CHAPTER-E

ECOLOGY

Abiotic factors that directly or indirectly affect the population of insects include temperature, moisture, light and several other physical/chemical parameters. Weather is a composite condition of influence of temperature, light, humidity, rainfall and wind at any given moment in time. It varies continually through days, week’s, months and years and exerts an influence on insect abundance, longevity and development rate and so on, from one year or season to the next. Hence, the effect of different ecological parameters of abiotic factors on the bug under study has been studied in the laboratory as well as in field.

The knowledge of ecological parameters which influence the distribution and abundance of insects will arm the applied entomologists better in their warfare against insect pests. Hence, knowledge of these aspects is essential. Following abiotic factors have been worked out in relation to *Eusarcocoris capitatus*.

1. EFFECT OF DIFFERENT LEVELS OF TEMPERATURE ON THE SURVIVAL OF THE ADULTS OF *E. CAPITATUS DISTANT*: - Temperature plays an important role in the longevity of adult insects. For recording the effect of different temperature levels on the survival of adults, after moulting, one week old adults were kept in hurricane glass lantern chimneys covered at top by fine muslin cloth placed in petridish. A healthy inflorescence of Tulsi (*Ocimum sanctum*) was also placed in the chimney as food for the adults. A cotton swab dipped into distilled water was also kept into a glass vial to maintain necessary R.H. The chimney was kept in the temperature and
humidity control cabinet (Plate - 8). R.H. was maintained at 75±5% level. Then, the adults were subjected to various temperature levels, viz., 0°, 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40° and 45°C to note the survivality of adults separately at different time. The data are pooled in the table - 26 and plotted in graph - 2.

Experimental observations data of aforesaid table - 26 and graph - 2 reveal that increase in temperature upto 30°C enhance population build and further increase in temperature upto 45°C decrease reproduction and survivality. Male and female do not survive at 0°C which is the lower lethal temperature level for adults. At 5°C, the male survived for 2 days and female for 4 days. Exposure to 10°C and 15°C resulted 12 and 15 days longevity for male respectively while 20 and 25 days for female. At 20°C and 25°C the male survived for 25 and 35 days respectively while female lasted for 35 and 42 days at the same temperature levels. Further increase in temperature to 30°C resulted 50 days longevity for male and 70 days for female. At 35°C the male lived for 25 days and female for 32 days. At 40°C the male lived for 1 day and female for 2 days. The shorter life span was recorded 1 hr for male and 2 hrs. for female at 45°C and it was upper lethal temperature. 40°C temperature is also not suitable of either sex for longer period. The experimental observations revealed that the female survives longer than male.

Examination of graph - 2 indicates the relationship between temperature and longevity of each sex increases with the increases in temperature upto 30°C and thereafter, it decreases with increase in temperature. Maximum survivality of both the sex was recorded at 30°C and minimum at 5°C and 45°C. Thus, experiments described above clearly revealed that the temperature has a direct effect on the survivality
of adults. Another ecological factor, i.e., relative humidity also influences the survivality of adults of *E. capitatus*.

2. EFFECT OF DIFFERENT LEVELS OF R.H. ON THE SURVIVALITY OF ADULTS OF *E. CAPITATUS*

DISTANT: - A very interesting point was observed during the field study that in July to October, the adult population increases to peak level and at low level during the month of November. It was felt by watching the meteorological data (Table - 28) that adult populations fluctuate in relation to the variations in relative humidity levels along with temperature.

Thus, to confirm the influence of variable R.H. levels on the adults of *E. capitatus*, after moulting, one week old adults were selected from the laboratory stock culture and were kept in temperature and humidity control cabinet after placing them in hurricane glass lantern chimney on healthy inflorescence of Tulsi (*O. sanctum*) (Plate - 8). The top of each chimney was covered by fine muslin cloth and bottom was placed in a petridish.

The temperature was kept optimum 30°C and effect of different R.H. levels, viz., 0, 30, 50, 70, 80, 90, and 100% were observed on adults at different times. The observations are recorded in table - 27.

