A STUDY ON THE EFFECT OF CONSTANT AND FLUCTUATING TEMPERATURES ON SOME ASPECTS OF BIOLOGY OF *NILAPARVATA LUGENS* (STÅL) AND *NEPHOTETTIX VIRESCENS* (HORV)

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ABSTRACT

Nilaparvata lugens (Stål) and *Nephotettix virescens* (Horv) are the two major rice pest in Bangladesh. Temperature response of these two species was studied in the laboratory.

The favourable range of temperature for preoviposition period was 30°C-40°C for both the species. The incubation and developmental period was found to be shortest at 40°C. The maximum and minimum adult longevity were at 25°C and 40°C respectively. The maximum hatchability was observed at 30°C and minimum at 20°C in both the species. The maximum survivality from egg to adult stage was found in 30°C in *N. lugens* and 25°C in *N. virescens*. The duration of the larval periods were 30 days at 20°C in *N. virescens* and 31 days in *N. lugens* at the same temperature. The egg viability was maximum in 25°C to 30°C and minimum at 20°C. The time required for hatching of eggs of both the species was almost same. At 10 and 45°C the development of eggs and larvae did not occur. The time required for development of eggs and larvae was more at fluctuating temperature than the constant temperature.

CHAPTER - I

INTRODUCTION

INTRODUCTION

Insects like other poikilothermic animals respond to change in environmental temperature possively conforming to the environment. Temperature influences the speed of development, the duration of life and their behaviour (Andrewartha and Birch 1954). Influence of temperature on insects has been studied by many workers, viz. Uvarov (1931) reported that weather induced mortality among insects has often been caused by excessively high temperatures, Ludwig and Cable (1933) reported that at low temperature partial development may occur but due to incomplete development, the percentage of adult emergence in D. melanogaster was low. Melvin (1934) carried out experiment on the incubation period of the eggs of Musca domestica and concluded that the peak temperature for egg development was 36°C. Voute (1936) studied on the rate of development of the eggs of E. kuhniella at constant temperature and found that at 13°C the moths laid very few eggs and eggs were laid at lower temperatures, the moths also laid very few eggs at 33°C and no eggs were laid at higher temperature. Davidson (1942) worked on the relationship between the temperature and speed of development of D. melanogaster at constant temperatures and reported that the speed of development of the eggs increases as the temperature rises, untill about 30°C is reached. Above the temperature, the speed of development decreases. Greenbank (1956) reported that large numbers of spruce budworm larvae died due to climatic factors and because of this the pest seldom reaches the epidemic level. Fye and Bonham (1979) showed that the soil surface temperatures in cotton fields are high enough to cause mortality of immature boll weevils, Anthonomus grandis Bonham. Fye (1971) reported that exposure to 43.9°C. for 3 hours caused substantial mortality of mature pink boll worm Pectinophora gossypiella and 90% mortality occurred when this exposure lasted 12 hours. The influence of temperature in determining the emergence and development of insect populations is well established by Eckenrode and Chapman (1972).

The brown plant hopper, Nilaparvata lugens (Stål) and Nephotettix virescens are major pests of rice in Asia. Both the larvae and adult of these species cause drastic damage to rice crop throughout Asia. Due to the attack of these pests the plant vigour is destroyed, the tiller number is lowered, percent of unfilled grain maximizes, vectors the virus and the yield is affected (Miyaka and Fugiwara 1962, Suenaga 1963, Nasu 1964, Kisimoto 1965, and Pathak 1968).

In nature temperature is not constant and as it is an important variable it has been observed that there is a great population fluctuation of N. lugens and N. virescens in different times of the year in Bangladesh. The population goes down in winter and build up during the summer. But to our knowledge no systematic study is available adequately describing the temperature tolerance limit and other temperature influenced factors on *N. lugens* and *N. virescens*. Such information is essential to formulate a better pest management system.

Therefore, the present work was undertaken to study the effect of constant and fluctuating temperatures on some biological aspects of *N. lugens* and *N. virescens* under laboratory condition.

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Literatures on the temperature effect on Nilaparvata lugens and Nephotettix virescens are scarce. Therefore, a brief review of the related literature to the present work available have been presented below.

Melvin (1934) observed that high temperatures actually prolonged the incubation period, especially in the case of Lucillia cuprina Wied. Time required for hatching of eggs were 15.06, 12.00, 9.81, 8.48, 7.80, 7.72 and 8.91 hours at 74, 79, 84, 89, 94, 99 and 104°F respectively. The time required for hatching of eggs of Musca domestica L. were 51.45, 33.28, 23.08, 17.16, 13.50, 10.65, 9.00, 8.14, 7.63 and 8.05 hours in 59, 64, 69, 74, 79, 84, 89, 94, 99 and 104°F, none of the eggs of any species hatched.

Voute (1936) did experiments on the rate of development of the eggs of the moth Ephestia kuhniella at constant temperatures. He found no eggs were laid at lower temperatures. At 13°C the moths laid very few eggs. The moths also laid very few eggs at 33°C, and no eggs were laid at higher temperatures. Although the lowest temperature at which records are given for hatching of the eggs in 13°C, complete embryonic development to hatching occurred, in a few instances, at 10°C, even at 8°C.

Davidson (1942) worked on the relationship between the temperature and rate of development of <u>Drosophila melanogaster</u> at constant temperatures. He pointed out that the speed of development of the eggs increased as the temperature rises until about 30°C is reached. Above this temperature the speed decreased.

Andrewartha and Birch (1954) opined that in nature temperature is not constant. It influences the speed of development, duration of life. The range of temperature favourable to any particular species is related to the prevailing temperatures in the places where the animal usually lives.

El-sawaf (1956) in Egypt reported some factors affecting the longevity, oviposition and rate of development of the Southern Cowpea Weevil, <u>Callosobruchus maculatus</u> F. and reared at a constant relative humidity and temperature of 75% and 25°C respectively. The preoviposition period was significantly increased to 0.38 and 1.07 days at the temperature of 18 days and 35°C respectively. He observed the highest number of eggs laid per female was on the average 89.6 at 25°C and 90% R.H. He concluded that the hatching period was 3.68 to 20.71 days at different temperatures, but at different relative humidity the incubation period was lowered from 9.14 to 9.30 days. He pointed out that the duration of the larval-pupal period was also considerably reduced as the temperature was increased. He noted that the temperature and humidities had no effect on the sex ratio in the emerged adult progeny. There was a slight preponderence of males, 50.33 to 52.98% of the progeny being males. His experiment on longevity of adult weevils revealed that in all cases the females lived longer than the males.

Hafez & Osman (1956) studied the biology of Bruchidius alfichii, Bruchidius trifolii Pic. in Egypt. They recorded the longevity, oviposition period of these species. The males lived longer than the females, the longevities were 3.7 and 8.7 days for B. trifolii females and males respectively.

Messenger & Flittens (1959) dealt with environment and its effects on insects. After experiment they found extreme constant temperatures involve sudden and possibly traumatic changes in thermal conditions, the effects of which on insects are unknown. The data obtained under constant temperature, may therefore, be markedly different from those obtained under fluctuating temperatures characteristic of natural habitats.

Bonnemaison (1961) studied on some factors affecting the fecundity and fertility of cabbage army worm Memestra brassicae L. He suggested that since the larval period is longer at lower temperatures, the larvae consume more food and thus become heavier.

Miyake & Fujiwara (1962) worked on brown rice plant hopper Nilaparvata lugens and noted that the maturation time of N. lugens is longer at low temperature, the emergence and reproductive performance were accelerated by the high temperature.

Hinckley (1963) reported that in Figi, the adult longevity of Nilaparvata lugens was about 2 weeks during the months of January-April. Within a temperature range of 20-30°C the preoviposition pweriod of brown plant hopper was reported to range from 1 to 6 days by Mochida (1964).

Suenaga (1963) studied on the ecology of N. lugens and N. virescens and reported that they cause considerable damage to growing rice plants throughout Asia. He reported that in Figi the adult longevity was about 2 weeks during the month of January-April. The number of eggs laid by N. lugens fluctuates widely among individuals of the same generation in the same or different years. He reported that the shortest nymphal period was at 27°C. This period increased with the increasing or decreasing of temperature.

Mochida showed (1964) within a temperature range of 20-30°C the pre-oviposition period of B.P.H. was reported to range from 1 to 6 days.

Nasu (1964) reported that the leaf duration of Geocoris punctipes (Say) decreased as the temperature increased. Apparently 10°C is below the developmental threshold to eggs and 40°C is above the limit at which hatching can occur. At 15°C only a few egg hatched and most nymphs lived less than 1 day. Like the eggs stage, nymphal stage duration decreased as temperature increased. Although no egg hatched at 40°C, 5 nymphs from eggs incubated at 35°C completed their development at 40°C. Temperature of 10°C were as lethal to nymphs as to eggs; though eggs hatched at 15°C, no nymphs developed into adults. At a given temperature, development of nymphs required about twice as much time as hatching of eggs.

Champlain and Sholdt (1967) showed that there is no significant difference in the rate of development of Lygus hesperus eggs or nymphs between fluctuating or constant temperatures.

Misra and Israel (1968) reported the incubation period of N. lugens during December (13.5-27.1°C; R.H. 81-90%) in India at Cuttack to be 12 days. The corresponding period of Sogata farcifera was 6 days during September. Israel *et al.* (1968) however, recorded that the maximum life span of the female of each of *N. lugens* and *N.* species was around 2 months.

Pathak (1968) pointed out that 25° to 30°C was considered by various workers as the optimum temperature range for rice leaf hoppers and plant hoppers. The adult of *N. lugens* remain active from 10 to 32°C. He stated usually the incubation period for most of the species of plant and leaf hoppers ranged between 4 and 8 days. The nymphal period ranges between 2 and 3 weeks during summer. *N. lugens* usually live for 10 to 20 days in summer. The females of *N. lugens* lay on average 300-350 eggs. *Nephotettix* species lay on average 200 to 300 eggs. The oviposition period at 20°C for *N. lugens* was 30-50 days in autumn.

Cheng (1969) from his work on *Nephotettix impicticeps* reported that in general the duration of the life cycle is prolonged at a temperature below the optimum, while the reverse is found at a temperature optimum. He found the longevity of female *N. impicticeps* being about 26 days at 20°C.

Fye & Bonham (1969) studied the developmental periods for boll weevils reared at several constant and fluctuating temperatures. They found that developmental period ranged from 88 days at 15°C to 17 days at 30°C, a temperature of 35°C increased the periods to 17.5 days. Developmental period of Anthonomy grandis thurberiae Pierce, ranged from 72.5 days at 15°C to 17.5 days at 30°C, a temperature of 35°C prolonged the developmental period of all strains. They reported that the extended period for development at 35°C indicated the slowing of undersigned physiological reactions by excessive heat. The extended developmental periods of boll weevils at 35°C indicate greater vulnerability to higher temperatures and a probable lack of intense selection for heat tolerance. They also observed that the best rearing efficiency in regard to survival was obtained at 20°C. However at 25°C the rearing period was by 2 weeks, but higher mortality occurred. Likewise, rearing time was shortened an additional 4-period by using a temperature of 30°C, but mortality increased. Thus "efficiency" is relative and can be geared to the requirements of the research of the control programme in progress.

Bae and Pathak (1970) observed that within a temperature range of 25 to 33°C the longevity shortened with increasing temperature and that the females lived longer than the male insects. The average longevity at 25°C was 3.4 and 4.1 day for male and female insects respectively.

Chen (1970) noted that the nymphal development of Nephotettix virescens was slower at lower temperatures and faster at higher temperatures for both male and female.

Raney et al. (1971) made laboratory studies of Aphelinus asychis (Walker) an imported internal parasite of aphids, conducted at 5-controlled temperatures. They found that the longevity of the adult female decreased with increasing temperatures and the 21.1-32°C alternating temperatures yielded an approximate midway response. The mean longevity of adults was approximately 18 days at 23.9°C and 9 days at 32.2°C. The highest ratio of females to males occur at the lowest temperature studied (23.9°C) with approximately 2.40 to 1.00, which at 32.2°C was about 1:1. The parasite took approximately 16 days to develop from egg to adult at 23.9°C and 10 days at 32.2°C. The developmental time for the fluctuating temperatures of 21.1-32°C was 12.5 days.

Cheng & Pathak (1971) reported that the rate of nymphal growth of N. virescens was very fast at 29, 33 and 35°C and the total larval period at this temperature averaged about 16 days. At lower temperature the larval development was slow. The average nymphal period at 20°C and 24°C was about 37 and 28 days for slow. The average nymphal period at 20°C and 24°C was about 37 and 28 days for female and 34 and 25 days for the males.

