II. REVIEW OF LITERATURE

Due to spectacular and devastating locust plagues, the study of the members of the family acrididae was considered a subject of considerable interest since ancient period. Taxonomic studies were carried out by Linnaeus (1758), Forskal (1775) and others. There was a rapid increase in researches during the second half of nineteenth century as compared with the first half. In twentieth century except during the second world war period, the number of studies steadily increased.

The researches on the applied aspects of acridid pests started in early twenties and notable contributions have been made on the biological aspects also by Fedorov (1927); Parker (1929, 1930); Boldyrev (1929); Uvarov (1928, 1943, 1948, 1966); Golding (193, 1948); Maxwell-Darling (1934); Faure (1935); Key (1936, 1938); Roomval (1936, 1937, 1954); Hamilton (1936, 1950); Jamone (1938, 1939); Kyl (1938); Chealer (1938); Pruthi and Nigan (1939); Kennedy (1939); Tinkham (1940); Shotwell (1941); Chauvin (1941); Burtt and Uvarov (1944); Husain et al. (1946); Salt (1949, 1952); Norris (1950, 1954, 1962, 1968); Joyce (1952); Katiyar (1952, 1955, 1956, 1961); Albrecht (1953); Richard and Maloff (1954); Agrawal (1955).
Shulov (1956); Antoniou and Hunter-Jones (1956, 1968); Nakhla (1957); Khalifa (1957); Popov (1958); Hafes and Ibrahim (1958); Ghoudhuri (1958); Chapaman (1959, 1961, 1965, 1972); Milliard (1959); Stover (1959); Pickford (1960, 1966, 1970); Hartley (1961); Dudley (1961); Birsh (1950, 1958, 1961); Hunter-Jones and Lumbert (1961); Pradhan and Phauvani (1961); Shulov and Fener (1961, 1963); Ashall and Ellis (1962); Despeter (1963); Dadd (1963); Jago (1963); Hunter-Jones (1964); Putman and Handford (1958, 1964); Hogan (1965); Jacobson (1965); Bivard and Bpp (1965); Riegert (1967); Grewal and Atwal (1968); Phipps (1969, 1970); Smith (1969); Moriarty (1969); Harjai and Sikka (1970); Parihar (1971); Pickford and Gillett (1972).

The mode of copulation in acridids is reported in detail by Fedorov (1927) in *Acanthocephalum lacustris*, Boldyrev (1930) in *Locusta migratoria* Kyl (1930) in *Melanoplus differentialis*, Pruthi and Nigan (1939) in *Passalocorus pictus*, Katyar (1952) in *Eupomponocera roseni*, Morris (1954) and Hunter-Jones (1960) in *Schistocerca gregaria*, and Pickford and Gillett (1972) in *Melanoplus sarcinina*. During the process of copulation the male grasps the pronotum of the female with its first two forelegs and curves down the abdomen so that the penis is introduced between the ventral ovipositor valves of the female. The tip of the penis reaches the spermathetcal
duct. This type of copulation known as "riding type" is most common among acridids (Uvarov, 1966). Katiyar (1952, 1956b) recorded a variety of copulation postures which he called 'riding' and 'lateral types'. In such forms where the ratio of male and female length was high a hanging posture has been described. Popov (1958) observed in *Schistocerca gregaria* that copulating female continue to feed, crawl and jump during mating process. La Bourse (1910) observed an abnormal mating between the males of *Locusta migratoria* and the females of *Oedaleus decorus*. Pickford and Gillett (1972) in *Melanoplus sanguinipes* reported that male aggressiveness, female docility and production of a chemical attractant by the female, are factors which have a great influence on the selection of a mate.