Examination of the data presented in the table - 27 clearly depict that all the adults died within few hours when kept at 0% R.H., by increasing R.H. to 30%, the survival time was raised to 2 days in male and 4 days in female with 80% mortality in male and 90% in female. Further increase in R.H. to 50% resulted increase in survival period of both the sexes, i.e., 12 days for male and 20 days for female with 50%
mortality in male and 40% in female. At 70% R.H. male lived for 25 days and female lived for 35 days with 30% in male and 25% in female. Subjection to 80% R.H. level had resulted the maximum longevity of 40 days male and 55 days for female *E. capitatus* with 20% mortality in male and 15% in female. At 90% R.H., maximum survivability of 50 days for male and 70 days for female was obtained with minimum mortality percentage, 10% in male population and 8% in female population.

Exposure to cent per cent R.H. level revealed that male lived for 35 days and female for 42 days with 20% mortality in either sex.

The experiment indicates clearly that females are more resistance than male in regard to the exposure to R.H. level.

Furthermore, table - 27 and graph - 3 indicates that minimum mortality of *E. capitatus* occurred at 90% R.H. with maximum longevity period. Decrease or increase beyond this level of R.H. increases mortality percentage and reduces longevity period. However, more mortality resulted at a low level rather than higher level. Higher humidity is favorable for both the sexes.

Thus, 70-90% R.H. is an optimum level for the survivality of adults of *E. capitatus*.

3. FEEDING BEHAVIOUR OF ADULTS AND NYMPHS: - Tulsi plants (*O. sanctum* L.) were planted in good number in well manured irrigated soil of earthen pots. These were kept in the open field and some were caged by fine wire mesh. Plants were irrigated at regular interval. *E. capitatus* were reared in laboratory as well as in field in wooden wire gauze cages (Plate - 7). At inflorescence and seed setting stage of Tulsi plants, in five cages two pairs of newly emerged bugs were
released in each and their feeding behaviour was observed by making close observations. Rearing in laboratory was carried out in hurricane glass lantern chimneys; five pairs of newly emerged bugs in each one were released. Healthy inflorescences of Tulsi (*O. sanctum*) were also placed in the chimney as food for the adults and nymphs. Cotton swab dipped into distilled water, into a glass vial was also kept to maintain necessary R.H. The chimney covered at top by fine muslin cloth (Plate - 6). Feeding behaviour was seen with the help of magnifying hand lens (20×) as well as under binocular microscope in reflected light.

The study of feeding behaviour in laboratory as well as in field has revealed that *E. capitatus* has piercing and sucking type mouthparts. It is a phytosuccivorous bug, which feeds upon the seeds, flowers, and leaves of Tulsi (*O. sanctum* L.) (Plate - 25). All five nymphal instars and adults suck the newly set seeds content as well as of flowers and sap from the leaves. Location of food is recognized with the help of fifth clavate segment of antennae (Fig. - 8), which bears olfactory sensory setae and the sensory setae of rostral tip (Fig. - 9). After approaching the feeding site, exploratory movements are performed by the tip of labium having sensory setae. Usually a soft feeding site is selected for easy penetration by its stylets. Piercing and sucking mouth parts of the bug, comprise a labium, a pair of each mandibular and maxillary stylets (Fig. - 28 and Plate - 26), hypopharynx and salivary syringe with sucking pump. These together form the main organs of ingestion. Prior to piercing operation by stylets, the insect probes the seed, leaf and flower with the proboscis 5 to 6 times. Stylets are able to pierce any part of the host tissue but generally more woody part is avoided. Mechanism of feeding is completed in two phases-(1) Piercing, (2) Sucking.
After selection of suitable feeding site, the tip of rostrum comes in contact with host surface and then the stylets pierce the host. In Heteropteran bugs, there is a little controversy regarding penetration capability of maxillary and mandibular stylets in relation to each other. Wobber (1933), Snodgrass (1935), Imm’s (1957), Livingstone (1969) and Dhiman (1985) believe that mandibular stylets are the chief piercing organs, a view which has been experimentally confirmed by Miles (1958, 1959 and 1960). On the other hand Qudri (1951) opine that maxillary stylets are the chief piercing organ.

