% and 0.08% concentrations, longevity was recorded as 158.63 ± 06.07 hours, 146.97 ± 05.32 hours, 133.87 ± 04.29 hours and 128.92 ± 05.20 hours against respective concentrations. While 0.01 and 0.025% multineem had no significant effect (t=01.614, P<0.05), (t=02.021, P<0.05). 0.05 and 0.08% concentrations were found highly effective and significant (t=02.452, P>0.05) & (t=02.495, P>0.05) when compared with the respective control (182.25 ± 09.65).

2.3.3. Unmated Male  (Table-8, Fig. 124)

The spraying application of multineem at 0.01%, 0.025%, 0.05% and 0.08% concentrations on the castor leaves and provided to the fifth and sixth instar larvae of *S. obliqua* up to pre-pupal stage were recorded. The longevity of unmated male was 133.97 ± 04.40 hours, 122.07 ± 04.06 hours, 113.92 ± 03.52 hours and 107.58 ± 06.47 hours against respective concentrations. While 0.025%, 0.05% and 0.08% concentrations were found statistically significant (t=02.667, P>0.05), (t=02.995, P>0.05) & (t=02.781, P>0.05) the minimal dose
i.e. 0.01% proved insignificant (t=0.219, P<0.05) when compared with the respective control (163.97 ± 06.15).

2.3.4. Unmated Female  (Table-8, Fig. 124)

The concentrations 0.01 and 0.025% of multineem remained less effective on the unmated female as the longevity observed was 155.68 ± 04.27 and 143.25 ± 02.92 hours against respective concentrations but insignificant (t=0.728, P<0.05) & (t=0.376, P<0.05). However, the other doses of multineem viz., 0.05 and 0.08% were found highly effective reducing the longevity significantly 132.53 ± 03.18 and 125.02 ± 04.24 hours as (t=0.718, P>0.05) & (t=0.803, P>0.05) when compared with respective control (174.58 ± 06.69).

2.4. EFFECT ON FECUNDITY  (Table-10, Fig. 127)

Different concentrations of multineem (0.01%, 0.025%, 0.05% and 0.08%) were applied on the castor leaves and provided to the fifth and sixth instar of S. obliqua up to pupal stage. Each emerged female adult moth laid average 609 ± 67.25, 556 ± 43.02, 363 ± 30.73 & 304 ± 27.97 eggs with the respective concentrations, which was significantly lower than the control. Average number of eggs laid by the single female derived from untreated larvae was 1182 ± 211.59. The dose i.e. 0.08% was found statically significant (t=0.520, P>0.05) but 0.01%, 0.025% and 0.05% concentrations proved insignificant (t=0.887, P<0.05), (t=0.064, P<0.05) & (t=0.420, P<0.05) when compared with the respective control (1182 ± 211.59).

2.5. EFFECT ON EGGS ECLOSION (FERTILITY)  (Table-10, Fig. 129)

Fertility was observed less than the control. First dose (0.01%) show reduced fertility (59.54 ± 06.55%) but was insignificant (t=0.201, P<0.05).
However, reduction in the fertility 42.12 ± 04.77%, 36.94 ± 05.92% and 24.70 ± 05.38% against respective doses were also statistically significant (t=03.261, P>0.05), (t=03.209, P>0.05) and (t=03.646, P>0.05) when compared with the respective control (93.15 ± 03.54).

2.6. EFFECT ON MALFORMATION (Table-10, Fig. 129)

The malformed pre-pupae, pupae and adult developed due to abnormal moulting and other physiological disturbances. Fifth and sixth instar larvae up to pupal stage were treated with different concentrations (0.01%, 0.025%, 0.05% and 0.08%) of multineem. Malformed adults emerged from treated pupa were 15.02 ± 03.30%, 13.84 ± 03.14%, 10.27 ± 03.15% and 08.21 ± 02.77% by respective concentrations. However, 0.01 and 0.025% concentrations were statistically significant (t=02.517, P>0.050) and (t=02.454, P>0.05) but 0.05 & 0.08% concentrations were insignificant (t=02.047, P<0.05) and (t=01.879, P<0.05) when compared with the control (02.10 ± 00.23).

The affected larvae were smaller in size. Only partial emergence of adults was observed in some abnormal pupae. These adults could manage only partial emergence from the pupal case and eventually died in their chamber. In addition, various other types of larval, pupal adult deformities were recorded. Pupal deformities usually begin at the 5th and 6th instar larval moulting. The affected individuals were unable to shed their old cuticle and died in phorate condition. The adult deformities were seen in the form of reduction, curled, crumpled and incompletely formed wings. Such individuals are called ‘adultoids’ which are unable to fly. Some of the adultoids failed even to shed their exuviae, which remained attached to their legs or crumpled wings.
2.7. EFFECT ON UNHATCHED PUPAE  (Table-10, Fig. 129)

Following the application of 0.01%, 0.025%, 0.05%, 0.08% concentrations against the fifth & sixth instar larvae, varying percentage of unemerged pupae were obtained. These treatments adversely affected the pupal formation. Against these treatment 13.05 ± 01.13%, 16.39 ± 02.00%, 18.25 ± 03.45% and 19.31 ± 01.85% unemerged pupae were obtained. 0.05% was not significant (t=02.314, P<0.05) while other three doses were very effective and unemerged pupal percentage was statistically significant (t=02.662, P>0.05), (t=02.631, P>0.05) & (t=03.025, P>0.05) respectively concentrations (0.01%, 0.025% & 0.08%) when compared with the control (04.76 ± 00.91).

2.8. EFFECT ON PUPAL LONGEVITY  (Table-10, Fig. 127)

The longevity of pupae treated with 0.01%, 0.025%, 0.05% & 0.08% was 296.02 ± 12.21 hours, 319.58 ± 11.32 hours, 348.53 ± 12.78 hours and 357.87 ± 10.74 hours respectively. Longevity of pupae was increased but all the doses were insignificant (t=00.331, P<0.05), (t=01.429, P<0.05), (t=02.032, P<0.05) & (t=02.308, P<0.05) respectively when compared with the control (294.63 ± 09.82).

2.9. EFFECT ON ADULT EMERGENCE  (Table-12, Fig. 131)

With the application of 0.01%, 0.025%, 0.05% and 0.08% concentrations of multineem on the castor leaves and provided to the fifth and sixth instar larvae up to pre-pupal stage, average adult emergence was 41.25 ± 05.38%, 25.92 ± 03.59%, 21.87 ± 04.31% and 15.26 ± 02.22% against respective concentrations. The results were found significant (t=02.985, P>0.05), (t=03.851, P>0.05), (t=03.788, P>0.05) and (t=04.638, P>0.05) when compared with the respective control (87.31 ± 03.58).
2.10. EFFECT ON PRE-OVIPOSITION (Table-12, Fig. 131)

Fifth and sixth instar larvae of *S. obliqua* were treated with different concentrations of multineem viz., 0.01%, 0.025%, 0.05% and 0.08% for determining the effect on the pre-oviposition period. The pre-oviposition period decreased to 24.35 ± 03.64 hours, 15.20 ± 03.79 hours, 11.63 ± 01.26 hours, and 09.30 ± 02.00 hours respectively. While 0.01 & 0.025% concentrations had no significant effect (*t*=01.904, *P*<0.05) & (*t*=01.722, *P*<0.05). 0.05 and 0.08% concentrations provided significant results (*t*=02.545, *P*>0.05) and (*t*=02.511, *P*>0.05) when compared with respective control (26.20 ± 02.64).

2.11. EFFECT ON OVIPOSITION (Table-12, Fig. 131)

The oviposition response of mated mature female moths against different concentrations of multineem 8 EC (neem product) was studied. It was observed that with all the concentration oviposition of moth was adversely affected as the total number of eggs laid by treated moth was much lower in comparison to the respective control.

The greater effects were noticed on the oviposition period of moth treated with 0.01%, 0.025%, 0.05% and 0.08% concentrations. All doses reduced oviposition period to 91.73 ± 04.10 hours, 84.92 ± 03.89 hours, 74.58 ± 02.87 hours and 68.53 ± 03.06 hours by respective concentrations. But 0.05 & 0.08% doses are significant (*t*=02.458, *P*>0.05) & (*t*=02.719, *P*>0.050). 0.01 and 0.025% concentrations the oviposition period was insignificant (*t*=01.171, *P*>0.05) & (*t*=01.712, *P*>0.05) when compared with the control (98.02 ± 03.85).

2.12. EFFECT ON POST-OVIPOSITION (Table-12, Fig. 131)

The castor leaves treated with the above concentrations were provided to fifth and sixth instar larvae of *S. obliqua* up to pre-pupal stage. Post-oviposition
period was decreased to $32.20 \pm 0.58$ hours, $27.58 \pm 0.25$ hours, $26.73 \pm 0.92$ hours and $17.43 \pm 0.33$ hours by the respective concentrations. In case of 0.01 and 0.08% concentrations the post-oviposition period was found to be statistically insignificant ($t=0.432$, $P<0.05$), ($t=0.785$, $P<0.05$) and ($t=0.908$, $P<0.05$). However, 0.08% proved significant ($t=2.470$, $P>0.05$) when compared with the control ($38.35 \pm 0.61$).
3. OBSERVATION & RESULTS (Treated with Achook)

An enriched neem formulation (Achook 0.15 EC) containing Nembocinal in the form of aqueous solution has been used. The functional effect of achook was evaluated under laboratory conditions on S. obliqua. Achook also affected the larval and pupal survival as well as adult emergence in a dose dependent manner. Further, achook reduced the larval growth and overall development, prolonged time of pupation, and lowered pupal weight, resulting in the formation of deformed individuals. Field evaluation of the said neem formulation against the insect pests of major crops such as cotton, okra, brinjal, cabbage, jute and castor are undertaken by various workers at different locations in the country.

In the present study, effect of application of different concentrations viz., 0.001%, 0.002%, 0.004% and 0.006% achook was undertaken. Through spray treatment was made on the fifth and sixth instar larvae of S. obliqua. The result on the longevity, malformation of pupae and adult as well as fecundity and fertility of adult were analyzed.

3.1. EFFECT ON MORTALITY OF FIFTH & SIXTH INSTAR LARVAE

The manifestation of abnormal moulting was usually in the terms of larval mortality. Due to toxic effect, abnormal moulting and mortality were recorded with all the concentrations.

3.1.1. Fifth Instar Larvae (Table-7, Fig. 120)

Following the application of 0.001%, 0.002%, 0.004% and 0.006% of achook, it was observed that average mortality was $16.49 \pm 0.32\%$, $24.26 \pm 0.36\%$, $27.93 \pm 0.43\%$ and $29.41 \pm 0.33\%$ respectively. Average mortality of three replicates was more than the untreated larvae. These doses were highly
effective but the lowest dose 0.001% proved insignificant (t=0.247, P<0.05). However, the next three concentrations 0.002%, 0.004% & 0.006% were found to be statistically significant (t=0.731, P>0.05), (t=0.762, P>0.05) and (t=0.171, P>0.05), when compared with the control (0.97 ± 0.08).

3.1.2. Sixth Instar Larvae (Table-7, Fig. 120)

The fifth instar treated replicates were continued up to pre-pupal stage. Average mortality of sixth instar larvae was observed as 11.36 ± 0.41%, 17.27 ± 0.43%, 21.56 ± 0.86% and 24.96 ± 0.09% with the respective concentrations. When 0.001 & 0.002% concentrations of the application were used, mortality percentage of this instar remained insignificant (t=0.034, P<0.05) & (t=0.341, P<0.05). While 0.004 and 0.006% concentrations were found as highly effective (t=0.222, P>0.05) & (t=0.022, P>0.05) when compared with the control (0.13 ± 0.05). A good percentage of sixth instar larvae did not grow to their full size but did change into pre-pupal stage although such larvae could not moult into pupa and eventually died.

The total larval mortality of fifth & sixth instar were recorded as 27.85%, 41.53%, 49.49% and 54.37% by the above respective concentrations, which is significant when compared with the respective control (07.10).

3.2. EFFECT ON LONGEVITY OF FIFTH & SIXTH INSTAR LARVAE

3.2.1. Fifth Instar Larvae (Table-7, Fig. 122)

Castor leaves treated with 0.001%, 0.002%, 0.004% and 0.006% achook concentrations were provided to fifth instar larvae. These were effective on the average longevity during fifth instar period. However, with the applications of all concentrations, the larval duration was considerably reduced 110.92 ± 0.457 hours, 93.35 ± 0.09 hours, 85.25 ± 0.79 hours and 81.92 ± 0.65 hours with
3.2.2. Sixth Instar Larvae (Table-7, Fig. 122)

The observations on the longevity of sixth instar larvae were made with different concentrations of achook. The longevity of sixth instar larvae treated with 0.001% concentration was decreased to 113.10 ± 0.49 hours which was not significant (t=0.1892, P<0.05). However, with 0.002%, 0.004% & 0.006% the longevity was highly reduced 98.25 ± 0.236 hours, 92.68 ± 0.564 hours and 88.58 ± 0.678 hours and proved statistically significant (t=0.2639, P>0.05) and (t=0.2624, P>0.05) when compared with the respective control (131.68 ± 0.04).
0.006% concentration was significant (t=0.2724, P>0.05) when compared with the respective control (171.58 ± 07.51).

3.3.2. Mated Female  (Table-9, Fig. 125)

The longevity of mated female was 140.35 ± 05.02 hours, 134.73 ± 04.94 hours, 131.07 ± 07.48 hours and 130.40 ± 05.20 hours with application of respective above concentrations. While the first two concentrations (0.001 & 0.002%) were statistically insignificant (t=0.2224, P<0.05) and (t=0.2377, P<0.05), the other 0.004 & 0.006% concentrations gave significant result (t=0.2275, P>0.05) and (t=0.2460, P>0.05) when compared with the respective control (182.25 ± 09.65).

3.3.3. Unmated Male  (Table-9, Fig. 126)

Average longevity of unmated adult was 127.92 ± 06.64 hours, 104.25 ± 04.65 hours, 91.12 ± 04.05 hours and 98.02 ± 06.36 hours with 0.001%, 0.002%, 0.004% and 0.006%. The 0.001% concentration was least effective and insignificant (t=0.209, P<0.05) but the other three concentrations gave significant results (t=0.3094, P>0.5), (t=0.3431, P>0.05) & (t=0.3242, P>0.05) when compared with the control (163.97 ± 06.15).

3.3.4. Unmated Female  (Table-9, Fig. 126)

The longevity of unmated female was 146.30 ± 04.65 hours, 118.97 ± 05.17 hours, 110.97 ± 07.88 hours and 96.25 ± 05.91 hours with the above mentioned respective concentrations of achook when compared with emerged untreated female. The concentration 0.001% was statistically insignificant (t=0.2079, P<0.05). Further, all three concentrations of achook showed significant results (t=0.2851, P>0.05), (t=0.2750, P>0.05) and (t=0.282, P>0.05) when compared with the control (174.58 ± 06.69).
3.4. EFFECT ON FECUNDITY  (Table-11, Fig. 128)

The fecundity of F₁ generation was analyzed and was found to be affected by the use of achook applications with different concentrations i.e. 0.001%, 0.002%, 0.004% and 0.006%. Treated female laid 521 ± 81.82, 446 ± 103.45, 318 ± 19.40 and 269 ± 43.92 eggs, which was considerably reduced. The fecundity of emerged female of 0.004 & 0.006% treated insects when compared with the control gave significant results (t=0.2.545, P>0.05) and (t=0.2.488, P>0.05). 0.001 & 0.002% concentrations gave insignificant results (t=0.1.975, P<0.05) and (t=0.2.012, P<0.05) when compared with the control (1182 ± 211.59).

3.5. EFFECT ON EGG ECLOSION (FERTILITY)  (Table-11, Fig. 130)

The fertility of the female of above treated larvae was analyzed. The average fertility was recorded as 50.41 ± 09.73%, 30.23 ± 06.19%, 21.71 ± 04.93% and 16.96 ± 03.87% with respective concentration. Last three (0.002, 0.004 and 0.006%) concentrations were significant (t=03.346, P>0.05), (t=03.822, P>0.05) and (t=04.219, P>0.05) respectively but 0.001% concentration remained insignificant (t=02.362, P<0.05) when compared with the control (93.15 ± 03.54).

3.6. EFFECT ON MALFORMATION  (Table-11, Fig. 130)

Malformation with various degrees in the wings, antennae, legs and whole body of adult that emerged from the affected pupae was observed with the doses of achook 0.15 EC. A large number of emerged adults were with deformed wings. Achook applications with different concentrations i.e. 0.001%, 0.002%, 0.004% and 0.006% resulted in noticeable malformation as 16.29 ± 03.01%, 12.71 ± 03.21%, 11.35 ± 02.41% and 09.59 ± 01.46%. The treatment i.e. 0.001%, 0.004% and 0.006% were statistically significant (t=02.755, P>0.05),
Kybderi/ation and le[ti](t=02.459, P>0.05) and (t=02.765, P>0.05). 0.002% was not significant (t=02.309, P<0.05) when compared with the control (02.10 ± 00.23). Treated larvae of S. obliqua either died within 4-6 days or changed into abnormal intermediates. Like wise affected pupae either remained unemerged or often-produced adults with deformed wings. It also showed certain characteristic symptoms, such as blackening of mouth parts and development of blackened pro-legs with spots on the body or inability of larva to spin a proper cocoon resulting in the formation of a fragile cocoon.

3.7. EFFECT ON UNHATCHED PUPA  (Table-11, Fig. 130)

Sixth instar treated larvae passed into pupal form and the percentage of unemerged pupae were 10.80 ± 01.31%, 19.61 ± 04.13%, 21.84 ± 02.08% and 22.33 ± 03.93%. The result of treatments i.e. 0.001 & 0.002% were statistically insignificant (t=02.172, P<0.05) & (t=02.259, P<0.05) but with the treatment i.e. 0.004 & 0.006% it showed significant results as (t=03.142, P>0.05) & (t=02.509, P>0.05) when compared with the control (04.76 ± 00.91).

3.8. EFFECT ON PUPAL LONGEVITY  (Table-11, Fig. 128)

The effect of different concentrations of achook viz., 0.001%, 0.002%, 0.004% and 0.006% was observed on the longevity of pupae. After treatment longevity was gradually increased to 312.20 ± 13.67 hours, 321.35 ± 18.05 hours, 337.53 ± 08.72 hours and 362.30 ± 10.88 hours with the respective concentrations. But the results with all concentrations were insignificant (t=01.138, P<0.05), (t=01.289, P<0.05), (t=02.002, P<0.05) and (t=02.380, P<0.05) when compared with the control (294.63 ± 09.82).
3.9. EFFECT ON ADULT EMERGENCE  (Table-13, Fig. 132)

The application of 0.001%, 0.002%, 0.004% and 0.006% achook concentrations were used through spray on the castor leaves which were provided to experimental instars. The adult emergence was affected and was found to decrease i.e. 36.25 ± 02.62%, 23.43 ± 03.35%, 19.45 ± 02.28% and 12.44 ± 02.89% with respective concentrations. All the concentrations including the lowest concentration had influenced the adult emergence (t=03.777, P>0.05), (t=03.996, P>0.05), (t=04.481, P>0.05) and (t=04.474, P>0.05) when compared with the control (87.31 ± 03.58).

