CHAPTER-D

LIFE HISTORY

Various events of the life cycle of *Eusarcocoris capitatus* have been explored successfully and description of these has been divided in following headings: -

1. SEXUAL DIMORPHISM: - Male and female *E. capitatus* (Figs. - 4, 5, 6 and Plates - 10 B, C, 11) were identified with their dimorphic character presented in table - 1. The head capsule of male measures 0.9 to 1.0 mm in length with an average of 0.960±0.43 mm and 0.83 to 0.9 mm in width with an average of 0.864±0.32 mm while head of female measures 1.0 to 1.167 mm in length with an average of 1.097±1.052 mm and 0.86 to 1.0 mm in width with an average of 0.914±0.431 mm (Fig. - 7 F, G). Dark brown head has black punctuations. Antennal length of male bug ranges from 1.42 to 1.62 mm with an average of 1.528±1.22 mm while in female it ranges from 1.66 to 1.84 mm with an average of 1.742±1.39 mm (Fig. - 8 F, G). The antennae are light brown with apical first and second segments and light brown basally fourth segment. Comparative length of various antennal segments is presented in table - 2. Rostrum of male (Fig. - 9 F) extends upto the hind coxae. In male it is brown apically and black basally and it measures 0.9 to 0.94 mm in length with an average of 0.96±0.924 mm in male while in female (Fig. - 9 G) it ranges from 1.02 to 1.1 mm with an average of 1.09±1.072 mm (Table - 1). In female rostrum also extend upto hind coxae. Comparative rostral segments length is given in table - 3. Brownish pronotum bears rounded dark brown punctuations. Its length in male ranges from 0.525 to 0.75 mm with an average of 0.63±0.21 mm while in female it measures
0.675 to 1.575 mm in length, average being 0.936±0.83 mm. The width of male pronotum is 1.5 to 1.725 mm with an average of 1.605±1.6 mm. Pronotum of female ranges 2.0 to 3.72 mm in width; average being 3.08±2.01 mm. Brownish mesothorax bears dense punctuations in male and less dense in female. Metathorax in both the sexes is also brownish having black punctuations (Table - 1). Hemelytra is whitish brown with black punctuations. The distal half part is whitish membranous, transparent and bears distinct and branched veins (Plates - 11 A, B and 29 C). In male its length ranges from 1.48 to 1.52 mm with an average of 1.504±1.20 mm and the width ranges from 0.6 to 0.64 mm with an average of 0.62±0.31 mm (Fig. - 10 A). In female, length of the fore wing ranges from 1.6 to 1.72 mm with an average of 1.656±1.281 mm and width ranges from 0.66 to 0.7 mm with an average of 0.68±0.12 mm (Fig. - 10 B and Table - 1). The hind wings are transparent whitish and having branched venations (Fig. - 11). Its length in male ranges from 1.16 to 1.24 mm with an average of 1.2±0.73 mm and width extends from 0.66 to 0.7 mm with an average of 0.69±0.12 mm. In female length of hind wing ranges from 1.28 to 1.32 mm with an average of 1.324±1.10 mm and width ranges from 0.76 to 0.84 mm with an average of 0.796±0.181 mm (Table - 1). Prothoracic leg is brown with hairy spines. There is a strip formed of less dense and small punctuations towards the distal end of femur in either sex posterior half of tibia is clothed with hairy setae. Tarsi are brown coloured and pretarsus is apically black. Claws are stout, black and hooked while pulvilli are whitish brown (Fig. - 13 B and Plate - 12 A, B). Length of prothoracic leg of male varies from 1.58 to 1.84 mm with an average of 1.7±1.63 mm and in female it ranges from 1.8 to 2.7 mm with an average of 1.974±1.825 mm (Fig. - 12 F, G and Table - 1). Comparative length of various segments of prothoracic leg is presented in table - 4. In male, a dark brown strip having less dense and small dark
brown punctuations is present from 3rd to 6th abdominal sternite on each side of middle line. Abdominal length in male ranges from 1.5 to 1.875 mm with an average of 1.695±1.371 mm while in female it ranges from 2.1 to 4.62 mm with an average of 3.054±2.1 mm. The width of abdomen in male ranges from 2.0 to 3.72 mm, average being 2.67±1.09 mm. In female it ranges from 2.72 to 5.2 mm, average being 4.0895±3.01 mm (Table - 1). Eighth abdominal sternite is reduced in both the sexes and lateral margins are dark brown. In female 7th sternite is bifid. Brownish white coloured scutellum in each sex has dark brown coloured depressed punctuation with black anterior margins. Metathoracic scent gland ostiole opens laterally on upper part of metathorax on each side (Fig. - 14). Three dorsal abdominal scent gland ostioles are situated in IIIrd, IVth and Vth abdominal segments respectively (Fig. - 37 and Plate - 12 D). Male external genitalia are blunt while in female it is boat shaped (Fig. - 15). Male is darker brown having black punctuations dorsally and more dark brown punctuations ventrally than female. Total length of male ranges from 2.77 to 3.52 mm with an average of 3.207±2.10 mm and 1.875 to 2.46 mm in width with an average of 2.29±1.18 mm. Female length ranges from 3.525 to 6.825 mm with an average of 5.275±3.24 mm and 2.25 to 4.41 mm in width with an average of 3.33±1.32 mm (Table - 1).