Most of the members of the sub-family Acridinae and Oedipodinae use acoustical means of communication during sexual activity (Jacob, 1953; Perdeck, 1953; Haskell, 1953; Ottes, 1970; Leber and Chandrachukran, 1970). Certain body parts like antennae, palpi, cerci, sense organs and some chemical stimuli and female sex attractant play an important role in the courtship activity (Griddle, 1933; Jacobson, 1965; Thomas, 1965; Kyl, 1933; Uvarov, 1966; Pickford and Gillett, 1972). In *Acrornmnina*, certain adaptation take place in the body parts, which help in swimming i.e. expansion of the tibial margin and the first tarsal joint. Hind legs play main role while first and second pair of leg move a little or not at all (Takahashi, 1921).
Fedorov (1927) in *Aeacridium sagratum* observed that the female prefers to lay eggs in moist soil. The nature of the soil is also an important factor for oviposition. In cases where the soil is extremely dry, females fail to oviposit at all (Morris, 1968; Ercolani and Epp, 1965) and sometimes the female dies without egg-laying (Katiyar, 1956). Female *Coleopia subgeniculata* oviposits in black soil (Uvarov, 1928). Katiyar (1955) in *Aularches punctatus* observed deposition of the eggs in sandy loam. Joyce (1952) reported that the female of *Coleopia nenalooxis* prefers to lay eggs in clay soil. Morlant (1969) reported decline of egg-laying capacity with the advancing age of the female as in *Gryllus bimaculatus* Thunberg. Rao (1921) reported egg-laying in *Gryllus* on leaves of aquatic and other plants. Pradhan and Posthumus (1961) observed egg laying in *Hieracorynium nigrofulvum* Bol. in the roots of various shrubs. Before oviposition the female makes a selection of the site. At suitable places it digs hole in which the eggs are deposited. The process of oviposition has been described in *Aeacridium sagratum* by Fedorov (1927), Pruthi and Nagar (1939) in *Pseailocerus pictus*; Agrawal (1955) in *Atractomorpha crumputa*, Katiyar (1955, 1956a) in *Aularches punctatus* and *Parahieracorynium bimaculatus*, Nafez and Ibrahim (1958) in *Acrida palludosa*. Richard and Haloff (1954) reported the arrangement of the eggs in an egg-pod of *Stenobothrus lineatus* and *Hecatomatus marmoratus*.

In *Locusta migratoria*, Roemel (1936a) reported increase in the size of the eggs due to the absorption of moisture during the course of embryonic development with the
exception of few highly Xerophilous species like *Daphia pulexrinosus* in which the eggs do not change in size (Skulov, 1952). The variation in size and shape of the egg-pods is related to the moisture, the food of the parent grasshoppers and the number of egg-pods laid previously (Morris, 1950) and the nature of the soil (Millard, 1959). In *Catalous decorus*, Plotnikov (1921) recorded parthenogenesis, where egg development takes place without fertilization, but mortality rate was higher in egg and hopper stage. Riley et al. (1960) in *Caelura pallucida*, Munkel d' Herondais (1890a, 1890b) in *Dociostaurus* and Mihalec (1922) in *Locusta* have lucidly described the process of hatching. Temperature and moisture have been reported to play an important role in successful hatching (Parker, 1930; Shotwell, 1941; Despeter, 1963).

Salt (1952) observed that grasshoppers eggs are well adapted to withstand desiccation during period of drought. They may lose up to one third of their total water content and still successfully hatch. Pickford (1966b) found that the rate of egg mortality goes up due to extreme or dry conditions. On the other hand, high moisture level of the soil show detrimental effect due to restricted supply of oxygen (Hunter-Jones, 1964). In most of the species of the grasshoppers it has been reported that the eggs take large part of the water required for normal embryonic development between the fifth and tenth day following oviposition as recorded by Salt (1959) in *Melanoplus*, Hunter-Jones and