3.10. EFFECT ON PRE-OVIPOSITION  (Table-13, Fig. 132)

The newly emerged female from fifth and sixth instar larvae treated with 0.001%, 0.002%, 0.004% and 0.006% concentrations of achook. The pre-oviposition period was recorded as 23.20 ± 03.01 hours, 19.68 ± 04.13 hours, 12.15 ± 01.44 hours and 08.58 ± 01.89 hours with the respective concentrations. The pre-oviposition period was decreased with all doses. The three concentrations i.e. 0.001%, 0.002% and 0.004% were statistically insignificant (t=01.806, P<0.05), (t=01.291, P<0.05) & (t=02.440, P<0.05) but 0.006% concentration significant (t=02.698, P>0.05) when compared with the control (26.20 ± 02.64).

3.11. EFFECT ON OVIPOSITION  (Table-13, Fig. 132)

Female adults emerged from pupa where larvae were fed on 0.001%, 0.002%, 0.004% and 0.006% concentrations of achook treated castor leaves showed changed oviposition period. The oviposition period was 82.25 ± 04.69 hours, 80.82 ± 04.61 hours, 71.58 ± 03.35 hours, 64.63 ± 04.22 hours with the respective concentrations. All the treatments caused considerable decrease in the period of oviposition. 0.004 & 0.006% concentrations were significant
(t=02.521, P>0.05) & (t=02.677, P>0.05) whereas 0.001 & 0.002% concentrations were not significant (t=01.789, P<0.05) & (t=01.877, P<0.05) when compared with the control (98.02 ± 03.85).

3.12. EFFECT ON POST-OVIPOSITION  (Table-13, Fig. 132)

The post-oviposition period of treated female was 34.02 ± 05.78 hours, 26.20 ± 03.29 hours, 21.15 ± 02.22 hours and 18.92 ± 02.66 hours. The 0.004 & 0.006% concentrations were highly effective and decreased the post-oviposition period which was statistically significant (t=02.504, P>0.05) & (t=02.528, P>0.05). Other concentrations (0.001 & 0.002%) insignificantly decreased the post-oviposition period (t=00.946, P<0.05), (t=01.882, P<0.05) when compared with the control (38.35 ± 02.61).
4. DISCUSSION

There are numerous reports that azadirachtin when applied topically prolongs larval period, arrests growth, development and causes mortality (Ruscoe, 1972; Rembold et al., 1981; Ladd et al., 1984). The effects are attributed mainly to azadirachtin interference with endocrine system. Azadirachtin however, has no direct toxicity (Schluter et al., 1985). The present investigation throws enough light on the eco-friendly insecticides, Multineem 8 EC and Achook 0.15 EC which show encouraging results on the control of Spilosoma obliqua. The mortality, longevity rate of reproduction, larval period, fertility and fecundity were greatly affected on treatment with 0.01%, 0.025%, 0.05% and 0.08% concentrations of multineem. The larval mortality with multineem treatment was greatly increased as compared to control such as in fifth instar 14.66 ± 03.57%, 23.33 ± 04.24%, 26.28 ± 04.86% and 32.42 ± 04.53%, and in sixth instar 10.82 ± 02.20%, 17.60 ± 03.25%, 27.43 ± 03.57% and 29.01 ± 02.73% whereas total mortality of fifth and sixth instar as 25.48%, 40.93%, 53.71% and 61.43% with respective concentration of multineem. Similarly, achook concentrations viz., 0.001%, 0.002%, 0.004% and 0.006% showed mortality of fifth instar larvae as 16.49 ± 03.22%, 24.26 ± 03.64%, 27.93 ± 04.36% and 29.41 ± 03.30% and in sixth instar larvae as 11.36 ± 02.41%, 17.27 ± 03.43%, 21.56 ± 03.86% and 24.96 ± 03.09%. Therefore, total mortality of fifth and sixth instar larvae of S. obliqua was increased as 27.85%, 41.53%, 49.49% and 54.37% with respective concentrations of achook. With the increase in concentration, the percentage mortality also increased which means that mortality is concentration (dose) dependent. In the present study, the laboratory results were in agreement with those of Saxena et al. (1981); Schmutterer et al. (1983); Agrawal and Mall (1988); Mikalajczak et al. (1989); Tanzubil & McCaffery (1990); Bhathal & Singh (1993); AliNiazee et al. (1997) and Srivastava et al. (1997). Pandey et al. (1987) reported that in Lipaphis erysimi (Kalt.) treated with
Azadirachta indica mortality ranged from 53.33 to 60.00% at 0.5% concentration, 63.33 to 80.00% at 1.0% concentration and 80.00 to 86.66% at 1.5% concentration. Similarly, Raman et al. (1993) reported that mortality in Earias vitella was 41.18% at 0.5% concentration, 59.41% at 1.0% concentration, 64.71% at 2.0% concentration and 88.24% at 3.0% concentration and in Helicoverpa armigera (Huber) 100.00% at 0.5% concentration, 100.00% at 1.0% concentration and 100.00% at 2.0% concentration of achook.

Data relating to the experiment were subjected to statistical analysis. The longevity of fifth and sixth instar, treated with 0.01%, 0.025%, 0.05% and 0.08% concentrations of multineem were analyzed. The fifth instar larval longevity was 116.15 ± 04.11 hours, 97.20 ± 04.88 hours, 89.07 ± 06.13 hours and 76.20 ± 06.40 hours and sixth instar larval longevity was 111.35 ± 05.05 hours, 94.53 ± 06.26 hours, 88.30 ± 05.92 hours and 73.40 ± 07.36 hours with respective concentrations of multineem. Application of 0.001%, 0.002%, 0.004% and 0.006% of achook reduced the longevity of fifth instar larvae as 110.92 ± 04.57 hours, 93.35 ± 06.09 hours, 85.25 ± 07.29 hours and 81.92 ± 06.65 hours, and sixth instar larvae to 113.10 ± 04.94 hours, 98.25 ± 02.36 hours, 92.68 ± 05.64 hours and 88.58 ± 06.78 hours with respective concentration of achook. Results obtained show that increase in concentration of both the insecticides reduce the larval longevity. But some workers reported that the increase of concentration also increases the longevity (Koul, 1984 and Saradamma et al., 1993). Jhansi and Singh (1993) reported that in H. armigera treated with Azadirachta indica A. Juss total larval longevity ranged from 15 to 45 days on different extracts. Similarly, Jeyabalan and Murugan (1997) recorded that larval longevity (days) in H. armigera was 12.0 with deacetylnimbin (150 ppm), 12.3 with 17-hydroxyazadiradione (30 ppm), 12.5 with gedunin (25 ppm), 13.0 with salannin (12 ppm) and 13.4 with deacetylgedunin (10 ppm) in comparison to 11 days (control).
Impact of various concentrations (0.01%, 0.025%, 0.05% and 0.08%) of multineem on the different aspects of adult longevity varied from 145.92 ± 0.466 to 110.87 ± 0.32 hours (mated male), 158.63 ± 0.670 to 128.92 ± 0.520 hours (mated female), 133.97 ± 0.440 to 107.58 ± 0.47 hours (unmated male) and 155.68 ± 0.427 to 125.02 ± 0.24 hours (unmated female). Similarly, significant reduction in adult longevity was obtained with achook treatment (0.001%, 0.002%, 0.004% and 0.006%) and it varied from 155.97 ± 0.487 to 112.53 ± 0.628 hours (mated male), 140.35 ± 0.052 to 130.40 ± 0.520 hours (mated female), 127.92 ± 0.664 to 98.02 ± 0.366 hours (unmated male) and 146.30 ± 0.465 to 96.25 ± 0.591 hours (unmated female). Present observations are in conformity with Saradamma *et al.* (1993). Murugan *et al.* (1993) recorded adult longevity in *Heliothis armigera* as 9.81 ± 0.285 (days) with 1% NSKE and 7.64 ± 0.447 (days) with 0.5% neem oil. Jeyabalan and Murugan (1997) reported adult male and female longevity of *H. armigera* treated with deacetylnimbin-6.00 and 7.23 days, with 17-hydroxyazadiradione-5.83 and 7.00 days, with gedunin- 5.51 and 6.85 days, with salannin 5.00 and 6.23 days and with deacetylgedunin-4.85 and 5.81 days.

In the present study neem products not only affected mortality and longevity but fecundity as well. Multineem concentrations (0.01%, 0.025%, 0.05% and 0.08%) and achook (0.001%, 0.002%, 0.004% and 0.006%) greatly affected the fecundity which was 609 ± 67.25, 556 ± 43.02, 363 ± 30.73, 304 ± 27.97 and 521 ± 81.82, 446 ± 103.43, 318 ± 19.40, 269 ± 43.92 respectively with the compared control (1182 ± 211.59). Murugan *et al.* (1993) also reported reduced fecundity in various insects as a result of juvenoid application. Fagoonee (1981) working with *Cricidolomia binatalis* reported a 20% reduction in egg laying with 2% concentration of the methanolic extract of neem seed kernel. Koul (1984) observed that after administration of azadirachtin, *Dysdercus koenigii* females showed trophocytes damage. Likewise azadirachtin affected ovaries in the last instar nymphs of *Oncopeltus fasciatus* (Dorn *et al.*, 1986) and
locustae (Rembold et al., 1987). Decreased fecundity and oocyte development could thus be a consequence of impaired vitellogenin synthesis and its uptake by the developing oocyte (Ludlum and Sieber, 1988). Ayyanagar and Rao (1989) reported that in *Spodoptera litura* the ovipositional deterrence of hexane extract (0.018%) lasted only for four days while in methanol extract it continued for more than five days. Saradamma et al. (1993) reported that the fecundity was significantly lowered with extracts of *Adathoda vesica* (5%), *Leucas aspera* (6.72%), *A. indica* (11.6%), *Theratia nerufolia* (12.1%) and *Nerium oleander* (12.38%) on *D. cingulatus*.

Fertility of eggs laid by treated adult moth of *S. obliqua* varied from 59.54 + 06.55 to 24.70 + 05.38% (multineem) and 50.41 + 09.73 to 19.96 + 03.87% (achook) against control (93.15 + 03.54). Neem products caused the production of some non-viable eggs. The average fecundity was also higher in control than in experimental groups. This finding is in conformity with those of Pandey et al. (1987); Murugan et al. (1993) and Saradamma et al. (1993). Neem oil is also reported to reduce egg hatching of *Callosobruchus* spp. (Luca, 1982; Yadava, 1985 and Ali et al., 1983). Jhansi and Singh (1993) reported that while CHEDK and EtoHSHE of different extracts caused substantial mortality of eggs the others had little effect in *H. armigera*.

Neem products not only affected the reproductive biology of *S. obliqua* but also caused deformed pupae and adults. Multineem and achook were toxic at high concentration but showed malformation of pupae-adults intermediates which increased at 0.01%, 0.025%, 0.05% and 0.08% (multineem) and 0.001%, 0.002%, 0.004% and 0.006% (achook) such as 15.02 + 03.30%, 13.84 + 03.14%, 10.27 + 03.15%, 08.21 + 02.77% and 16.29 + 03.01%, 12.71 + 03.21%, 11.35 + 02.41%, 09.59 + 01.46% with respective concentrations of insecticides against 02.10 + 00.23% (control). The malformed adults were characterized by twisted and crumpled wings, shrunken abdomen and in extreme cases, there were patches of de-scaled cuticle in abdominal region. Failure of separation of
pupal exuviae from adult during metamorphosis was also observed. The abnormal adults were found to have shorter life span than normal adult moths. These results are similar to those reported in *Ephestia kuehniella* where reproduction of abnormal adults on pupal treatment with azadirachtin was reported (Rembold *et al.*, 1980, 1981 & 1982; Sharma *et al.*, 1980) and in *S. litura* (Gujar and Mehrotra, 1983). Similarly growth regulatory type effects have been demonstrated for other lepidopterans (Schmutterer, 1990), in *Lipaphis erysimi* (Bhathal and Singh, 1993), in *D. cingulatus* treated with juvenile hormone (Saradamma *et al.*, 1993) and in *Archips rosanus* with neem insecticide (Ali-Niazee *et al.*, 1997).

In the present study *S. obliqua* treated with multineem and achook greatly affected and considerably reduced pre-oviposition, oviposition and post-oviposition period. Lower concentrations of both insecticides were less effective, but higher concentrations produced significant results. Although such studies have not been conducted so far, but the biological parameters are broadly in agreement with those of Murugan *et al.* (1993) in *Heliothis armigera*, Jeyabalan and Murugan (1997) in *Helicoverpa armigera*.
5. SUMMARY

1. Two commercial neem products (Multineem 8 EC and Achook 0.15 EC) were evaluated by spray method with different concentrations i.e., 0.01%, 0.025%, 0.05%, 0.08% and 0.001%, 0.002%, 0.004%, 0.006% respectively on castor leaves for their biological activity against *Spilosoma obliqua* Walker.

2. Multineem was quite toxic, but achook proved to be more effective when compared to the control against different aspects of biology of *S. obliqua* in the laboratory.

3. The observations on mortality, longevity of larvae & adults, adult emergence, fertility and fecundity pupal and adult malformation and unhatched pupa, pre-oviposition, oviposition and post-oviposition etc., have been presented.

**Multineem treated**

4. Different concentration of 0.01%, 0.025%, 0.05% and 0.08% multineem were used with castor leaves against two days old fifth instar larvae upto the beginning of pre-pupal stage.

5. The total average mortality of fifth & sixth instar larvae was 25.48, 40.93, 53.71 and 61.43% against respective concentrations, the last two concentrations 0.05 & 0.08% were more effective than the 0.01 & 0.025%, when compared with the control (07.10).

6. The fifth instar larva reduced longevity as 116.15 ± 04.11, 97.20 ± 04.88, 89.07± 06.13 & 76.20 ± 06.40 hours were obtained against respective concentrations when compared with the control (139.30 ± 06.86).
7. The sixth instar larval longevity was adversely affect being 111.35 ± 05.05, 94.53 ± 06.26, 88.30 ± 05.92 & 73.40 ± 07.36 hours against respective treatment when compared with the control (131.68 ± 04.06).

8. Mated & unmated adult longevity were affected and considerably reduced as compared to control. The higher concentration proved highly effective and gave significant results compared to lower concentrations.

9. Multineem treated adult moth laid average of 609 ± 67.25, 556 ± 43.02, 363 ± 30.73 & 304 ± 27.97 eggs with the respective concentrations when compared with the control (1182 ± 211.59).

10. The average fertility was 59.54 ± 06.55, 42.12 ± 04.77, 36.94 ± 05.92 and 24.70 ± 05.38% against respective concentrations when compared with the control (93.15 ± 03.54).

11. Malformed adults emerged from treated larvae were 15.02 ± 03.30, 13.84 ± 03.14, 10.27 ± 03.15 and 08.21 ± 02.77% by respective concentrations when compared with the control (02.10 ± 00.23).

12. Pupal longevity was increased but all doses were insignificant. However, longevity was 296.02 ± 12.21, 319.58 ± 11.32, 348.53 ± 12.78 and 357.87 ± 0.74 hours against respective concentrations. When compared with the control (294.63 ± 09.82).

13. The adult emergence was 41.25 ± 05.38, 25.92 ± 03.59, 21.87 ± 04.31 & 15.26 ± 02.22% against respective concentrations. The results found were significant when compared with the control (87.31 ± 03.58).
14. The pre-oviposition period decreased to 24.35 ± 03.64, 15.20 ± 03.79, 11.63 ± 01.26 & 09.30 ± 02.00 hours respectively when compared with the control (26.20 ± 02.64).

15. The greater effects were noticed on the oviposition period. All doses reduced the oviposition period which was 91.73 ± 04.10, 84.92 ± 03.89, 74.58 ± 02.87 and 68.53 ± 03.06 hours by respective concentrations when compared to control (98.02 ± 03.85).

16. Post-oviposition period was also decreased to 32.20 ± 02.58, 27.58 ± 03.25, 26.73 ± 02.92 & 17.43 ± 03.33 hours by the respective concentrations when compared to control (38.35 ± 02.61).

**Achook Treated**

17. In the present study, effect of application of different concentrations of Achook 0.15 EC viz., 0.001%, 0.002%, 0.004% and 0.006% was studied.

18. The total larval motility of fifth & sixth instar treated with different selected concentrations of achook were recorded as 27.85, 41.53, 49.49 and 54.37% respectively, which are significant when compared with the control (07.10).

19. The fifth instar larval duration was considerably reduced, 110.92 ± 04.57, 93.35 ± 06.09, 85.25 ± 07.29 and 81.92 ± 06.65 hours with respective concentration when compared with control (139.30 ± 06.86). Also highly reduced sixth instar larval longevity as 113.10 ± 04.94, 98.25 ± 02.36, 92.68 ± 05.64 and 88.58 ± 06.78 hours respectively as compared to control (131.68 ± 04.06).

20. Longevity of mated & unmated adult moth emerged from treated larvae with different concentrations of achook was considerably reduced. The higher concentrations proved statistically significant as compared to the control.
21. The fecundity of emerged female from treated larvae was reduced as 521 ± 81.82, 446 ± 103.45, 318 ± 19.40 and 269 ± 43.92 eggs when compared with the control (1182 ± 211.59).

22. The average fertility was reduced as 50.41 ± 09.73, 30.23 ± 06.19, 21.71 ± 04.93 and 16.96 ± 03.87 with respective treatments when compared with the control (93.15 ± 03.54).

23. Malformed adult percentage was increased as 16.29 ± 03.01, 12.71 ± 03.21, 11.35 ± 02.41 and 09.59 ± 01.46% respectively as compared with the control (02.10 ± 00.23).

24. The pupal longevity was gradually increased to 312.20 ± 13.67, 321.35 ± 18.05, 337.53 ± 08.72 and 362.30 ± 10.88 hours, with respective concentrations when compared with the control (294.63 ± 09.82).

25. The adult emergence was affected and was found to decrease i.e. 36.25 ± 02.62, 23.43 ± 03.35, 19.45 ± 02.28 and 12.44 ± 02.89% with respective doses. All the doses including the lowest dose had influenced the adult emergence when compared to the control (87.31 ± 03.58).

26. Pre-oviposition, oviposition and post-oviposition period was greatly reduced.
Table: 6. Showing the Mortality and Longevity of V & VI instar larvae of *S. obliqua* treated with Multineem 8 EC.

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Treatment</th>
<th>Concentration (%)</th>
<th>V Instar (Mean ± S.E.)</th>
<th>VI Instar (Mean ± S.E.)</th>
<th>Total V &amp; VI Instar</th>
<th>V Instar (Mean ± S.E.)</th>
<th>VI Instar (Mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multineem (8 EC)</td>
<td>A₁</td>
<td>0.01</td>
<td>14.66±0.357 (t=01.997)</td>
<td>10.82±0.20 (t=02.028)</td>
<td>25.48</td>
<td>116.15±04.11 (t=01.911)</td>
<td>111.35±05.05 (t=01.966)</td>
</tr>
<tr>
<td></td>
<td>A₂</td>
<td>0.025</td>
<td>23.33±04.24 (t=02.511)</td>
<td>17.60±03.25 (t=02.416)</td>
<td>40.93</td>
<td>97.20±04.88 (t=02.492)</td>
<td>94.53±06.26 (t=02.497)</td>
</tr>
<tr>
<td></td>
<td>A₃</td>
<td>0.05</td>
<td>26.28±04.86 (t=02.550)</td>
<td>27.43±03.57 (t=03.017)</td>
<td>53.71</td>
<td>89.07±06.13 (t=02.588)</td>
<td>88.30±05.92 (t=02.744)</td>
</tr>
<tr>
<td></td>
<td>A₄</td>
<td>0.08</td>
<td>32.42±04.53 (t=02.963)</td>
<td>29.01±02.73 (t=03.446)</td>
<td>61.43</td>
<td>76.20±06.40 (t=02.870)</td>
<td>73.40±07.36 (t=02.974)</td>
</tr>
<tr>
<td>Control (Untreated)</td>
<td>C</td>
<td>----</td>
<td>03.97±01.08</td>
<td>03.13±01.05</td>
<td>07.10</td>
<td>139.30±06.86</td>
<td>131.68±04.06</td>
</tr>
</tbody>
</table>
Table 7. Showing the Mortality and Longevity of V & VI instar larvae of *S. obliqua* treated with Achook 0.15 EC.