In *E. capitatus*, the mandibular stylets perform the major piercing organ, while maxillary stylets in addition to suction also contribute towards the cutting of parenchymal tissue so as to ensure a continuous flow of sap. This penetration probably does not take place in one stroke, but in several rhythmic steps protruding the stylets little by little till they are fully protruded. The movements of stylets during feeding can be observed under binocular microscope in reflected light. After penetration of mandibular stylets a wound develops in host tissue. Simultaneously, with the entrance of distal portion of the mandibular stylets into tissue, the whole stylets fascicle is twisted with the help of contraction of mandibular rotator muscles along with transverse-constrictor muscle of third rostral segment, deepening the rostral groove. As a result of this twisting action of stylet fascicle downwardly curved, maxillary stylets hold stylet fascicle into wound of the host.

Further, maxillary stylets with the help of their lanceolated tips reach deeply into the host food to get more sap. Simultaneously, the saliva is pumped into the wound. The piston of salivary syringe is pulled out by the contraction of dilator muscles of salivary syringe and salivary duct opens and saliva enters into the salivary chamber of syringe. Due to
relaxation of the aforesaid muscles, accompanied by the flexibility of lever, piston regains original position, thereby closing afferent salivary duct. Thus, pressure increases by force, which forces saliva into ejaculatory canal through efferent salivary duct. By repetition of above action, saliva constantly goes into the wound of host food and saliva mixed sap or seed content is sucked up by powerful cibarial pump. Beyond this level, the suction pressure is carried by the alternate contraction and relaxation of cibarial muscles of sucking pump. This lifts the sap into cibarium. Conveyance of the sap posterior to cibarium is managed by the pharyngeal dilators. The pumping action is responsible for the rhythmic movements and the steady flow of sap into food canal of the stylets.

When the feeding is over, the stylets are withdrawn from the host food with a fairy great effort by means of retractor muscles. As soon as stylets are withdrawn, air bubbles are sucked-up into the food canal along with the sap column which ultimately reaches the midgut and cleaned proboscis and antennae by antennae and rostrum cleaning device situated at the tibial extremities of for leg (Fig. - 13 A and Plate - 28 C) as also described by Dhiman and Dhiman (1985).

Generally, *E. capitatus* (nymphs and adults both) are seeds sucker but, some time they also feeds upon the leaves and flowers. The seeds of Tulsi, *O. sanctum* are dry have rich amino acids, carbohydrate, protein and fatty contents (Fig. - 29 and Plate - 27 A, C). The bug pierces the testa so as to reach the stylets to food content. A constant flow of saliva into wound is maintained till the food is well dissolved for sucking. This is the reason; a single penetration by the stylets may last upto 25 to 40 minutes in case of seed feeding. Saliva probably contains amylase and lipase which helps in dissolving the food. Salivary fluid might act as a
lubricant also which helps in penetration of stylets. After feeding, labium is withdrawn from the seed and the tip is invariably cleaned between the fore-tarsi having antennae and rostrum cleaner device.

They picked up the seed with the help of tibia and tarsi of fore-legs and then punctuation occurs with the aid of mandibular and maxillary stylets as described above. Moreover, damaged seeds lost viability and weight. Only covering of seeds is left while soft cotyledon content is sucked up (Fig. - 29 B, C and Plate - 27 B, D). When *O. sanctum* seeds are not available, generally in the months of April to July, they feed on the seeds of other host plant such as *Ocimum basilicum* in the same manner (Plate - 3 C).

Likewise, fresh flower of *O. sanctum* (Plate - 2 B) are taken as food source by all five nymphal instars and adults of *E. capitatus*.