2. COPULATION: - Reproductive behaviour of any organism is of paramount significance for continuing the generation. In insects for sexual reproduction, mating is essential by which male transfer its sperm into female genital chamber. Male recognize its own species female by perceiving its chemical molecules (pheromone) by antennal sensillae. Copulation takes place at any time in the day preferably in the morning and evening, on the inflorescence and leaf sites in laboratory as well as in field (Plate - 13).
Adult *E. capitatus* does not copulate at once after moulting from fifth instar. Instead, before actual copulation, it needs a pre- copulation period of 3 to 15 days with an average 7.28±3.86 days (Table - 5). This variation in pre - copulation period depends upon environmental factors, viz; temperature, R.H. and food factors. In nature, optimum condition for this behaviour occurs during raining months July to October, though bug population found from March to November or first week of December. This act of reproduction can be divided into following three parts:

**A. Preparatory phase:** - Sex pheromones are emitted by individual of one sex in order to attract members of the opposite sex, resulting in the location of emitter and subsequently mating (Baker, 1989). Sex pheromones have been chemically identified for stink bugs (Pentatomidae) (Aldrich, 1996). In this phase, pheromones emitted by female *E. capitatus* are perceived through the antennae of male bug. After that male becomes restless and cleans its antennae and rostrum regularly and rapidly with the help of antennae and rostrum cleaner device situated at tibial extremity (Fig. - 13 A and Plate - 28 C). Antennal activity increases and male moves quickly to find out its mare. On finding female, it further cleans its antennae and touches her antennae as well as abdomen by his antennae. The male performs this action repeatedly. After repeated touching and stimulating the female, the male mounts on her back and taps her head and again touches antennae as well as its vaginal part with the help of antennae. Mostly, female remains immobile and only antennal activity increases. On getting excited, female raises its abdomen a bit and this is signal for male to copulate.

In field it was observed that adults as well as nymphs come out of hibernation in March as the temperature rises and begins this act of copulation.
B. Mating: - After appropriate signaling and excitement, the mounted male opens vaginal opening of the female with the help of claspers or paramers and tries to insert its erected aedeagus into the intervalvular space of ovipositors and vagina. After several repeated attempts, male gets success in its mission (Fig. - 16). After this male first comes at 45° angle and then attains tail to tail position at 180° angle (Fig. - 17 E and Plate - 14). During copulation male and female rubs abdomen of each other gently with the help of hind legs. The pair stays in the same position without any movement for 40-45 min. Sometimes, they may move to other places, and in such cases female leads the path. After this period, male and female suddenly starts shaking their raised abdomen backwardly and forwardly as well as upward and downward. This phenomenon remains upto 80 seconds. After first phase of shaking, the adults remains calm for 10-15 minutes and further shaking starts, this time, the period of shaking reduces to 50-60 seconds. The time between shaking and resting ranges between 10-15 minutes. The shaking period of abdomen ranges from 40 seconds to 6 minutes. After each shaking phase abdomen is raised from the substratum a bit and it reaches a maximum height of 1cm. at the end of copulation. At last, suddenly both male and female raises their abdomen much high and male flutters its wings and separates off from the female (Fig. - 17 F). Male retracts its aedeagus and female ovipositor come in normal position. Now, they move in opposite direction without showing any affection (Fig. - 17 G).

The entire process of copulation period ranges from 2 to 35 hrs. with an average of 17.07±9.05 hrs. (Table - 6).

C. Post copulation period: - The time taken in re-engagement for copulation in *E. capitatus* is 5 to 291:05 hrs. with an average of 54.92±60.80 hrs. (Table - 7). The duration of copulation ranges 01:30 to
29:00 hrs. in second copulation with an average of 13.503±6.79 hrs. (Table - 8). Repeated copulation was seen a biological necessity for oviposition.

After copulation, each sex cleans its antennae with the help of antennae and rostrum cleaner device of fore legs named by Dhiman and Dhiman (1985). Further effect of repeated copulation was observed on the fecundity and it has been seen that more than twice mated female laid less number of eggs than once mated female. However, if the couple is disturbed soon after resuming copulation then both may recopulate with in short period of two to four hours.

3. PRE-OVIPOSITION PERIOD: - Prior to oviposition, the copulated female requires a pre-oviposition period of 4 to 122 hrs. with an average of 28.58±28.61 hrs. (Table - 9). It depends upon climatic conditions and food factors.