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Treatment</th>
<th>Concentration (%)</th>
<th>V Instar (Mean ± S.E.)</th>
<th>VI Instar (Mean ± S.E.)</th>
<th>Total V &amp; VI Instar</th>
<th>V Instar (Mean ± S.E.)</th>
<th>VI Instar (Mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achook (0.15 EC)</td>
<td>B₁</td>
<td>0.001</td>
<td>16.49±0.322</td>
<td>11.36±0.241</td>
<td>27.85</td>
<td>110.92±0.457</td>
<td>113.10±0.494</td>
</tr>
<tr>
<td></td>
<td>B₂</td>
<td>0.002</td>
<td>24.26±0.364</td>
<td>17.27±0.343</td>
<td>41.53</td>
<td>93.35±0.609</td>
<td>98.25±0.236</td>
</tr>
<tr>
<td></td>
<td>B₃</td>
<td>0.004</td>
<td>27.93±0.364</td>
<td>21.56±0.386</td>
<td>49.49</td>
<td>85.25±0.729</td>
<td>92.68±0.564</td>
</tr>
<tr>
<td></td>
<td>B₄</td>
<td>0.006</td>
<td>29.41±0.30</td>
<td>24.96±0.309</td>
<td>54.37</td>
<td>81.92±0.665</td>
<td>88.58±0.786</td>
</tr>
<tr>
<td>Control (Untreated)</td>
<td>C</td>
<td>----</td>
<td>03.97±0.108</td>
<td>03.13±0.015</td>
<td>07.10</td>
<td>139.30±0.866</td>
<td>131.68±0.046</td>
</tr>
</tbody>
</table>
Table 8. Showing the Adult Longevity of *S. obliqua* treated with Multineem 8 EC.

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Treatment</th>
<th>Concentration (%)</th>
<th>Adult Longevity (hrs.)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mated</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Unmated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Mean ± S.E.)</td>
<td>(Mean ± S.E.)</td>
<td>(Mean ± S.E.)</td>
<td>(Mean ± S.E.)</td>
<td>(Mean ± S.E.)</td>
</tr>
<tr>
<td>Multineem (8 EC)</td>
<td>A₁</td>
<td>0.01</td>
<td>145.92±04.66</td>
<td>158.63±06.07</td>
<td>133.97±04.40</td>
<td>155.68±04.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A₂</td>
<td>0.025</td>
<td>127.92±03.80</td>
<td>146.97±05.32</td>
<td>122.07±04.06</td>
<td>143.25±02.92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A₃</td>
<td>0.05</td>
<td>123.73±06.04</td>
<td>133.87±04.29</td>
<td>113.92±03.52</td>
<td>132.53±03.18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A₄</td>
<td>0.08</td>
<td>110.87±04.32</td>
<td>128.92±05.20</td>
<td>107.58±06.47</td>
<td>125.02±04.24</td>
<td></td>
</tr>
<tr>
<td>Control (Untreated)</td>
<td>C</td>
<td>-----</td>
<td>171.58±07.51</td>
<td>182.25±09.65</td>
<td>163.97±06.15</td>
<td>174.58±06.69</td>
<td></td>
</tr>
</tbody>
</table>
Table: 9. Showing the Adult Longevity of S. obliqua treated with Achook 0.15 EC.

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Treatment</th>
<th>Concentration (%)</th>
<th>Adult Longevity (hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male (Mean ± S.E.)</td>
</tr>
<tr>
<td>Achook (0.15 EC)</td>
<td>B₁</td>
<td>0.001</td>
<td>155.97±04.87 (t=01.478)</td>
</tr>
<tr>
<td></td>
<td>B₂</td>
<td>0.002</td>
<td>138.12±04.98 (t=02.154)</td>
</tr>
<tr>
<td></td>
<td>B₃</td>
<td>0.004</td>
<td>125.48±06.47 (t=02.390)</td>
</tr>
<tr>
<td></td>
<td>B₄</td>
<td>0.006</td>
<td>112.53±06.28 (t=02.724)</td>
</tr>
<tr>
<td>Control (Untreated)</td>
<td>C</td>
<td>------</td>
<td>171.58±07.51</td>
</tr>
</tbody>
</table>
Table: 10. Showing the No. of laid eggs (Fecundity), Egg Eclosion (Fertility), Malformation, Unhatched Pupae and Pupal Longevity of *S. obliqua* treated with Mutineem 8 EC.

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Treatment</th>
<th>Concentration (%)</th>
<th>Fecundity (Mean ± S.E.)</th>
<th>Fertility (%) (Mean ± S.E.)</th>
<th>Malformation (%) (Mean ± S.E.)</th>
<th>Unhatched Pupae (%) (Mean ± S.E.)</th>
<th>Pupal Longevity (hrs.) (Mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multineem (8 EC)</td>
<td>A₁</td>
<td>0.01</td>
<td>609±67.25 (t=01.887)</td>
<td>59.54±06.55 (t=02.401)</td>
<td>15.02±03.30 (t=02.517)</td>
<td>13.05±01.13 (t=02.662)</td>
<td>296.02±12.21 (t=00.331)</td>
</tr>
<tr>
<td></td>
<td>A₂</td>
<td>0.025</td>
<td>556±43.02 (t=02.064)</td>
<td>42.12±04.77 (t=03.261)</td>
<td>13.84±03.14 (t=02.454)</td>
<td>16.39±02.00 (t=02.631)</td>
<td>319.58±11.32 (t=01.429)</td>
</tr>
<tr>
<td></td>
<td>A₃</td>
<td>0.05</td>
<td>363±30.73 (t=02.420)</td>
<td>36.94±05.92 (t=03.209)</td>
<td>10.27±03.15 (t=02.047)</td>
<td>18.25±03.45 (t=02.314)</td>
<td>348.53±12.78 (t=02.032)</td>
</tr>
<tr>
<td></td>
<td>A₄</td>
<td>0.08</td>
<td>304±27.97 (t=02.520)</td>
<td>24.70±05.38 (t=03.646)</td>
<td>08.21±02.77 (t=01.879)</td>
<td>19.31±01.85 (t=03.025)</td>
<td>357.87±10.78 (t=02.308)</td>
</tr>
<tr>
<td>Control (Untreated)</td>
<td>C</td>
<td>------</td>
<td>1182±211.59</td>
<td>93.15±03.54</td>
<td>02.10±00.23</td>
<td>04.76±00.91</td>
<td>294.63±09.82</td>
</tr>
</tbody>
</table>
Table: 11. Showing the No. of laid eggs (Fecundity), Egg Eclosion (Fertility), Malformation, Unhatched Pupae and Pupal Longevity of *S. obliqua* treated with Achook 0.15 EC.

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Treatments</th>
<th>Concentrations (%)</th>
<th>Fecundity (Mean ± S.E.)</th>
<th>Fertility (%) (Mean ± S.E.)</th>
<th>Malformation (%) (Mean ± S.E.)</th>
<th>Unhatched Pupae (%) (Mean ± S.E.)</th>
<th>Pupal Longevity (hrs.) (Mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achook (0.15 EC)</td>
<td>B&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.001</td>
<td>521±81.82</td>
<td>50.41±09.73</td>
<td>16.29±03.01</td>
<td>10.80±01.31</td>
<td>312.20±13.67</td>
</tr>
<tr>
<td></td>
<td>B&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.002</td>
<td>446±103.45</td>
<td>30.23±06.19</td>
<td>12.71±03.21</td>
<td>19.61±04.13</td>
<td>321.35±18.05</td>
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<td>B&lt;sub&gt;3&lt;/sub&gt;</td>
<td>0.004</td>
<td>318±19.40</td>
<td>21.71±04.93</td>
<td>11.35±02.41</td>
<td>21.84±02.08</td>
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<td>B&lt;sub&gt;4&lt;/sub&gt;</td>
<td>0.006</td>
<td>269±43.92</td>
<td>16.96±03.87</td>
<td>09.59±01.46</td>
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<td>Control (Untreated)</td>
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<td>1182±211.59</td>
<td>93.15±03.54</td>
<td>02.10±00.23</td>
<td>04.76±00.91</td>
<td>294.63±09.82</td>
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<td>Name of Insecticide</td>
<td>Concentration (%)</td>
<td>Treatment</td>
<td>Pre-oviposition period (hrs.) (Mean ± S.E.)</td>
<td>Oviposition period (hrs.) (Mean ± S.E.)</td>
<td>Post-oviposition period (hrs.) (Mean ± S.E.)</td>
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<td></td>
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<tr>
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<td>--------------------------------------------</td>
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<tr>
<td>Multineem (8 EC)</td>
<td></td>
<td>A₁</td>
<td>24.35±0.364</td>
<td>91.7±04.10</td>
<td>32.20±02.58</td>
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<tr>
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<td></td>
<td>A₂</td>
<td>25.92±0.359</td>
<td>84.92±03.25</td>
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<td></td>
<td></td>
<td>A₃</td>
<td>21.87±0.31</td>
<td>74.58±02.87</td>
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<td>A₄</td>
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<td>68.53±03.06</td>
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<td></td>
<td>38.35±03.68</td>
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</table>

*Showing the Adult emergence, Pre-oviposition, Oviposition and Post-oviposition of S. oblique treated with Multineem 8 EC.*
Table: 13. Showing the Adult emergence, Pre-oviposition, Oviposition and Post-oviposition period of *S. obliqua* treated with Achook 0.15 EC.

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Treatment</th>
<th>Concentration (%)</th>
<th>Adult Emergence (%) (Mean ± S.E.)</th>
<th>Pre-oviposition period (hrs.) (Mean ± S.E.)</th>
<th>Oviposition period (hrs.) (Mean ± S.E.)</th>
<th>Post-oviposition period (hrs.) (Mean ± S.E.)</th>
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</thead>
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<tr>
<td>Achook (0.15 EC)</td>
<td>B₁</td>
<td>0.001</td>
<td>36.25±0.262 (t=03.777)</td>
<td>23.20±0.031 (t=01.806)</td>
<td>82.25±0.041 (t=01.789)</td>
<td>34.02±0.057 (t=00.946)</td>
</tr>
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<td></td>
<td>B₂</td>
<td>0.002</td>
<td>23.43±0.35 (t=03.996)</td>
<td>19.68±0.13 (t=01.291)</td>
<td>80.82±0.14 (t=01.877)</td>
<td>26.20±0.031 (t=01.882)</td>
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<tr>
<td></td>
<td>B₃</td>
<td>0.004</td>
<td>19.45±0.28 (t=04.481)</td>
<td>12.15±0.14 (t=02.440)</td>
<td>71.58±0.35 (t=02.521)</td>
<td>21.15±0.22 (t=02.504)</td>
</tr>
<tr>
<td></td>
<td>B₄</td>
<td>0.006</td>
<td>12.44±0.89 (t=04.474)</td>
<td>08.58±0.19 (t=02.698)</td>
<td>64.63±0.22 (t=02.677)</td>
<td>18.92±0.66 (t=02.528)</td>
</tr>
<tr>
<td>Control (Untreated)</td>
<td>C</td>
<td>------</td>
<td>87.31±0.58</td>
<td>26.20±0.64</td>
<td>98.02±0.35</td>
<td>38.35±0.61</td>
</tr>
</tbody>
</table>
Fig. 119: Showing the Larval Mortality of S. obliqua treated with Multineem 8 EC

5th Instar □ 6th Instar □ Total 5th & 6th Instar

Mortality (%)

Concentration

Fig. 120: Showing the Larval Mortality of S. obliqua treated with Achook 0.15 EC

5th Instar □ 6th Instar □ Total 5th & 6th Instar

Mortality (%)

Concentration (%)
Fig. 121: Showing the Larval Longevity of *S. obliqua* treated with Multineem 8 EC

![Graph showing larval longevity of Multineem 8 EC treated *S. obliqua*.](image)

Fig. 122: Showing the Larval Longevity of *S. obliqua* treated with Achook 0.15 EC

![Graph showing larval longevity of Achook 0.15 EC treated *S. obliqua*.](image)
Fig. 123: Showing the Mated Adult Longevity of *S. obliqua* treated with Multineem 8 EC

![Bar graph showing mated adult longevity](image)

Fig. 124: Showing the Unmated Adult Longevity of *S. obliqua* treated with Multineem 8 EC

![Bar graph showing unmated adult longevity](image)
Fig. 125: Showing the Mated Adult Longevity of *S. obliqua* treated with Achook 0.15 EC

- Male
- Female

Fig. 126: Showing the Unmated Adult Longevity of *S. obliqua* treated with Achook 0.15 EC

- Male
- Female
**Fig. 127:** Showing the Fecundity & Pupal Longevity of *S. obliqua* treated with Multineem 8 EC

![Graph](image1.png)

**Fig. 128:** Showing the Fecundity, Pupal Longevity of *S. obliqua* treated with Achook 0.15 EC

![Graph](image2.png)
Fig. 129: Showing the Fertility, Malformation & Unhatched Pupae of *S. obliqua* treated with Multineem 8 EC

Fig. 130: Showing the Fertility, Malformation & Unhatched Pupae of *S. obliqua* treated with Achook 0.15 EC
Fig. 131: Showing the Adult emergence, Pre-oviposition, Oviposition & Post-oviposition period of *S. obliqua* treated with Multineem 8 EC

- **Adult Emergence (%)**
- **Pre-oviposition (hrs.)**
- **Oviposition (hrs.)**
- **Post-oviposition (hrs.)**

Fig. 132: Showing the Adult Emergence, Pre-oviposition, Oviposition & Post-oviposition period of *S. obliqua* treated with Achook 0.15 EC

- **Adult Emergence (%)**
- **Pre-oviposition (hrs.)**
- **Oviposition (hrs.)**
- **Post-oviposition (hrs.)**
PART - C. MORPHOLOGY AND HISTOLOGY OF MALE AND FEMALE REPRODUCTIVE ORGANS

1. INTRODUCTION

Reproductive system in insects is well organized and is concerned with the succession of generation. Many of the activities of the organism must be correlated with reproductive function (Snodgrass, 1935). The form and structure of reproductive organs present a very wide range of variation in different insects (Imms, 1977). The class 'Insecta' is a diverse group and in no other system is this diversity more strikingly revealed as in the reproductive system which makes them better adapted towards their environment.

Insects possess great power of multiplication and develop very rapidly. A good majority of insects reproduce sexually. In most sexually reproducing insects, the female's energetic investment in the next generation is greater than that of the male is because she must produce and deposit numerous, relatively large, eggs (Thornhill and Alcock, 1983). In some species males are not known to exist and in such cases reproduction is brought about by parthenogenesis. The majority of insects are oviparous and the entire development of the fertilized eggs occurs outside the body of the female. Viviparity is also noted among insects of several orders, their eggs or the larvae, being retained within the female's body where they complete a part or all of their development.

The reproductive organs differ from all the other organs of the body in that their functions do not contribute primarily to the welfare of the individual, of which they are a part; their chief concern lies in the perpetuation of generation. The reproductive system of insects is a complex of organs derived from three anatomical sources. Its parts, therefore, may be classed in three morphological groups as follows: (i) primary internal mesodermal organs (ii) secondary
ectodermal parts, produced from invaginations of the body wall, forming the usual exit apparatus; and (iii) external appendicular derivatives of the integument.

For convenience the whole complex of reproductive system may be divided into internal and external genitalia. The internal genitalia are composed of primary mesodermal organs and secondary ectodermal organs derived from invagination of the body wall. It is meant for the production of germ cells, to provide for their nutrition and give passage for their expulsion. The external genitalia consist of external appendicular structures, which help in copulation and oviposition.

Although the importance of reproductive organs as the basic taxonomic characters has been realised (Spradbery & Sands, 1976) but due to the existence of a number of lacunae in our present knowledge on their vital organs, it has not been possible to make use of them in several Orders of insects.

Among lepidoptera, several families include a large number of insect pests of agricultural importance. As such morphological studies substantiated by histological observations of the reproductive organs of *S. obliqua* present a wide scope for the control of this insect and other related pests. The transmission and movement of sperm through the reproductive tracts of lepidoptera has not been previously studied. Musgrave (1937) in an excellent study described the histology of reproductive organs of the male and female of *Anagasta kuhniella* (Zeller) and Weidner (1934) presented histological treatment of portions of the female reproductive tracts of several species of lepidoptera. Ruckes (1919), Eidmann (1929 & 1931) and Hewer (1932, 1934) have all contributed histological work on the reproductive tracts of members of this order.

The Bihar hairy caterpillar, *Spilosoma obliqua* Walker, a major pest of agricultural crops has been selected for the present study. The observations include histomorphology, histopathology and histology of the reproductive
system of both the sexes. The results of the present study may prove to be of immense help towards understanding the structure of reproductive organs in both the sexes, which is likely to provide basis for further research.

2. OBSERVATION & RESULTS

2.1. MALE REPRODUCTIVE ORGANS

The testes may lie above or below the gut in the abdomen and are generally placed close to the mid-line. The male reproductive system of the *S. obliqua* consists of usual components of two completely fused testes, a pair of vasa deferentia, a pair of seminal vesicles, a pair of accessory glands and unpaired ejaculatory duct.

The testes (Tes) are unified into a single globular mass, which represents the condition of 'complete fusion' of the gonads as has been recorded in higher lepidoptera. Each testis gives out from the ventral side a pair of vasa deferentia (vd), which opens into the corresponding seminal vesicle (Vsm). The latter is continued further by a narrow seminal duct (Sd) which opens into the reservoir of accessory gland (ResAcGI). The accessory glands (AcGI) consist of a pair of long narrow convoluted tubes, which basically dilate to form the reservoirs. The latter converge posteriorly to open into the common duct of the accessory glands (CdAcGI). This duct is large and highly convoluted and ends into the ejaculatory duct (Dej) which subsequently enters into the aedeagus (Aed) as endophallus to open at the apex of the invaginated endophallus.

2.1.1. Testes (Tes) (Plate-V, Fig. 17 to 20)

In a freshly killed moth the two testes in fused condition form a spherical body which is usually pink, often brown in colour. It is enclosed in a peritoneal
sheath (Psh) and lies dorsally over the alimentary canal (Ac) in the fifth abdominal segment. Fine branches of testicular trachea externally wrap the testes.

**Histology of Testes** (Plate-V, Fig. 19 & 20)

The testis is surrounded by outer capsular and inner testicular tube coat. The shape of the nuclei (Nu) varies in different layers. The inner coat extends into the testis as partitioning walls (PtW) or septa, so as to form testicular follicles. Each follicle (Fol) contains different stages of sperms. Several spermatogonia (Spg) are grouped together and form sperm-cyst. Mature spermatozoa (Spz), which originate from sperm-cyst (Cst) form a bundle. In freshly emerged unmated moth, the cysts of different stages of spermatogenesis could be observed. The mature sperm-cyst is somewhat elongated and all the heads in a cyst are arranged parallel to each other to form a bundle.