After feeding on leaf, a punctured decolorized area is left and chlorophyll content in that part is lost (Fig. - 30 and Plate - 28 A, B). On a single leaf many such areas develop after 4 to 6 hours of feeding. Such leaf, lateron turns brown and wilts up. Punctuation on the leaf can be seen with the aid of artificial light after feeding is over. This reflects the magnitude of damage caused of this bug. Some punctuation on the leaf can be seen without the aid of artificial light after feeding is over. It was further observed that on *O. sanctum* leaf feeding start at the tip and proceeds towards posterior broader part. Due to this leaves turns brown from that area (Fig. - 31 and Plate - 28 A, B).

The ascent of sap in the food channel is probably due to combined effects of turger pressure, similar as observed by Dhiman (1985) in
Metacanthus pulchellus Dall. But, during seeds feeding only capillary action and suction pressure works.

In another experiment, no food was provided to them. Hence, due to starvation, firstly the I\textsuperscript{st}, II\textsuperscript{nd} and III\textsuperscript{rd} nymphs were died within 2 days and IV\textsuperscript{th}, V\textsuperscript{th} and adults died within 4 days.

For further confirmation, feeding behaviour was observed in field as well as in laboratory by rearing the bugs in cage (30×30×30 cm) which revealed that all five nymphal instars and adults suck the newly set seeds content as well as flowers and sap from the leaves. Carbohydrates and fat are taken from seeds while water, amino acid, minerals and vitamins are taken from leaf sap.

4. FOOD PREFERENCE: - Every living organism on our planet has a preferential feeding on food. Same is true for the insect *E. capitatus*. Food preference experiments were mainly conducted in laboratory. For this purpose, following experiments were conducted.

A. Food preference among different pulses: - For this purpose seeds of different pulses were taken such as moong (*Vigna radiata*), malka (*Vigna mungo*), urad (*Vigna mungo*), kabuli chana (*Cicer arietinum*) and arhar (*Cajanus cajan*). The seeds were kept over night in water to become soft. These seeds were placed in a wooden wire gauze cage at equal distance on a white paper. 35 starved bugs (10 adults + 5 number of each nymphal instars) were released in the cage. Their preference and orientation towards different sources of food was keenly observed and plotted on a paper diagrammatically (Fig. - 32). Data were recorded after each 2 hours interval and maintained in the table - 29. The data of this table depict that first preference was given to kabuli chana (*Cicer arietinum*) and second
preference has gone to moong \((Vigna radiata)\). However, no preference was given to malka \((Vigna mungo)\), urad \((Vigna mungo)\) and arhar \((Cajanus cajan)\).

**B. Food preference to different cereals:** - For this purpose different cereals were taken such as wheat \((Triticum astivum)\), jawar \((Sorglum vulgare)\), bajra \((Pennisetum typhodum)\), maize \((Zea mays)\) and rice \((Oryza sativa)\). The cereals were over night placed in water to become soft. These cereals were placed in a wooden wire gauze cage at equal distance on a white paper. 35 starved bugs (10 adults + 5 number of each nymphal instars) were released in the cage. Their preference and orientation towards different cereals was keenly observed and plotted on a paper diagrammatically (Fig. - 33). Data were recorded after each 2 hours interval and maintain the table - 30. The data of this table depict that adults and nymphs firstly preferred maize \((Zea mays)\) and second preference has gone to wheat \((Triticum astivum)\) and bajra \((Pennisetum typhodum)\). No preference was given to jawar \((Sorglum vulgare)\) and rice \((Oryza sativa)\).

**C. Food preference among the leaves of different host plants:** - For this purpose fresh leaves of different host plants such as mint \((Mentha arvensis)\), marva \((Ocimum basilicum)\) and Tulsi \((Ocimum sanctum)\) were taken. These leaves were placed in a wooden wire gauze cage at equal distance on a white paper. Like that of previous experiments, 35 starved bugs (10 adults + 5 number of each nymphal instars) were released in the cage. Their preference and orientation towards different host plant leaves was keenly observed and plotted on paper diagrammatically (Fig. - 34). Data were recorded after each 2 hours interval and maintained in the table - 31. The data of this table depict that first preference was given to Tulsi
and second preference has gone to marva leaves, only for short time. However, no preference was given to mint.