Shulov (1956) in *Anacridium aegyptium* observed that the development of eggs is normally completed in 30 days under suitable moisture conditions but is extended for more than two months due to water deficiency. The rate of mortality increases with higher soil moisture levels (Harjai and Sikka, 1970; Shulov and Pener, 1961). Grewal and Atwal (1968) found in *Chrotogonus trachypterus* that the incubation period of the eggs was inversely proportional to the temperature and moisture, but the moisture directly affects the viability of the eggs. The increase in moisture level at a given high temperature shows an adverse effect on hatching as well as on incubation period. Parker (1929) recorded higher hatching percentage of eggs laid in damp soil than in *Gomphra pellucida* Scudd. In *Schistocerca gregaria* Hunter-Jones (1964) observed that eggs did not hatch either in waterlogged soil (25 cc water per 100 g sand) or almost dry soil (0.6 cc water per 100 g sand). The water contents of the sand in the range between these two extremes made no difference and eggs in dry sand die within two days.
Antoniou and Hunter-Jones (1956) observed that the eggs of *Euprepocnemia capitata* Miller at 32°C hatched in 19 days while decrease of temperature to 28°C shows an increase in incubation period (27.5 days). Antoniou and Hunter-Jones (1968) recorded that the eggs of *Euprepocnemia plorana ornata* Walk. when incubated at 32°C hatched in 18 days. Similarly the incubation period of eggs at the same temperature in *Euprepocnemia plorana meridionalis* was 19 days.

Bodine (1925a) in *Melanoplus femurrubrum* observed that exposure to low temperature for a short time retards the development of grasshopper embryo. Uvarov (1928) found that alternating low and high temperatures greatly influence hatching.

Notable contributions have been made on hopper development in relation to different levels of temperature and humidity conditions (Parker, 1930; Suce, 1936; Rusain et al., 1946; Hamilton, 1936, 1950; Burnett, 1952; Antoniou and Hunter-Jones, 1956, 1968; Pradhan and Pashwani, 1961; Grewal and Atwal, 1968; Parihar, 1971). In American species of grasshoppers, Parker (1930) reported that the temperature and humidity accelerate the rate of development and shorten the hopper period. Hamilton (1936, 1950) discussed the effect of
different levels of temperature and humidity on hopper period and found that the hopper period decreased with the rise in temperature. The optimum conditions for the rate of development and the survival do not coincide. In *Locusta m. migratoria*, hopper developed faster at 42.2°C, while the lowest mortality rate was at 34.4°C. The respective optimum temperatures for *Schistocerca gregaria* being 38.3°C and 32.2°C. According to Hamilton, *Schistocerca gregaria* hoppers complete their development at 32.2°C and 45% R.H. while at 26.7°C and 25% R.H., no development takes place. Hamilton also observed that the rate of development is slowed down at low humidity than at higher, which contradicts the findings of Husain et al. (1946) and Chauvin (1941b) in *Schistocerca gregaria*. Khan (1949) studied the development of eggs and larvae of grain weevils (*S. oryzae* L. and *S. gregaria* L.) in relation to different temperatures and relative humidities. He observed that the rate of development is decreased at low temperature and low humidity. Simultaneously, the duration of larval period increased. It reduces as the temperature and relative humidity reaches to the optimum, again when the conditions reach above the optimum the development is retarded. Rate of mortality was also high at low temperature and low relative humidity. Grewal and Atwal (1968) in *Schistococcus trachini* found that hopper duration at 25°C, 30°C, 35°C and 40% R.H. was 50.7, 44.1 and 38.8 days respectively, but increase in relative humidity to 70% R.H. reduced the hoppers duration i.e., 46.5, 42.2 and 33.8 days at respective temperatures. The lowest survival percentage was observed at 40% R.H. Antoniou and
Hunter-Jones (1956) found that hopper duration at 20°C in *Hyperenemia cavitata* was 52.0 days for males and 62.5 days for females. In *E. nippedus ematinae* at 28°C duration of male hoppers was 37.0 days and 42.0 days in females while in *E. nippedus mercidentalis* 52.0 and 62.5 days in males and females respectively were recorded at the same temperature (Antonieou and Hunter-Jones, 1968). In *Erotylsus microphthalmus* Bol., Pradhan and Peshwani (1961) reported that hopper development is completed at 25°C in 71.0 days while at 32.5°C it takes only 35.1 days. Development was not completed at 20°C and 40°C. Similar results were obtained by Parihar (1971) in *Pogocerus pictus*, where at 25°C, 30°C, 35°C and 40°C, the rate of development was accelerated with the rise of temperature from 25°C to 35°C. The temperature beyond 35°C was unfavourable and no hopper completes the development at 40°C.