4. OVIPOSITION BEHAVIOUR AND OVIPOSITION PERIOD (Figs. - 18, 19, 20 and Plates - 15, 16, 17):-
Oviposition behaviour was observed in the laboratory as well as in the field which revealed that ovipositing female selects a suitable ovipositing site with the help of rostral tip having sensory setae (Fig. - 9 G) and antennal sensillae present at the terminal clavate segment (Fig. - 8 G). After probing a suitable site, its leans forward, levels her abdomen and opens intervalvular space through which egg starts its journey out. As soon as caudal end of egg is exposed, a sticky substance is exuded, secreted from accessory gland which serves two main purposes, firstly it acts as lubricant for smooth egg laying and secondly it glues the egg with the substratum (Fig. - 20 B and Plate - 17). Eggs are laid in nature on the
inflorescence in between the flowers and seeds (Fig. - 18 and Plate - 15 B, C). Eggs are laid side by side at any time of day or night. However, in laboratory rearing, eggs were oviposited by copulated female in the petridish or on the muslin cloth (Plate - 16), on the moist cotton swab kept in the rearing chimney or gauze of the rearing cage and on the inflorescence of Tulsi (*Ocimum sanctum*) supplied as food for the bug (Table - 10). Rarely female laid eggs on the leaves of Tulsi (*O. sanctum*) when only leaves of Tulsi supplied as food for the bug (Fig. - 19 and Plate - 15 D). Generally, 14 eggs were laid but sometimes 2 eggs were also laid after first copulation. Eggs were laid singly or in the groups of 2 or 3 eggs and rarely in cluster. 1st batch of eggs consisted of 2 to 14 eggs with an average 8 eggs after first copulation. Second batch of eggs was laid without any copulation after 4 to 24 hrs. with an average of 14 hrs. In this batch number of eggs varied from 4 to 8 eggs with an average of 6 eggs. The third batch of eggs was laid without any copulation after 6 to 18 hrs. with an average of 10 hrs. In this batch, number of eggs varied from 2 to 6 eggs with an average of 4 eggs. The fourth batch of eggs was laid without any copulation after 6 to 12 hrs. with an average 8 hrs. In this batch number of eggs varied from 2 to 5 eggs with an average of 3 eggs (Table - 11). The egg laying occurred after 6 to 150 hrs. with an average period of 87 hrs. after re-engagement of copulation. The number of eggs varied from 2 to 10 eggs with an average of 8 eggs. Second batch of eggs after re-engagement in copulation varied in between 2 to 6 eggs with an average of 4 eggs and the third batch of eggs after re-engagement varied in between 2 to 5 eggs with an average of 3 eggs. The fourth batch of eggs laid after re-engagement of copulation varied in between 0 to 2 with an average of 1 egg. It was found that many times copulated female laid comparatively less eggs in comparison of once mated female. Thus, in this case, multi-copulation does not seem a biological necessity.
In a batch, eggs are placed closely keeping their opercular end upward and caudal end attached with the substratum (Fig. - 20 A and Plate - 17 A). A single egg for deposition requires 2 to 5.15 minutes with an average 2.72±1.12 minutes while complete batch of eggs took 5 to 27 min. with an average of 13.15±7.19 min. for oviposition (Table - 12). Times between successive egg laying extends from 3 to 8 min. Eggs are glued to the substratum by a sticky substance exuded by the accessory gland of female reproductive organs (Plate - 15 B, C). A female lays maximum 102 eggs and minimum 64 eggs during her life time with an average of 80 eggs (Table - 13). The ovipositing female frequently copulated with male after laying eggs. It was further observed that if a copulated female could not lay eggs for some time due to unfavorable condition, she deposited maximum 10 eggs at one time. However, number of laid eggs reduced with the age of female (Table - 13 and Graph - 1).

5. EGG STRUCTURE (Fig. - 20 B, C and Plates - 15 A, 17, 18, 19): - Newly laid egg is milky white in colour (Plate - 15 A), shape of egg is cylindrical having cephalic end (CPE) and caudal end (CDE). Eggs are adhered to each other if in group as well as to the substratum with glued substance secreted by accessory gland (Fig. - 20 B and Plate - 17). Each egg measures 0.44 to 0.62 mm in length with an average of 0.54±0.073 mm and 0.32 to 0.42 mm with an average of 0.36±0.036 mm in width (Table - 14).