D. Food preference of *E. capitatus* on the extract of leaves of different plants: - For knowing the food preference of the bug towards the extract of the leaves of different plants viz. tomato (*Lycopersicon esculentum*), marva (*Ocimum basilicum*), Tulsi (*O. sanctum*), citrus (*Citrus limon*), chrysanthemum (*Chrysanthemum morifolii*), mint (*Mentha arvensis*) and thuja (*Thuja occidentalis*). Their leaves were plucked and grinded with the help of a grinder. 10cc distilled water was added to the grinded paste. In this manner extract of this leaves was prepared. 5cc of each extract was placed in petridish inside a cage at equal distance on a white paper. Thereafter, 35 starved bugs were released in the cage (10 adults + 5 number of each nymphal instars). Orientation towards different extracts was keenly observed and plotted on a paper diagrammatically (Fig. - 35) and data were recorded after 2 hours intervals for 24 hours and recorded in table - 32. The data of aforesaid table clearly depict that no preference was given to citrus and thuja leaves extract. Beside this, the bug population fed on the extract of almost all leaves (Tulsi, tomato, marva and mint leaves extract). However, no clear preference for any leaves extract was seen.

E. Food preference of *E. capitatus* on different parts of *O. sanctum*: - For this purpose different parts of *O. sanctum* such as mature seeds, young seeds, fresh flowers and fresh leaves were taken and placed separately in a wooden wire gauze cage at equal distance on a white paper. 35 starved bugs (10 adults + 5 number of each nymphal instars) were released in the cage. Their preference and orientation towards different parts of food was keenly observed and plotted on a paper diagrammatically (Fig. - 36). Data were recorded after each 2 hours
interval for 48 hours and maintain in the table - 33. The data of the table clearly depict that no preference was given to mature seeds. Beside this, maximum population of the bugs has given preference to young seeds and moderate population of the bugs has given preference to leaves. Minimum bug population was observed on young leaves and fresh flowers.

5. MIGRATION: - The flight may functionally classified as migratory flight, long range and short range or local flight. In the long range flight or so called “Trivial flight”, the insects travel for suitable habitat and their flights are generally concerned with feeding, mating or oviposition. (Johnson, 1969 and Baker, 1978).

Migration of *E. capitatus* was studied in Saharanpur where the abundance of two main food plants, *Ocimum sanctum* and *O. basilicum* exist in nature as well as in kitchen garden (Plates - 1 A, B and 3 C).

However, no true migration is observed in case of *E. capitatus* but the local fights were recorded within territory in different seasons. When the climatic conditions become unsuitable it goes to other suitable host plants for the purpose of feeding, moulting, sheltering and breeding. The unsuitability arises due to extreme lowering of temperature, 0° to 5°C in winter and high temperature upto 45°C in summer, low R.H. 0% and absence of food plants.

In rainy months, July to September, due to heavy rains, heavy winds and storms it migrates to the safe place, such as trunk holes and crevices and inside rolled leaves (Plate - 29 A, B). It migrates in a specified area on its main food plants. The bug, as already said, is not a true flier and only able to take short distance flight and it can only fly for
few seconds to one minute and can travel few meters to 25 meters at a time.

Leaf fall of *O. sanctum* begins from December last to the end of February. In first week of March new leaves and inflorescence begin to appear. Hence, during this period the bugs do not occur on this main host plant. In the month of November late, the leaves dried and roll up prior to leaf fall and the bugs are well protected in cylindrical purse of such leaves. Lateron, such leaves fell down on ground or entangled on the shrubs. As the temperature rises, they come out from the rolled leaves. During winter months, mid December to late February, the bug population goes under hibernation. From February late to mid March, the bugs and 4\textsuperscript{th} and 5\textsuperscript{th} nymphs feeds on the seeds of *O. basilicum* which contains similar fatty acids as in *O. sanctum*, and during this period they also suck the sap from the leaves, which meet the requirement of amino acids and water.