Atwal and Singh (1972) studied on the development of <u>Euproctis lunata</u> Walker they reported that laboratory studies on the development of Euproctis lunata showed at constant temperatures of 20, 25 and 30°C, the duration of the egg stage lasted 11.26, 7.23 and 6.00 days and the viability was 78.00, 84.1 and 88.1 percent respectively. At variable temperatures of 20 to 30°C the duration of the egg stage was 5.96 and 4.87 days respectively. The females always lived longer than the males.

Hiraro (1972) found that nymphal period varied from 14.4 to 15.3 days at 25°C but at 20°C it varied from 25.4 to 27 days. He observed that males lived slightly longer than females.

Stenseth (1972) investigated on the effect of temperature as a factor in the ecology of <u>Thomasiniana theobaldi</u>. He reported that development was completed at all temperatures between 12 and 30°C on the basis of the mean hatching of the eggs, the incubation period ranged from 10 days at 12°C to 2 days at 30°C and the timee of larval development from 40 days at 12°C to 8 days at 24°C.

There was a considerable variation or spread between the minimum and maximum time required to complete the larval development, especially at the lower temperatures. On average, the time required for the development from oviposition to full grown larvae varied from 50 days at 12°C to 11 days at 24°C. After this, developmental period increased.

Rose (1973) studied the biology of different species of Cicadulina (Hom., Cicadellidae) to collect some informations with particular reference to the effect of temperature. The developmental period for eggs at constant temperatures of 23, 25, and 30°C were 14.0, 9.4 and 7.2 days respectively. The time required for the developmental periods from egg to adult was 40.8, 29.0 and 21.2 days for male and 39.0, 28.3 and 19.7 days for the females at the same temperatures respectively. The developmental period decreased with the increase of temperature. The optimum period for development was observed at 30.1°C. Regarding sex ratio, he reported that a preponderance of males was noticed among eggs laid by young females at 22, 26 and 28°C and more even sex ratioes amongst eggs laid by an older females.

Mueller and Stern (1973) studied the reproductive potential, survival rate, maturation and longevity of Lygus hesperus Knight and L. elisus Van Duzee at 26.7 and 20°C and 14 and 12.5 hours light regimes respectively. There was no significant difference between the pre-oviposition period of time required for nymphal development in either species at the same temperature.

Madubunyi and Koehler (1974) conducted experiments on the Albizia Pdyllid, Psylla uncatiodes (Ferris and Klyver) under constant temperatures (12°C) ranging from 15 to 45°C. At 45°C, oviposition and embryonic development were inhibited and adults did not survive beyond 4 days. Although 76.9% of the eggs hatched at 30°C all the resultant nymphs died without completing development and generation time were inversely related to temperature between 15 to 25°C. Egg survived at all temperatures in which complete development occurred.

Ash and Greenberg (1975) reported the influence of temperature on the developmental rates of eggs, larvae, and pupae of Phaenicia pallescens (Shannon) at 19, 27 and 35°C. The median time from egg to adult for Sericata was 53.9 days at 19°C, 13.5 days at 27°C and 11.3° days at 19°C, 12.8 days at 27°C and 10.4 days at 35°C. The time of incubation for both the species increased with the decrease of temperature.

Tanigoshi _et al._ (1975) studied the effect of constant temperatures on the biological development of the Mc Daniel Spider Mite, _Tetranychus mcdanieli_ Mc Gregor. _T. mcdanieli_ populations attained their optimum growth and reproductive rates at 35°C.

Jacob _et al._ (1977) worked on the life cycle of _Ephestia Kuhniella_. He found that the incubation period of the eggs of _E. Kuhniella_ depends upon temperature. The minimum incubation period was 3 days at 31°C. This period rose to about 7 days at 22°C, 14 days at 15°C and 28 days at 12°C.

MATERIALS AND METHODS

Temperature has a great influence on the life cycle of insects. In the present study attempts were made to determine the effect of temperatures on the various stages of life cycle of Nephotettix virescens and N. lugens in laboratory conditions and following materials and methods were employed.

Collection of initial stock

The experiments were set up by collecting adult green leaf hoppers and brown plant hoppers from rice field specially from seed beds of BRRI Farm at Gazipur. The insects were collected from the field by a standard sweeping net and separated from the net by a mouth aspirator. They were then caged with myler film (43.2 cm in length and 7.6 cm in diameter).

Culture of the insects

For experiment the stock culture of insect was set up in rearing cages. The cages measured 76.2 cm X 61.0 cm X 80 cm made of nylon net and wooden frame. The two species were maintained in separate rearing cages.

The adult green leaf hoppers and brown plant hoppers were released on 30-35 days old potted rice plants. The potted plants were kept inside the rearing cages to facilitate oviposition by experimental insects. Before introducing the potted plants inside the rearing cages, the plants were cleaned and the outer leaf sheaths were removed to destroy any possible oviposition by other insects. Necessary precautions were taken to keep the insects free from predators, pathogenges and other unwanted species of insects. The plants used for rearing and breeding of the experimental insects were earlier shown in earthen pots. Six pots were kept in each cage. Thus a series of stock culture were maintained to get a constant supply of insects during the experiment. The cages were kept in the departmental lawn.

Experimental procedure

a) Effect of constant temperature :

To study the effects of constant temperatures on some biological aspects of the experimental insects, the experiment was conducted in an incubator at constant temperatures of 20, 25, 30, 35, 40 and 45°C. The seedlings of two to three weeks old were placed in the glass jars (17.5 cm X 3 cm dia.) and few drops of water were added to avoid dehydration of seedlings. Adult males and females from the stock culture were released on the seedlings in the jar and were kept in the incubator at desired temperature to study the pre-oviposition period incubation period, developmental period, fecundity, egg hatchability, longevity and survivality. The mouth of the jars were covered with fine muslin cloths and secured with rubber bands to prevent the escape of experimental insects.

For each experimental temperature four replications were considered and for each experiment one set of control was maintained at room temperature.

In all experiments, 75% relative humidity was maintained by using super saturated Nacl solution in a glass tray at the bottom of the incubator (Birch 1954). Relative humidity of 75% would probably be close to that to which the insects are exposed in the field even under extreme high temperature.

Pre-oviposition period :

Freshly emerged adults were collected from stock culture and placed in another rearing cage containing potted rice seedlings to facilitate mating. To ensure mating, after two days the adults were removed from the cage and introduced into the glass jar containing seedling and water and kept in the incubator at desired temperatures. Everyday the seedlings were checked to observe the first egg laying and pre-oviposition period was recorded.

Incubation period :

To determine the incubation period of the egg the seedlings containing the egg masses were taken out from the incubator.every day and checked whether eggs have hatched or not. The egg hatch was observed by examining the eggs under the binocular microscope and counting the 1st instar larvae. The larvae after hatching leave their original place and move towards the tender leaves of the seedlings for feeding.

Hatchability :

The egg hatchability in a particular temperature has been tested by counting the number of eggs incubated and the number of 1st instar larvae hatched.

Developmental period :

Seedlings were checked daily to record the durations of 1st, 2nd, 3rd, 4th and 5th instar larvae. The developmental period was recorded by counting the day from egg laying upto the day of adult emergence.

Fecundity :

To observe the fecundity, every day the seedlings were checked to record the number of eggs laid by the female at each temperature

Survivality :

Survivality was assessed by counting the number of exuvae left after each ecdysis.

Longevity :

To find out the influence of temperature on the longevity, dead insects were taken out every day and recorded. The adult longevity was determined by counting the days from final emergence to death.

b) <u>Effect of fluctuating temperatures</u> :

In nature, temperature fluctuates more or less regularly with a 24 hour periodicity. Experiments with extreme constant temperatures involve sudden and possibly traumatic changes in thermal conditions. The data obtained under constant temperature may, therefore, be markedly different from those obtained under fluctuating temperatures characteristic of natural habitats (Messenger & Flitters 1959). For these reasons part of the present experiment of fluctuating temperatures were used. Varying temperature patterns were designed and programmed into the incubator for 6, 15 and 18 hours duration per day.

To determine the effects of 6, 15 and 18 hours exposure per day the experiment was designed on the two species of insects in the incubator. The incubation period, egg hatchability, developmental period and adult longevity of the experimental insects were studied at 20, 25, 29, 32 and 35°C.

The method was same as in case of constant application of temperature excepting that the insects were treated in the incubator for the desired durations.

CHAPTER - IV

EFFECTS OF CONSTANT TEMPERATURES ON SOME ASPECTS OF BIOLOGY OF *N. LUGENS*

Effect of constant and fluctuating temperatures on some aspects of biology of Nilaparvata lugens and Nephotettix virescens were studied and results obtained are stated below.

Studies on the effect of constant temperatures on N. lugens were conducted at 10, 20, 25, 30, 35, 40 and 45°C. The effect of various temperatures was studied on the pre-oviposition period, incubation period, egg hatchability, developmental period (from egg to adult), adult longevity, fecundity and survivality of the insects.

Effect of constant temperatures on N. lugens

Pre-oviposition period :

The pre-oviposition period of N. lugens recorded during the course of experiment is summarised in Table 1. The effect of temperatures on the pre-oviposition period was observed by exposing the mated females to various constant temperatures. The mean pre-oviposition periods of N. lugens ranged from 12 to 4 days over a range of constant temperatures from 20°C to 40°C. The mean pre-oviposition periods were 12.2, 11.2, 6.9, 5.1 and 4.1 days at 20, 25, 30, 35 and 40°C respectively (Table 1). The maximum period required for depositing the first egg at 20°C (12.2 days). The minimum pre-oviposition period was observed at 40°C. The optimum temperatures for ovi-position was 35°C to 40°C. Above the optimum range of temperature the insects failed to oviposit.

Table 1. Effect of constant temperatures on the preoviposition period of Nilaparvata lugens.

Temperature in (°C)	Rep.1	Rep.2	Rep.3	Rep.4	Average	Control 28°C-32°C
	Preoviposition period in days					
20	12.2	12.1	12.0	12.3	12.2	8
25	11.5	11.5	11.0	11.0	11.2	10
30	6.1	7.0	7.0	7.1	6.9	10
35	5.0	5.1	5.2	5.3	5.1	8.1
40	4.3	4.0	4.0	4.1	4.1	8
45	all died without laying					7

Observed value of F 9.58

Tabulated value of F at the level of 1% 5.29

5% 3.24

Mean of 4 replications

At extreme low (10°C) and extreme high (45°C) temperatures the insects died without laying egg after 4 and 1 days respectively. The statistical analysis of the variance of the effect of temperature on the pre-oviposition period of *N. lugens* was highly significant.

Incubation period :

The incubation period of *N. lugens* under different constant temperatures is presented in Table 2 & Fig.1. The data on Table 2 shows that the incubation period was largely dependent on the prevailing temperatures. Under different temperatures the mean incubation periods were 10.1, 8.9, 6.4, 2.5 and 3.1 days at 20, 25, 30, 35 and 40°C respectively but eggs did not hatch at two extreme experimental temperatures i.e. 10 and 45°C.

At 45°C the eggs lost their shape, became shrunken and blacken. The incubation period was longest at 20°C, it then decreased as the temperature was increased upto 35°C. Above 35°C incubation period increased again. The threshold temperature extrapolated from the observed incubation period was 19°C. The effect of temperatures on the incubation period of *N. lugens* was highly significant.

Table 2. Effect of constant temperatures on the incubation period of *N. lügens*.