The number of hopper instars in acridids varies from species to species. Chooser (1938) reported that male and female pass through five instars in *Gedalia microphthalmus*. In *O. johnstonii*, the number of instars varies from seven to ten (Joyce, 1952). Bereshkov (1956) in *E. decorus* reported five instars in both sexes. The number of hopper instars in *E. holturnensis* was six in male and seven in female (Tinkham, 1940). In *E. cavitata*, six in male and seven in female (Antonieou and Hunter-Jones, 1956). In *E. nippedus* both sexes pass through six instars (Nakhla, 1957). In *E. rogersi*, five in male and six in female (Katiyar, 1961) and Antonieou and Hunter-Jones (1968) reported in *E. p. ematinae* that male and
female hoppers pass through six instars in both sexes while
in *E. n. meridionalis*, male has six instars while seven are
found in female hoppers. Hodge (1933) reported that addi-
tional instar in acridids, is due to different size of male
and female. He further reported that there is no correlation
of an extra instar with food or sex as in *Helanogonus*. In
*Locusta*, Key (1936) assumed that the additional instar is an
inherited character, and temperature and relative humidity
having no effect on it.

The longevity of the adult is affected by temperature.
Parker (1930) observed that *Camula pellucida* survived for
only 15.8 days at 37°C and laid 4.2 egg-pods per female during
this period, whereas the span of life at 27°C increased to
double (36.6 days) but only 1.0 egg-pods per female were laid.
In *Chortogonus trachypterus*, Grewal and Atwal (1968) found
that female lived longer at 25°C, as compared with 30°C and 35°C.
The maximum egg-laying was recorded at 30°C. The relative
humidity has little effect on the reproductive potential.
Several studies on the seasonal life-history of grasshoppers
have been done, notable among them are (Rao, 1921; Uvarov,
1923; Pruthi and Nigam, 1939; Shotwell, 1941; Richard and
Raleff, 1954; Agarwal, 1955; Katiyar, 1955, 1956; MacCarthy,
1956; Edvard, 1960; Pickford, 1960, 1966; Riegert and Pickford,
1963). Climatic conditions play an important role in overall
fluctuation of grasshopper population. It is also correlated with the availability of the food. Favourable ecological conditions increase biological activities. No information is available on seasonal life-history of \textit{D. abruptus} Thumb. and \textit{E. alae}ria Serv. Only brief descriptions are available on allied species.

In \textit{D. senegalensis}, Maxwell-Darling (1934) reported that it is found throughout the year in Sudan. In Nigeria, it is found after the rains. There is only one generation in a year and maximum number of hoppers were found in the last week of August till mid September (Golding, 1934, 1948). Chesler (1938) found two generations of \textit{D. nigrofasciatus} in a year in South Africa. Joyce (1952) observed that the \textit{D. johnstoni} and \textit{D. senegalensis} have two generations in a year in Sudan. He also reported that the survival of the species is possible in egg stage during dry season and number of the adults was maximum in September and October. Some brief notes regarding seasonal abundance of \textit{E. ibidana} and \textit{E. plurana} have been published by Golding (1934, 1948) in Nigeria. Very brief account has been given by Joyce (1952) on the seasonal life-history of \textit{E. noxius} and \textit{E. ibidana}, Tinkham (1940) in \textit{E. kobutensis}, Khalifa (1957) and Nakhla (1957) in \textit{E. plurana} Charp. Antoniou and Hunter-Jones (1956) studied the life-history of \textit{E. sanitata} Miller. He also
published an account on life-history of *E. n. ondatros* in 1968. Jago (1963) described the life-history of *E. n. meridionalis*, and presented a key for identification of each instar. In South Africa, Phipps (1970) recorded the seasonal history of *E. meridionalis*. Only Katiyar (1961) from India has described a detailed account of seasonal life-history of *E. n. ondatros*. 