In last March, *E. capitatus* starts to report back on his main food plant. In the month of late May to June they are reported on other host plant e.g. *Ocimum basilicum*, but in the month of July, rain starts and the inflorescence of *O. sanctum* grow up. The bugs start report back on its main food plant, *O. sanctum*. In July to October, the bug population reaches on the peak level on this plant. In November, due to the shortage of *O. sanctum* seeds, these bugs migrate to other food plant and feed on the leaves. As the temperature starts declining, the adult bugs migrate to safer places for hibernation.

Due to heavy winds and storms as well as rains, high mortality is resulted in the migratory population. Field investigation has revealed that
due to these factors, the mortality of the male, female and 5\textsuperscript{th} nymphal instars occurred in strictly preferential order.

Thus, true migration in \textit{E. capitatus} is not well developed as the insects are incapable to travel long distance. This is probably due to less developed hind wings and flight muscles as also have been mentioned by Dhiman and Garg (1985). However, local migration and dispersal due to climatic and food factors exists truly in \textit{E. capitatus}.

6. DEFENSIVE BEHAVIOUR: - The defensive behaviour among insects is a complex one encompassing structural physiological, biochemical and behavioural adaptation. Self defence against parasites and predators is a basic biological problem faced more or less by all species.

The defensive behaviour of \textit{E. capitatus} was studied in the field as well as in laboratory in rearing cages (30×30×30 cms). A culture of \textit{E. capitatus} was maintained in wooden wire gauze cage as well as hurricane glass lantern chimneys covered at top by fine muslin cloth. Inflorescences of Tulsi were supplied as fresh food and the stale food was replaced daily. A water dip cotton swab was kept to maintain necessary humidity (Plates - 6 and 7). Mechanical irritation was provided to the bug to study defensive mechanism. Some behavioural defensive activities were observed in the bug during the course of field investigations. Perhaps, the most straight forward approach to defence is to flee, this is extremely effective in case of \textit{E. capitatus} and their nymphs too, because of their small size and their ability to accelerate very rapidly. Taking flight is a particular effective means of escape. The bugs are good flier and have wing coupling device for efficient flight (Fig. - 10 and Plate - 29 C). Whenever attempts were made to capture them, adults usually took flight.
and tried to escape. The same case was observed in case of I\textsuperscript{st} to V\textsuperscript{th} instars, on disturbance, nymphs flee rapidly and hide in between the flowers, inflorescence, in holes and crevices in the soil. The degree of speed of fleeing is inversely proportional to the size of nymphs, particularly, I\textsuperscript{st} nymphaal instars run rapidly than that of other stages.

On feeling the danger, nymphs often hide in between the flowers and seeds, and become motionless for sometime. It seems that there is visual sense of adaptation by which it can protect itself against predation. During the laboratory studies, the running or moving bugs, when disturbed either by hand or stick, they flee rapidly in other direction. It is defence against natural enemies which prefer live-prey. It was also noticed during field study as well as in laboratory, when the nymphs and adults \textit{E. capitatus} forced to move in a particular direction for feeding on the inflorescence of Tulsi (\textit{O. sanctum}), they did not move in that particular direction and moved in opposite or other direction.

Chemical defence also has been observed. On disturbance, either sex of adults and nymphaal stages used to spray a jet of scent fluid from the metathoracic scent glands through scent gland ostioles (Fig. - 14) which emits foul, very bad, and pungent smell due to which enemy avoids these bugs. Secretion of scent fluid is seen as reflex action. Nymphaal instars also emit jet of scent fluid from dorsal abdominal scent glands through their ostiole (Fig. - 37 and Plate - 12 D). It was further observed that II\textsuperscript{nd} to V\textsuperscript{th} nymphaal instars change their body colour greenish to camouflage with the green leaves and inflorescence of host plant. It prevents their easy detection by natural enemies (Plates - 30 and 31). The egg colour is bright red which pause a warning coloration for enemies for defence (Plates - 15 B, C and 16).
7. PHOTOTROPIC BEHAVIOUR: - In field *E. capitatus* shows generally positive phototropic response and prefers to live in medium intensity of light. It has been observed that during summer months (May and June) when the days are long with long photoperiod (L: D: 14:10) and intensity of solar light is on the peak, these bugs are rarely found on the inflorescence of Tulsi. However, in the morning hours these can be seen on dorsal surface of the leaf and at 7:00-8:00 a.m. these can be seen on the inflorescence. In the evening hours too, these can be seen on the under surface of the leaf and between the flower. In cloudy days when intensity of light gets lowered, the life activities of the bugs increases and they come in open area of host plant like inflorescence and leaves.