	Incubation period in days					Control
Temperature (in (°C)	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Average	25°C-33°C
20	10.1	11.0	10.1	10.2	10.1	10
25	8.5	8.5	9.7	9.0	8.9	8
30	5.9	6.8	6.5	6.6	6.4	7
35	2.5	2.5	2.5	2.5	2.5	5
40	3.0	3.0	3.1	3.2	3.1	5
45			all died			

Observed value of F 17.1

Tabulated value of F at the level of 1% 5.29
5% 3.24

Average of 4 replications

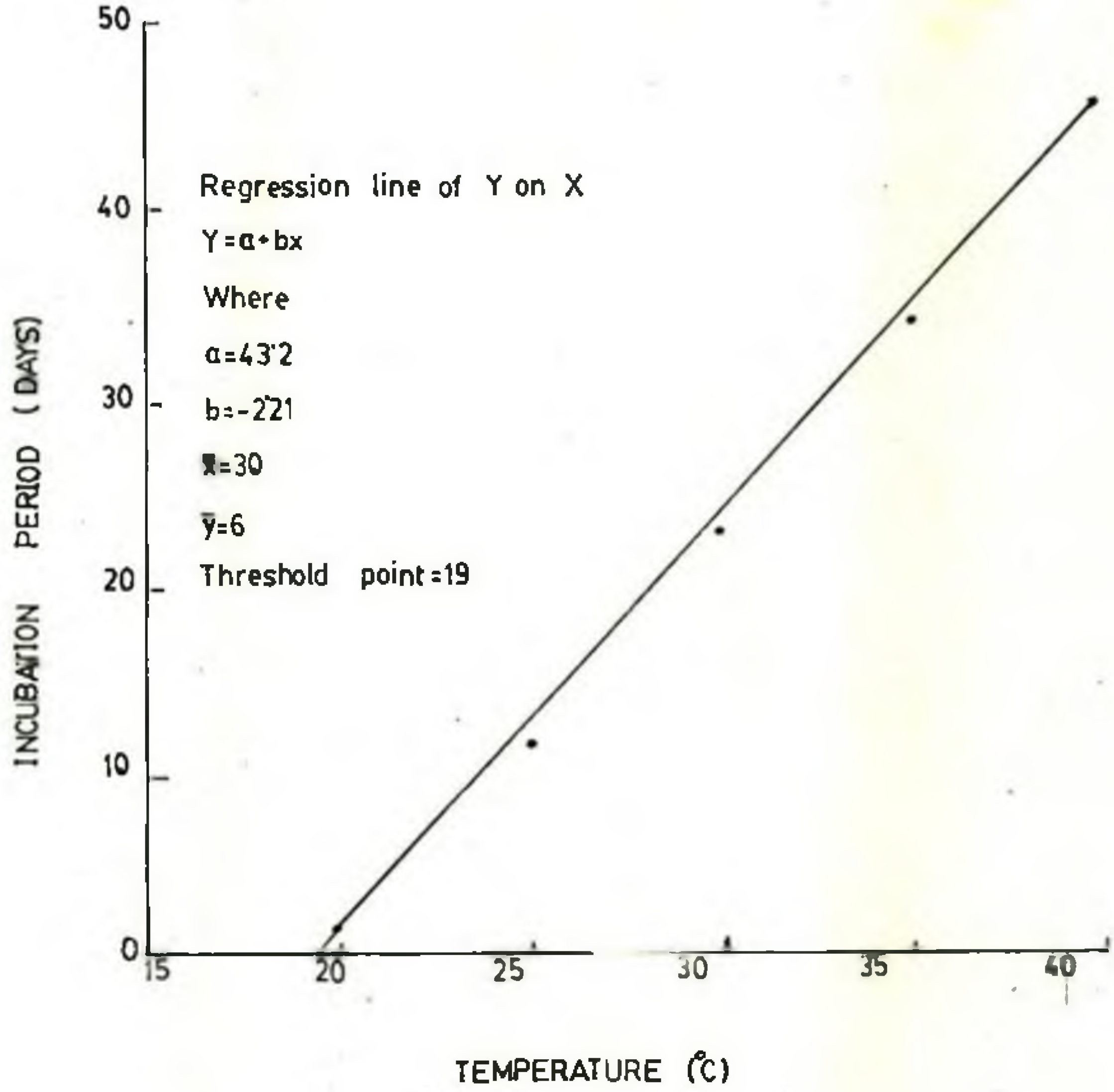

Fig. 1. Effect of constant temperature on the incubation period of N. lugens.

Egg hatchability :

The results recorded in Table 3 indicate the percentage of egg hatching of N. lügens at different constant temperatures. The total percentage of egg hatch were 40, 91, 100 80 and 83 at 20, 25, 30, 35 and 40°C respectively. The percentage of hatching was maximum at 30°C. At the two extreme experimental temperatures (10 and 45°C) the eggs did not hatch. The egg hatchability was found to be temperature dependent i.e., with the increase of temperatures the percentage of egg hatching also increased. The lowest percentage of hatching was observed at 20°C.

Larval period :

The data in Table 4 represents the larval period of N. lügens at different constant temperatures. The mean duration of five larval instars at different temperatures of 20, 25, 30, 35 and 40°C were 32.6, 28.6, 20.9, 15.6 and 15.8 days respectively. The incubation period was longest at low temperature (20°C) and shortest at 40°C, the results indicate that the temperature had a significant effect on the total larval period.

Life Cycle :

Table 5 reveals that temperatures affected the life cycle of N. lügens. It was found that the time required for egg

Table 3. Effect of constant temperatures on the egg hatchability of *N. lügens*.

Temperature in (°C)	No. of egg incubated	No. of egg hatched	% of hatching	Control 28°C-31°C
20	20	8	40	60%
25	33	30	91	66%
30	29	29	100	75%
35	30	24	80	71%
40	24	19	83	66%

Average of 4 replications

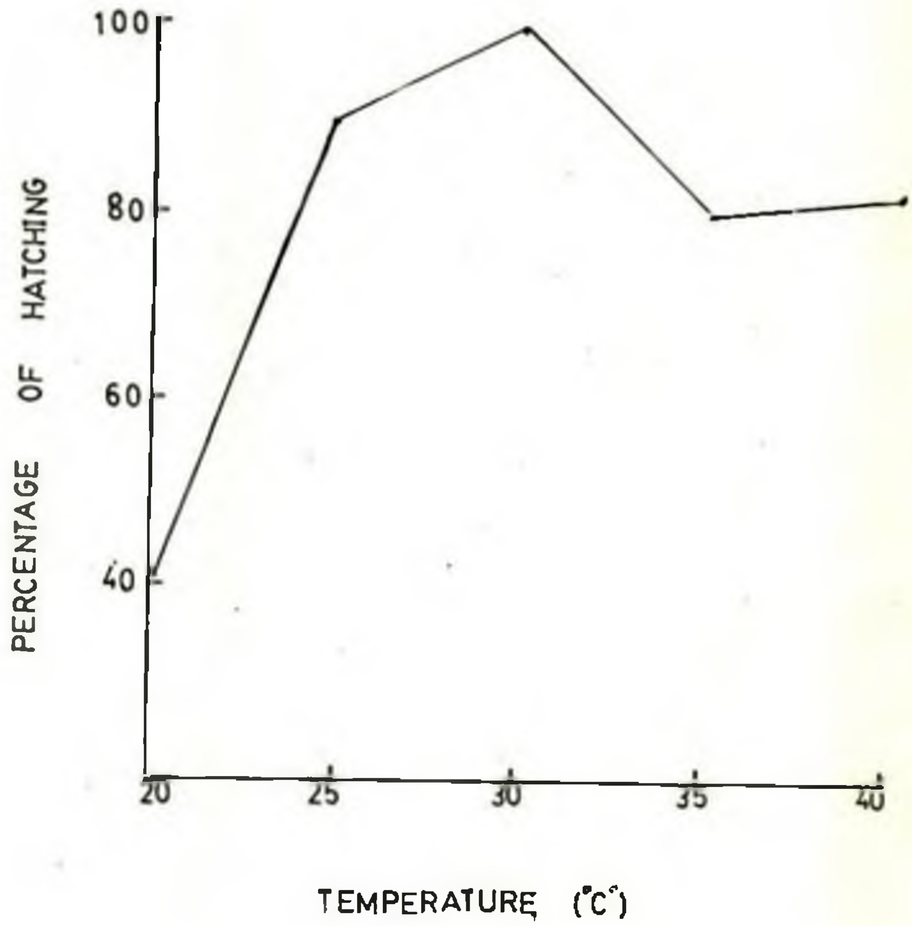

Fig. 1. Effect of constant temperature on the hatchability of N. *lugens*.

Table 4. Effect of constant temperatures on the developmental period (in days) from egg to adult stage of [redacted]. lügens.

Temperature (in °C)	Duration of egg incubation in days	Duration in days					Total duration from egg to adult
		1st instar	2nd instar	3rd instar	4th instar	5th instar	
20	10.1	9.0	7.2	6.1	5.3	5.0	42.7
25	8.8	8.3	7.0	5.1	4.0	4.2	37.4
30	5.5	6.2	4.3	4.1	3.2	3.1	26.4
35	2.5	3.0	3.2	3.0	3.4	3.0	18.1
40	3.5	3.4	3.1	3.0	3.0	3.3	18.3
45		None hatched					
Control 28°C–32°C	8	3.2	3.0	3.1	3.1	3	23.4

Observed value of F 12.4
Tabulated value of F at the level of 1% 5.29
5% 3.24

Average of 4 replications

Table 5. Effect of constant temperatures on the life cycle of *N. lugens*.

Temperature (in °C)	Pre-oviposition period in days	Incubation on period (in days)	Developmental period (in days)	Total duration of life cycle (in days)
20	12.2	10.1	32.6	54.9
25	11.2	8.9	28.6	48.7
30	6.9	6.4	20.9	34.2
35	5.1	2.5	15.6	23.2
40	4.1	3.1	15.8	23.0

development ranged from 10.1 days at 20°C to 3.1 days at 40°C. The mean time for the egg incubation were 10.1, 8.9, 6.4, 2.5 and 3.1 days at 20, 25, 30, 35 and 40°C respectively. The total duration required for larval development were found to be as 32.6, 28.6, 20.9, 15.6 and 15.9 days respectively. Hence, the total duration required to complete the life cyle were 54.3, 48.7, 34.2, 23.2 and 23.0 at the temperatures mentioned above. So, the shortest period required to complete a life cycle was 25.1 days at 35°C.

Survivality :

The percentage of emergence of N. lugens at different constant temperatures is presented in Table 6 & Fig. 3. The mean percentage of emergence ranged from 20 to 37 over a range of constant temperatures from 20 to 40°C. The mean survivality rate from egg to adult stages were 20, 60, 80, 50 and 37 percent at 20, 25, 30, 35 and 40°C respectively. The maximum number of adult emerged at 30°C with the least number of immature mortality indicating the most suitable temperature for survivorship (Fig. 3).

It was observed that when the temperature was raised from 20 to 30°C the percentage of emergence increased accordingly. Again the percentage of emergence decreased as the temperature was increased above 30°C indicating the positive relation of immature mortality. At 20°C the percentage of survivality was 66.6 and 83.3 at 1st and 3rd instar respectively and in all other stages cent percent survivality was observed (Table 6).

At 25°C the percentage of survivality was 70 and 85 at 1st and 2nd instar respectively and cent percent survivality was observed at 3rd, 4th and final instar.

At 30°C 100 percent survivality was observed at all larval instars except the 1st and 2nd instars where the survivality rate was 70 percent and 94.1 percent respectively.

At 35°C the percentage of survivality was 88 and 75 at 1st and 2nd larval instar respectively. In 3rd, 4th and 5th instars the survivality was 100 percent.

At 40°C the survivality rate was 83 percent and 88.8 percent at 1st and 2nd larval instar respectively. In 3rd, 4th, and 5th instars the survivality was 100 percent.

<u>Sex ratio</u> :

The mean percentage of F_1 males was 60.0, 58.3, 50, 41.0, and 37.5 at 20, 25, 30, 35 and 40°C respectively. The mean percentage of females was 40, 41.6, 50, 58.3 and 37.5 at the temperatures of 20, 25, 30, 35 and 40°C respectively. Males predominated the females at the lower temperatures. The number of males were inversely and that of females were directly related to the temperature upto 35°C Table 6.

Table 23. Effect of constant temperatures on the survivality in days of different stages in life cycle of N. virescens.