The walls of the follicles consist of a thin epithelium (Epth) resting on a basement membrane (BMb) and in some cases the epithelium consists of two layers of cells (Snodgrass, 1935). The follicles are bound together by a peritoneal sheath (Psh).

**2.1.2. Vasa defferens and seminal vesicle** (Plate-V, Fig. 18)

The two short vasa deferentia (vd) arise separately by broad base from the ventral surface of the testes and gradually become narrow. Each vasa deferens descends dorso–ventrally, thus flanking the mid-gut from sides. These open separately into the seminal vesicle (Vsm). The outermost layer of the seminal vesicle is the peritoneum, which is a continuation of the peritoneum of the vasa deferens.
2.1.3. Reservoir of Accessory Glands (ResAcGI)  (Plate-V, Fig. 18)

There is a pair of long and highly convoluted tubular accessory glands. The two glands adhere to each other through the connecting tracheae. Each gland is of uniform width and is apically somewhat broad at the base and gradually tapers to end blindly. The gland opens into a wide tubular reservoir gland (ResGI). The latter converge posteriorly to open into the common duct of the accessory gland (CdAcGI) which is a long, highly convoluted tube opening into the ejaculatory duct (Dej).

The common duct of the accessory gland (CdAcGI) functions as a passage for the descent of sperms and is also secretory in nature. On the basis of different secretions this duct may be conveniently divided into four portions which are separated from each other by distinct constrictions. The reactions of their secretions to the stains (Haematoxylin with eosin as counter stain) have been taken as criteria for subdividing the common duct of the accessory gland into four portions as : the first longest portion, separable from the reservoir by a distinct constriction, the second portion is sub-equal to the first. The third portion is the shortest and the fourth is longer than the third and opens posteriorly into the ejaculatory duct (Dej).

2.1.4. Ejaculatory duct (Dej)  (Plate-V, Fig. 18)

The short unpaired ejaculatory duct is convoluted and measures about one third of the length of common duct of the accessory glands. Anteriorly, it communicates with the end of common duct of the accessory gland, while posteriorly it opens into the aedeagus to open at the apex of the endophallus through the gonopore. The entire ejaculatory duct is enveloped by a thin peritoneum, which is fairly loose in the region of aedeagus. The ejaculatory duct, which leads into the aedeagus, is ectodermal in origin and is lined with intima.
2.2. FEMALE REPRODUCTIVE ORGANS

The female reproductive system consists of a pair of ovaries, paired lateral oviduct, and unpaired common oviduct (Odc), unpaired spermatheca and a pair of accessory glands (AcGI). Each ovary consists of four ovarioles (Ovl) followed by two lateral ducts (Odl), which unite to form the common oviduct (Odc). The oviduct opens posteriorly into a genital chamber. The genital chamber may form a tube, the vagina, and this is often developed to form a bursa copulatarix for reception of the endophallus. Opening into the genital chamber or the vagina there is a spermatheca for the storage of sperm, and frequently a pair of accessory glands. The ovaries are the largest organs in the abdomen and occupy most of the cavity.

*S. obliqua* is a distinct example of Dytrisia possessing independent openings of bursa copulatrix (Bcpx) and of the vagina (Vag). The latter communicates with the exterior in the fused ninth and tenth segment through the oviporous. The bursal orifice (bo) leads into a short bursal duct (bd). A narrow seminal duct (Sd), arising from the bursal duct, opens ventrally into the anterior end of the vagina. The unpaired spermatheca (Spt) with its tubular gland (SptGI) and a pair of accessory glands (AcGI) complete the female reproductive organs.

2.2.1. Ovary (Ov) (Plate-IV, Fig. 13 & 14)

The ovaries lie in the abdomen above or lateral to the gut. Each ovary consists of a number of egg–tubes (ovarioles), comparable with the testis follicles in the male. Development of the oocytes takes place in the ovarioles.

The two ovaries, long and conspicuous, are placed dorso–laterally to the digestive tract from seventh to second abdominal segments. When fully mature, these occupy the major portion of the visceral sinus. Each ovary consists of four very long and coiled ovarioles which are held together by fine branches of tracheae and fat bodies. The developing eggs are semi-translucent and become
yellowish when mature. Each ovariole is divisible into an apical germarium (Grm) and a long convoluted, beaded vitellarium (Vtl).

2.2.2. Ovariole (OvI) (Plate-IV, Fig. 13 to 16)

Each ovariole is divisible into two regions, the apical germarium and the long beaded vitellarium (Vtl), which forms the major portion of the ovariole. The ovariole is externally covered over by a thin smooth non-nucleated peritoneal layer (Pl) and is filled up with a mass of primordial germ cells (Grs).

The germanium is followed by the conspicuously beaded vitellarium. The beads are the follicles (egg chambers) which become bigger towards the end of the oviduct. The germ cells develop into oocytes (Ooc), nurse cells (Nrc) and the follicular cells (Fc). The follicles (egg chambers) become bigger in apico basal direction. Each follicle contains a posterioly placed oocyte (Ooc) and anteriorly placed nurse cells (Nrc). This type of arrangement gives ‘polytrophic’ condition to the ovary.

In the vitellarium (Vtl), the peritoneal layer (Pl) is followed by a distinct syncytial epithelium (Septh) having finely granulated cytoplasm and small nuclei. The follicular epithelium is demarcated from the syncytial epithelium (Epth) enclosing the oocyte (Ooc) which consists of distinct columnar cells having large nuclei and granulated cytoplasm. The epithelium (Epth) around the nurse cells (Nrc) however undergoes gradual disintegration and finally loose its cellular nature. The epithelium of the follicle extends in the form of incomplete septum between the oocyte and nurse cells leaving a conspicuous communicating passage between the two chambers. Each oocyte (Ooc) is more or less spherical in shape and filled with yolk (Ylk). Its rounded nucleus (Nu) is least granulated. A structure less chorion (Ch) is secreted by the follicular epithelium around the fully developed oocyte. The nutritive cells are large and irregular in shape having densely granulated and large nuclei. Each ovariole communicates
with the paired oviduct of its side by a short pedicel (Pe). The wall of pedicel is composed of a conspicuously thickened epithelium thrown into folds.

2.2.3. Lateral oviduct (OdI) (Plate-IV, Fig. 13 & 14)

The four ovarioles of each side unite basally to form the short lateral oviduct (OdI) which converge to open into the short common oviduct (Odc). The muscle layer is followed by convoluted epithelium (Epth) of the lateral oviduct, which consists of cuboidal cells having very faint boundaries, but their nuclei (Nu) are distinct. Both the nuclei and the cytoplasm are densely granulated.

2.2.4. Common oviduct (Odc) (Plate-IV, Fig. 13 & 14)

The common oviduct is a short, straight tube connecting the lateral oviducts with the anterior end of the vagina. The histological details of the common oviduct are almost similar to that of the lateral oviduct, with the difference that its lumen is comparatively reduced.

2.2.5. Vagina (Vag) (Plate-IV, Fig. 13 & 14)

The common oviduct opens through the gonopore into the tubular vagina of almost uniform diameter, which communicates with the exterior through the oviportal (Opr). The opening of the spermatophore (Spt) anatomically marks its anterior limit. Similarly, the opening of the accessory glands (AcGI) externally represents the posterior limit.

2.2.6. Spermatophore (Spt) (Plate-IV, Fig. 13 & 14)

The spermatophore is broadly tubular in shape. It is distinguished into a spermatophoral gland reservoir (SptR) and a spermatophoral gland (SptGI). The
latter opens into the vagina (Vag). The spermatothical gland lies coiled among the female reproductive organs. The reservoir of the spermatotheca (SptR) is somewhat oval and sac-like structure. It is connected with vagina (Vag) through a coiled spermatothical duct (SptD). Before opening into the vagina the spermatothical gland (SptGI), gets dilated to form a distinct reservoir. The lumen is narrow and is lined with a prominent wavery chitinous intima.

2.2.7. Bursa copulatrix (Bcpx)  (Plate-IV, Fig. 13 & 14)

The bursa copulatrix is a fairly large sac-like structure leading to the exterior through the bursal duct (bd) at the bursal orifice (bo) and extends into the visceral sinus under the digestive tract and extending up to the fourth abdominal segment. It is distinguishable into a bursal sac (bs) and a bursal duct (bd) through which it opens to the exterior at the bursal orifice (bo). A narrow highly convoluted ductus seminalis (Sd) connects the bursal duct with the vagina. The bursal duct (bd) is curved and dorso-ventrally flattened. It opens at one end into the bursal sac while at the other end it communicates with the exterior through the bursal orifice.

2.2.8. Seminal duct (Sd)  (Plate-IV, Fig. 13 & 14)

This narrow duct (Sd) connects the bursal duct with the vagina. The proximal half of the seminal duct is comparatively broader than its distal half.

2.2.9. Accessory glands (AcG)  (Plate-IV, Fig. 13 & 14)

The paired accessory glands (AcG) are long, tubular and convoluted structure located in the posterior region of the visceral sinus. Each gland opens into a pear-shaped transparent reservoir. The latter, laying dorsal to the rectum tapers to unite with its counterparts of the other side of the duct of the accessory
gland, which is much broader than the gland to form a small common reservoir. The latter opens into the vagina through a short and narrow common duct (Odc). The fused portion is now drawn out into a short, narrow duct of the accessory gland. The fluid discharge of the gland is transparent and is used for gluing the eggs on to the substratum.

2.2.10. Ovariole sheath  (Plate-IV, Fig. 13 & 14)

Cellular sheaths from the tips of the terminal filament (TF) to the base of the pedicel enclose each ovariole. These can be easily distinguished by the different shaped nuclei. As the oocyte develops this sheath gets stretched considerably and is very difficult to differentiate unless the oocyte and sheath are separated. However, the presence of nuclei indicates its existence.

2.2.11. Vitellarium (Vtl)  (Plate-IV, Fig. 13 & 14)

The major part of the ovariole, is formed of the vitellarium, which has oocytes arranged in a single or more row in various stages of their development. Each of these oocytes is surrounded by follicular epithelium. Distinct shelves formed by intercellular tissue separate the oocytes from each other.

2.2.12. Terminal Filament (TF)  (Plate-IV, Fig-13 & 14)

The apically placed terminal filament of the ovariole consists of irregularly arranged round cells with well-defined boundaries. These are separated from the contents of the germarium through a basal septum.
3. DISCUSSION

Male Reproductive Organs

There are certain structural differences in the reproductive organs of *Spilosoma obliqua* as compared to those of other lepidopterans. General morphology of male reproductive system and histology of testis of *S. obliqua*, show some basic similarities with other lepidopteran insects (Swart, 1966; Davis, 1968; Fatziger 1970; Beals & Berberet 1976). The most conspicuous organ of the male genital system is the bright brown testes which are fused together to give it a spherical shape. Cholodkovsky (1884) listed four types of lepidopteran testes: Type ‘A’ found in the genus *Hepialus*, where the testes are completely separated and four-lobed; type ‘B’ as in the genus *Saturnia*, in which they are completely separated but rounded and three-lobed; type ‘C’ where the testes are lodged in a single scrotum and type ‘D’ where both testes are so closely united that they appear to be round organ, as in the genus *Pieris*. The enclosing peritoneal sheath, which is structure less and transparent, surrounds the testes. Ruckes (1919) in Lepidoptera finds a similar layer over the entire reproductive system and considered it to have formed from the fused walls of the tracheal cells, the ‘tracheal membrane’. However, Srivastava (1960) in *Leucinodes orbonalis* and Mathur (1966) in *Utetheisa pulchella* did not report any such layer. Although Cholodkovsky (1884) and Demokidoff (1902) did not record the presence of tracheoles in the follicular epithelium but Ruckes (1919) observed them in a number of lepidopterous insects.

The peritoneum is followed by two distinct cytoplasmic layers which are called inner and outer epithelium a view shared with Mathur (1966) in *U. pulchella*. However, Murad (1969) reported the outer epithelium of *Spodoptera mauritia*, as a thin syncytial layer with oval nuclei having thick chromatin granules. The nuclei are oval and scattered under no definite plan. Ruckes
(1919) calls such outer epithelial layer in lepidoptera as 'capsular coat' consisting of single row of distinct cuboidal cells with spongy and granular cytoplasm. Alam (1953) in Stenobracon deesae has described the outer epithelium as thin and non-nucleated comparable with the 'outer tunica' of Diptera. Akbar (1958) in Leptocorisa varicornis has also reported the presence of an outer epithelium containing pigment granules. The inner epithelium is also syncytial and as thick as the outer epithelium. Its oval and granulated nuclei are less numerous. The epithelial layer is easily detectable with the presence of pink and brown pigments, which give dark brown colour to the testes. Musgrave (1937) reports similar syncytial inner layer in Ephesia kuhniella. Ruckes (1919) in lepidoptera calls such pigmented layer as the 'testicular tube coat' and suggests that the cells may be separated from one another by larger intercellular spaces containing cytoplasmic ramifications. Srivastava (1960) in L. orbonalis calls the inner epithelium as the 'inner cellular layer' consisting of strongly pigmented flat cells with rounded nuclei. Alam (1953) and Akber (1958) in S. deesae and L. varicornis respectively have recorded syncytial inner epithelium. The inner epithelium is continued for short distance into the testicular lumen in the form of seven filamentous septa, which divide the testes into eight incomplete testicular follicles. Each septum is fairly thick at the base and gradually thins out.

In most insect, the vasa deferentia is formed of a narrow tube and an enlarged seminal vesicle (Snodgrass, 1935; Imms, 1964 and Wigglesworth, 1965) and those of meloids have been assumed to fill this pattern (Gupta, 1965, 1966a, 1966b & 1967) and in L. nuttalis (Gerber et al., 1971). In S. obliqua, the relatively narrow part of the vas deferens next to the testes is the seminal vesicle, followed by an enlarged section leading to the base of the common accessory gland. The two short vasa deferentia arise separately by broad base from the ventral surface of the testes, gradually becoming narrow. However, Mathur (1967) reported it to originate broadly from the deep folds on the ventral
side of the testes, contrary to the position recorded in *Ephestia* and *Plodia* Norris (1932), *Gallaria mellonella* Rakshpal (1944) and *L. orbonalis* Srivastava (1960). The seminal vesicle opens into the reservoir of the accessory gland by a narrow tubular duct as demonstrated by Murad (1969) in *S. mauritia*. The opening of the seminal duct directly into the reservoir of the accessory gland may be a novel feature in lepidoptera: but it does occur in other higher insect as demonstrated by Alam (1953) in *S. deesae*. There may be no enlargement of the vas deferens before entering the ductus ejaculatorious duplex, as in *Rheumaptera hastata* (L) (Werner, 1977).

The fairly elongated ejaculatory duct leading to the aedeagus is ectodermal in origin and is lined with cuticle. At least a part of the wall of ejaculatory duct is muscular, but the same in *Apis* is reported to be without muscles (Snodgrass, 1956). The ejaculatory duct of *Oncopeltus* is also externally complex, being specialized for the erection of the penis (Bonhay and Wick 1953). The ductus ejaculatorious simplex in lepidoptera was shown by Ruckes (1919) to contain internal lining throughout its length. This portion corresponds to the combined form of the common duct of accessory glands and the ejaculatory duct of *S. obliqua*. Srivastava (1960) in *L. orbaonalis* also showed one long ejaculatory duct with internal lining confined to its distal end only, which he called 'muscular chitinous region of the unpaired ejaculatory duct'. It can be compared with the ejaculatory duct of *S. obliqua*. The non-muscular glandular region of the ejaculatory duct was also shown as part of the ejaculatory duct in *L. orbanalis*. (Gupta, 1965, 1966a, 1966b & 1967) considered the expanded region at the anterior end of the ejaculatory duct to be morphologically, part of the duct in the family Meloidae. Norris (1932) in *E. kuhniella* and *P. interpunctella* and Musgrave (1937) in *E. kuhniella* have shown a short 'ductus ejaculatoris' which can be compared with the ejaculatory duct of *S. obliqua*. Such end-to-end relationship of these glands is not in consonance with the general mode of opening of the glands in the ejaculatory duct (independent communication with
the ejaculatory duct or through a common duct). Zacharuk (1958) however, held the view that the ejaculatory duct is the only ectodermal part of the male internal reproductive system in the elaterid *Ctenicera aerpinnis destructor*.

The present study on *S. obliqua*, therefore, holds the views that the entire structure is common duct of accessory glands secondarily equipped with secretory function. The paired accessory glands are highly convoluted and open into a wide tubular reservoir, which converge posteriorly to open into the common duct. However, in *Boarmia selenaria*, the accessory glands are not closely united (Scheebens, 1986). They are joined together by connective tissue and small tracheae (Callahan and Chapin, 1960; Fatziger, 1970; Outram, 1971 and Werner, 1977). Imms (1964) has emphasized that this classification of accessory glands should be taken with reservation. Three pairs of male accessory glands, have been reported in most Meloids (Gupta, 1965, 1966a, 1966b, 1967 and Gerber et al., 1971). The common duct of the accessory gland functions as a passage for the descent of sperms but is also secretory in nature. Studies by Callahan (1958), Callahan and Chapin (1960), Callahan and Cascio (1963) on several species of moth suggest that sperm bundles move from the testes down the vas deferens into the ductus ejaculatorius duplex, where they are incorporated in the secretions of the ductus ejaculatorius duplex and accessory glands.

**Female Reproductive Organs**

The number of ovarioles is roughly constant within a species, although in locusts it is reported to become affected by the breeding environment of the parental population. Thus, *Schistocerca* reared from parents bred in a crowd have an average of 96 ovarioles in the two ovaries, while others bred in isolation have about 116 ovarioles (Uvarav, 1966). Present study reveals that each ovary contains 4 ovarioles. Similarly Tedders and Calcote (1967) recorded 4 ovarioles
in *Laspeyresia caryana*. Bansal and Murad (1987) in *Chrysomya megacephala* have recorded 100-110 ovarioles, and Spradbery & Sands (1976) in *C. bezziana* 70-115 ovarioles in wild flies and 50-91 ovarioles in laboratory reared flies.

Each ovariole is functionally identifiable into an apical germarium and a long, convoluted, beaded vitellarium. The terminal filament is however not traceable, consequently there is no suspensory ligament. However, Callahan and Chapin (1960) in *Agrotis ypsilon*, Murad (1969) in *S. mauritia* and Mathur (1977) in *U. pulchella* also do not record suspensory ligament.

However, two to three follicles are present in *Culicidae* (Clements, 1963), five follicles are evident in *Haematobia irritans* (L) (Schmidt, 1972), *Stomoxys calcitrans* L (Scholl, 1980). Tabanid species, *Hybomitra illota* Ostem-Sacken and *H. frontalis*, had two and three distinguishable follicles, respectively (Thomas, 1972), two follicles per ovariole are found in *Tabanus abacto* (Perich et al., 1985).