It is further observed that the photoperiod plays an important role in the copulation of *E. capitatus*. Low intensity of light is required to initiate the copulation which always occurs in evening time (before two hour of sun set). High intensity of light reduces the mating as well as feeding activity. Further, the female *E. capitatus* lays egg in between the flower to avoid the direct sunlight exposure (Fig. - 18 and Plate - 15 B, C).

Few experiments were conducted in laboratory to confirm the phototropic behaviour of *E. capitatus* on artificial light. In one experiment, a wooden cage was taken and it was divided into five chambers by cardboard partitions. In each cardboard, a central hole of two inch diameter was made. Thus, each chamber communicated with each other through this hole. A central chamber was kept dark. 15 watt bulbs of four different shades: viz; blue, green, red and yellow were fitted in each respective chamber, except the centre chamber. The bulbs were connected to main switch by a wire (Plate - 32 A). In the central chamber
of wooden cage, 50 adults *E. capitatus* were released and the bulbs were lighted for 4-6 hours. The number of bugs found in each chamber attracted after this period was noted. The data are recorded in table - 34 which indicate that maximum number of *E. capitatus* were attracted towards yellow light and then the preference had gone to blue light. Least number was attracted on green light and dark (releasing point). No response was observed towards red light.

In another experiment a wooden cage was taken and it was divided in two chambers by cardboard partition. In each cardboard a central hole of 2 inch diameter was made. Thus, each chamber communicated with each other through this hole. 9 watt fluorescent tube was fitted in one chamber and 40 watt non-fluorescent bulb was fitted in another chamber. These light were connected to main switch by a wire (Plate - 32 B). In this wooden cage, 50 adults of *E. capitatus* were released and the lights were lighted for four hours. Maximum 45 *E. capitatus* were found attracted to the fluorescent light and minimum 5 to the non-fluorescent light. The average number of insects attracted to the different colour of light during three consecutive years 2007-2009 are presented in table - 35.

This experiment was repeated 25 times and the average number of insects attracted to different shades of light was noted. These observations clearly depict that *E. capitatus* has positive phototropic response, though not equal response to all shades of light.

**8. CHEMOTROPIC RESPONSE:** - *E. capitatus* is a phytosuccivorous bug which attacks the medicinal plant, *Ocimum sanctum*. The plant sap possesses carbohydrate like sucrose, glucose, and cellulose, different amino acids and crude proteins. Besides these, it also
possesses many inorganic minerals like Ca, P, K, Mg, Cu, Fe and I etc. This prompted to workout the preference of this bug towards some chemicals and for this some simple experiments were carried out in laboratory.

**Experiment:** - The experiment was conducted in a rearing cage (45×30×30cm). On the bottom of cage 3cm. thick moist sand layer was spread. On it and in the centre, a watch glass was kept having a cotton swab dipped in solution of specific chemical. Now, 10 adults and 10 nymphs of *E. capitatus* were released in the cage. During the experiment 44 chemicals and biochemical were replaced one by one and observations thus sought are recorded in the table - 36.

A perusal of the table - 36 reveals that most of the chemicals used in the experiments showed negative response to *E. capitatus*. Adults as well as nymphs showed irritating action for some chemicals like sodium hydroxide, acetic acid, acetone and potassium bromide and they retracted their rostrum. The bug showed positive response towards most of the chemicals like- camphor, magnesium oxide and gave negative response to rest of the chemicals mentioned in table - 36. However, chloroform and ammonium sulphate attracted the male and female but these have gone in quiescent stage within 2-3 minutes.