Temperature in °C	No. of egg incubated	No. of egg hatched	% of hatching	No. of 1st instar larva	% of 1st instar larva	No. of 2nd instar larva	% of 2nd instar larva	No. of 3rd instar larva	% of 3rd instar larva	No. of 4th instar larva	% of 4th instar larva	No. of 5th instar larva	% of 5th instar larva	No. of adult		% of adult
														Male	Female	
20	18	8	44	8	100	6	75	4	66	4	100	4	100	1	3	22
25	22	20	90.91	20	100	16	80	16	100	16	100	16	100	7	9	72
30	19	19	100	19	100	15	78	15	100	15	100	14	100	7	7	73
35	20	16	80	16	100	14	87	14	100	14	100	14	100	7	5	60
40	12	10	83.33	10	100	9	90	9	100	4	44	4	100	2	1	25
Control 27-34°C	12	9	75	9	100	9	100	8	88	8	100	6	75	3	3	

Average of 4 replications

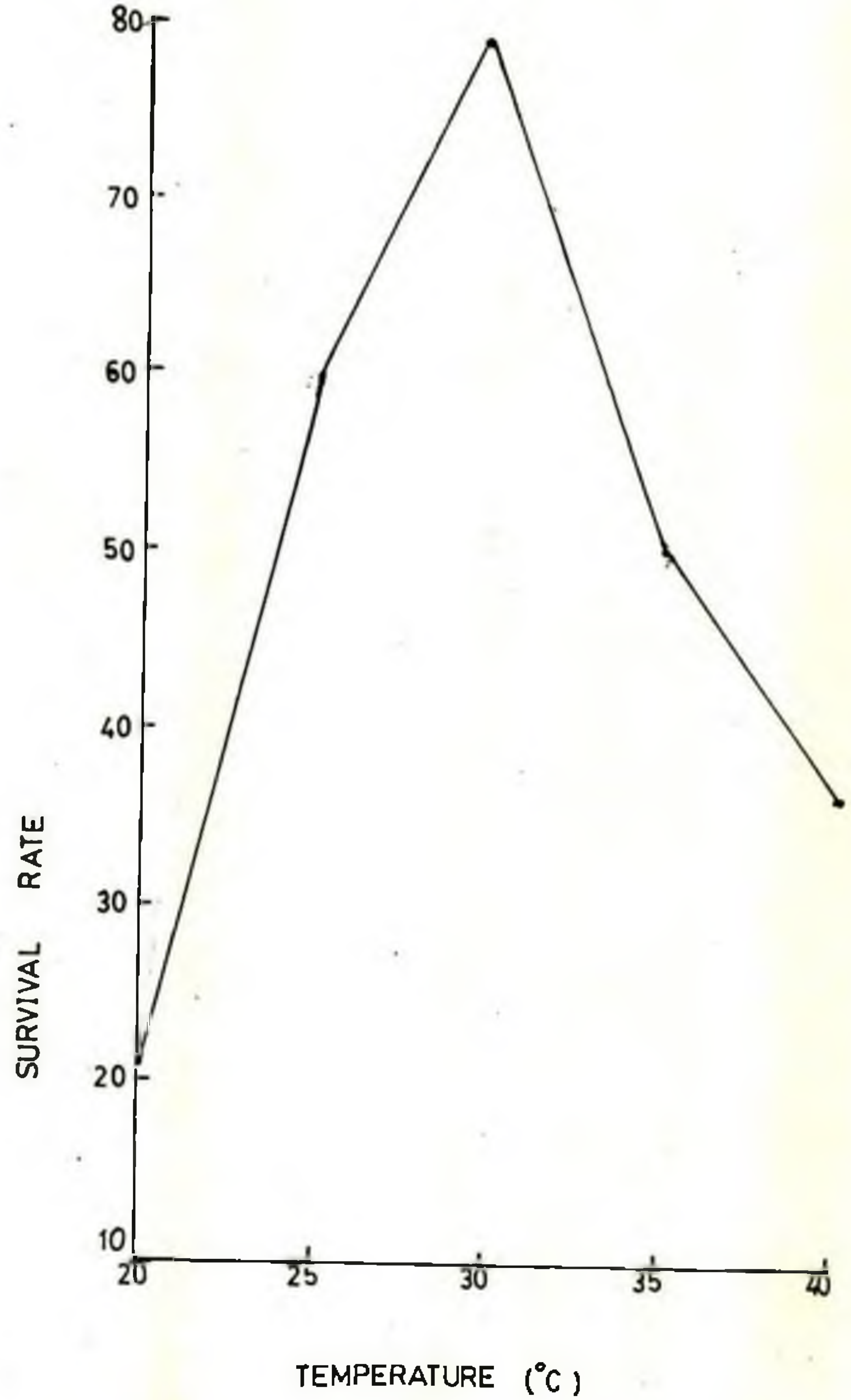

Fig. 3. Effect of constant temperature on the survival rate of *N. lugens*.

Fecundity :

The fecundity rate of *N. lugens* is recorded in Table 7. The fecundity was found to be highly influenced by the temperatures. At extreme low and high temperatures i.e., 10 and 45°C all the insects died without laying eggs. The optimum range of temperature for egg laying ranged from 30 to 35°C (Table 7). The maximum number of eggs laid by per female was at 30°C. At 20 and 25°C the females laid 11 and 13 eggs respectively.

Longevity :

The longevity of the male and female *N. lugens* recorded during the study is shown in Table 8. When the insects were confined at the desired temperature, the mean longevity of males were 6, 16.5, 10, 8.5, 6, 2.5 and 2 days at 10, 20, 25, 30, 35 40 and 45°C respectively.

The mean longevity of females were 5, 12, 10, 7.1, 4.2, 2 and 1 day at 10, 20, 25, 30, 35, 40 and 45°C respectively. In all the cases the males lived longer than the females. At 10°C both the males and females remained in motionless condition. Table 8 indicates the longevity of adult males and females *N. lugens* decrease as the temperature was increased within a range of 20 to 45°C.

Table 7. Effect of constant temperatures on the fecundity of mated female *N. lugens*.

Temperature (in °C)	No. of females	Average number of eggs laid by females										
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day
10	4	0	0	0	0	0	All died					
20	4	0	0	0	0	0	0	0	0	0	0	42
25	4	0	0	0	0	0	0	0	0	0	0	52
30	4	0	0	0	0	0	81					
35	4	0	0	0	0	77						
40	4	0	0	0	21							
45	4	0	0	all died								
Control 27°C-34°C	4	0	0	0	0	0	59					

Average of 4 replications

Table 8. Effect of constant temperatures on the adult longevity of N. lügens.

	Adult longevity in days											
Temperature (°C)	Rep. I		Rep. II		Rep. III		Rep. IV		Average		Control 26°C-32°C	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
10	16	5	6	5	6	6	6	5	6	5	10	9
20	17	12	16	12	16	12	17	12	16.5	12	10	9
25	10	10	6	10	12	10	12	10	10	10	9	8
30	8	7	10	7.5	9	7	8	7	8.5	7.1	11	11
35	6	5	5	4	6	4	6	4	6	4.2	10	10
40	3	2	2	2	3	2	2	1	2.5	2	8	8
45	2	1	2	1	2	1	2	1	2	1	9	8

Average of 4 replications

CHAPTER - V

EFFECTS OF FLUCTUATING TEMPERATURE ON SOME ASPECTS OF BIOLOGY OF *N. LUGENS*

The temperature does not remain constant within 24 hours of the day. Therefore, the experiment was designed to expose the experimental insects to desired temperature for 6, 15 and 18 hours per day in the incubator. Rest of the period of the day they were kept at room temperature.

Effect of fluctuating temperature on N. lugens

Incubation period :

The incubation period of N. lugens was studied at temperatures ranging from 20°C-35°C is shown in Table 9. The mean incubation period was 12.1, 9.3, 6.0, 4.1 and 6.2 days at 20, 25, 29, 32 and 35°C when the eggs were exposed for 6 hours per day (Table 9). At 15 hours exposure per day, the mean period for incubation was found as 11.2, 8.0, 6.1, 4.2 and 5.3 days at 20, 25, 29, 32 and 35°C respectively (Table 9). At 18 hours exposure per day, the mean incubation period was 10.2, 8.0, 5.3, 4.2 and 6.1 days at the temperatures mentioned above. The incubation period gradually decreased as the duration of exposure to temperature increased upto 32°C. But at 35°C the incubation period increased again. The statistical analysis of variance on egg incubation period at different temperatures when exposed at 6, 15, and 18 hours per day was significant.

Table 9. Incubation period (days) of eggs of *N. lugens* exposed for various periods per day to different temperatures.

Temperature (in °C)	Exposed for 6 hrs./day	Exposed for 15 hrs./day	Exposed for 18 hrs./day
20	12.1	11.2	10.2
25	9.3	8.0	8.0
29	6.0	6.1	5.3
32	4.1	4.2	4.2
35	6.2	5.3	6.1

Observed value of F 11

Tabulated value of F at the level of 1% 7.59
5% 4.01

Average of 4 replications

Effect of fluctuating temperatures on N. lugens :

Egg hatchability :

At 25°C the mean percentage of egg hatching was found to be 51, 56.8 and 61.3 at 6, 15 and 18 hours of exposure per day respectively (Table 10).

Table 11 shows the percentage of egg hatching at different temperatures during the experiment. The mean percentage of hatching was 51.6, 60.7 and 53.4 at 29°C when the duration of exposure time was 6, 15 and 18 hours per day respectively.

The mean percentage of egg hatching was 53.9, 65.8 and 71 at 32°C when exposed for 6, 15 and 18 hours per day (Table 12).

The mean percentage of egg hatching was found to be 61.2, 71.4 and 76 at 35°C when exposed for 6, 15 and 18 hours per day respectively (Table 13).

The egg hatchability is directly related to the duration of exposure of the eggs per day to 6, 15 and 18 hours. With the increase of duration of exposure the hatchability rate increased.

Developmental period :

The effect of temperatures on the developmental period after exposure to 6, 15 and 18 hours per day was recorded in Tables 14, 15, and 16. The mean developmental period were 22.2, 19.2 and 17.1 days at 29, 32 and 35°C when exposed for 6 hours per day. The mean period required for development at 29, 32 and 35°C were 19.3, 19.2 and 15.2 days respectively when exposed for 15 hours per day (Table 15). The mean time required for development was 19.1, 19.1 and 16.1 days at 29, 32 and 35°C respectively when exposed for 18 hours per day. The developmental period was found to be influenced by the fluctuating temperatures. The developmental period of N. lugens was inversely proportional to the exposure period at different temperatures. Analysis of variance of the mean developmental period was highly significant when exposed for 6, 15 and 18 hours per day to each of the selected temperatures.

Longevity :

From the present observations it was found that the variable temperatures when applied to the adult insects, showed marked effect on their longevity (Table 17). The mean longevity of adult female N. lugens under different temperatures of 20, 25, 29, 32 and 35°C were 7.1, 5.1, 5.0, 5.0 and 5.1 days respectively when the duration of exposure was 6 hours per day. But when the adults were exposed for 15 hours per day at 20, 25, 29, 32 and 35°C the longevity were 6.1, 6.2, 6.0, 5.2 and 5 days respectively. Again at 18 hours exposal per day the longevity were 8.2, 4.3, 3.1, 4.0 and 4.2 days at 20, 25, 29, 32 and 35°C respectively.

Table 10. Effect of temperature (25°C) on the egg hatchability of *N. lügens*.

Temperature in °C	Exposure time in hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control	
					No. of egg used	% of egg hatching
	6	49	25	51	14	85.7
25	15	44	25	56.8	10	100
	18	44	27	61.3	11	81.9

Average of 4 replications

Table 11. Effect of temperature (29°C) on the egg hatchability of *N. lugens*.

Temperature in °C	Exposure time in hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control No. of egg used	Control % of egg hatching
	6	47	24	51.6	21	95.4
29	15	51	31	60.7	7	71.4
	18	53	31	53.4	12	100

Average of 4 replications

Table 12. Effect of temperature (32°C) on the egg hatchability of *N. lügens*.

Temperature in °C	Exposure time in hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control: No. of egg used	Control: % of egg hatched
	6	39	21	53.9	7	100
32	15	47	31	65.8	11	72.7
	18	45	32	71	16	56.2

Average of 4 replications

Table 13. Effect of temperature (35°C) on the egg hatchability of *N. lugens*.

Temperature in °C	Exposure time in hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control	
					No. of egg used	% of egg hatched
	6	49	30	61.2	8	75
35	15	42	30	71.4	16	75
	18	46	35	76	12	75

Average of 4 replications

Table 14. Effect of temperature on the developmental period of *N. lugens* when exposed for 6 hours/day.

Temperature in °C	Egg incubation	Duration in days					
		1st instar	2nd instar	3rd instar	4th instar	5th instar	Total days
29	4.3	4.1	4.2	4.0	3.1	3.0	22.2
32	3.2	4.0	4.0	3.0	3.2	2.4	19.2
35	3.0	4.1	3.2	3.0	2.3	2.0	17.1

Observed value of F 41

Tabulated value of F at the level of 1% 7.59
5% 4.07

Average of 4 replications

Table 15. Effect of temperature on the developmental period of *N. lugens* when exposed for 15 hours/day.

Temperature in °C	Egg incubation	Duration in days					
		1st instar	2nd instar	3rd instar	4th instar	5th instar	Total
29	3.1	4.1	3.2	3.4	3.1	3.4	19.3
32	3.1	4.0	4.0	3.2	3.2	2.2	19.2
35	3.2	3.3	3.2	2.1	2.0	2.1	15.2

Observed value of F 16.21

Tabulated value of F at the level of 1% 7.59

5% 4.07

Average of 4 replications

Table 16. Effect of temperature on the developmental period of *N. lugens* when exposed for 18 hours/day.