Egg surface or chorion is rough having elongated rod shaped many protuberances (Plates - 17 B and 18 A). Operculum is a circular lid like part situated at the dorsal side of the egg on cephalic end. On its cephalic end, there is a ring of micropylar process (MP) which helps in giving the
passage for sperm entry during fertilization and for respiration as well (Fig. - 20 C and Plate - 18). The number of micropyles varies from 10 to 16, average number being 12±4.93 (Table - 15). The length of micropylar process is 0.04 to 0.06 mm (average 0.05±0.0063 mm) (Table - 16). Each micropylar process is comma (,) shaped having cup like head, and a bent stem. Cavity of cup [micropylar opening (MPOP)] leads into a micropylar canal (MPC) which opens inside the egg through the chorion (Fig. - 20 C and Plate - 18 B).

On seeing egg chorion under light microscope it appears rough but SEM study revealed that it bears rod like protuberances placed vertically and horizontally according to the shape of egg i.e., horizontally towards rounded caudal and cephalic ends, vertically in between the two ends (Plate - 19). Smooth chorion is seen in between micropylar process and slightly above the margin of rings (Plate - 18). This helps in rupturing the operculum lid during absence of protuberances eclosion. Protuberances provide rigidity and strength to chorion as well as firmly anchoring in between inflorescence of O. sanctum.

6. INCUBATION PERIOD: - During embryonic development, the egg colour changes from milky white to dark red (Plate - 20). Prior to hatching, the eggs of E. capitatus require an incubation period of 2 to 11 days with an average of 3.98±2.42 days (Table - 17). The sequence of gradual changes in egg colour till hatching is presented as under -
<table>
<thead>
<tr>
<th>Days</th>
<th>Change in colour</th>
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<tbody>
<tr>
<td>First day</td>
<td>Milky white</td>
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<tr>
<td>Second day</td>
<td>Light pinkish</td>
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<tr>
<td>Third day</td>
<td>Light reddish</td>
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<tr>
<td>Fourth day</td>
<td>Dark red before hatching</td>
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**7. HATCHING:** - After incubation period of above said days hatching takes place. During hatching, cephalic end of the egg chorion ruptures by the pressure exerted by the head of the nymph. This cephalic end opens or separate off like a lid along with micropylar process. This opercular lid may be left attached with egg chorion some times (Fig. - 20 D). The first instar nymph protrudes out through the opening of egg shell; its head first and antennae, rostrum, legs, thorax, and at last abdomen is pulled out of empty egg shell. During hatching, egg or chorionic membrane also ruptures and the instar also get free from it. A few nymphs could not emerge out in the act of emergence as they could not free their appendages from the egg shell membrane. It was further observed that as the nymph half emerged, it takes a rest for few seconds and then emergence process continues. Duration of hatching varies from 3 to 8 min. with an average of 5.24±1.61 min. (Table - 18).

After hatching, the egg shell along with exuvium of the post natal moult is left between the flowers which appear to be white membrane (Plate - 21). The newly emerged nymph dries its body and then moves
forward and starts feeding on the host soft tissue such as flower buds, newly set seed etc.

8. DESCRIPTION OF FIRST INSTAR NYMPH (Fig. - 21 and Plate - 22): - There are five nymphal instars of E. capitatus (Plate - 10 A). The newly emerged I\textsuperscript{st} instar nymph is reddish black in colour. Later on, it changes gradually to reddish brown on exposure to atmosphere. Newly emerged instars are somewhat globular shape. It measures 0.86 to 1.0 mm in length with an average of 0.934±0.63 mm and 0.6 to 0.72 mm in width with an average of 0.674±0.67 mm (Table - 19). Appendages are clothed with fine spines. A light brown mid dorsal line is present from pronotum to abdominal end. The head is ophisthorhynclus and broadly triangular in shape (Fig. - 7 A). It has one pair of laterally bulging eyes and one pair of reddish ocelli. Average width in between the eyes is 0.274±0.171 mm and across the eye 0.41±0.29 mm (Table - 20). Antennae (Fig. - 8 A) are clavate and 4 segmented, I\textsuperscript{st} and II\textsuperscript{nd} flagellar segment are basally reddish brown while rest part of it is brownish. It measures 0.536±0.212 mm in length (Table - 20) and comparative length of its segments are, scape 0.08 mm, pedicel 0.098 mm, first flagellar segment 0.122 mm and second flagellar segment 0.236 mm (Table - 2). Pronotum, mesonotum and metanotum are distinctly marked, wing buds are absent. Pronotum is blackish brown in colour. It measures average 0.124±0.113 mm in length (Table - 20) and average width of pronotum is 0.396±0.194 mm (Table - 21). Three dorsal abdominal scent glands openings are present and they can be distinguished by bulged out openings and dense punctuations at the base of scent gland opening. Lateral margins of each segment of abdomen bears horizontal ‘U’ shaped punctuations which are a bit bigger in size than rest part of the body. Rostrum (Fig. - 9 A) is light brown in colour
and the tip is dark black which extends up to the level of middle coxae. It is 4 segmented. Sensory setae are present on the tip of rostrum. Maxillary and mandibular stylets are lying in mid of rostrum in the rostral groove giving an impression of dividing rostrum into two lateral parts. In first rostral segment, maxillary and mandibular stylets can be differentiated, which comes together at the end of first segment. Rostrum measures average 0.38±0.362 mm in length (Table - 20) and comparative length of its segments are first 0.09 mm, second 0.13 mm, third 0.07 mm and fourth 0.09 mm (Table - 3). Prothorax, mesothorax and metathorax are blackish brown in colour and clearly distinguished, having moderately sized legs. Legs are brown in colour with black spines on distal tibia as well as on tarsi. Prothoracic leg measures average 0.694±0.63 mm in length (Fig. - 12 A and Table - 20) and its segments measures; coxa 0.064 mm, trochanter 0.084 mm, femur 0.148 mm, tibia 0.23 mm and tarsi is dark brown and two segmented, first segment measures 0.07 mm and second segment 0.098 mm (Table - 4), with a total length of 0.168 mm. Prothoracic leg has antennae and rostrum cleaner device at the tibial extremity, named by Dhiman and Dhiman (1985), to clean and remove foreign particles from antennae and rostrum. Abdomen is reddish brown with brown punctuations; brown spiracles are present which can be identified from punctuations by its comparative bigger size. The abdominal tip is brown black in colour. This is a feeding stage and remains in dispersed condition. It generally feeds upon young seeds, fresh leaves and fresh flowers of Tulsi (O. sanctum). Duration of this instar varies from 2 to 12 days with an average of 4.28 days after which it moult into second instar nymph (Table - 22).