Regarding the biochemical’s such as carbohydrates, amino acids and fatty acids, bugs and nymphs exhibited positive response against carbohydrates like glucose, fructose, maltose, sucrose and some extend to glycogen and negative response to starch.

The bug show positive response towards most of the amino acids like: L-arginine, L-tyrosine, DL-Isoleusine, Threonine, L (+) cystein, 4-
aminobutyric acid and negative response to rest of the amino acids mentioned in the table - 36.

Moreover, two fatty acids were taken for knowing chemotropic response of the bugs. *E. capitatus* indicated positive response towards oleic acid and negative response towards stearic acid.

Thus, a perusal of the table - 36 shows that almost some of the used chemicals have attractant property for the bugs but the biochemical substances, carbohydrates, amino acids and fatty acids which are the main component of the food, have shown positive response.

9. EFFECT OF FEEDING ON THE SEEDS VIABILITY:-  
*E. capitatus*, as already said, is a phytosuccivorous bug, drains out sap from the seeds and inflorescence of Tulsi. It bears piercing and sucking mouth parts by which it drains out content of the host part. For the observations of the effect of feeding on seed viability experiments were conducted. Field collected seeds were examined carefully in the laboratory to separate the healthy one from damaged seeds. Two chimneys marked as ‘A’ and ‘B’ were taken and each one was covered by fine muslin cloth at top and base was placed in a petridish. A wet cotton swab was kept in each chimney to maintain humidity. Two hundred healthy seeds were kept in each chimney (Plate - 33). Ten adults and ten nymphs of the bug were released in chimney ‘A’ while the seeds of chimney ‘B’ were kept as control. The bugs (pest) were allowed to feed on the seeds of chimney ‘A’ for two week. After this the bugs were removed from the chimney and seeds were taken out from both the chimneys and sown separately in well manured and irrigated beds. A constant vigil was kept to observe the germination for about 30 to 45 days. The experiment was repeated several times with variable number of
seeds of each plant and the data are recorded in table - 37. Same experiment was conducted in field in wooden wire gauze cages during 2007-2009. A perusal of the table - 37 shows that most of the affected seeds of *O. sanctum* could not germinate even after a period of 40 days causing 96 to 99.67% with an average of 97.83±13.94% damage in laboratory feeding, while those kept under control germinated upto 78.4 to 83.0% after 30-45 days. The damaged seeds, loss viability, weight and become unfit for germination.

To assess the field damage seeds, two hundred field collected seeds of *O. sanctum* from infected *E. capitatus* were sown in the well manured and irrigated soil. It was observed that only 5 per cent of the seeds were germinated (Table - 38).

To observe the loss of weight in the seeds of *O. sanctum* due to the feeding of this pest, 20 pairs of adults and 40 nymphs were released for feeding on 200 fresh healthy seeds in a wire gauze cage. After 15 days of feeding, the seeds were removed from the cage. The weight of seeds prior to feeding and after feeding was taken by an electronic chemical balance (Plate - 9 B). Thereby, the experiment was repeated during 2007, 2008 and 2009 with 200, 400 and 300 seeds respectively. The loss in weight was determined and presented in table - 39. The fatty oil (eugenole) obtained from the seeds of *O. sanctum* has great commercial value. *E. capitatus* feeds preferably on the fatty content of the seeds and this causes a great loss to the yield of oil. The data of table - 39 clearly reveal that loss in weight varied from 48.38 to 55.0 per cent and thus the oil extraction is approximately reduced to 50.0 per cent.

It was further observed that damaged seeds remained floated while the healthy seeds settled down on the bottom of the water filled container.
Thus, the healthy seeds can be easily separated from the damaged ones. However, data of the tables revealed that this bug is damaging a sizeable number of seeds every year and there is a need to find out a suitable control measure for this pest.