Temperature in °C	Egg incubation	Duration in days					
		1st instar	2nd instar	3rd instar	4th instar	5th instar	Total
29	3.1	4.0	3.0	3.0	3.1	3.1	19.1
32	3.4	3.1	3.0	3.1	3.0	3.5	19.1
35	3.2	3.2	3.2	3.1	2.0	2.4	16.1

Observed value of F 13.5

Tabulated value of F at the level of 1% 7.59

5% 4.07

Average of 4 replications

Table 17. The adult longevity of *N. lugens* exposed for various periods/day to different temperatures.

Temperature in °C	20		25		29		32		35	
Duration of heating (in hrs.)	Adult longevity in days									
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
6	10.1	7.1	10.0	5.1	8.0	5.0	6.2	5.0	6.1	5.1
15	8.0	6.1	9.2	6.2	7.0	6.0	5.1	5.2	5.3	5.0
18	8.0	8.2	8.0	4.3	7.2	3.1	5.1	4.0	5.0	4.2

Observed value of F 16

Tabulated value of F at the level of 1% 7.59

5% 4.07

Average of 4 replications

CHAPTER - VI

EFFECTS OF CONSTANT TEMPERATURES ON SOME ASPECTS OF BIOLOGY OF *N. VIRESCENS*

Experiments on the effect of constant temperatures on *Nephotettix virescens* were conducted at 10,20, 25, 30, 35, 40 and 45°C. The effects of various temperatures were studied on the pre-oviposition period, incubation period, egg hatchability, developmental period from egg to adult, adult longevity, fecundity and survivality of the insects.

Effect of constant temperatures on *N. virescens* :

Pre-oviposition period :

The pre-oviposition period of *N. virescens* recorded during the course of experiment is presented in Table 18. The effect of temperatures on the pre-oviposition period was observed by exposing the mated females to various constant temperatures. The mean pre-oviposition period ranged from 12.2 to 4.2 days over a range of constant temperatures from 20 - 40°C. The mean pre-oviposition period were 12.2, 8.4, 6.4, 5.3 and 4.2 at 20, 25, 30, 35 and 40°C respectively. The maximum period required for depositing the first egg at 20°C was 12.2 days. The minimum pre-oviposition period was observed at 40°C. The optimum temperature for oviposition was 35 - 40°C. Above the optimum range of temperature, the insects failed to oviposit. At extreme low (10°C) and extreme high (45°C) temperatures the insects died without laying egg after 3 days in both the cases. The effect of temperature on the pre-oviposition period of *N. virescens* was statistically significant.

Table 18. Effect of constant temperatures on the pre-oviposition period of *Nephotettix virescens*.

	Pre-oviposition period in days					
Temperature in °C	Rep. I	Rep. II	Rep. III	Rep. IV	Average	Control 28°C–32°C
20	12.2	12.3	12.1	13.3	12.2	8
25	7.5	8.2	8.5	9.4	8.4	9.1
30	6.3	6.4	6.5	7.3	6.4	10
35	5.5	5.4	5.1	5.1	5.3	8.5
40	4.2	4.5	4.3	4.0	4.2	8
45	All died without laying					

Observed value of F 8.44

Tabulated value of F at the level of 1% 5.29
5% 3.24

Mean of 4 replications

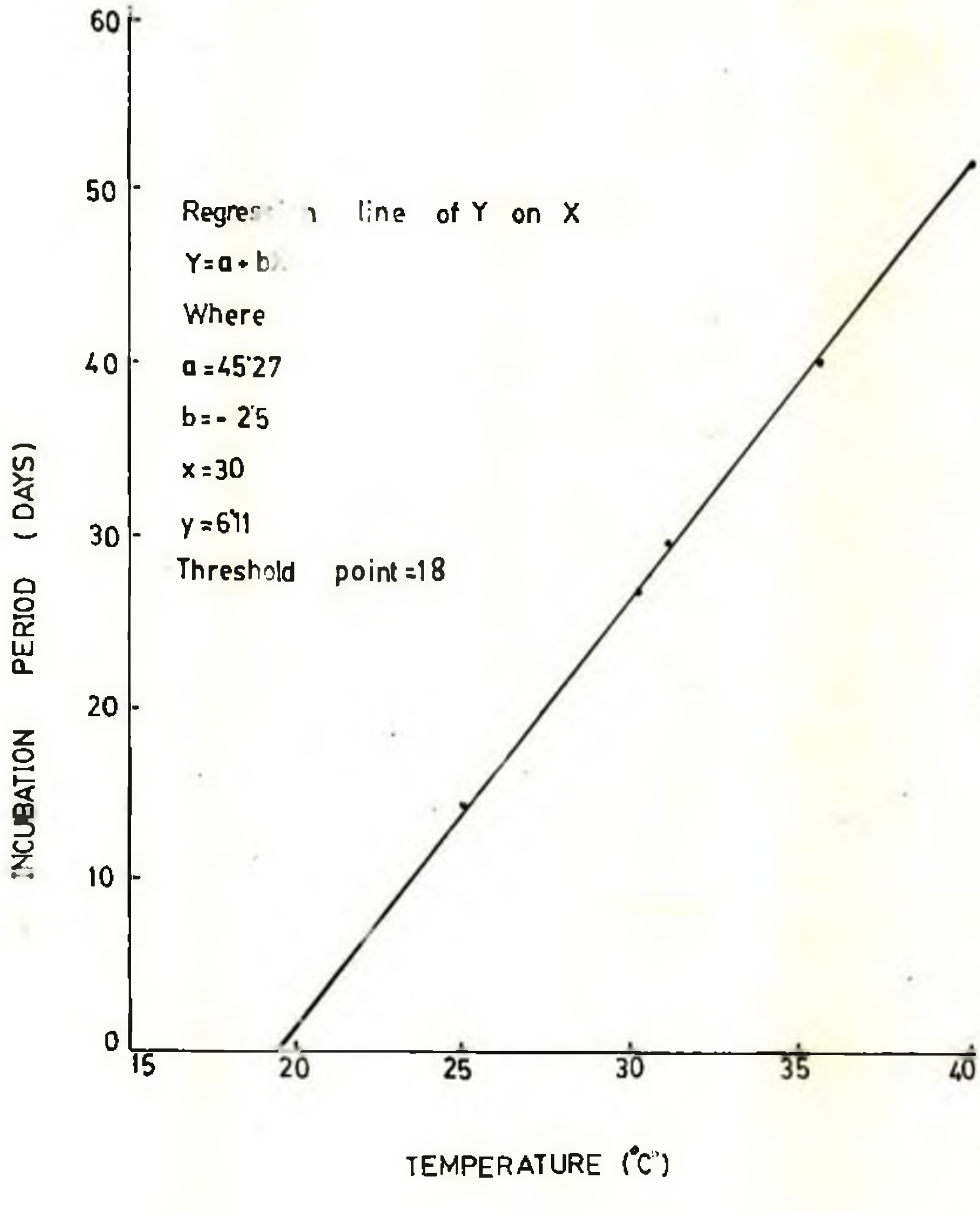

Fig. 4. Effect of constant temperature on the incubation period of _N. virescens_.

Incubation period :

The incubation period of N. virescens in response to different constant temperatures is shown in Table 19 & Fig.4. The incubation period was largely dependent on the prevailing temperatures. Under different temperatures the mean incubation periods were 10.2, 8.1 5.8, 3.4 and 3.2 days at 20, 25, 30, 35 and 40°C respectively, but no egg hatched at two extreme experimental temperatures i.e. 10°C and 40°C.

At 45°C the eggs lost their shape, became shrunken and blacken. The incubation period was longest at 20°C, it then decreased as the temperature was increased upto 40°C. The threshold temperature extrapolated from the observed incubation periods was at 18°C. The effect of temperature was highly significant on the incubation period of N. virescens.

Egg hatchability :

The results recorded in Table 20 & Fig.5 indicate the percentage of egg hatchability at different constant temperature. The total percentage of egg hatch were 40, 100, 100, 75 and 72 at 20, 25, 30, 35 and 40°C respectively. The percentage of hatching was maximum at the range of 25 - 30°C. At the two extreme experimental temperatures (10 and 45°C) the eggs did

Table 19. Effect of constant temperatures on the incubation period of *N. virescens*.

Temperature in °C	Rep. I	Rep. II	Rep. III	Rep. IV	Average	Control 28-32°C
	Incubation period in days					
20	10.2	10.1	10.3	10.2	10.2	10
25	8.3	8.1	8.0	8.2	8.1	10.3
30	5.5	5.5	5.6	6.4	5.8	8
35	3.4	3.4	3.4	3.4	3.4	8.1
40	3.0	3.2	3.2	3.1	3.2	7.8
45	Eggs died and blackened					

Observed value of F 15.3

Tabulated value of F at the level of 1% 5.29
5% 3.24

Mean of 4 replications

Table 20. Effect of constant temperatures on the egg hatchability of *N. virescens*.

Temperature in °C	No. of egg incubated	No. of egg hatched	% of hatching	Control 28°C-31°C
20	50	20	40	65%
25	47	47	100	75%
30	45	45	100	92%
35	54	40	75	62%
40	16.1	12	72	66%

Average of 4 replications

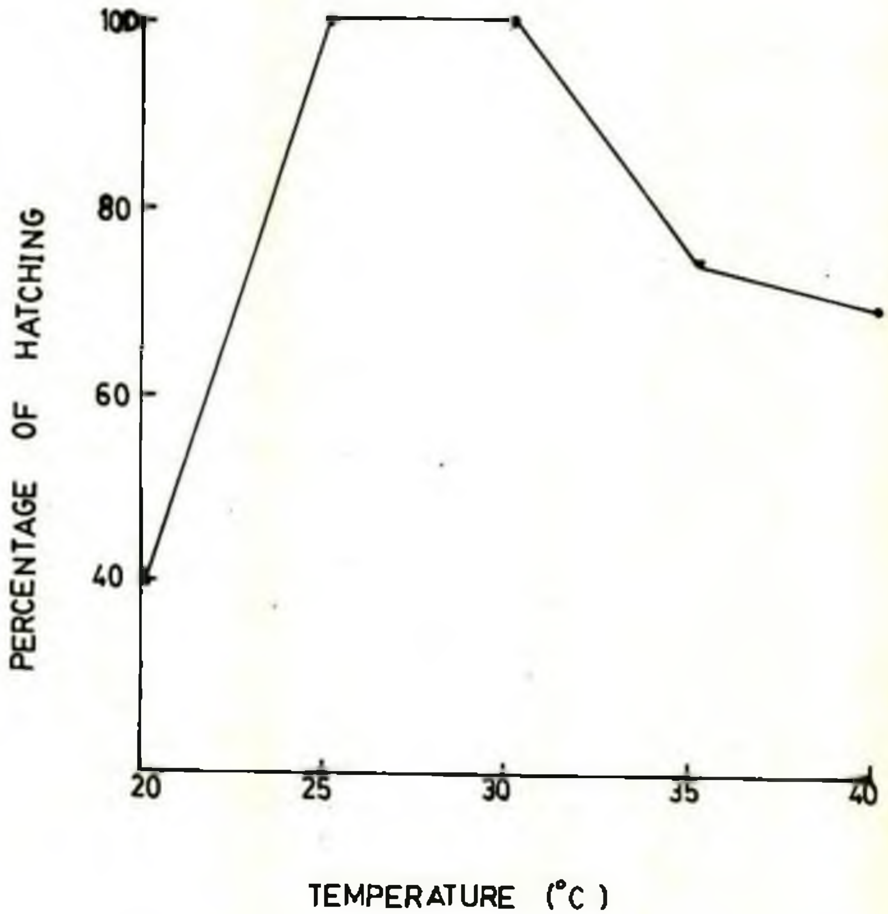

Fig. 5. Effect of constant temperature on the hatchability of *N. virescens*.

not hatch. The egg hatchability was found to be temperature dependent i.e., with the increase of temperature the percentage of hatching also increased. The lowest percentage of hatching was observed at 20°C.

Larval period :

The data in Table 21 represents the larval period of N. virescens at different constant temperatures. The mean durations of five larval instars at different temperatures of 20, 25, 30, 35 and 40°C were 31.6, 25.2, 18.5, 15.9 and 14.7 days respectively. The egg incubation period was longest at low temperature (20°C) and shortest at (40°C), the results indicate that the temperature had a significant effect on the total larval period.

Life cycle :

The effect of temperature on the total life cycle of N. virescens is presented in Table 22. It was found that the time required for egg development ranged from 10 days at 20°C to 3 days at 40°C. The mean time for the egg incubation were 10, 8, 5.8, 3.4 and 3 days at 20, 25, 30, 35 and 40°C respectively. The total duration required for larval development were found to be as 31.6, 25.2, 18.5, 15.9 and

Table 21. Effect of constant temperatures on the developmental period from egg to adult stage of _N. virescens_.