The proximal half of the seminal duct is comparatively broader than its distal half from the middle of the duct with a small diverticulum in *E. kuhniella* and *P. interpunctella* (Norris, 1932). No such structure has been reported (Srivastava, 1960) in *L. orbonalis*. The outermost layer of the lateral oviduct is the thick longitudinal muscle layer followed by circular muscle layer. A similar arrangement of the muscular is reported in *L. varicornis* (Akbar, 1958) while a reverse condition exists in *Leucinodes orbonalis* (Srivastava, 1960). Allman (1930) in *C. pomonella*, and Alam (1953) in *S. deesa* recorded only the circular muscle layer in their respective insect of study. Malouf (1933) and Snodgrass (1956) in *Nezara viridula* and the honeybee, respectively, have shown longitudinal muscle layer only. In *L. orbonalis* (Srivastava, 1960) the epithelium of lateral oviduct is similar to that of *S. obliqua*. However, Musgrave (1937) has shown the basement membrane as indistinct. The common oviduct is a short, straight tube connecting the lateral oviducts with the anterior end of the vagina.
The spermathecal gland lies coiled among the ovarioles. The number and form of spermathecae is however, subject to considerable variation. Similarly single and tubular spermathecae is found in *L. caryana* (Tedders & Calcote 1967). Bansal and Murad (1987) in *C. megacephala* have observed rounded spermathecae. The presence of 3 spermathecae has also been recorded in *Lucilia cuprina* (Clift and McDonald, 1973), *C. bezziana* (Spradbery and Sands, 1976), and *Physiphora aenea* (Sareen and Kaur, 1982).

The reservoir of the spermatheca is somewhat oval and sac-like structure. It is connected with vagina through a coiled spermathecal duct. Before opening into the vagina the spermathecal duct is dilated to form a distinct reservoir on the basis of opening of the spermathecal duct, Williams (1941) listed three classes of Lepidoptera: Class A, having the aperture of the spermatophore placed in direct contact with the seminal duct; class B, having a large secretion-filled reservoir between the aperture of the spermatophore and the seminal duct; and class C, which includes a few primitive families, species of which have no seminal duct and only one external opening instead of two as is typical of most lepidoptera.

The bursa copulatrix is a fairly large saclike structure opening to the exterior though the bursal duct as also reported in *S. mauritia* (Murad, 1969). The bursa copulatrix is the largest and most conspicuous organ in the female insect as has been recorded in *H. zea* by Callahan (1958).
4. SUMMARY

Male Reproductive organs

1. The male reproductive system of S. obliqua consists of usual components of two completely fused testes, a pair of vasa deferentia, a pair of seminal vesicles, a pair of accessory glands and unpaired ejaculatory duct.

2. Each testis gives out from the ventral side a pair of vasa deferentia which open into the corresponding seminal vesicle.

3. The accessory glands consist of a pair of long narrow and highly convoluted tubes, which basically dilate to form the reservoirs. The latter converge posteriorly to open into the common duct of the accessory glands. This duct is large and highly convoluted and ends into the ejaculatory duct, which subsequently enters into the aedeagus as endophallus.

4. The testis is surrounded by outer capsular and inner testicular tube coat. The shape of the nuclei varies in different layers. The inner coat extends into the testis as partitioning walls or septa, so as to form testicular follicles. Each follicle contains different developmental stages of sperm.

5. The mature sperm-cyst is somewhat elongated and the heads of sperm are arranged parallel to each other to form a bundle.

6. The two short vasa deferentia arise separately by broad base from the ventral surface of the testes and gradually become narrow. Each vasa deferens descends dorso-ventrally, thus flanking the mid-gut from sides. These open separately into the seminal vesicle.
7. The entire ejaculatory duct is enveloped by a thin peritoneum, which is fairly loose in the region of aedeagus. The ejaculatory duct, which leads into the aedeagus, is ectodermal in origin and is lined with intima.

Female Reproductive organs

8. The female reproductive system consists of a pair of ovaries, paired lateral oviduct, unpaired common oviduct, unpaired spermatotheca and a pair of accessory glands.

9. Each ovary consists of four ovarioles followed by two lateral ducts, which unite to form the common oviduct.

10. Each ovariole is divisible into an apical germarium and a long convoluted, beaded like vitellarium.

11. The germ cells develop into oocytes, nurse cells and the follicle cells. Each follicle contains a posterioly placed oocyte and anteriorly placed nurse cell.

12. The epithelium of the follicle extends in the form of incomplete septum between the oocyte and nurse cells leaving a conspicuous communicating passage between the two chambers.

13. Each oocyte is more or less spherical in shape and filled with yolk. Its rounded nucleus is lightly granulated.

14. The common oviduct is a short, straight tube connecting the lateral oviducts with the anterior end of the vagina. Common oviduct opens through the gonopore into the tubular vagina of almost uniform diameter, which communicates with the exterior though the ovipositor.
15. The opening of the spermatophoca anatomically marks its anterior limit. Similarly, the opening of the accessory glands externally represents the posterior limit.

16. The reservoir of the spermatophoca is somewhat oval and sac-like structure. It is connected with vagina through a coiled spermatophocal duct.

17. The seminal duct is narrow and connects the bursal duct with the vagina. The proximal half of the seminal duct is comparatively broader than its distal half.

18. The paired accessory glands are long. Tubular and convoluted structure located in the posterior region of the visceral sinus. The latter opens into the vagina through a short and narrow common duct.

19. Vitellarium is major part of the ovariole, which has oocytes arranged in a single row in various stages of their development.
PART – D. EFFECT OF MULTINEEM 8 EC AND ACHOOK 0.15 EC ON MORPHOLOGICAL & HISTOPATHOLOGICAL CHANGES IN REPRODUCTIVE ORGANS

1. INTRODUCTION

Toxically effect of biocides on the external anatomy of reproductive system of two days old adult of *S. obliqua* has been observed. Pupal and adult malformations were also observed under similar conditions. Effect of different concentrations of biocides was observed by measuring the length and diameter of the testes and ovarioles of affected insects. The gross morphological changes in the gonads following the application of different concentrations of neem products (Multineem 8 EC and Achook 0.15 EC) beginning from fifth and sixth instar larva is given under the following headings.

2. OBSERVATION & RESULTS (Morphological)

2.1. EFFECT OF 0.01 & 0.025% MULTINEEM

2.1.1. Male Reproductive Organs

In the multineem treated *S. obliqua*, slightly shrinkage occurred in the testes with both the concentrations. However, with 0.01% concentration the shrinkage was less pronounced (Plate-VI, Fig. 22 & 23). The vasa deferentia, accessory glands and ejaculatory ducts were found to be slightly deformed at certain points. The fused testis, which is in the form of spherical body, became dark brown in colour. Testicular tracheal branches were found broken and even displaced from original position. The vesicula seminalis was noticed having little shrinkage in anterior region with the application of 0.025% multineem (Plate-VII, Fig. 27 & 28).
2.1.2. Female Reproductive Organs

Some morphological changes were observed in the treated female reproductive system. Application of 0.01 and 0.025% multineem was started from two days old fifth to sixth instar larvae and was continued up to its active stage. Varying changes were observed in the treated ovary as compared with the respective control (untreated). 0.01% concentration of multineem caused some shrinkage in the ovariole (Plate-VI, Fig. 21 & 26). Similar changes were recorded with 0.025% multineem (Plate-VII, Fig. 28 & 29). Ovaries were found shrunken and retracted from 7th to 3rd abdominal segments besides becoming coiled and distorted. The eggs which are normally transparent turned to dull white or even yellowish.

2.1.3. Malformation- Pupae and Adults

The morphological changes were noticed after 0.01% multineem treatment (Plate-VI, Fig. 24 & 25). The main changes found in the pupae are darkening of colour and reduction in the size. Newly emerged adults had their wings crumpled or not fully expanded. In addition to this a slight deformity in forelegs was also observed.

Effect of 0.025% multineem on pupae and adults of S. obliqua (Plate-VI, Fig. 31 & 32) was examined. In comparison to 0.01% treatment, more deformities/ abnormalities were noticed with 0.025% multineem application. The first abnormality observed was in the pupa formation i.e. larvae pupated successfully but failed to shed-off their old exuviae due to which normal emergence of adults was hindered. Pupae with exuvium attached to the posterior region of the body were also observed. The deformities noticed in adults were in the form of reduced, curled, crumpled and incompletely formed wings.
2.2. EFFECT OF 0.05% MULTINEEM

2.2.1. Male Reproductive Organs

A number of changes occurred after treatment with 0.05% multineem on the male reproductive organs of the adult of *S. obliqua* (Plate-VIII, Fig. 33 to 35). Morphological changes were observed in the treated reproductive organs as compared to the respective control conditions. Testes of treated insects showed elliptical (el) enlargement with narrow anterior region, which gradually increased, in the posterior region. 0.05% concentration caused comparatively more pronounced effect in the testes, which showed some shrinkage along with displacement of peritoneal sheath (Psh). The anterior and posterior enlargement of vasicula seminalis was also seen. The peritoneal sheath was seen broken at certain places.

2.2.2. Female Reproductive Organs

Application of 0.05% concentration, produced considerable and significant alterations in the external anatomy of female reproductive organs of *S. obliqua* (Plate-IX, Fig. 38 to 41). The ovarioles of treated females were much shorter than in the normal females. The oocytes were found arrested at an early stage of vitellogenesis. Vitellarium and germarium were found to be shrunken resulting in the reduction of the size of ovarioles. Irregular swellings (Irs) have also been observed at different places along the whole length of ovaries from oviduct to terminal filament. Eggs were found greatly reduced in size but major losses occurred in the terminal filament and germarium regions. While the shape of vitellarium broadly, remained normal, its size was considerably reduced as compared to the control. In some cases more than one oocyte was noticed in a single egg chamber. The shape and size of the lateral as well as common oviduct mostly remained unchanged whereas, the bursa copularterix which is
fairly large sac like structure in the normal females become slender, soft and short in the treated female. Female accessory glands were also shortened.

2.2.3. Malformation—Pupae & Adults

Effect of 0.05% multineem on the pupae and adult moths of S. obliqua (Plate-VIII, Fig. 36 & 37) was observed. The deformation and concomitant reduction in the fitness of the pupa and the adults that develop from treated larvae can be of considerable significance. Reduction or loss of flight ability, feeding impediments, impairment of communication among individuals of the same species, leading to either loss of the ability or readiness to copulate or caused by the loss of antennae, along with deformed compound eyes and curly and coiled wings are some of the manifestations of 0.05% multineem application.

2.3. EFFECT OF 0.08% MULTINEEM

2.3.1. Male Reproductive Organs

Alteration in the external anatomy of male reproductive system of S. obliqua (Plate-X, Fig. 42 to 44) were noticed with the application of 0.08 percent of multineem. The very first observation noticed is the loss of circular shape of testes, because the peritoneal sheath become damaged, resulting in the appearance of two greatly compressed and fissured testes. The enlargement of vasisula seminalis, some shrinking and location disturbance in case of accessory glands and ejaculatory ducts were also observed. Damage and dislocation in testicular tracheal branches was also observed. In general, at this concentration of multineem, the male reproductive organs showed considerable damage and malformations.
2.3.2. Female Reproductive Organs

With the application of 0.08 percent of multineem, the female reproductive system of adult moth of *S. obliqua* also showed several changes (Plate-XI, Fig. 47 to 50). The terminal filament and germanium were found broken at many places. The size of the vitellarium was proportionally reduced in comparison to the control. Ovarioles showed bulging and loop formation (Bl) at several places deviating considerably from the normal shape. Number of eggs were found reduced and their colour also changed to dark brown. The overall size of ovariole and eggs was found greatly reduced. Younger oocytes were found arrested at an early stage of yolk incorporation. The number of chorionated eggs was greatly reduced.

The shape and size of the lateral oviducts as well as common oviduct remain unchanged. The internal sclerotisation in the bursa copulatrix having been greatly reduced under the effect of multineem concentration of 0.08% further became soft. The shape and size of the spermatopheca however remain unchanged, whereas the accessory gland was found reduced.

2.3.3. Malformation-Pupae & Adults

With the application of 0.08% multineem, maximum damage was recorded during the formation of pupa and transformation into adult stage (Plate-X, Fig. 45 & 46). Treated larvae changed to pupae, which were greatly curled besides losing their dark colour. The size of these pupae was much less than the control. The longevity of adult was very short and the mobility of the adult was also adversely affected. Crumpling of one pair or both the pairs of wings was observed. Shortening of antennae & legs was also noticed.
2.4. EFFECT OF 0.001 & 0.002% ACHOOK

2.4.1. Male Reproductive Organs

To study the effect of 0.001 and 0.002% of achook, two days old fifth instar larvae of S. obliqua were selected for application and the treatment was continued until they reached pre-pupal stage. The male reproductive system of adult S. obliqua as a whole got a little shrunken under the effect of these concentrations. The shrinkage was clearly noticed, as smaller testes size and reduced peritoneal sheath. However, the accessory gland, common duct and ejaculatory ducts were mostly unaffected. Although the overall effect of 0.001 & 0.002% while achook application did not evoke significant response on the male reproductive organs of S. obliqua, it may be noted that the effect of 0.002% (Plate-XIII, Fig. 56 & 57) was more pronounced as compared to 0.001% (Plate-XII, Fig. 53) which suggest that with higher doses encouraging results could be obtained.

2.4.2. Female Reproductive Organs

Moderate reduction in the size of female reproductive system as a whole was observed with the application of 0.001 & 0.002% achook. No effect was observed in the case of vitellarium and germarium region. The colour of eggs inside the ovariole, changed from yellow to dull white besides the reduction in their number. As expected, the effect on the female reproductive organs is dose dependent as 0.002% concentration of achook (Plate-XIII, Fig. 58 & 59) gave significant results in comparison to 0.001% (Plate-XII, Fig. 51 & 52), which proved insignificant.
2.4.3. Malformation-Pupae & Adults

With the lower concentration of achook viz., 0.001% the pupae formation was hampered and their colour also turned dull (Plate-XII, Fig. 54 & 55). Slight morphological changes were also noted in the adults especially in the hind-wings, which remained short and partially closed. Prolonged pre-pupal & pupal period and reduction in the weight of pupae are other notable effects of achook treatment at the given concentration.

0.002 percent achook produced many morphological changes in the pupae and adult of *S. obliqua* (Plate-XIII, Fig. 60 & 61). The process of formation of pupae was affected, rendering it into a curve shape. The colour of pupae also changed to dark brown. The adult emergence was considerably reduced as compared to control. Both the wings become crumpled, antennae were found to be somewhat curved, the legs were weak and disproportionate. All these morphological changes cast their shadow on the behaviour of the moth as well. The flight of adults was adversely affected and overall activity was greatly reduced. The average life span of adult moth also was shortened.

2.5. EFFECT OF 0.004% ACHOOK

2.5.1. Male Reproductive Organs

The 0.004 percent concentration of the achook caused considerable shrinkage in the testes of adult moth of *S. obliqua* (Plate-XIV, Fig. 62 to 64). The outer layer of testes i.e. peritoneal sheath (Psh) was found to be broken at places. This damage in peritoneal sheath is proportionally in line with the previous treatment. The peritoneal sac was found to be exited out from the damaged places of peritoneal sheath. The testes changed their shape from oval to irregular and colour from brown to red. The location of testes was also altered. As a result they descend downwards from fifth to sixth abdominal segments. The other parts of male reproductive system e.g. vas deference, seminal duct,
Accessory glands and ejaculatory duct did not show any significant morphological or other changes, at this concentration.

2.5.2. Female Reproductive Organs

0.004 percent of achook concentration, show similar alteration in the morphology of female reproductive organs as was observed after treating with 0.002 percent (Plate-XV, Fig. 67 & 70). The application of these treatments was started at the two days old fifth instar larval stage and were continued up to prepupal stage. As first hand observations the whole female reproductive organs was found moderately damaged. This damage was more pronounced in the ovariole region. The other parts e.g. terminal filament and germarium became less developed and irregular swelling (Irs) was observed in the ovariole region. This irregular swelling results in the disturbance of the normal shape of ovariole which in turn disturbed the regular arrangement of developing eggs within the ovariole. Further, 30-40 percent of these eggs perished under the effect of 0.004% achook. Reduction in size of lateral oviduct was pronounced, whereas certain other regions of female reproductive organs of treated insects, were only mildly affected.

2.5.3. Malformation- Pupae and Adults

The tropical application on the fifth instar larvae resulted into a delay in moulting, thus prolonging the overall developmental period (Plate-XIV, Fig. 65 & 66). The defects encountered in the process of larval development of S. obliqua were of higher nature with 0.004% achook, which was in line with the previous doses. Besides this the malformation found in the emerged moth were manifold. The defects produced in the antennae, legs and wings were although similar but more intense than with the 0.002% concentration. The wings of newly emerged
adults were rudimentary and unable to serve any purpose. The pupae size was also reduced besides being curved.

2.6. EFFECT OF 0.006% ACHOOK

2.6.1. Male Reproductive Organs

Although the changes and alterations produced under the effect of 0.006 percent of achook were same as in the case of former concentration of achook, but these were greater in intensity. Further, the reproductive organs as a whole was shortened under the effect of treatment, vasa deferentia, accessory glands and common accessory gland were adversely affected. A major damage was observed at the site of testes, where the whole peritoneal sheath was found to be shrunken leaving no gap between the testes, but unlike the previous doses, it did not cause rupture of the sheath. The vas deferent and vesiculus seminalis also presented normal length & thickness. While accessory glands were found to be poorly formed the ejaculatory duct and aedeagus were only slightly affected. All the changes / abnormalities as noted above are highly significant (Plate-XVI, Fig. 71 & 73).

2.6.2. Female Reproductive Organs

Two days old fifth instar larvae of S. obliqua were treated with 0.006 percent achook (Plate-XVII, Fig. 76 to 79). A number of morphological changes in the female reproductive organs were observed in the treated insect. The diameter of ovariole was found greatly reduced resulting in the compression of developing eggs.

The basal portion of ovariole however, becomes distended due to accumulation of large number of non-viable eggs. Total number of viable eggs present was less than in the control. As an estimate, 60-70 percent of eggs was
found damaged under the effect of present dose of achook. The colour of eggs also tuned dark brown with some blackened eggs were also spotted in the bulged portion of the ovariole. The lateral duct was also shrunken. The bursa copulatrix which is fairly large sac like structure in the normal insects, become short, slender & delicate under the effect of 0.006% achook. The shape and size of spermatheca was however, normal, while the size of accessory gland was considerably reduced. No change was observed in the terminal filament. The results as a whole signify the adverse effect of 0.006% achook on the female reproductive organs.

2.6.3. Malformation-Pupae & Adults

The present study clearly demonstrated the adverse effects of 0.006% achook on the pupae and subsequent emergence of adults (Plate-XVI, Fig. 74 & 75). The very first abnormality observed after achook treatment was at the time of pupation, with malformation in the resultant pupae causing considerable mortality of the latter. The adult emergence was thus greatly affected. Further, the emerged adults were with deformed wings and were unable to fly. Even the mouthparts were affected due to which the adults were unable to feed properly. The other morphological deformations observed in the adults included shortening of pronotum and somewhat exposed mesonotum of the thorax. In severely affected cases the moths were unable to crawl out from the pupal covering, or could only partly do so, as their abdominal region remained trapped within the pupal case.
3. OBSERVATION & RESULTS (Histopathological)

3.1. EFFECT OF 0.01% MULTINEEM

3.1.1. Testes (Tes.) (Plate-VI, Fig. 23)

With sub-lethal dose as above the spermatogenesis was slightly affected. Only spermatogonia, spermatocyte and spermatid cysts were present along with reduced testicular cysts in each testis. Inter follicular partitions were found broken at some places. There seems little effect on the germ cells except that the late spermatids (Spd) and the spermatozoa (Spz) appeared clumped as giant sperm bundles. The size of testes also was somewhat reduced.

3.1.2. Ovariole (OvI) (Plate-VI, Fig. 21)

Application of 0.01 percent concentration of multineem on the fifth instar larvae of *S. obliqua* brought some histopathological change in the ovarioles of the affected females. The cellular nature of the germarium however remained unchanged. In the treated ovariole, fragmentation of the oocyte (Ooc) was observed along with distorted shape and shrunken ooplasm (op). The follicular epithelial cells also got affected and the yolk (Ylk) bodies become disintegrated. The chorion layer was immensely affected and even damaged.

