1984

Biology and Ecology of Predaceous Coccinellids with Special Reference to their Incidence In Response to Aphid Population and Temperature

Rahman, A.S.M.Shafiqur

University of Rajshahi

BIOLOGY AND ECOLOGY OF PREDACEOUS COCCINELLIDS WITH SPECIAL REFERENCE TO THEIR INCIDENCE IN RESPONSE TO APHID POPULATION AND TEMPERATURE

D - 1118

By

A.S.M.Shafiqur Rahman, B.Sc (Hons), M.Sc.

Department of Zoology
Rajshahi University
Rajshahi

Thesis submitted for the Degree of
MASTER OF PHILOSOPHY
of the University of Rahshahi, Rajshahi
1984

DEDICATED

TO MY PARENTS

Who brought me the opportunity
to see the ever beautiful light
and beauties of this world.

DECLARATION

I declare that the present work is original and has not been published or submitted in part or in full for any degree or prize.

A.S.M. Rahman.

(A.S.M. Shafiqur Rahman)

Rajshahi
August, 1984

CERTIFICATE

Certified that this is a bonafide research work of Mr. A.S.M. Shafiqur Rahman.

10/11/84

(Dr. M.A. Quayum)
Professor,
Department of Zoology
Rajshahi University
Rajshahi

Rajshahi University
August, 1984

ACKNOWLEDGEMENT

This study was financed by the Science and Technology Division, People's Republic of Bangladesh under N.C.S.T. Fellowship plan, to whom the author remains grateful.

The author would like to extend his sincere gratitude and heart-felt indebtedness to his supervisor, Dr. M.A. Quayum, Professor, Department of Zoology, Rajshahi University for providing proper guidance, valuable suggestions, constructive criticisms and patient inspiration, without which the work would have been far from completion.

Sincere thanks are due to Dr. M.A. Hossain, Associate Professor and Chairman, Department of Zoology, Rajshahi University for providing space and required laboratory facilities in the department and for his keen interest and valuable suggestions.

The author is also grateful to Professor Mustafizur Rahman, Mr. Sayedur Rahman, Assistant Professor, Mr. Sohrab Ali, Mr. Khalequzzaman, Mr. Safinur Rahman, Assistant Professor, and other fellows of the department for their sympathetic cooperation and inspiration. Grateful thanks are due to Mr. Sarwar Jahan, Assistant Professor, Department of Zoology, and Mr. Azfar Ahmed, Lecturer, Department of Zoology, Pabna Edward College, for their constructive criticism from time to time, valuable advice and assistance in statistical analyses.

The author wishes to extend his sincere thanks to Dr. Md. Ataur Rahman Khan, Assistant Professor, Department of Zoology, Rajshahi University, for going through the manuscripts and valuable criticism.

The author is thankful to Dr. T.G. Vazirani of the British Museum (Natural History) for identifying the beetles.

Sincere thanks are also due to the authors friends, Mr. Abdul Mannan, Assistant Professor, Mrs. Selina Perween, Lecturer, Department of Zoology, Rajshahi University, Mr. Mojarul Haque, Lecturer, Rangpur Carmichael College, Mr. Rafiqun Nabi, Research Fellow, Department of Zoology, Rajshahi University for their help and interests during the work.

The valuable service in careful typing by Mr. Ajit Kumar Chakrabarty, Stenographer, Institute of Bangladesh Studies, Rajshahi University is thankfully acknowledged.

Last but not the least, the author wishes to acknowledge with grateful thanks to all concerned who directly or indirectly came into assistance during the course of investigation and finalizing the thesis.

The Author

CONTENTS

INTRODUCTION

INTRODUCTION

Ladybirds, or preferably lady beetles, have been reported through the centuries as the vernacular indicates for the term 'lady' in reference to biblical Mother Mary (Roache, 1960). This group of insects belongs to the family Coccinellidae and comprises a lerge number of insects under Coleoptera with about 490 genera and 4,200 species (Sasaji, 1971), whereas in the latest report the family comprises nearly 5,000 species (Imms, 1977). Latereille (1807) for the first time established the member of the family Coccinellidae which are extremely diverse in their habits. They are either predaceous or phytophagous.

Valuable works have been done with entomophagous species (Lefroy, 1909; Hagen, 1962; Alam et al.,1964; Thomson and Simmond, 1965; Hodek, 1967). Diek (1947) reported that about 5/6ths of all described species of the family Coccinellidae belong to the sub-family Coccinellinae, the predaceous group and the rest belong to the sub-family, Epilachninae, the phytophagous group. The typical reddish or orange coloured lady beetles make up only 4,000 species of the worldwide family Coccinellidae (Korschefsky, 1931). This species, including darker species, are frequently the key factors in regulating many homopterous insects, spider and mite pests (Clausen, 1956; Sweetman, 1958). The number and position of the spots on the elytra are not enough to identify them. The taxonomy of

various higher categories of Coccinella have been treated recently (Timberlake, 1945; Watson, 1956).

After having made a successful use of the cocciphagous Coccinellidae in the biological control against Coccidae in the tropical and sub-tropical countries, the aphidophagous Coccinellidae was once a great hope for using them in biological control of harmful aphids (Hodek, 1958). A most remarkably effective control and often total elimination of some scale insects and exposed mealybugs by lady beetles occurred on the tropical island of puerto Rico, affecting such introduced plants as coconut palm, grape fruit, bamboo and Australian pine (Wollcott, 1960).