Temperature in °C	Duration in days						Total duration from egg to adult
	Egg incubation	1st instar	2nd instar	3rd instar	4th instar	5th instar	
20	10.2	8.3	7.8	5.1	5.2	5.2	41.8
25	9.0	7.0	6.2	4.0	4.0	4.0	34.2
30	6.2	5.2	4.1	3.0	3.1	3.1	24.7
35	4.3	3.4	3.0	3.1	3.4	3.0	20.2
40	3.2	3.0	3.0	3.2	3.2	2.3	17.9
45	None hatched						
Control 28 - 32°C	8.1	4.0	4.1	3.2	3.1	3	25.5

Observed value of F 10.5

Tabulated value of F at the level of 1% 5.29
5% 3.24

Room temperature range 28°C-32°C

Mean of 4 replications

Table 22. Effect of constant temperatures on the life cycle of *N. virescens*.

Temperature (in °C)	Pre-oviposition period (in days)	Incubation period in (days)	Developmental period of larvae (in days)	Life cycle (in days)
20	12.2	10.2	31.6	54.0
25	8.4	8	25.2	41.6
30	6.4	5.8	18.5	30.7
35	5.3	3.4	15.9	24.6
40	4.2	3.2	14.7	22.1

and 14.7 days at 20, 25, 30, 35 and 40°C respectively. Hence, the total duration required to complete the life cycle were 54, 41.6, 30.7, 24.6 and 22.1 days at 20, 25, 30, 35 and 40°C respectively. So, the shortest period required to complete a life cycle was 22.1 days at 40°C temperature.

Survivality :

The percentage of emergence of N. virescens at different temperatures is listed in Table 24 Fig. 6. The mean percentage of emergence ranged from 22 to 25 over a range of constant temperatures from 20 to 40°C. The mean survivality rate from egg to adult was 22, 72, 73, 60 and 25 at 20, 25, 30, 35 and 40°C respectively. The maximum number of adult emerged at 30°C with the least number of immature mortality indicating the most suitable temperature for survivorship. It was observed that when the temperature was raised from 20 to 30°C, the percentage of emergence increased accordingly. Again the percentage of emergence decreased as the temperature was increased above 30°C indicating the positive relation of immature mortality. At 20°C the percentage of survivality was 75 at first instar and in all other stages cent percent survivality was observed.

At 25°C the percentage of survivality was 80 at 1st instar and in all other stages cent percent survivality was observed.

Table 6. Effect of constant temperatures on the survivality in days of different stages in life cycle of <u>N</u>. <u>lügens</u>.

Temperature in °C	No. of egg incubated	No. of egg hatched	% of hatch-ing	No. of 1st instar larva	% of 1st instar larva	No. of 2nd instar larva	% of 2nd instar larva	No. of 3rd instar larva	% of 3rd instar larva	No. of 4th instar larva	% of 4th instar larva	No. of 5th instar larva	% of 5th instar larva	No. of adult		% of adult
														Male	Female	
20	24	9	37.5	9	100	6	66.6	6	100	5	83.33	5	100	3	2	20
25	20	20	100	20	100	14	70	12	85	12	100	12	100	7	5	60
30	20	20	100	20	100	17	70	16	94.12	16	100	16	100	8	8	80
35	24	18	75	18	100	16	88	12	75	12	100	12	100	5	7	50
40	18	12	75	12	100	10	83	10	100	9	90	8	88.83	3	3	37
Control 27-34°C	14	12	85	12	100	12	100	12	100	10	83	10	100	6	4	

Average of 4 replications

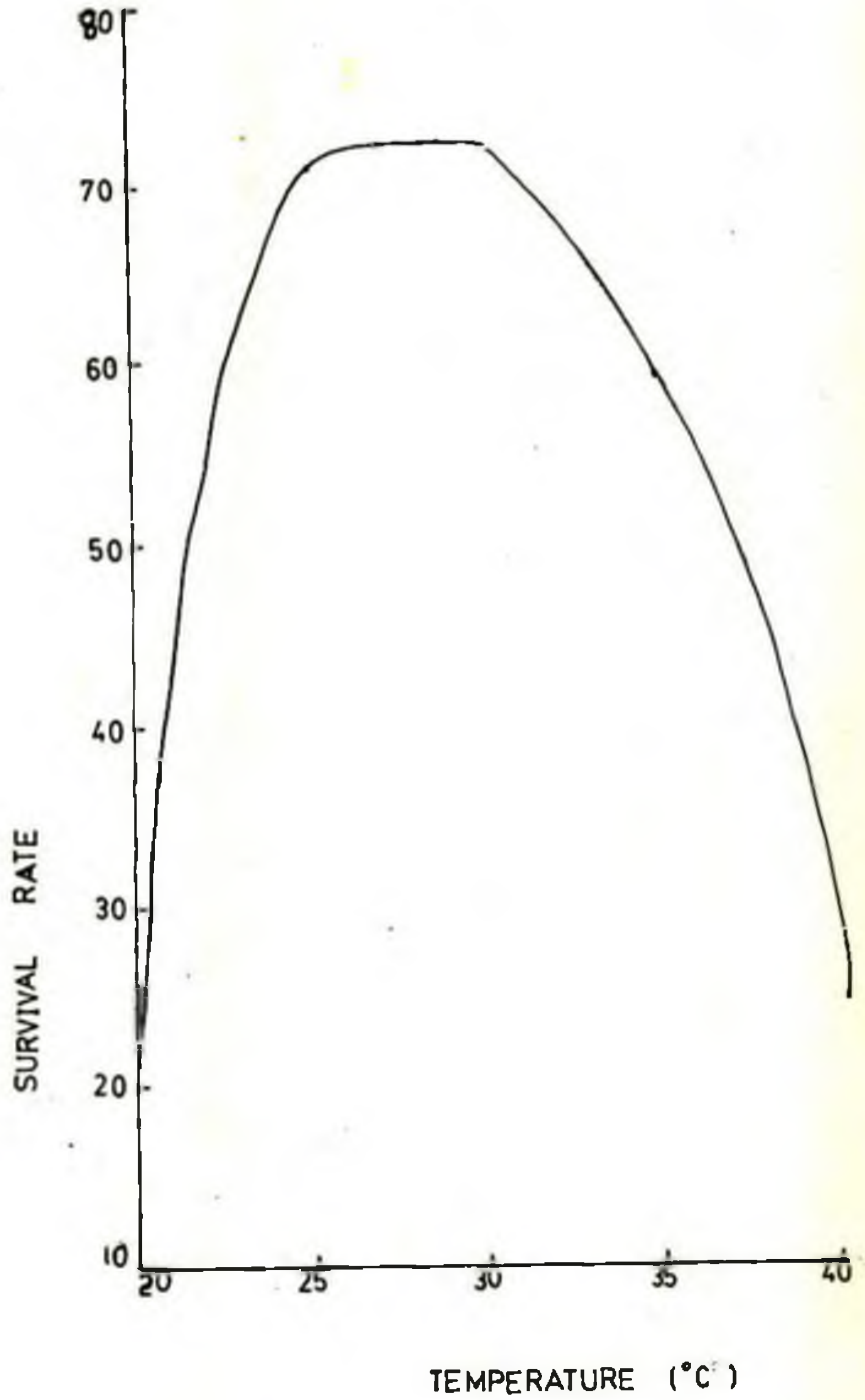

Fig. 6. Effect of constant temperature on the survival rate of *N. virescens*

At 30°C 100 percent survivality was observed at all larval instars except the 1st instar, where the survivality rate was 78 percent.

At 35°C the survivality rate was cent per cent in all larval instars except the 1st instar larva where it was 87%.

At 40°C the percentage of survivality was 90 and 44 at 1st and 3rd instar larva and in all other larval instars cent percent survivality was observed.

Sex ratio :

The mean percentage of F_1, males were 25, 43.7, 50, 50 and 50 at 20, 25, 30, 35 and 40°C respectively. The mean percentage of females were 75, 56.2, 50, 35.8 and 25 at the temperatures of 20, 25, 30, 35 and 40°C. Males predominated the females at the higher temperatures. The number of males were directly and that of females were inversely related to the temperature upto 35°C Table 24.

Fecundity :

The fecundity rate of N. virescens is recorded in Table 23. The fecundity was found to be highly influenced by the temperatures used. At extreme low and high temperatures

Table 24. Effect of constant temperatures on the fecundity of mated female N. virescens.

Temperature (in °C)	No. of females	Average number of eggs laid by females										
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day
10	4	0	0	0	0	0	0	All died				
20	4	0	0	0	0	0	0	0	0	0	0	39
25	4	0	0	0	0	0	0	40				
30	4	0	0	0	0	0	58					
35	4	0	0	0	0	73						
40	4	0	0	22								
45	4	0	0	All died								
Control	1	0	0	0	22							

Room temperature range 29°C–32°C

i.e. 10°C and 45°C all the insects died without laying eggs. The optimum range of temperature for egg laying was 30 to 35 . The maximum number of eggs laid by per female was at 35°C.

Longevity :

The longevity of the male and female N. virescens is shown in Table 25. When the insects were confined at the desired temperatures, the mean longevity of males were 5.1, 15, 10.2, 9.2, 7.1, 3.4 and 2 days at 10, 20, 25, 30, 35, 40 and 45°C respectively. The mean longevity of females were 4.7, 10, 9.8, 8.5,6, 2.2 and 1 day at 10, 20, 25, 30, 35, 40 and 45°C respectively.

In all the cases the males lived longer than the females. At 10°C both the males and females remained in motionless condition. The longevity of adult males and females N. virescens decreased as the temperature increased within a range of 20 to 45°C.

Table 25. Effect of constant temperatures on the adult longevity (days) of N. virescens.

Temperature in °C	Rep. I		Rep. II		Rep. III		Rep. IV		Average		Control 26°C-32°C	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
10	6.0	5.1	5.0	5.3	4.1	4.2	5	5	5.1	4.7	10.1	9
20	15.0	9.5	15.0	10.2	16.0	10	15.2	11	15.0	10	10.4	10.0
25	10.2	9.5	9.5	10.0	9.5	9.5	10.0	10	10.2	9.8	9.2	9.3
30	9.0	8	9.2	8.5	9.0	9	9.0	8.5	9.2	8.5	11.0	11.1
35	7.1	6	7.1	6.1	7.1	6	7.0	6	7.1	6	11.0	10.0
40	3.3	2.5	3.0	2.0	3.2	2	3.4	2.5	3.4	2.2	8.3	7.0
45	2.2	1	2.0	1.0	2.0	1.0	2.3	1.0	2	1	9.2	9.1

Average of 4 replications

CHAPTER - VII

EFFECTS OF FLUCTUATING TEMPERATURES ON SOME ASPECTS OF BIOLOGY OF *N. VIRESCENS*

Effect of fluctuating temperatures on *N. virescens*

The temperature does not remain constant within 24 hours of the day. Therefore, experimental insects were exposed to desired temperature for 6, 15 and 18 hours per day in the incubation. Rest of the period of the day they were kept at room temperature.

Incubation period :

The incubation period of *N. virescens* was studied at temperatures ranging from 20-35°C and is shown in Table 26. The mean incubation period was 12.2, 9.1, 6.2, 4.3 and 6.2 when the eggs at 20, 25, 29, 32 and 35°C respectively when the eggs were exposed for 6 hours per day. At 15 hours exposure per day, the mean period for incubation was found as 11.4, 8.5, 6.4, 4.5 and 5.5 days at 20, 25, 29, 32 and 35°C respectively. At 18 hours exposure per day, the mean incubation period was 10.8, 8.1, 5.2, 4.4 and 6.3 days at 20, 25, 29, 32 and 35°C respectively. The incubation period gradually decreased as the duration of exposure to temperature increased upto 32°C. But at 35°C the incubation period increased again. The statistical analysis of egg incubation periods at different temperatures was significant.

Egg hatchability :

Table 27 shows the percentage of egg hatching at different temperatures during the experiment. The mean

Table 26. Incubation period (days) of eggs of N. *virescens* exposed for various periods per day to different temperatures.

Temperature in °C	Exposed for 6 hrs./day	Exposed for 15 hrs./day	Exposed for 18 hrs./day
20	12.2	11.4	10.3
25	9.1	8.5	8.1
29	6.2	6.4	5.2
32	4.3	4.5	4.4
35	6.2	5.5	6.3

Observed value of F 14

Tabulated value of F at the level of 1% 7.59
5% 4.07

Average of 4 replications

percentage of hatching was 53, 56 and 60 at 25 when the duration of exposure time were was 6, 15 and 18 hours per day respectively.