3.2. EFFECT OF 0.025% MULTINEEM

3.2.1. Testes (Tes.) (Plate-VII, Fig. 28)

At sub-lethal dose, the size of testes remained unchanged. Spermatogenesis was however inhibited as the testicular follicles got reduced and deformed. In a few cases the histoarchitecture of testis showed only spermatocytic cysts. The primary spermatogonia showed abnormally thickened ring shaped chromosomes, whereas the chromosomes of the secondary
spermatogonia (Spg) were deeply stained and their seemed to be clumping among them. The spermatocytes were minutely vacuolated (Vo) while the spermatids were with pycnotic nuclei and the spermatozoa (Spz) showed loose arrangements. The peritoneal sheath at certain points was found broken.

3.2.2. Ovariole (Ovl) (Plate-VII, Fig. 30)

A number of changes occurred after treatment with 0.025 percent concentration of multineem in S. obliqua. At sub-lethal dose, the maximum effect was noticed on the oocytes (Ooc) and yolk (Ylk), which had lost contact with each other. Most of the oocytes were depleted, the follicular epithelium appeared as very thin pycnotic layer and the tunica propria was distorted having detached from the oocytes. Certain oocytes become vacuolated in central portion. The cytoplasm also become reduced and filled up with greatly enlarged vacuoles (Vo). In certain areas of ovariole sections, epithelium (Epth) became invaginated and nurse cells were also found damaged. No significant alteration was observed in the other cellular structures with this treatment. The formation of chorion was however greatly affected. In some ovariole, the size of the chorionating eggs remained small having little yolk compared to the control. As a whole the application of selected sub-lethal concentration did not evoke significant histological damage and the ovaries of the treated female remained mostly unaffected.

3.3. EFFECT OF 0.05% MULTINEEM

3.3.1. Testes (Tes.) (Plate-VIII, Fig. 35)

Application of 0.05% multineem showed low to moderate alteration in the cellular structure of treated testes of adult moth of S. obliqua. Consequent to the effect of treatment, the testes slightly lost its circular shape. Most of the testicular
cysts attained final stage of spermatogenesis but these spermatid cysts undergo necroses. Reduction in the number of sperm-bundle and presence of thin, short and deformed spermatozoa (Spz) were also observed. The spermatogonia (Spg) and the spermatocytes showed pycnotic nuclei. The spermatozoa were scattered to the extent that entity of the bundle became inconspicuous. The cytoplasm of the testis was found having accumulated (Al) at certain places.

3.3.2. Ovariole (Ovl) (Plate-IX, Fig. 41)

The oocytes (Ooc) were found distorted with contracted ooplasm (op) and distorted tunica propria. Most of the oocytes got disintegrated. Extensive damage was noticed in the follicular epithelium (Epth), which appeared as pycnotic layer. A mass of pycnotic follicular epithelial cells was also seen accumulated at the apical portion around the oocyte. The peritoneum and basement membrane (BMB) got considerably shrunken and broken showing further damage to the primordial germ cells. The main damage of this layer resulted in reduction in the cellular component of the egg leading to reduction in the size of ovariole (Vo). In some ovarioles the number of immature oocytes were very few as compared to the control. However, in other ovarioles the development and maturation of the young oocytes was not normal resulting in the pushing of trophocytes in its upper region. The stretching and vacuolization was also observed at particular places inside the egg.

3.4. EFFECT OF 0.08% MULTINEEM

3.4.1. Testes (Tes.) (Plate-X, Fig. 44)

The loss of chorion among the germ cells was more pronounced and the follicle were found vacuolated. The spermatogonia were smaller in size with pycnotic nuclei and the spermatocytes with reduced cytoplasmic contents. The spermatozoa were hypertrophied and scattered in the lumen. The
spermatogonia (Spg) remained immature, the spermatocytes got degenerated and further hypertrophied spermatids (Spd) were observed in the lumen. The sperm-cysts (Cst) lost their tails, between inter follicular spaces and at few other places 'brown coloured bodies' could be seen. Melanization of the margins of the follicles was further increased and the spermatocytes showed excessive fragmentation of their chromatin thereby leading to their disintegration. Hypertrophied spermatids were found to be displaced from their position and hyper-trophied spermatozoa were also dissociated. The peritoneal sheath (Psh) was highly broken at many places. All the above abnormalities are of significant nature.

3.4.2. Ovariole (Ovl) (Plate-XI, Fig. 50)

The section of the ovarioles of the female treated with 0.080% concentration of multineem showed clumping of chromatin material of the nuclei of the nurse cells along with oocytes (Ooc) and other observations similar to earlier concentrations. However, the degeneration of follicular (Fol) chamber was evident. Although semblance of follicles was seen, there was lack of differentiation of the nurse cells, oocytes and follicular cells. The peritoneal sheath became obliterated and also broken at many places. The cytoplasm got reduced and vacuolated.

3.5. EFFECT OF 0.001% ACHOOK

3.5.1. Testes (Tes.) (Plate-XII, Fig. 53)

Following the application of sub-lethal concentration of achook on castor leaves which were provided to fifth instar (two days old) larvae, the affected male showed some cellular damage in the testes. Inter-follicular septum (PtW) becomes thin. Reduction of testicular cysts and inhibition of spermatogenesis were observed. Spermatozoa (Spz) were less than normal. In
exceptional cases all the developmental stages of testicular cysts underwent necrosis-showing signs of dissolution. This concentration of the insecticide caused considerable shrinkage in the testes. No significant changes were however observed in other cellular structures.

3.5.2. Ovariole (OvI) (Plate-XII, Fig. 51)

At sub-lethal dose, certain histological disturbances occurred in the developing ovary. More than half of oocyte (Ooc) became disintegrated and damaged. Some of the oocytes presented changed features, which were due to less deposition of yolk (Ylk) material in it. Egg cells developed small vacuoles (Vo) and showed scanty cytoplasmic material in the outer regions. No significant changes were however, observed in other cellular structure.

3.6. EFFECT OF 0.002% ACHOOK

3.6.1. Testes (Tes.) (Plate-XIII, Fig. 57)

Histopathological changes were observed in the treated testis section as compared to the control. At sub-lethal dose, the testis size remained normal, but cellular structures got affected. Inter-follicular portions (PtW) were broken or unclear. Spermatogenesis was considerably inhibited and spermatogoneal and spermatocytic cysts got disturbed. In a few cases undifferentiated cysts could be observed. Epithelium (Epth) showed considerable shrinkage in size with no clear basement membrane (BMb). The peritoneal sheath (Psh) was however normal.

3.6.2. Ovariole (OvI) (Plate-XIII, Fig. 59)

This concentration also caused damage and alterations similar to the previous dose of achook. However, affected females showed some other cellular damage in their ovaries with 0.002 percent concentration. Histologically, the germinal portion of the ovariole of the affected females remained intact having
large number of primordial germ cells. At the posterior region, each of the primary oogonia along with few trophocytes or nutritive cells was enclosed in a thin epithelial layer, which was made up of cuboidal cells. A number of vacuoles (Vo) also appeared in the ooplasm (op).

3.7. EFFECT OF 0.004% ACHOOK

3.7.1. Testes (Tes.) (Plate-XIV, Fig. 64)

This concentration also caused changes and alterations like the earlier lower concentrations of the insecticide. At sub-lethal dose, degenerative changes were noticed in the spermatogonia (Spg), spermatocytes, spermatids (Spd) and spermatozoans (Spz). While the spermatocytes showed diffused chromatin material in their nuclei and consequently sperm cysts (Cst) were damaged, which later on become pycnotic. Further, damage of the spermatozoa continued and the pycnotic spermatocytes showed loss of cohesion among them selves. The spermatids were displaced and the spermatozoans got effected showing clumped heads and weak tails. General size of the testes remained smaller and further excessive damage lead to severe melanization of the follicles. Germ cells, which survived, lost their identity and got disintegrated later. Cytoplasmic material also showed clumping at many places along with some vacuoles (Vo). The nuclei of the cells also lost their usual shape. The peritoneal sheath (Psh) was found broken.

3.7.2. Ovariole (Ovl) (Plate-XV, Fig. 70)

At the sub-lethal dose, the sections of ovarioles of S. obliqua fed with 0.004 percent concentration of achook presented crumpling of chromatin. In the transverse sections some of the ovarioles were seen completely disintegrated and follicles degenerated. Crumpling of chromatin material was found in the nurse cells as well. The ovariole contained large number of immature oocytes.
(Ooc). In some ovarioles, the follicular epithelium (Epth) became thin and loose. The oocytes contained less ooplasm (op) and had small vacuoles (Vo) at the centre. The development of these oocytes was highly affected resulting in smaller size as compared to the control. Further in most of the ovarioles, the development and maturation of the oocytes were slow. The chorion was found shrunken inward and large gaps appeared between ovariole and chorion.

3.8. EFFECT OF 0.006% AHOOK

3.8.1. Testes (Tes.) (Plate-XVI, Fig. 73)

At sub-lethal concentration, histopathological changes include decline in the occurrence of spermatogonia (Spg), spermatocytes, and spermatids (Spd). A few accumulated weak sperm heads could also be seen. Severe vacuolization of the follicles (Fol) was evident and the apical cells as well as the germinal epithelium (Epth) of the follicle were also affected. There was further decline in the testicular contents and the testis follicle showed necrosis. The germinal epithelium was further interrupted and only remnants of degenerated cells could be seen. An excessively long sperm bundle was seen as additional feature.

3.8.2. Ovariole (OvI) (Plate-XVII, Fig. 79)

At sub-lethal concentration, ovarian development revealed adverse effects on the follicular epithelium and vitelline membrane formation. Damage to the follicular epithelium increased with the age of the ovary and the inter-follicular tissue became disrupted and other changes were observed similar to earlier concentrations. A greater vacuolization appeared in the centre and yolk (Ylk) granules were observed in the ooplasm (op) of the treated insects. The wall of ovariole showed breakage at certain points. The sections of treated ovariole disclosed the crumpling of chromatin in the nuclei of nurse cells and oocytes (Ooc).
4. DISCUSSION

The present findings demonstrate the impact of neem products i.e. biocides (Multineem 8 EC and Achook 0.15 EC) on the reproductive biology, behaviour and histopathological changes of Spilosoma obliqua, and that the complex process could be disturbed at several points. Pupal and adult malformations were also observed. The different concentrations of multineem and achook showed morphogenic defects in pupal and adult formation. Treated larvae changed to pupae with typical and abnormal moulting. The pupae were highly curly. Newly emerged adults presented wings, which were crumpled, incompletely expanded and unable to serve any purpose. Either only fore wings or both the wings were crumpled. Small sized antennae and legs were also noticed. Developmental abnormalities have also been reported in Diacrisia obliqua (Singh, 1977; Singh and Jakhmola, 1980), Eariae vitella (Raman et al., 1993), Helicoverpa armigera (Jhansi and Singh, 1993), Dysdercus cingulatus (Saradamma et al., 1993), Lipaphis erysimi (Bhathal and Singh, 1993), and Schistocerca gregaria (Nicol and Schmutterer, 1991; Wilps et al., 1993), S. gregaria, Achaea janata and Spilosoma obliqua (Subrahmanyam and Rao, 1993).

The present study in S. obliqua, show tissue hyperactivity and cellular deformations of testis. The multineem was also applied topically to the fifth and sixth larval instar. At 0.01 and 0.025% multineem treatment, certain changes were observed. Inter follicular partitions were often found broken. The size of testis also became reduced. Consequent to this, reduction in the size of the cellular part of testis was observed. In few cases the histoarchitecture of testis shows only presence of spermatocytic cysts. Spermatogenesis was inhibited and a reduction of testicular follicles was observed. Present observations are in conformity with those of Misra (1981) and Paul et al. (1991) in D. obliqua. The testicular cysts attained final stage of spermatogenesis but these spermatid
cysts underwent necroses with higher concentrations of multineem (0.05 and 0.08%). A number of deformed sperm-bundles and short spermatozoa were also observed. The spermatozoa were scattered to the extent that individual entity of the bundle becomes inconspicuous. The cytoplasmic material of the testis cells aggregated at certain places, which appear as large spots in cross sections. The sperm cysts lose their tails. Between the inter-follicular spaces and at few other places ‘brown coloured bodies’ could be seen under the microscope. The peritoneal sheath was extensively damaged at many places. Bhuya & Dash (1976) and Paul et al. (1991) in D. obliqua and Vishwanath et al. (1978) in Locusta migratoria have also reported degeneration of apical cells with apholate treatment.

In the present observation on S. obliqua, histopathological changes of testis treated with 0.001 and 0.002% achook showed no apparent damage in structure. A general reduction in size was found in treated testis, and developmental stages of testicular cysts undergo necrosis-showing sign of dissolution. Inter-follicular portions were broken or become invisible. Epithelium shows considerable shrinkage with no clear basement membrane and vacuoles were abundantly present. Vishwanath et al. (1978), Ahi (1988a, b) in Poekilocerus pictus and Paul et al. (1991) in D. obliqua have also recorded similar damages. In the present study insects treated with 0.004 and 0.006% achook showed degenerative changes which was particularly noticed in the spermatogonia, spermatocytes, spermatids. While the spermatocytes show diffused chromatin material of their nuclei, the sperm cysts were considerably damaged. General size of testes became smaller and further damage lead to severe melanization of the follicles. Cytoplasm also showed clumping at many places along with the appearance of some vacuoles. The nuclei of the cells also lose their original shape. The peritoneal sheath was broken at many places. Severe vacuolization of the follicles was evident and the apical cells as well as the germinal epithelium of the follicle were also affected. Misra (1981), Bhuya
and Dash (1976) and Paul et al. (1991) also noticed the hyperactivity and cellular deformations.

The treated ovarioles were much smaller than in the normal. Appearance of swelling has also been observed at different intervals along the whole length of ovaries. The eggs inside the basal portion of ovariole became dead, chorionated and desiccated resulting into a heavy bulging. Similar observations have been recorded in azadirachtin treated adults of *Epilachna varivestis* (Schulz, 1981; Schulz and Schluter, 1984) and last instar larval ovaries of *Oncopeltus fasciatus* (Dorn et al., 1986).

The histopathological findings of *S. obliqua* treated with different doses (0.01 and 0.025%) of multineem the ovariole showed abnormal fragmentation of the oocyte along with distortion in shape and shrunken ooplasm. The follicular epithelial cells also got effected and showed pycnosis, while the yolk bodies became disintegrated. Ovariole became weak and chorion layer highly distorted and damaged. Most of the oocytes were depleted, the follicular epithelium appeared as very thin pycnotic layer and the tunica prapria was distorted having detached from the oocytes. Certain oocyte became vacuolated in the central portion. The cytoplasm also became reduced and vacuoles became greatly enlarged. Saxena and Aditya (1974) in *P. pictus* observed inhibited maturation of oocytes after treatment, a view shared with Mittal et al. (1978). Ahi (1988a) in *P. pictus* observed the gonads with visible damage to the ovaries due to the effect of aldrin where vitellogenesis was arrested in most of the stages. With 0.05 and 0.08% multineem treatment ovary showed a mass of pycnotic follicular epithelial cells which got accumulated at the apical portion around the oocyte. The peritoneal membrane and basement membrane were considerably shrunkened and broken causing further damage to the primordial germ cells. In some ovarioles the number of immature oocytes was very low. The stretching and vacuolization also took place at particular parts inside the egg. The clumping of chromatin material of the nuclei of the nurse cells were seen along with oocytes. Such a
Clumping has also been noted in the housefly (Morgan and LaBreeque, 1962 & 1964) and in *Cadra caulella* (Gangrade and Pant, 1970). LaChance and Riemann (1964) showed chromatin breakdown of follicles of the ovarioles in screw worm fly, while apholate affected follicles of the ovariole in *Aedes aegypti* (Rai, 1964). *Drosophila melanogaster* (Cantwell and Henneberry, 1963) and in *C. caulella* (Gangrade and Pant, 1970).

The present investigation revealed that both 0.001 and 0.002% concentrations of achook produced histopathological changes in the ovariole of *S. obliqua*. Some of the oocytes showed changes in their structure, which was due to less deposition of yolk material in it; egg developed vacuoles and showed scanty cytoplasmic material in the outer regions. The germinal portion of the ovariole of the affected female was intact which contain large number of primordial germ cells. At the posterior region, each of the primary oogonia along with the few trophocytes or nutritive cells were found enclosed in a thin epithelial layer which was made up of cuboidal cells. However, greater vacuolization and yolk granules were seen in ooplasm of the treated insects (Gupta, 1988). Schulz (1981) and Schluter (1984) in *Epilochna varivestis* reported histological disturbances in developing ovary in adults treated with neem extract. Ovary of *S. obliqua* treated with 0.004 and 0.006% achook revealed crumpling of chromatin material in the nurse cells and the oocytes. The ovarioles were completely disintegrated and appeared as degenerated follicles at the center. The chorion was shrunken inward and caused a huge gap between ovariole wall and chorion and further, yolk was also reduced. The neem extract drastically affects the follicular epithelium and vitellin membrane formation. The damage in the follicular epithelium increased with the age of the ovary and the inter-follicular tissue was disrupted.
5. SUMMARY

Morphological changes

1. Toxic effect of different concentrations of multineem and achook on the external anatomy of reproductive organs of adult moth of *S. obliqua* emerged from treated larvae has been observed.

2. Slight and less pronounced shrinkage occurred in male & female reproductive organs of few insects with 0.01 & 0.025% multineem.

3. Pupae with exuvium attached to the posterior region of the body were often observed. Deformities were noticed in some adults, with their wings crumpled and deformed with 0.01 & 0.025% multineem.

4. Testes of adult moth emerged from larvae treated with 0.05% multineem showed elliptical enlargement with narrow anterior region, which gradually increased, in the posterior region. The peritoneal sheath was also broken at certain places.

5. The ovaries of adult moth emerged from larvae treated with 0.05% multineem were much shorter than in the normal insects. Vitellarium and germanium were found to be shrunken and reduction of the size of ovarioles and abnormal swellings has also been observed.

6. Loss of flight ability, feeding impediments, impairment of communication among individuals of some species, curly and coiled wings are some of the manifestations of 0.05% multineem application.

7. With the application of 0.08% multineem, loss of circular shape of testes were observed which is perhaps due to the damage of peritoneal sheath, resulting in the appearance of two greatly compressed and fissured testes. Some shrinkage and location disturbance in case of ejaculatory duct and accessory glands were also observed.
8. With the application of 0.08% multineem, germanium was found broken and vitellarium was proportionally reduced in comparison to the control. Ovariole bulging and loop formations at several places were also observed. The overall size of ovariole and eggs was found greatly reduced.

9. With the application of 0.08% multineem, maximum damage was recorded during the formation of pupa and transformation into adult. Crumpling of one pair or both the pairs of wings, shortening of antennae & legs were also noticed.

10. 0.001 & 0.002% achook, affected the male and female reproductive organs of *S. obliqua* which suggest that with higher doses further encouraging results could be observed. Malformation in pupae and adult decolouration also observed.

11. 0.004% achook caused considerable shrinkage in the testes and peritoneal sheath was broken. The testis was seen from oval to irregular shape and colour from brown to red.

12. With 0.004% achook female reproductive organs was found significantly damaged. The irregular swellings in the ovariole brought further irregularities in the arrangement of developing eggs within the ovariole.