During moulting, the first instar at first tightly holds the substratum (such as twig) with powerful claws and then slowly body cuticle ruptures
through mid cranial sulcus which extends up to metathorax. After rupturation, a longitudinal slit appears extending from the middle of the head to metathorax and through this slit second instar makes its way out. At first, its head is pulled out from exuvium, then antennae, rostrum and thorax. Gradually, legs are pulled from moulted skin and at last abdomen is pulled out leaving the empty exuvium behind. After protruding out from the exuvium of first moult, the second instar takes rest to dry its appendages so that its cuticle gets hard. Then, the instar cleans its head and other parts and moves for feeding in nearby vicinity. The entire process of moulting lasts from 5 to 15 minutes with an average of 8 minutes. It was further noticed that in some cases, the instar could not free itself from the moulted skin and remained entangled and died later on.

9. DESCRIPTION OF SECOND INSTAR NYMPH (Fig. - 22 and Plate - 22 B, C): - The newly emerged second instars are pinkish white in colour which changes into reddish dark brown with brown punctuations on exposure to air. Newly emerged instars are laterally biconvex, dorsally convex and ventrally flat in shape. Body of second instar measures 0.88 to 1.07 mm in length with an average of 1.09±1.0 mm and 0.65 to 0.78 mm in width with an average of 0.709±0.67 mm (Table - 19). Appendages are clothed with fine spines. It has light brown mid dorsal line from pronotum to abdominal end. Head is triangular with laterally bulging eyes (Fig. - 7 B). Two reddish coloured ocelli are present behind eyes on occiput. Average width in between the eyes is 0.349±0.144 mm and across the eyes 0.479±0.371 mm (Table - 20). Antennae (Fig. - 8 B) are clavate and 4 segmented. Antennae has brownish colour, pedicel and 1st flagellar segment are basally reddish brown in colour. It measures average 0.634±0.431 mm in length (Table -
and comparative length of its segments are; scape 0.102 mm, pedicel 0.122 mm, first flagellar segment 0.146 mm and second flagellar segment 0.264 mm (Table - 2). Like first instar, pronotum, mesonotum and metanotum are distinctly marked, wing buds are absent. Pronotum is dark brown in colour. It measures average 0.1485±0.132 mm in length (Table - 20) and average width of pronotum is 0.539±0.222 mm (Table - 21). Three dorsal abdominal scent glands opening are now more prominent with dark punctuations. Lateral margins of abdominal segments have horizontal “U” shaped punctuations like preceding instar. Rostrum is brownish colour and four segmented (Fig. - 9 B). Tip of fourth rostral segment is black with a bunch of sensory setae. In first rostral segment, maxillary and mandibular stylets can be differentiated and they unite at the base of first rostral segment. In further rostral segments they lie in the middle of rostrum in the rostral groove. Rostrum measures average 0.48±0.27 mm (Table - 20) in length and comparative length of its segments are; first 0.11 mm, second 0.18 mm, third 0.08 mm and fourth 0.11 mm (Table - 3). Prothorax, mesothorax and metathorax are dark brown in colour and clearly distinguished, having moderately size legs. Legs are brown in colour with black spines on distal tibia as well as on tarsi. Prothoracic leg (Fig. - 12 B) measures average 0.816±0.314 mm in length (Table - 20) and comparative length of its various segments are; coxa 0.072 mm, trochanter 0.09 mm, femur 0.2 mm, tibia 0.256 mm and tarsus 0.198 mm. Tarsus is two segmented and their comparative length are; first segment 0.086 mm and second segment 0.112 mm (Table - 4). Abdomen is reddish dark brown with brown punctuations. Spiracles on lateral side of abdomen are much clear now.