The mean percentage of hatching were 51, 54 and 54 at 29°C when the duration of exposure were 6, 15 and 18 hours per day respectively (Table 28).

The mean percentage of egg hatching were 55, 60 and 76 at 32°C when exposed for 6, 15 and 18 hours per day respectively (Table 29).

The mean percentage of egg hatching were found to be 61, 65 and 73 at 35°C when exposed for 6, 15 and 18 hours per day respectively (Table 30).

The egg hatchability is directly related to the duration of exposure of the eggs per day to 6, 15 and 18 hours. With the increase of duration of exposure the hatchability rate was also increased.

<u>Developmental period</u> :

The developmental period of the experimental insects exposed 6, 15 and 18 hours per day to different temperatures are were recorded in Table 31, 32 and 33. The mean developmental periods were 23.2, 19.2 and 18.9 days at 29, 32 and 35°C respectively when exposed for 6 hours per day (Table 31). The mean duration required for development at 29, 32 and 35°C were 22.6, 18.2 and 17.7 days respectively when exposed

Table 27. Effect of temperature (25°C) on the egg hatchability of _N. virescens_ exposed for various periods/day.

Temperature (in °C)	Exposure time in hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control	
					No. of egg used	No. of egg hatching
	6	49	26	53	12	66.6
25	15	44	25	56	18	77.7
	18	46	28	60	14	100

Average of 4 replications

Table 28. Effect of temperature (29°C) on the egg hatchability of *N. virescens* exposed for various periods/day.

Temperature (in °C)	Exposure in time hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control	
					No. of egg used	% of egg hatching
	6	79	41	51	10	100
29	15	79	43	54	12	91.6
	18	55	30	54	8	100

Average of 4 replications

Table 29. Effect of temperature (32°C) on the egg hatchability of *N. virescens* exposed for various periods/day.

Temperature (in °C)	Exposure time in hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control	
					No. of egg used	% of egg hatching
	6	57	33	55	15	80
32	15	74	45	60	10	81
	18	82	63	76	11	9

Average of 4 replications

Table 30. Effect of temperature (35°C) on the egg hatchability of *N. virescens* exposed for various periods/day.

Temperature (in °C)	Exposure in time hrs./day	No. of egg used	No. of egg hatched	% of hatching	Control	
					No. of egg used	% of egg hatching
	6	34	24	61	22	100
35	15	41	27	65	19	69.8
	18	49	36	73	8	87.5

Average of 4 replications

Table 31. Effect of temperatures on the developmental period of *N. virescens* when exposed for 6 hour duration per day.

Temperature in °C	Duration of egg incubation in days	Duration in days					Totala days
		1st instar	2nd instar	3rd instar	4th instar	5th instar	
24	4.5	4.2	4.1	4.2	3.2	3.0	23.2
32	4.2	4.0	3.2	3.2	2.1	2.5	19.2
35	4.3	3.1	3.0	3.3	3.1	2.1	18.4

Observed value of F 50

Tabulated value of F at the level of 1% 7.54
5% 4.07

Average of 4 replications

Table 32. Effect of temperatures on the developmental period of *N. virescens* when exposed for 15 hours duration per day.

Temperature (in °C)	Duration of egg incubation in days	Duration in days					
		1st instar	2nd instar	3rd instar	4th instar	5th instar	Total days
29	4.5	4.1	4.0	4.1	3.0	3.0	22.6
32	4.3	3.2	3.1	3.0	2.1	2.5	18.2
35	4.0	3.0	3.2	3.2	2.0	2.3	17.7

Observed value of F 17.2

Tabulated value of F at the level of 1% 7.54

5% 4.07

Average of 4 replications

Table 33. Effect of temperatures on the developmental period of *N. virescens* when exposed for 18 hours duration per day.

Temperature (in °C)	Duration of egg incubation in days	Duration in days					
		1st instar	2nd instar	3rd instar	4th instar	5th instar	Total days
29	3.4	4.0	3.1	3.0	3.4	2.2	19.1
32	3.3	3.2	3.1	3.2	2.5	2.4	17.7
35	3.0	3.2	3.0	3.3	2.0	2.1	16.6

Observed value of F 6.14

Tabulated value of F at the level of 1% 7.54
5% 4.07

Average of 4 replications

for 15 hours per day (Table 32). The mean time required for development were 19.1, 17.7 and 16.6 days at 29, 32 and 35°C respectively when exposed for 18 hours per day (Table 33). The developmental period was found to be influenced by the exposure duration to temperatures. The developmental period of N. virescens was inversely proportional to the fluctuating temperature. Analysis of variance of the mean developmental period at fluctuating temperature was highly significant.

Longevity :

From the present observation it was found that the fluctuating temperatures when applied to the adult insects showed marked effect on their longevity (Table 34). The mean longevity of adult female N. virescens under different temperatures of 20, 25, 29, 32 and 35°C were 8.2, 5.2, 5.0, 6.0 and 4.0 days respectively when the duration of exposure was 6 hours/day. When the adults were exposed for 15 hours per day the longevity were 8.1, 5.2, 5.1, 6.1 and 3.0 days at 20, 25, 29, 32 and 35°C respectively. Again at 18 hours exposure per day the longevity were 8.2, 4.1, 3.0, 4.0 and 3.0 days at 20, 25, 29, 32 and 35°C respectively.

The mean longevity of males were 10.5, 9.1, 7.0, 6.1 and 5.2 days at 20, 25, 29, 32 and 35°C respectively when exposed for 6 hours per day. The mean longevity were 9.4, 9.0,

Table 34. The adult longevity of *N. virescens* exposed for various periods/day to different temperatures.

Temperature in °C	20		25		29		32		35	
	Adult longevity in days									
Duration of heating in (hrs.)	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
6	10.5	8.2	9.1	5.2	7.0	5.0	6.1	6.0	5.2	4.0
15	9.4	8.1	9.0	5.2	7.2	5.1	5.0	6.1	4.0	3.0
18	9.0	8.2	7.0	4.1	6.1	3.0	4.0	4.0	4.0	3.0

Observed value of F 22

Tabulated value of F at the level of 1% 7.59
5% 4.07

Average of 4 replications

7.2, 5.0 and 4.0 days at 20, 25, 29, 32 and 35°C respectively when exposed for 15 hours per day. At 18 hours exposure per day the mean longevity of male adult N. virescens were 9, 7, 6.1, 4.0 and 4.0 days at 20, 25, 29, 32 and 35°C respectively.

CHAPTER - VIII

DISCUSSION

DISCUSSION

The literature on the effect of temperature on the biological aspect on N. lugens and N. virescens is very scanty. Therefore, the related works on other insects is discussed in this chapter. The present study was carried out in the laboratory and aimed at clarifying the relationship between combinations of temperatures and some biological aspects of the two species. The experiment was conducted at 10, 20, 25, 29, 30, 32, 35, 40 and 45°C.

Preoviposition period

Preoviposition periods of N. lugens and N. virescens were observed at different constant temperatures ranging from 20 to 40°C. It was found that this period lasted from 4 to 12 days in both the species depending on the temperature. This period was shortest 40°C. At extreme low temperature (10°C) the adult insects died after 4th day of treatment without laying eggs. At extreme high temperature (45°C) both the species died after 2nd day of treatment without laying eggs. The pre-oviposition period at 25°C was found to be as 11.2 days in N. lugens and 8.4 days in N. virescens. This results indicates that the pre-oviposition period is shorter in N. virescens and longer in N. lugens in this temperature. In other temperatures duration of pre-oviposition period was more or less same for both the species.

Muller and Stern (1973) observed that the pre-oviposition period of Lygus hesperus was 9.8 days at 26.7°C which increased to 21.1 days at 20°C. This period decreased with the increase of temperature.

Mochida (1964) worked on the pre-oviposition period of brown plant hopper and found that the pre-oviposition period ranged from 1 to 6 days within a range of temperature 20-30°C. In the present experiment this range was 8-10 days at 20-30°C.

The present observation on the pre-oviposition period is partially in compliance with Muller and Stern (1973).

Incubation period

In the present experiment the incubation period of two species of insects ranged from 3 to 10 days at the temperature ranging from 20 to 40°C. The optimum temperature for hatching was 35°C in case of N. lugens above or below this temperature, incubation period increased (Table 2). In N. virescens the optimum temperature for egg hatching was 40°C. Above this temperature eggs could not hatch, they became dry and blackened. Below this temperature prolonged the incubation period. So it was found that N. virescens eggs were more tolerant to heat when compared to that of N. lugens.

Melvin (1934) reported that high temperature actually prolonged the incubation period of Lucillia cuprina. El-sawaf (1956) concluded that the hatching period decreased as the temperature was increased from 18 to 35°C in case of Callosobruchus maculatus. Hafez and Osman (1956) reported that the duration of egg stage depends greatly on temperature. It was shorter at high temperature (32°C) and increased with the decrease of temperature. At 16°C the eggs failed to develop. Howe and Currie (1964) recorded that the mean egg period of Acanthoscelides obtectus decreased as the temperature increased from 15°C to 32.5°C but above this temperature the incubation period increased at 35°C. Atwal and Singh (1972) showed that at constant temperature of 20, 25 and 30°C the duration of egg stage of Ephestia lunata lasted 11.26, 7.26 and 6 days respectively. Rose (1973) found that the developmental periods of the eggs of Cicadulina at constant temperatures of 23, 25 and 30°C were 14.0, 9.4 and 7.2 days respectively. Jacob and Cox (1977) found that the incubation period of the egg of Ephestia kuhniella depends upon temperatures. The minimum incubation period was 3 days at 31°C. This period rose to about 7 days at 22°C, 14 days at 15°C and 28 days at 12°C to 2 days at 30°C. Champlain and Sholdt (1967) recorded that constant temperature of 40°C was lethal to eggs of Geocoris punctipes (Say). Eggs did not hatch at 10°C. Ash and

Greenberg (1975) worked on the developmental rate of *Phaenicia pallescens* egg and reported that the time of incubation for the species increased with the decrease of temperature. Pathak (1968) stated that usually the incubation period for most of the species of plant and leaf hoppers ranged between 4 and 8 days at the range 25 to 30°C. In the present experiment this range of period is 6 to 8 days at 25 to 30°C. Stenseth (1972) reported that the incubation period of *T. theobaldi* ranged from 10 days at 12°C to 2 days at 30°C. The incubation period in the present observations for *N. lugens* and *N. virescens* eggs at different constant temperature was in agreement with the findings of the above mentioned authors.

Hatchability

The egg hatchability of *N. lugens* and *N. virescens* at different constant temperatures were measured in the present study. The percentage of egg hatching was highest at 30°C in N. lugens (Table 3, Fig. 3) but in *N. virescens* the highest percentage of egg hatching was obtained at the range of 25 to 39°0 (Table 20, Fig. 4). Below or above this range of temperature the rate of hatching decreased. Egg did not hatch at 10°C.

Champlain and Sholdt (1967) recorded that constant temperature of 40°C was lethal to eggs of <u>Geocoris punctipes</u> (Say). This relationship between egg hatching and constant temperatures found in the present observation was in agreement with the result of Champlain and Sholdt (1967).

<u>Developmental period</u>

The developmental period from egg to adult stage of <u>N. lugens</u> and <u>N. virescens</u> was observed and found to vary at different constant temperatures. The total developmental period from egg to adult stage ranged from 42.7 days to 19.3 days at the range of temperature 20 - 45°C in case of <u>N. lugens</u>. In <u>N. virescens</u> the developmental period from egg to adult stage ranged from 41.8 to 17.9 days at the range of temperature 20-45°C. The developmental period decreased as the temperature was increased. Above this range of temperature eggs could not develop, though the larvae survived for few days; perhaps due to some undetermined physiological reactions at high temperature. The tolerable range of heat required for development was more or less same in both the species. Suenaga (1963) reported that the shortest nymphal period of <u>N. virescens</u> was at 27°C. In the present study the shortest nymphal period of <u>N. virescens</u> was at 35°C.

El-sawaf (1956) recorded that the developmental period decreased as the temperature was increased.