13. 0.004% achook on application resulted in malformed pupae & adult. The deformities in the antennae, legs, wings of newly emerged adult were such that there appendages were unable to serve any purpose. The pupa size was also reduced besides being curved.

14. 0.006% achook adversely affected the vasa deferentia, accessory glands and common accessory glands. A major damage was observed at the site of testes, leaving no gap between peritoneal sheath and testes. All the abnormalities as noted above are highly significant.
15. With the application of 0.006% achook, morphological changes in the female reproductive organs were observed. The colour of eggs also tuned dark brown with some blackened eggs also spotted in the bulged portion of ovariole. The bursa capulatrix become short, slender & delicate. The result as a whole signifies the adverse effect of achook on the female reproductive organs.

Histopathological Changes

1. Effect of 0.01% multineem on testes and ovariole the spermatogonia, spermatocyte and spermatid cysts was recorded. Inter follicular partitions were found broken at some places. In the treated ovariole, fragmentation of the oocyte was observed along with distorted shape and shrunken ooplasm. The follicular epithelial cells also got effected and the yolk bodies becoming disintegrated.

2. With 0.025% multineem, the primary spermatogonia showed abnormally thickened ring shaped chromosomes and their seemed to be clumping among them. The peritoneal sheath of the testes was broken at certain points.

3. With the application of 0.025% multineem, the oocytes become depleted, the follicular epithelium appeared as very thin pycnotic layer and the tunica propria was distorted being detached from the oocytes. The cytoplasm was also reduced with greatly enlarged vacuoles. In certain areas of ovariole sections epithelium became invaginated and nurse cells were also found damaged.

4. 0.05% multineem showed low to moderate alteration in the cellular structure of testes. Reduction in the number of sperm-bundle and presence of thin,
short and deformed spermatozoa were observed. The spermatozoa were scattered to the extent that entity of the bundle became inconspicuous.

5. 0.05% multineem caused extensive damage in the follicular epithelium, which appeared as pycnotic layer. The peritoneum and basement membrane got considerably shrunken and broken showing further damage to the primordial germ cells. In some ovarioles the number of immature oocytes were very few as compared to the control.

6. With the application of 0.08% multineem, the spermatogonia in the testes remained immature, the spermatocytes got degenerated and further hypertrophied spermatids were observed in the lumen. The sperm cysts lose their tails, at few places 'brown coloured bodies' could be seen. The peritoneal sheath was highly broken at many places. All the above abnormalities are of significant nature.

7. 0.08% multineem, application caused clumping of chromatin material of the nuclei of the nurse cells along with oocytes of the ovariole. There was lack of differentiation of the nurse cells, oocytes and follicular cells. The cytoplasm got reduced and vacuolated while other damages were almost similar to 0.05% multineem.

8. 0.001% achook caused the reduction of testicular cysts and inhibition of spermatogenesis. Some of the oocytes also presented changed features, which was due to less deposition of yolk material in it.

9. With 0.002% achook, inter-follicular portions were broken or became invisible. Spermatogenesis was considerably inhibited and spermatogoneal and spermatocytes cyst got disturbed. Epithelium showed considerable shrinkage.

10. With 0.002% achook, the germinal portion of the ovariole remained intact having large number of primordial germ cells. At the posterior region, each of the primary oogonia along with few trophocytes or nutritive cells was
enclosed in a thin epithelial layer. A number of vacuoles also appeared in the ooplasm.

11. 0.004% achook caused histopathological changes of testes. The spermatocytes showed diffused chromatin material in their nuclei and consequently sperm cysts were damaged. Germ cells, which survived, lost their identity and got disintegrated later. The spermatids were displaced and the spermatozoans got affected showing clumped heads and weak tail.

12. 0.004% have achook caused adverse changes as the ovariole became comparatively disintegrated and follicles degenerated. In some ovarioles, the follicular epithelium became thin and loose. The oocytes contained less ooplasm and showed small vacuoles at the center. The chorion was found shrunken inward and large gaps appeared between ovariole and chorion.

13. With 0.006% achook, the testes presented crumpled weak sperm heads. The testicular contents and the testis follicle showed necrosis. The germinal epithelium was further interrupted and only remnants of degenerated cells could be seen.

14. 0.006% achook, caused considerable damage to the ovariole. A greater vacuolization appeared in the centre and spare yolk granules were observed in the ooplasm. Ovariole exhibited the clumping of chromatin in the nuclei of nurse cells and oocytes. Damage to the follicular epithelium and the interfollicular tissue was observed.
PART – E. HISTOCHEMISTRY OF REPRODUCTIVE ORGANS

1. INTRODUCTION

In most insects, large amounts of proteinaceous yolk are deposited in the developing oocytes. The protein may be synthesized within the follicle cells (Anderson and Telfer, 1969 & 1970) or in tissue outside the oocyte (Telfer, 1965 and Engelmann, 1970). The simple polytrophic ovary of Anisolabis and Labidura (Bonhag, 1956 and Nath et al., 1959) contains lipid yolk and the protein yolk along with the nucleoproteins, which are directly contributed by the single trophocyte to the oocyte through the pore in the inter-follicular septum. In the more complex type of the polytrophic ovary of Culex, the trophocytes do not seem to play a significant role in the nourishment of the developing oocyte, but the follicular epithelium is the major source of the raw material for the oocyte (Nath et al., 1958). According to Manser (1968) and Pratt & Davey (1972), extracellular protein is believed to reach the oocyte surface by an intercellular route and incorporated as yolk by pinocytosis (Elliott and Gillott, 1976).

A close scrutiny of the existing literature reveals that our present knowledge of the histochemical accounts of polytrophic ovarioles is confined to a few species only (Pollack & Telfer, 1969 and Tripathi & Choudhry, 1979 & 1981). The present study has therefore been undertaken to investigate the origin and chemical nature of nourishing substances found in the treated and untreated male and female internal reproductive organs. Since all of the chemical substances received by the oocytes from the blood are mediated by the nurse tissues (Bonhag, 1955a,b), this study involves histochemical observations of the trophocytes and follicular epithelium. Much of the chemical material received from the nurse tissue is further elaborated by the oocytes before it becomes part
of the definitive yolk of the ova (Banhag, 1955b). Present investigation has been undertaken to study the testes and ovariole of adult moth of *Spilosoma obliqua*.

Ovarian and testes maturation in the adult moth of *S. obliqua* requires about two days and is characterized by numerous histochemical and morphological changes within the follicular epithelium and other zones. At the end of the growth period, a chorion is deposited around each mature oocyte by the follicular epithelium. Histochemical studies on this score are also limited to a few species. The results of the present investigations have been carefully integrated with an attempt to study the histochemical characteristics (Nucleic acid, Protein and Glycogen) of the testicular and ovarian secretory granules of *S. obliqua*. 
2. OBSERVATION AND RESULTS

2.1. HISTOCHEMISTRY OF UNTREATED REPRODUCTIVE ORGANS

2.1.1. NUCLEIC ACID

2.1.1.1. Ovariole (Ovl) (Plate-XVII, Fig. 81 & 82)

Since the nucleic acid have already been dealt in detail by Colombo (1956) in the oogenesis of silkworm, the present account is mainly confined to be follicular epithelial cells and the possible role of the nuclei of these cells in the formation of chorion. Prior to yolk formation, the cytoplasm of the follicular epithelial cells is rich in RNA (bright red). With the beginning of the yolk formation, the RNA of follicular epithelium decreases considerably. The nurse cells also appear to be strongly RNA positive. The nuclei, that are strongly red positive, do not show any increase or decrease in their DNA (clear green) contents, and at the time of chorion formation, the chromatin material doses do not pass either into the layers of chorion or the ooplasm. The DNA granules are seen in the present material as clear green in outer layer of ovariole after Methyl Green and Pyromin-Y staining. Nuclei as clear red in the cytoplasm are easily observed.

2.1.1.2. Testes (Tes.) (Plate-XVIII, Fig. 80)

The present study investigates the histochemical nature of the various cytoplasmic granules during the testis development of adult of S. obliqua. The presence of nucleic acid at various zones of testes is varied. Spermatogonial (Spg) and follicular epithelial region show moderate to low spermatocytic zones whereas spermatid (Spd) and sperm-cyst (Cst) zones show normal reactions for nucleic acid.
2.1.2. PROTEIN

2.1.2.1. Ovariole (Ovi) (Plate-XXI, Fig. 93)

The transverse section of ovariole of adult moth of S. obliqua showed high protein content after using Millon Reaction which was stained pink to brick red. All components of ovariole show strong positive reaction for protein. The granulated cytoplasm is intensely stained indicating large quantity of protein while it is slightly reduced within the ovariole but considerably increased in the outside of ovariole.

2.1.2.2. Testes (Tes.) (Plate-XXI, Fig. 94)

The protein analysis of testes was carried out of the adult of S. obliqua. The reaction for protein, stained, as pink to brick red was maximum is spermatogonial (Spg) zone and spermatid (Spd) zone leaving the other zones including follicular zones as moderate. The mature sperm-cysts (Cst) zone was very rich and showed slight vacuolization. In the ooplasm (op), it was uniformly distributed.

2.1.3. GLYCOGEN

2.1.3.1. Ovariole (Ovl) (Plate-XXIV, Fig. 108)

The present investigation shows that glycogen appears early in the follicles and is contributed to the ooplasm mainly by the trophocyte. After the Periodic acid & Schiff-reagent treatment the glycogen appears as fine granules in the trophocyte and the oocyte (Ooc) but soon it increase quantitatively in the trophocyte and subsequently infiltrates into the ooplasm (op) where it gets uniformly distributed. The glycogen and other periodate reactive carbohydrate were in magenta while the nuclei are in blue colour.
2.1.3.2. Testes (Tes.) (Plate-XXIV, Fig. 107)

Periodic acid & Schiff-reagent was employed to detect the glycogen in the formalin fixed testes of adult moth of *S. obliqua*. The glycogen and other periodic reactive carbohydrate turned magenta and nuclei blue. The reaction for glycogen was strong in interlobular partition wall (PtW) and follicular epithelium. Moderate in spermatid (Spd), sperms and spermatocytes, but slightly weak in spermatogonia (Spg) and other zones.

2.2. HISTOCHEMISTRY OF TREATED REPRODUCTIVE ORGANS

2.2.1. EFFECT OF MULTINEEM ON NUCLEIC ACID

2.2.1.1. Ovariole (OvI)

The use of Methyl Green-Pyromin Y has revealed the presence of nucleic acid in the ovariole of adult moth of *S. obliqua*. The reaction for nucleic acid was considerably reduced and shows irregular distribution with increasing multineem concentrations at some places. In cytoplasm zone RNA / DNA was weak and remained accumulated (Al) at certain points. Ovarioles were slightly affected with lower concentration of multineem (Plate-XIX, Fig. 83 & 84). Nucleic acid presence was very poor in ovarioles treated with 0.05 & 0.08% multineem. Follicular epithelial zone appears to possess a weak concentration of nucleic acid stain (Plate-XX, Fig. 87 & 90).

2.2.1.2. Testes (Tes.)

Effect of 0.08% multineem on the distribution of Nucleic acid of testis of adult moth of *S. obliqua* was studied (Plate-XX, Fig. 89). At low concentrations, multineem effect was not significant but higher concentrations gave significant results. At 0.08%, multineem very poor percentage and weak reaction for nucleic acid is observed. Spermatogonial and follicular (Fol) zone show moderate to
Lyberi/allon and others weak and other zones of testes show absence of colour of Methyl Green-Pyromin Y in the longitudinal section.

2.2.2. EFFECT OF ACHOOK ON NUCLEIC ACID

2.2.2.1. Ovariole (Ovi)

In the present observations, the effect of achook concentrations on ovariole development for distribution of nucleic acid was undertaken. Reaction for nucleic acid was almost similar to the control at lower concentrations (Plate-XIX, Fig. 85 & 86), but presence of nucleic acid was highly affected at higher concentrations of achook. The cytoplasm of nurse cells and follicular epithelial cells remain unstained and seem to be DNA negative. Nucleic acid reaction was positive at certain zone but show irregular distribution as compared to control. Cytoplasmic material was accumulated (Al) at the epithelial living and vacuoles (Vo) were developed (Plate-XX, Fig. 88 & 92).

2.2.2.2. Testes (Tes.)

Longitudinal section of testis of adult moth of S. obliqua shows the distribution of nucleic acid in treated larvae with 0.006% achook (Plate-XX, Fig. 91). At lower concentrations the effect was insignificant. However, higher concentration (0.006%) gave significant results. The spermatogonial (Spg) zone shows total absence of nucleic acid substance while in follicular (Fol) and epithelium (Epth) wall it was moderate to weak.

2.2.3. EFFECT OF MULTINEEM ON PROTEIN

2.2.3.1. Ovariole (Ovi)

Effect of multineem concentrations on ovariole development of adult moth of S. obliqua was undertaken for the presence of Protein. 0.01% concentration
reveals no change and was almost similar to the control (Plate-XXI, Fig. 95). Protein yolk was accumulated (Al) at outside and inside of ovariole and formed a ring shape structure. Moderate to low presence was in epithelium (Epth) and oocyte (Ooc) zone (Plate-XXII, Fig. 97 & 100). Higher concentration (0.08%) gave significant results, with about more than half zone of ovariole devoid of protein yolk (Plate-XXIII, Fig. 104).

2.2.3.2. Testes (Tes.)

Effect of multineem concentration for reaction of protein in testes of male adult moth of S. obliqua was studied (Plate-XXIII, Fig. 103). Lower concentrations show no significant effect, but high concentration (0.08%) brought remarkable changes. The distribution of protein was irregular in the whole testes. However, in some area it gave maximum presence while other areas showed insignificant presence and formed a ring shape of vacuoles (Vo). Its presence was strong in peritoneal sheath (Psh), which showed shrinkage as well, at certain points.

2.2.4. EFFECT OF ACHOOK ON PROTEIN

2.2.4.1. Ovariole (OvI)

Effect of achook concentrations on ovariole of adult moth of S. obliqua for the distribution of protein was studied. At lower concentration the effect was slight but higher doses gave significant results (Plate-XXII, Fig. 98 & 102). Reaction of protein, treated with achook was almost similar as with multineem treatment. At 0.006% the proteins containing tyrosine percentage was reduced and cytoplasm material was moderate to low in protein analysis test (Plate–XXIII, Fig. 106).
2.2.4.2. Testes (Tes.)

The section of testes of adult moth of S. obliqua shows the reaction for protein in the treated larvae with 0.004% achook concentration (Plate-XXII, Fig. 101). The distribution of protein was moderate to low in spermatogonial zone, spermatid (Spd) zone and follicular (Fol) wall. However, epithelium (Epth) zone shows almost normal reaction. Reaction for protein was irregular in whole testis section.

2.2.5. EFFECT OF MULTINEEM ON GLYCOGEN.

2.2.5.1. Ovariole (Ovl)

The reaction for glycogen in ovariole of adult moth of S. obliqua emerged from treated larvae with multineem was undertaken. At low concentration (0.01%) glycogen distribution was slightly reduced (Plate–XXIV, Fig. 109). 0.025 & 0.05% multineem greatly affected the distribution of glycogen and its presence very reduced in cytoplasm (Plate-XXV, Fig. 111 & 113).

2.2.5.2. Testes (Tes.)

Effect of multineem on testes of adult moth of S. obliqua was ascertained for reaction of glycogen. Lower concentrations show no change and were almost similar to the control. 0.08% concentration affected the distribution of glycogen and was moderate to weak in follicular epithelium, zone of spermatid (Spd) and reduced in spermatozoa (Spz) (Plate–XXVI, Fig. 115).
2.2.6. EFFECT OF ACHOOK ON GLYCOGEN

2.2.6.1. Ovariole (Ovl)

Distribution of glycogen in ovariole of adult moth of *S. obliqua* emerged from treated larvae with achook concentration was studied. Lower concentrations effect was similar to multineem observations, but at high dose (0.006%) its distribution was greatly reduced besides being irregular. The glycogen granules are evenly distributed in ooplasm in between yolk spheres and are more densely present in the peripheral region of ooplasm. More than half of the area of yolk was glycogen deficient (Plate-XXVI, Fig. 118).

2.2.6.2. Testes (Tes.)

Effect of 0.006% achook concentration on testes of adult moth of *S. obliqua* was studied (Plate-XXVI, Fig. 117). Reaction for glycogen in interlobular partition wall and spermatocyte zone was insignificant. However, it was normal to moderate in other zone of the testes.
4. DISCUSSION

The present study demonstrates the general distribution of nucleic acid, protein and glycogen in the testes and ovariole of adult moths of *Spilosoma obliqua* emerged from larvae treated with different concentrations of multineem and achook. Histochemical investigations were made using standard methods and then compared to the control ovariole and testes of same age group. The lower concentrations of insecticides did not evoke much response, but higher doses provided signified results. Achook was more potent than multineem affecting the various regions of ovariole and testes.

The cytoplasm of the follicular epithelial cells of ovariole is rich in RNA, but in the beginning of the yolk formation its concentration was on the lower side. The nuclei, that are strongly red positive, do not show any increase or decrease in their DNA distribution, and at the time of chorion formation the chromatin materials do not pass either into the layer of chorion or to the ooplasm. These findings and almost similar to those described by Aggrawal (1962) in *Bombyx mori*. In accordance with the above observations the follicular epithelial cells in a variety of insects have been reported to be rich in RNA content (Ramamurty, 1963; Pollack and Telfer, 1969; Sidhra et al., 1984 and Bansal, 1988). The nurse cells of *S. obliqua*, also appear to be strongly RNA positive. Several workers (Bier, 1963; Ramamurty, 1963; and Bansal, 1988) have reported similar results compared to the present results. Cummings and King (1969) in *Drosophila melanogaster* reported that the DNA content of nurse cell nucleus increases during the previtellogenic and early vitellogenic stages. Thereafter, a decrease in DNA content follows as reported by Aggrawal (1967) in *Callosobruchus analis* and Bansal (1988) in *Chrysomya megacephala*. Tripathi and Chaudhry (1981) pointed contrasting results as compared to the
above observations where oocyte nucleus show increase in DNA content in *Sarcophaga ruficornis*.

The present study throws light on the presence of nucleic acid and nature of the various cytoplasmic granules during the testes development. Spermatogonial and follicular epithelium zones show moderate to low spermatocytic zones whereas spermatid sperm-cyst zone shows normal reaction for nucleic acid. Banarjee and Raychaudhuri (1972) have suggested that in *Gesonula punctifrons* the spermatocytic and spermatid zones show strong, follicular epithelium moderate, whereas spermatogonial zone and sperms show very weak reactions for DNA. The follicular wall and spermatocytic zone give strong and spermatogonial zone, spermatozoa and the zone of the spermatids give moderate reaction for RNA.

The ovariole of adult moth of *S. obliqua* showed higher protein content with Millon's reagent, which was stained to brick red. Proteins are the basic materials used in the foundation of new cells in all living systems. All components of ovariole show strong positive reaction for protein. The granulated cytoplasm is intensely stained indicating positive response, while it is slightly reduced within the ovariole while it increases in the periphery of ovariole. Proteins are omnipresent components of all tissues (Bonhag, 1955a, b). Telfer (1960) in cecropia moth has reported that in the female, protein is taken up from the haemolymph through the follicular epithelium and deposited in the oocyte yolk. According to Telfer and Smith (1970) in *Hyalophora* about 10,000,00 vesicles are required for the formation of each protein yolk sphere. Bier (1963) also noted that in *Calliphora* and *Musca* the follicle cells secrete protein in the oocyte. deLoof and deWilde (1970) have demonstrated that in lepidoptera, about 75% of the proteins of the yolk are taken from the blood proteins. In the present study the reaction for protein, stained as pink to brick red was maximum is spermatogonial zone and spermatid zone leaving the other zones and
 follicular as moderate. Banerjee and Raychaudhuri (1972) in *G. punctifrons* have also supported this view.