This is a feeding stage and remains in dispersed condition. It generally feeds upon young seeds, fresh leaves and fresh flowers of Tulsi,
O. sanctum. This stage lasts from 2 to 12 days with an average of 4.71 days (Table - 22). The moulting process is like preceding instar. After coming out of exuvium the third instar hardens its cuticle on exposure to air and turns from pinkish white to brownish red with brown punctuations. It cleans its different body parts with the help of cleaning device present in prothoracic leg and goes to nearby feeding side for feeding.

10. DESCRIPTION OF THIRD INSTAR NYMPH (Fig. - 23 and Plate - 23 A): - Newly emerged third instars are somewhat globular and pinkish white in colour which changes into light brown, brown and then brownish red with brown punctuations. It measures 1.75 to 2.25 mm in length with an average of 1.96±1.04 mm and 1.4 to 1.65 mm in width with an average of 1.56±1.03 mm (Table - 19). Appendages are clothed with fine spines. It has light brown mid dorsal line from pronotum to abdominal end. Head is triangular, brownish with laterally bulging red eyes (Fig. - 7 C). Two red ocelli are present behind the eyes on occiput which are prominent. Average width of head capsule in between the eyes is 0.433±0.212 mm and across the eyes 0.652±0.432 mm (Table - 20). Antennae (Fig. - 8 C) are clavate, four segmented, dark brown coloured and has brown scape, dark brown pedicel and third segment dark brown and upper half segment is dark brown with sensory hairs. It measures average 0.756±0.73 mm in length (Table - 20) and comparative length of antennal segments are; scape 0.12 mm, pedicel 0.14 mm, first flagellar segment 0.21 mm and second flagellar segment 0.286 mm in length (Table - 2). Pronotum of this instar is brown with black punctuations. It measures 0.41±0.371 mm in average length (Table - 20) and average width of pronotum is 0.822±0.217 mm (Table - 21). Small wing buds start appearing and touch first abdominal tergum (Fig. -
Abdominal scent glands are like preceding instars except bigger in size and colouration around them is more darker. Lateral abdominal margins are also like preceding instar. Rostrum is brownish colour and four segment (Fig. - 9 C). The fourth rostral segment is black having a tuft of sensory setae on its tip. Rostrum measures average 0.594±0.59 mm in length (Table - 20) and comparative length of its segments are; first 0.12 mm, second 0.25 mm, third 0.1 mm and fourth 0.12 mm (Table - 3). Different thoracic segments are brown in colour with black punctuations and clearly distinguished as in second instar, having moderately size legs. Legs are brown in colour with hairy setae on distal tibia as well as on tarsi. Prothoracic leg (Fig. - 12 C) measures average 1.014±1.02 mm in length (Table - 20) and comparative length of its various segments are; coxa 0.074 mm, trochanter 0.108 mm, femur 0.276 mm, tibia 0.316 mm and tarsus 0.24 mm. Comparative length of two tarsal segments are; first 0.108 mm and second segment 0.132 mm in length (Table - 4). Abdomen is brownish with dark brown punctuations. Spiracles on lateral side of abdomen are clear and punctuations around them are darker.