Madubunyi and Koehler (1974) studied the development of Hypera brunneipennis (Bohemann) at 5 evenly spaced constant temperatures ranging from 15 to 35°C. They observed that the developmental time was inversely related to the temperature. They also mentioned that the optimum temperature range for development was 15 to 25°C. Atwal and Singh (1972) reported that the period of development of Euproctis lunata decreased with the increase of temperature. Rose (1973) recorded the negative relationship of developmental period of Cicadulina with temperature. Raney et al. (1971) found that Aphelinus asychis took approximately 16 days, to develop from egg to adult at 23.9°C and 10 days at 32.2°C. Fye et al. (1969) studied the developmental periods of 5 strains of Anthonomus grandis Boheman from cultivated cotton. The period ranged from 88 days at 15°C to 17 days at 30°C, at temperature of 35°C, extended the developmental periods of weevils to 18.5. Ash and Greenberg (1975) found that the median time from egg to adult for Phaenicae sericata was 53.9 days at 19°C; for P. pallescence it was 30.3 days at 19°C, 12.8 days at 27°C and 10 days at 35°C. Jacob and Cox (1977) found that the egg developmental period from egg to adult was dependent on temperature. Stenseth (1972) concluded that the complete development from egg to adult of Thomasiniana theobaldi depended on the mode of development in successive stages. As the larval and pupal development were inversely related with temperature, it was found that, the total time from egg to adult development was shortened as the temperature was increased. Voute (1936) did experiments on the rate of development of the eggs of the moth Ephestia kuhniella at constant temperatures and found that eggs can not develop at lower temperatures except in a few cases at 10°C. Davidson (1942) worked on Drosophila melanogaster and pointed out that the speed of development of the eggs increased as the temperature rises until about 30°C is reached. Above this temperature the speed decreased. Chen (1970) noted that the nymphal development of Nephotettix virescens was slower at lower and faster at higher temperature for both male and female. Cheng et al. (1971) reported that the rate of nymphal growth of N. virescens was very fast at 29, 33 and 35°C and the total larval period at this temperature averaged about 16 days. The average nymphal period at 20°C and 24°C was about 37 and 28 days respectively. Hiraro (1972) found that nymphal period of rice and leaf hoppers varied from 14.4 to 15.3 days at 25°C but at 20°C it varied from 25.4 to 27 days.

The present findings on the effect of constant temperatures on developmental period of N. lugens and N. virescens agreed with the results of El-Sawaf (1956), Davidson (1942), Fye et al. (1969), Chen (1970), Voute (1936), Raney et al. (1971), Atwal and Singh (1972), Cheng (1971), Stenseth (1972), Rose (1973), Ash and Greenberg (1975) but not in compliance with Hiraro (1972).

Fecundity

The effect of temperatures on the fecundity of N. lugens and N. virescens were determined. The highest mean number of eggs obtained per female per day was 20.5 at 30°C in N. lugens. Below or above this temperature the fecundity decreased. The females layed most eggs at the range of 30-35°C. In N. virescens the highest mean number of eggs recorded per female per day 18.2 at 35°C. Below or above this temperature the fecundity decreased. The mean number of eggs obtained per female of N. virescens per day was slightly more than that in N. lugens. The fecundity rate generally increased with increasing temperature.

Howe and Currie (1964) reported that the highest mean number of eggs laid by a female of C. analis was 76.6 at 35°C. They recorded a range of 22.5 to 35°C for laying most eggs by Bruchid females. Hafez and Osman (1956) reported that the maximum total number of eggs per female of _B. trifolli_ was about 52.5 at 28°C and 90% R.H. Atwal and Singh (1972) reported that the fecundity increased with the increase of temperature and the highest fecundity was obtained at 30°C. Tanigoshi _et al._ (1975) studied with _Metasciulus occidentalis_ and commented that with the increase of temperature upto a certain range fecundity rate increased. Bonnemaison (1961) studied on the fecundity of _Memestra brassicae_ L. He suggested that since the larval period is longer at lower temperature the larvae consume more food and produce more eggs.

The present observations are similar to that of Tanigoshi _et al._ (1975), Atwal and Singh (1972), Howe and Currie (1964).

Survivality

The highest percentage of survivality of _N. lugens_ and _N. virescens_ and _N. virescens_ occurred at 30°C indicating the optimum temperature for population increase. Fig. 5 and 6 indicates that 2nd, 3rd and 4th instar larvae of _N. lugens_ and _N. virescens_ were susceptible to the experimental constant temperatures. The percentage of survivality of 5th instar larvae was 100 at all experimental temperatures except 40°C in case of _N. lugens_. But in _N. virescens_ the percentage of survivality of 5th instar larvae was 100 at all experimental temperatures. The exact nature of physiological process that leads to mortality of insects at extreme high or low temperature are not well understood. Mortality may be due to heat naturization of one or more critical enzymes or to dissociation of epicuticle, monomolecular wax layer and subsiquent desiccation (Beament 1958).

Fye et al. (1969) worked on ball weevils Anthonomus grandis and observed that the best rearing efficiency in regard to survival was obtained at 20°C. At 25°C the rearing period shortened but higher mortality occurred. Likewise at 30°C the rearing period shortened more but mortality increased. Madubunyi and Kochler (1974) concluded experiments on the Albizia psyllid Psylla uncutiodes. He found at 45°C constant temperature adults did not survive beyond 4 days.

The present work is in agreement with Madubunyi and Kochler (1974) and not in agreement with Fye et al. (1969).

Adult longevity

The longevity of the males and females of N. lugens and N. virescens was determined at different constant temperatures. Longevity decreased with the increase of temperature. The highest longevity for both male and female of both species was observed at 20°C. In all cases males lived longer than the females (Tables 8 and 25). The longevity of adults decreased as the temperature range increased from 20 to 40°C. Kehat and Wyndham (1972) recorded an increase relationship between longevity of _N. vinitor_ and temperature. Hafez and Osman (1956) reported that males of _Bruchidius trifolii_ and _Bruchidius alfierii_ were longer lived than females in all temperatures. El-Sawaf's (1956) experiment on longevity of adult weevils _C. maculatus_ revealed that in all cases of temperatures, females were longer lived than the males. Atwal and Singh (1972) found that the females of _Euproctis lunata_ lived longer than the males. Hinckley (1963) reported that in Fiji, the adult longevity of _N. lugens_ was about 2 weeks during the months of January-April. Misra & Israel (1968) reported that the maximum life spawn of the female of each of _N. lugens_ was around 2 months.

Bae and Pathak (1970) observed that the average longevity at 25°C was 3.9 and 4.1 days for male and female insects respectively. Raney _et al._ (1971) studied on _Aphelinus asychis_ and found that the longevity of adult female decreased with increasing temperatures. The mean longevity of adults was approximately 18 days at 23.9°C and 9 days at 32.2°C. In the present study the female adult longevity was 8 days at 25°C and 11 days at 30°C temperature. Cheng (1969) from his work on _Nephotettix impicticeps_ reported that the longevity of female being 26 days at 20°C.

The present results on longevity of *N. lugens* and *N. virescens* at different constant temperatures were in agreement with Hafez and Osman (1956), Misra & Israel (1958), Kehat and Wyndham (1972) but not in agreement with El-Sawaf (1956) and Bae & Pathak (1970).

Fluctuating temperature

The reports on the effects of fluctuating temperatures on the life cycle of *N. lugens* and *N. virescens* are not available. In the present experiment both the species were subjected to temperatures 20, 25, 29, 32 and 35°C for 6, 15 and 18 hours duration / day.

Incubation period

It was observed that the incubation period decreased as the duration of exposure per day increased in all the temperatures for both the species (Figs. 1 and 2). The incubation period of *N. lugens* was 8.9 days at 25°C constant temperature, but in a fluctuating condition of 25°C the incubation period was 9.3, 8 and 8 days when exposed for 6, 15 and 18 hours / day respectively. At 30°C constant temperature, the incubation period of the same species was 6.4 days but in a fluctuating condition of 29°C the incubation period was 6, 6.1 and 5.3 days at the exposure of 6, 15 and

18 hours duration/day. At 35°C constant temperature the incubation period was 2.5 days where in fluctuating condition the incubation period was 6.2, 5.3 and 6.1 days at the exposure of 6, 15 and 18 hours duration/day respectively. In N. virescens the incubation period was 8.1 days at 25°C constant temperature. At fluctuating condition the incubation period was 9.1, 8.5 and 8.1 days when exposed for 6, 15 and 18 hours duration/day respectively. At 30°C constant temperature the incubation period was 5.8 days; at fluctuating condition of 29°C the incubation period was 6.2, 6.4 and 5.2 days at the exposure of 6, 15 and 18 hours duration/day respectively. At 35°C constant temperature the incubation period of N. virescens was 3.4 days but in fluctuating condition of 35°C the incubation period was 6.2, 5.5 and 6 days respectively.

So, it was observed that in most cases the constant temperature treatment shortens the incubation period.

Hatchability

The duration of heating per day influences the probability of hatching the egg. The percentage of hatching increased as the duration of heating per day increased. It has been found from the Tables 3 and 10 that the hatchability rate was found maximum when the insects were kept in constant temperature rather than fluctuating temperature. The percentage of egg hatching of *N. lugens* at 25°C was 91 and it was 51, 56.8 and 61.3 at 6, 15 and 18 hours exposure/day respectively. In *N. virescens* the percentage of egg hatching at 25°C was 100 but in fluctuating temperature the percentage was 53, 56 and 60 when exposed for 6, 15 and 18 hours/day respectively. So it is found that rate of hatching was maximum at constant temperature than the fluctuating temperature.

Developmental period

The developmental period from egg to adult stage has been found to be affected by the duration of heating per day. At fluctuating temperatures the developmental period decreased as the duration of exposure per day increased Tables 14, 15, 16, 31, 32, and 33).

The developmental period from egg to adult stage of *N. lugens* at 35°C constant temperature was 18.1 days. At fluctuating condition this period was 17.1, 15.2 and 16.1 days at 6, 15 and 18 hours/day respectively. The developmental period at 35°C constant temperature of *N. virescens* was 20.2 days which was 18.4, 17.7 and 16.6 days when exposed for 6, 15 and 18 hours/day respectively.

In both the species it required shorter time to complete development from egg to adult at fluctuating condition than the constant temperature condition.

Adult longevity

The fluctuating temperature influences the adult longevity of both the species found in the present experiment. With the increase of exposing duration the longevity has been found to decrease. Adult longevity has been found to be shorter at fluctuating condition when treated for 15 and 18 hours/day in a particular temperature compared with the constant treatment in both the species (Table 17 & 34)

SUMMARY AND CONCLUSION

Laboratory cultures of *Nilaparvata lugens* (Stal) and *Nephotettix virescens* (Horv) derived from rice field at Joydevpur, Gazipur, during July, 1983 to October, 1984 were maintained on caged pots of rice seedlings. At different constant and fluctuating temperatures, some biological aspects of the experimental insects were determined.

The preoviposition period ranged from 12.2 to 4 days at the temperatures ranging from 20°C to 40°C in both the species. The least time for preoviposition was recorded 40°C in *N. lugens* and 35°C in *N. virescens*. At higher temperatures the insects become stimulated to lay egg within a short period. This shortening of oviposition period was related with decreasing of the longevity of female at higher temperature. The post oviposition period was shortest at 40°C in *N. lugens* and at 35°C in *N. virescens*. The suitable range of temperature for hatching was about 30°C to 35°C for N. lugens and 25 to 30°C for *N. virescens*.

The incubation period was shortest at 35°C in *N. lugens* and at 40°C in *N. virescens*. Any change of temperature above or below this, increased the incubation period. At 10 and 40°C embryonic development did not occur. The threshold temperature extrapolated from the observed incubation period was 19 in *N. lugens* and 18 in *N. virescens*.

The total time required for development from egg to adult stage was maximum at 20°C and minimum at 40°C. This period was 42.7 days and 18.3 days in N. lugens and 41.8 days and 17.9 days in N. virescens at 20°C and 40°C respectively.

The highest percentage of adult emergence (80) was recorded at 30°C in N. lugens and in N. virescens. The adult emergence was 73 percent at the same temperature. The suitable range of temperature for emergence of adult N. lugens and N. virescens was 25°C to 30°C. The temperatures above this range were not suitable for the completion of development which was indicated by the increasing mortality of the immature stages. The males outlived the females.

To complete the life cycle the maximum duration at 20°C (54.9 days) and the least period (23.2 days) at 35°C in case of N. lugens. The maximum duration (54 days) required at 20°C to complete the life cycle, and the minimum duration (24.6 days) at 35°C in case of N. virescens.

The fecundity was maximum at 30°C in N. lugens and at 35°C in case of N. virescens. The adult longevity was longest at 20°C in both the species. In all cases males outlived the females.

Under In the laboratory conditions it has been observed that the insects complete their life cycle earlier, with maximum hatchability, and fecundity, and adult emergence and lived longer in the constant temperature than the fluctuating temperature. 30-35°C temperature has been found to be more suitable for accelerating the life processes.

CHAPTER - X

LITERATURE CITED

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