While glycogen is not reported in all insect oocytes (Chapman, 1985), the present investigations show that glycogen appears early in the follicle and is contributed to the ooplasm mainly by the trophocyte. With periodic acid & Schiff-reagent treatment the glycogen appears as fine granules in the trophocyte and the oocyte but soon it concentrates in the trophocyte and subsequently infiltrates into the ooplasm where it gets uniformly distributed. These findings receive support from studies on other insects (Bonhag, 1955a; Kugler et al., 1956 and Aggrawal, 1967). Shiomi and Kitazume (1956) in the case of unfertilized *Drosophila* eggs have reported that the 6% of ooplasm content are glycogen. Though the presence of glycogen in the follicular epithelium has been described in number of insects (Aggrawal, 1960), nevertheless Bonhag (1955b) who investigated *Anisolablis* does not preclude the possibility of the glucose passing from the follicular epithelium to the oocyte and finally getting converted in to glycogen seem to be the natural course. In the present observation the reaction for glycogen was strong in interlobular partition wall and follicular epithelium, moderate in spermatid, sperms and spermatocytes, but slightly weak in spermatogonia and other zones. Thus the present investigations are in conformity with the views of Banerjee and Raychoudhuri (1972) who maintains that PAS positive substances are most abundant in apical cell, moderately present in follicular epithelium, zones of spermatid and spermatozoa and weakly so in spermatocytic zone.
5. SUMMARY

Control (Untreated)

1. Ovarian and testis maturation in the adult moth of *S. obliqua* is characterized by numerous histochemical changes within the follicular epithelium and other zones.

2. Prior to yolk formation, the cytoplasm of the follicular epithelial cells is rich in RNA (bright red). The nuclei do not show any increase or decrease in their DNA (clear green) contents. The chromatin materials do not pass either into the layers of chorion or the ooplasm at the time of chorion formation.

3. The DNA granules are seen as clear green in outer layer of ovariole after Methyl Green - Pyromin Y staining.

4. The presence of nucleic acid at different zones of testes is varied. Spermatogonial and follicular epithelium zones show moderate to low spermatocytic zones, whereas spermatid sperm-cyst zones show normal reaction for nucleic acid.

5. The components of ovariole show strong positive reaction for protein. The granulated cytoplasm is intensely stained indicating large quantity of protein while it is greatly reduced within the ovariole but considerably increased is the periphery of the ovariole.

6. The reaction for protein was positive in spermatogonial zone and spermatid zone leaving the other zone including follicular zone as moderate. In the ooplasm, it was uniformly distributed.

7. The glycogen appears as fine granules in the trophocyte and the oocyte but soon it increases quantitatively in the trophocyte and subsequently infiltrates into the ooplasm where it gets uniformly distributed.
8. The reaction for glycogen was strong in intralobular partition wall and follicular epithelium, moderate in spermatid, sperms and spermatocytes but slightly weak in spermatogonia and other zones.

**Treated**

Different concentration of multineem viz., 0.01%, 0.025%, 0.05%, 0.08% and achook viz., 0.001%, 0.002%, 0.004%, 0.006% were used against histochemical parameters.

**Nucleic acid**

1. The reaction for nucleic acid in ovariole was slightly affected with lower concentration and irregular distribution with the increasing multineem concentrations. Nucleic acid presence was very poor in ovariole treated with 0.05 and 0.08% multineem.

2. 0.08% multineem shows very poor percentage and weak reaction for nucleic acid in testes. The spermatogonia and follicular zone show moderate to weak and other zones of testes show absence of colour of Methyl Green-Pyromin Y.

3. Reaction for nucleic acid in ovariole was almost similar to the control at lower concentration, but highly significant with the higher concentrations of achook.

4. 0.004 & 0.006% achook shows the nucleic acid reaction in ovariole as positive at certain zone but irregular distribution as compared to control. Cytoplasm material was accumulated at the epithelial lining and vacuoles developed.

5. 0.006% achook shows the spermatogonial zone with total absence of nucleic acid substance while in follicular and epithelium wall it was moderate to weak.
Protein

6. 0.01% multineem reveals no change of protein in ovariole when compared to the control.

7. 0.025 & 0.05% multineem shows the protein yolk accumulated at outside and inside of ovariole and formed a ring shape structure. Moderate to low presence was observed in epithelium and oocyte zone.

8. 0.08% multineem gives significant results, with about more than half zone of ovariole having devoid of protein yolk.

9. 0.08% multineem shows the irregular distribution of protein in the whole testes. However, in some area it gave maximum presence while other areas showed insignificant presence and formed a ring shape of vacuoles.

10. At 0.006% achook the proteins containing tyrosine percentage was reduced and cytoplasm materiel was moderate to low in protein analysis test of ovariole.

11. 0.004% achook shows the distribution of protein as moderate to low in spermatogonial zone, spermatid zone and follicular wall. However, epithelium zone shows almost normal reaction. Reaction for protein was variable in whole testis section.

Glycogen

12. 0.01% multineem shows the glycogen distribution as slightly reduced in ovariole region.

13. 0.025 & 0.05% multineem greatly affected the distribution of glycogen and its presence was greatly reduced in cytoplasm of ovariole.
14. 0.08% multineem affected the distribution of glycogen which was moderate to weak in follicular epithelium, zone of spermatid and reduced in the spermatozoa.

15. Lower concentrations of achook show the glycogen reaction as similar to multineem distributions.

16. Higher concentration (0.006%) of achook affected the distribution of glycogen which was greatly reduced and irregular. The glycogen granules are evenly distributed in ooplasam in between yolk spheres and are more densely present in the peripheral region of ooplasam.

17. 0.006% achook shows the reaction for glycogen in interlobular partition wall and spermatocyte zone which are insignificant. However, it was normal to moderate in other zone of the testes.
LIST OF ABBREVIATIONS

Ac  Alimentary canal
AcGl Accessory Gland
Aed Aedeagus
Al Accumulate
aza Azadirachtin
bd Bursal duct
Bcpx Bursa copulatrix
Bl Bulging & Loop formation
BMb Basement Membrane
bo Bursal orifice
BOD Biological Oxygen Demand
bs Bursal sac
CdAcGl Common Duct of Accessory Gland
Ch Chorion
Cst Sperm-cyst
Dej Ejaculatory duct
DNA Deoxy ribo Nucleic Acid
EC Emulsifier Concentration
el Elliptical
Epth Epithelium
Fc Follicular cells
Fig Figure
Fol Follicles
g gram
Grm Germarium
Grs Germ celis
hac Hectare
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>hrs</td>
<td>hours</td>
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<tr>
<td>Irs</td>
<td>Irregular swelling</td>
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<tr>
<td>L:D</td>
<td>Light : Dark</td>
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<tr>
<td>LC</td>
<td>Lethal Concentration</td>
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<td>µm</td>
<td>Micrometer</td>
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<tr>
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<td>Milliliter</td>
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</tr>
<tr>
<td>Nu</td>
<td>Nucleus</td>
</tr>
<tr>
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<td>Common oviduct</td>
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<td>Peritoneal layer</td>
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<td>Psh</td>
<td>Peritoneal sheath</td>
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<tr>
<td>PtW</td>
<td>Partitioning Wall</td>
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<td>Private Limited</td>
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<td>Reservoir Accessory Gland</td>
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</tr>
<tr>
<td>RH</td>
<td>Relative Humidity</td>
</tr>
<tr>
<td>RNA</td>
<td>Ribo Nucleic Acid</td>
</tr>
<tr>
<td>Sd</td>
<td>Seminal duct</td>
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| SD           | Standard Deviation
SE  Standard Error
Septh  Distinct cytcytial epithelium
Spd  Spermatid
Spg  Spermatogonia
Spt  Spermatheca
SptD  Spermathecal Duct
SptGl  Spermathecal Gland
SptR  Spermathecal Reservoir
Spz  Spermatozoa
t  Significant test
Tes  Testes
TF  Terminal Filament
Vag  Vagina
vd  Vasa deferentia
Vo  Vacuole
Vsm  Seminal vesicle
Vtl  Vitellarium
Ylk  Yolk
PLATE-I

EXPLANATION OF FIGURES

Fig. 1. Freshly laid egg mass of *Spilosoma obliqua*.

Fig. 2. Egg mass of *S. obliqua*. Just before hatching.

Fig. 3. First instar larvae of *S. obliqua*.

Fig. 4. Second instar larvae of *S. obliqua*.
PLATE-II

EXPLANATION OF FIGURES

Fig. 5. Third instar larvae of S. obliqua.

Fig. 6. Fourth instar larvae of S. obliqua.

Fig. 7. Fifth instar larvae of S. obliqua.

Fig. 8. Sixth instar larvae of S. obliqua.
PLATE-III

EXPLANATION OF FIGURES

Fig. 9. Newly formed pupae of *S. obliqua*.

Fig. 10. Fully mature pupae of *S. obliqua*.

Fig. 11. Adult female moth of *S. obliqua*.

Fig. 12. Adult male moth of *S. obliqua*. 
PLATE-IV

EXPLANATION OF FIGURES

Fig. 13 & 14. Normal female reproductive system of adult moth of *S. obliqua*.

Fig. 15. Longitudinal section of ovariole (100X) of untreated adult moth of *S. obliqua*.

Fig. 16. Longitudinal section of ovariole (450X) of untreated adult moth of *S. obliqua*. 
EXPLANATION OF FIGURES

Fig. 17 & 18. Normal male reproductive system of adult moth of S. obliqua.

Fig. 19. Transverse section of testis (450X) of untreated adult moth of S. obliqua.

Fig. 20. Transverse section of testis (100X) of untreated adult moth of S. obliqua.
PLATE-VI

EXPLANATION OF FIGURES

Fig. 21. Longitudinal section of ovariole (100X) of affected female emerged from larvae treated with 0.01% multineem.

Fig. 22. Reproductive system of male adult moth of *S. obliqua* emerged from larvae treated with 0.01% multineem.

Fig. 23. Longitudinal section of testis (100X) of male adult moth of *S. obliqua* emerged from larvae treated with 0.01% multineem.

Fig. 24. Incomplete emergence in pupae affected with 0.01% multineem.

Fig. 25. Malformation in wings of adult moth of *S. obliqua* emerged from larvae treated with 0.01% multineem.

Fig. 26. Coiled ovary of adult female moth of *S. obliqua* treated with 0.01% multineem.
PLATE-VII

EXPLANATION OF FIGURES

Fig. 27. Reproductive organs of male adult moth of *S. obliqua* emerged from larvae treated with 0.025% multineem.

Fig. 28. Longitudinal section of testis (450X) of male adult moth of *S. obliqua* emerged from larvae treated with 0.025% multineem.

Fig. 29. Coiled ovary of adult female moth of *S. obliqua* emerged from larvae treated with 0.025% multineem.

Fig. 30. Longitudinal section of ovariole (100X) of female adult moth of *S. obliqua* emerged from larvae treated with 0.025% multineem.

Fig. 31. The malformed pupae which failed to emerge under 0.025% multineem treatment.

Fig. 32. Malformed adults under 0.025% multineem treatment.
PLATE-VIII

EXPLANATION OF FIGURES

Fig. 33 & 34. Male reproductive organs of adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem.

Fig. 35. Section of testis (450X) of male adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem.

Fig. 36. Deformities at the larval-pupal transformation of *S. obliqua* larvae treated with 0.05% multineem.

Fig. 37. Characteristic deformities of adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem.
EXPLANATION OF FIGURES

Fig. 38 & 39. Female reproductive organs of *S. obliqua* emerged from larvae treated with 0.05% multineem.

Fig. 40. Coiled ovaries of adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem.

Fig. 41. Longitudinal section of ovariole (450X) of female adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem.
PLATE-X

EXPLANATION OF FIGURES

Fig. 42 & 43. Male reproductive organs of S. obliqua emerged from larvae treated with 0.08% multineem.

Fig. 44. Transverse section of testis (450X) of male adult moth of S. obliqua emerged from larvae treated with 0.08% multineem.

Fig. 45. Deformities at the larval-pupal transformation of S. obliqua larvae treated with 0.08% multineem.

Fig. 46. Malformed adult moths of S. obliqua emerged from larvae treated with 0.08% multineem.
EXPLANATION OF FIGURES

Fig. 47 & 48. Female reproductive organs of *S. obliqua* emerged from larvae treated with 0.08% multineem.

Fig. 49. Coiled ovaries of adult moth of *S. obliqua* larvae treated with 0.08% multineem.

Fig. 50. Longitudinal section of ovariole (450X) of female adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem.
PLATE-XII

EXPLANATION OF FIGURES

Fig. 51. Longitudinal section of ovariole (450X) of female adult moth of *S. obliqua* emerged from larvae treated with 0.001% achook.

Fig. 52. Coiled ovaries of adult moth of *S. obliqua* emerged from larvae treated with 0.001% achook.

Fig. 53. Longitudinal section of testis (100X) of male adult moth of *S. obliqua* emerged from larvae treated with 0.001% achook.

Fig. 54. Deformities in adult moths of *S obliqua* emerged from larvae treated with 0.001% achook.

Fig. 55. Incomplete emergence as affected by 0.001% achook.
PLATE-XIII

EXPLANATION OF FIGURES

Fig. 56. Male reproductive organs of adult moth of *S. obliqua* emerged from larvae treated with 0.002% achook.

Fig. 57. Longitudinal section of testis (100X) of male adult moth of *S. obliqua* emerged from larvae treated with 0.002% achook.

Fig. 58. Coiled ovaries of adult moth of *S. obliqua* larvae treated with 0.002% achook.

Fig. 59. Longitudinal section of ovariole (450X) of female adult moth of *S. obliqua* emerged from larvae treated with 0.002% achook.

Fig. 60. Malformed adult moths of *S. obliqua* emerged from larvae treated with 0.002% achook.

Fig. 61. Incomplete larval-pupal transformation larvae treated with 0.002% achook.
PLATE-XIV

EXPLANATION OF FIGURES

Fig. 62 & 63. Male reproductive organs of *S. obliqua* emerged from larvae treated with 0.004% achook.

Fig. 64. Transverse section of testis (450X) of male adult moth of *S. obliqua* emerged from larvae treated with 0.004% achook.

Fig. 65. Incomplete pupal formation larvae treated with 0.004% achook.

Fig. 66. Malformed adult moths of *S. obliqua* emerged from larvae treated with 0.004% achook.
Fig. 67 & 68. Female reproductive organs of adult moth of *S. obliqua* emerged from larvae treated with 0.004% achook.

Fig. 69. Coiled ovaries of adult moths of *S. obliqua* emerged from larvae treated with 0.004% achook.

Fig. 70. Longitudinal section of ovariole (450X) of female adult moth of *S. obliqua* emerged from larvae treated with 0.004% achook.
EXPLANATION OF FIGURES

Fig. 71 & 72. Male reproductive organs of adult moth of S. obliqua emerged from larvae treated with 0.006% achook.

Fig. 73. Transverse section of testis (450X) of male adult moth of S. obliqua emerged from larvae treated with 0.006% achook.

Fig. 74. Incomplete emergence in the affected pupae of S. obliqua larvae treated with 0.006% achook.

Fig. 75. Incomplete larval-pupal transformation caused by 0.006% achook.
PLATE-XVII

EXPLANATION OF FIGURES

Fig. 76 & 77. Female reproductive organs of male adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook.

Fig. 78. Coiled ovaries of adult moths of *S. obliqua* emerged from larvae treated with 0.006% achook.

Fig. 79. Longitudinal section of ovariole (450X) of female adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook.
EXPLANATION OF FIGURES

Fig. 80. Longitudinal section of normal testis of adult moth of *S. obliqua* showing distribution of Nucleic acid (450X).

Fig. 81. Longitudinal section of normal ovariole of *S. obliqua* showing distribution of Nucleic acid (450X).

Fig. 82. Transverse section of normal ovariole of *S. obliqua* showing distribution of Nucleic acid (450X).
PLATE-XIX

EXPLANATION OF FIGURES

Fig. 83. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.01% multineem showing distribution of Nucleic acid (450X).

Fig. 84. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.025% multineem showing distribution of Nucleic acid (450X).

Fig. 85. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.01% achook showing distribution of Nucleic acid (450X).

Fig. 86. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.002% achook showing distribution of Nucleic acid (10.0X).
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Fig. 87. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem showing distribution of Nucleic acid (450X).

Fig. 88. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.004% achook showing distribution of Nucleic acid (450X).

Fig. 89. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.08% multineem showing distribution of Nucleic acid (450X).

Fig. 90. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.08% multineem showing distribution of Nucleic acid (450X).

Fig. 91. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook showing distribution of Nucleic acid (450X).

Fig. 92. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook showing distribution of Nucleic acid (450X).
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Fig. 93. Longitudinal section of normal ovariole of adult moth of S. obliqua showing distribution of Protein (450X).

Fig. 94. Longitudinal section of normal testis of adult moth of S. obliqua showing distribution of Protein (450X).

Fig. 95. Longitudinal section of ovariole of adult moth of S. obliqua emerged from larvae treated with 0.01% multineem showing distribution of Protein (450X).

Fig. 96. Longitudinal section of ovariole of adult moth of S. obliqua emerged from larvae treated with 0.001% achook showing distribution of Protein (450X).
Fig. 97. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.025% multineem showing distribution of Protein (450X).

Fig. 98. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.002% achook showing distribution of Protein (450X).

Fig. 99. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem showing distribution of Protein (450X).

Fig. 100. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem showing distribution of Protein (450X).

Fig. 101. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.004% achook showing distribution of Protein (450X).

Fig. 102. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.004% achook showing distribution of Protein (450X).
PLATE-XXIII

EXPLANATION OF FIGURES

Fig. 103. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.08% multineem showing distribution of Protein (450X).

Fig. 104. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.08% multineem showing distribution of Protein (450X).

Fig. 105. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook showing distribution of Protein (450X).

Fig. 106. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook showing distribution of Protein (450X).
PLATE-XXIV

EXPLANATION OF FIGURES

Fig. 107. Longitudinal section of normal testis of adult moth of *S. obliqua* showing distribution of Glycogen (450X).

Fig. 108. Longitudinal section of normal ovariole of adult moth of *S. obliqua* showing distribution of Glycogen (450X).

Fig. 109. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.01% multineem showing distribution of Glycogen (450X).

Fig. 110. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.001% achook showing distribution of Glycogen (450X).
EXPLANATION OF FIGURES

Fig. 111. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.025% multineem showing distribution of Glycogen (450X).

Fig. 112. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.002% achook showing distribution of Glycogen (450X).

Fig. 113. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.05% multineem showing distribution of Glycogen (450X).

Fig. 114. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.004% achook showing distribution of Glycogen (450X).
PLATE-XXVI

EXPLANATION OF FIGURES

Fig. 115. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.08% multineem showing distribution of Glycogen (450X).

Fig. 116. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.08% of multineem showing distribution of Glycogen (450X).

Fig. 117. Longitudinal section of testis of adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook showing distribution of Glycogen (450X).

Fig. 118. Longitudinal section of ovariole of adult moth of *S. obliqua* emerged from larvae treated with 0.006% achook showing distribution of Glycogen (450X).