This instar is also a feeding stage and feeds upon young seeds, fresh leaves and fresh flowers of Tulsi (O. sanctum L.). This stage lasts for 3 to 13 days with an average of 4.91 days (Table - 22). The moulting process is like preceding instar. After coming out of exuvium the fourth instar hardens its cuticle on exposure to air and turns from pinkish brown to blackish brown with dark brown punctuations. It cleans its different body parts with the help of cleaning device present on prothoracic tibial extremity and goes to nearby feeding side for feeding.
11. DESCRIPTION OF FOURTH INSTAR NYMPH (Fig. - 24 and Plate - 23 B): - Newly emerged fourth instars are somewhat globular and pinkish white in colour at the time of emergence and gradually turn into blackish brown with dark brown punctuations. It measures 2.03 to 2.41 mm in length with an average of 2.165±2.10 mm and 1.5 to 1.72 mm in width with an average of 1.61±1.55 mm (Table - 19). Appendages are clothed with fine spines. It has light brown mid dorsal line from pronotum to abdominal end. Head is almost triangular with laterally bulging red eyes (Fig. - 7 D). Two red ocelli are present behind the eyes on occiput which can be seen clearly in this nymphal instar. Average width of head capsule in between the eyes is 0.514±0.112 mm and across the eyes 0.79±0.68 mm. (Table - 20). Antennae are clavate and four segmented (Fig. - 8 D). Antennae has dark brown colour, brown scape, dark brown pedicel, third segment dark brown and upper half segment is dark brown with sensory hairs. It measures average 0.97±0.90 mm in length (Table - 20) and comparative length of its segments are; scape 0.138 mm, pedicel 0.218 mm, first flagellar segment 0.262 mm and second flagellar segment 0.352 mm in length (Table - 2). Wing buds are prominent, may go to beyond second abdominal tergum (Fig. - 26 B). Second and third abdominal scent glands are more prominent than previous instar. Three scent gland markings and lateral margins of abdomen are same as in third instar except proportionally bigger in size. Pronotum of this instar is blackish brown with black punctuations. It measures 0.475±0.43 mm average in length (Table - 20) and average width is 1.1±1.0 mm (Table - 21). Rostrum is brownish and four segmented (Fig. - 9 D). The fourth rostral segment is black having a tuft of sensory setae on its tip. Rostrum measures average 0.71±0.7 mm in length (Table - 20) and comparative length of its segments are; first
0.13 mm, second 0.34 mm, third 0.11 mm and fourth 0.13 mm in length (Table - 3). Different thoracic segments are clearly distinguished as in third instar having moderately sized legs with hairy setae on distal tibia as well as tarsi. Prothoracic leg (Fig. - 12 D) measures average 1.19±1.15 mm in length (Table - 20) and comparative length of its various segments are; coxa 0.084 mm, trochanter 0.112 mm, femur 0.366 mm, tibia 0.382 mm and tarsus 0.246 mm. Comparative length of two tarsal segments are; first 0.112 mm and second segment 0.134 mm in length (Table - 4). Abdomen is brownish with dark brown punctuations. Spiracles on lateral side of abdomen are clear and black in colour punctuations around them are darker.

This is also an active feeding stage and feeds upon young seeds and fresh leaves of Tulsi (O. sanctum). This stage lasts from 3 to 11 days with an average of 5 days (Table - 22). After this period it moult into fifth nymphal instars. The moulting process is like preceding instar. After coming out of exuvium the fifth instar hardens its cuticle on exposure to air and turns from pinkish white to dark brown with black punctuations. It cleans its different body parts with the help of cleaning device present on tibial extremity of prothoracic leg and goes to nearby feeding side for feeding.

12. DESCRIPTION OF FIFTH INSTAR NYMPH (Fig. - 25 and Plate - 23 C): - Newly emerged fifth instars nymph are somewhat globular and at the time of emergence it is pinkish white which on exposure to air first turns pinkish brown then light brown and at last dark brown with black punctuations. Its body measures 2.5 to 3.25 mm in length with an average of 2.905±1.72 mm and 1.75 to 2.25 mm in width with an average of 1.92±0.98 mm (Table - 19). Appendages are clothed
with fine spines. Head is like previous instar with laterally bulging red eyes. Two red coloured ocelli are present behind the eyes on occiput (Fig. - 7 E). Average width of head capsule in between the eyes is 0.572±0.270 mm and across the eyes 0.833±0.76 mm (Table - 20). A dorso-median brown coloured line is present from pronotum to last abdominal segment. Pronotum of this instar is dark brown with black punctuations. It measures 0.66±0.57 mm in average length (Table - 20) and average width being is 1.4675±1.03 mm (Table - 21). Antennae (Fig. - 8 E) are clavate, four segmented and dark brown in colour. It has brown scape, dark brown pedicel, third segment dark brown and upper half segment is dark brown with sensory setae. Its length in average 1.076±1.071 mm (Table - 20) and comparative length of antennal segments are; scape 0.152 mm, pedicel 0.264 mm, first flagellar segment 0.296 mm and second flagellar segment 0.364 mm in length (Table - 2). Different thoracic segment and markings of thoracic scent gland ostioles are clear. Wing buds are larger and extends upto the third abdominal tergum (Fig. - 26 C and Plate - 12 C). Abdominal scent glands are like preceding instars and are much more bulged out. They are situated in 3rd, 4th and 5th abdominal segment. Semicircular markings around the scent gland and lateral abdominal margins like fourth instar but area around it is darker than fourth instar nymph (Fig. - 37 and Plate - 12 D). Rostrum is brownish and four segmented (Fig. - 9 E). The fourth rostral segment is black having a tuft of sensory setae on its tip. Rostrum measures average 0.862±0.85 mm in length (Table - 20) and comparative length of its segments are; first 0.17 mm, second 0.38 mm, third 0.14 mm and fourth 0.16 mm in length (Table - 3). Prothoracic leg (Fig. - 12 E) measures average 1.416±1.32 mm in length (Table - 20) and comparative length of its segments are; coxa 0.106 mm, trochanter 0.122 mm, femur 0.432 mm, tibia 0.482 mm and tarsus 0.274 mm. Comparative length of two tarsal segments are; first
Like preceding instars, it is also an active feeding stage and feeds upon young seeds and fresh leaves of Tulsi (*O. sanctum*). This stage lasts from 4 to 14 days with an average of 5.32 days (Table - 22). After completing the nymphal life, the fifth instar nymph moults into imago. For this process, the fifth instar first tightly holds the twig of plant, main stem or side branch by its claws and then slowly a split appears mid dorsally in the skin of the instar through ecdysial line. The split begins from mid cranial sulcus upto the metathorax. Now, after rupture, the split gets wide and through this, the imago first protrudes out its head, then thorax, rostrum and antennae. At last defolded wing, abdomen and legs are pulled out. The imago rest for a while on the host nearby to exuvium and dries its appendages, body and defolds its wings. In the folded wings blood circulation in the veins occurs and the wings are unfolded, gets hard on exposure to air. The entire process of moulting lasts from 10 to 20 minutes with an average of 12 min. The exuvium either is left attached with the stem or branch of host plant or is blown away by air current. The exuvium is grey brown in colour and thin (Fig. - 27 and Plate - 24 A).

**13. DESCRIPTION OF IMAGO (Plate - 24 B, C): -** After the fifth and final moult, the nymph becomes an adult imago which is pinkish white at first and then gradually changes from pinkish white to dark brown with black punctuations after moulting on exposure to air. During this period, the imago cleans its appendages with the help of antennae and rostrum cleaner device situated at the proximal rim of prothoracic tibia (Fig. - 13 A and Plate - 28 C). It also flexes its wings so as to dry and harder them. Tarsi are three segmented, antennae five and rostrum is four
segmented. Metathoracic scent gland opening is present just anterior to the meta-coxa. Sexual dimorphism is clearly visible, i.e., the last few segments of abdomen already make the presence of male and female genitalia. After moulting and resting the imago turned into adult, move forward and starts feeding. It takes 6 to 32 hrs. with an average 17.13±8.16 hrs. to become fully developed dark brown coloured adult. The duration of egg to adult takes 15 to 44 days with an average of 28.16±7.721 days (Table - 23).

14. LONGEVITY OF ADULT: - Along with the biological experiments, the rearing experiments were carried out for knowing longevity of adult male and female bugs. For this, several hurricane glass lantern chimneys and wooden wire gauze cages (30 × 30 × 30 cms) were taken. The chimneys were kept in petridish having water filled vial with healthy inflorescence of O. sanctum. Then, a newly emerged couple was introduced in each chimney and cage. The chimney was finally covered with fine muslin cloth. The stale food was daily replaced by fresh one and a close vigil was kept to record the mortality of the bug. The experiments were repeated during 2007-2009 and the data are recorded in table - 24.

It is clearly evident from the table - 24 that maximum longevity of female is 70 days and minimum 40 days with an average of 52±18.24 days. The male survives for 50 days as maximum and 28 days as minimum with an average of 39±12.04 days in laboratory conditions.

The female survives for longer days than the male. Maximum longevity of both the sexes is recorded during August to October. The reason for this may be the availability of suitable temperature and R.H. for maximum life activities, i.e., 25 C to 35°C.
15. NUMBER OF GENERATIONS PER YEAR: - The seasonal occurrence of *E. capitatus* was studied on *O. sanctum* during 2007-2009 at Saharanpur (Table - 25).

To study the number of generation of *E. capitatus* in a year, an adult couple was taken up on 21- March- 07, the rearing was done in hurricane glass lantern chimney and wooden wire gauze cage as mentioned in material and methods chapter. Inflorescence of Tulsi (*O. sanctum*) were provided daily as food and a water dipped cotton swab was also kept to maintain necessary R.H. Copulation started at 4:00 p.m. on 28- March- 07 and it ended at 10:00 a.m. on 29- April- 07, taking a copulation period of 18:00 hrs. Copulated male and female were reared separately. The first batch of 3 eggs was laid on 30- March- 07. First instars from eggs emerged on 2- April- 07 and second instars developed on 5- April- 07. From second instars, third instars developed on 8- April-07, which moulted into fourth instars on 12- April- 07. Fourth instars developed into fifth instars on 17- April- 07. Fifth instar nymphs of 17- April- 07 developed into adults on 23- April- 07. Fifth instar nymph developed into adult in first week of December. After this, the newly developed adults did not lay any egg, although, they copulated and went into hibernation as winter started.

The same experiment was repeated for the year 2008 and 2009, and the data are recorded in the table - 25.

Thus, it is clearly evident from the above description and data of the table - 25 that there are only 5 to 7 generations in a year. Our field observations further supported the laboratory data.