Increasing interests in the study of predaceous coccinellids is undoubtedly due to the harmful side effect of toxic chemicals and the intensiveness of research on biological and integrated controls of pests (Hodek, 1967). Recently an increasing amount of research has been done on the possibilities of using lady birds for the biological control of insect pests (Hamalainin and Markkula, 1972)

Both the larvae and adults of these beetles are often encountered in large numbers on the aphid infested areas. They prey on these destructive insects and thereby often play a positive role in bringing them under control. In Bangladesh, these beetles are very common in aphid infested cotton, egg

plant, bean, mustard and wheat during the months from November to March but gradually the number decreases with the rise of temperatures. They almost disappear in the late summer.

Beneficial nature of these beetles have been reported by various workers all over the world. Alam et al (1964) reported that Coccinella repanda Thunb. is one of the important predators of Lipaphis pseudobrassica D. and Aphis gossypii Glov., common pests of mustard and cotton respectively. Extensive works on the life history of these beetles were carried out by several workers (Kamal, 1951; Ibrahim, 1955; Brettell, 1964; Roy, 1976; Islam and Nasiruddin, 1978) Semyanov (1974) studied the method of breeding of Coccinella septempunctata L. in the laboratory. Butler and Dickerson (1972) studied the life history of convergent lady beetle in relation to temperature. Nielson and Currie (1960) studied the biology of the Adalia bipunctata L. in Arizona. C. septempunctata was introduced in 1847 from England to New Zealand in an attempt to control different species of aphids (Sweetman, 1936).

The distribution of coccinellids in relation to their prey and temperature have been studied by several workers. Bishop and Blood (1978) observed the population abundance of six coccinellids in relation to that of aphids. Ibrahim (1955) studied the distribution of Coccinella undecimpunctata aegyptiaca Reiche. in Egypt. Besides these some ecological

works on C. septempunctata have been done by Banks (1955) and Okamoto (1974) in Britain and Japan respectively.

From the economic point of view the reproductive potentiality of this harmful aphid is immense due to parthinogenesis, viviparity and fast development. Under suitable conditions their number rapidly increases above economic threshold levels. Sound knowledge on bionomics and ecology of aphidophagus insects is, therefore, indispensable if they are to be used to the best advantage in the control of aphids. For this perception, the present observations have been aimed at studying the biology of these coccinellid beetles involved in predation of different species of aphids at Rajshahi University Campus and their incidence in response to their aphid prey and temperature.

CHAPTER -I COMPARATIVE BIOLOGY

COMPARATIVE BIOLOGY OF PREDACEOUS COCCINELLIDS

The biology of an insect is an important factor to be studied for obtaining a knowledge on the nature and extent of damage to a particular crop. Thus, the biology of predaceous coccinellids have been undertaken for investigation with a view to finding out of its economic importance as well as to comparing their efficiency with other predaceous insects.

Our knowledge on the biology of these predaceous insects is very scanty in our country. However, Hagen (1962) and Hodek (1967) studied the biology of some predaceous coccinellids in California and Czechoslovakia respectively. Savoiskaya (1974) studied the biology and morphology of coccinellid beetles and gave an estimated economic value in the process of biological control of insect pests. Islam and Nasiruddin (1978) studied the life-histories of C. repanda and C. septempunctata in Bangladesh. Abraham et al. (1976) studied the biology of C. arcuata, a predator of the rice pest, Nilaparvata lugens in India.

Besides those some biological works have been conducted on C. undecimpunctata aegyptiaca Reiche. (Kamal, 1951; Ibrahim, 1955), on A. bipunctata L. (Nielson and Curri, 1960; Butler and Dickerson,1972), on Diloponis inconspicuus Pope (Brettell, 1964).

The biology of five species of predaceous coccinellids have been studied under laboratory conditions. These are as follows :

1. Coccinella repanda Thunb.

It is small species (Length 5.63 mm and width 3.94 mm), orange red to completely deep red with a number of black wavy markings on its elytra. It was abundantly found in aphid infested crops, viz. cotton, brinjal. wheat, soybean etc.from September to March. Alam et al. (1964) listed C. repanda as a predator of the aphid, A. gossypii in Bangladesh. Thomson and Simmond (1965) reported C. repanda to be a predator of aphids, namely Diaphorina citri Kuw. in India, A. nerii Kalt., Macrosiphum rosae L., Myzas persicae Sulz. in Australia and A. tevarsi Del. in Malaya.

2. Coccinella septempunctata L.

Comparatively large than C. repanda (Length 6.66 mm and width 4.95 mm), orange red with a number of black spots on its elytra. It was very common in aphid infested wheat fields from January to March. Alam et al. (1964) listed this predator as C. 7-punctata. Lefroy (1909) considered it a very active and voracious feeder of the wheat aphid, Macrosiphum granarium and the mustard aphid,A. brassicae. Fletcher (1914) stated that this predator occurred chiefly on wheat, mustard and sometimes on paddy and other crops all the year round throughout southern India.

3. Menochilus sexmaculatus Fab.

Smaller in size (Length 4.55 mm and width 3.53 mm), mostly creamy white with blackish wavy markings on their elytrae and some were black. This species was found abundantly in most aphid infested

areas, viz. cotton, brinjal, mustard and soybean from August to March. Islam and Nasiruddin (1976) reported it earlier from Bangladesh as a predator of different species of aphids.

4. Micraspis discolar Fab.

Smaller species (Length 3.75 mm and width 3.00 mm), yellowish in colour without any spot on its elytra. It was collected from aphid infested soybean and cotton fields from September to March. Rahman et al,(1983) reported it earlier from Bangladesh.

5. Micraspis cerocea Fab.

Oval smaller species (Length 4.5 mm and width 4.00 mm) found in aphid infested field in association with M. discolar. It is orange red in colour without any spot on its elytra. Rahman et al.(1983) reported it earlier from Bangladesh.

FIG. 1. Different species of coccinellids

Above (From left)

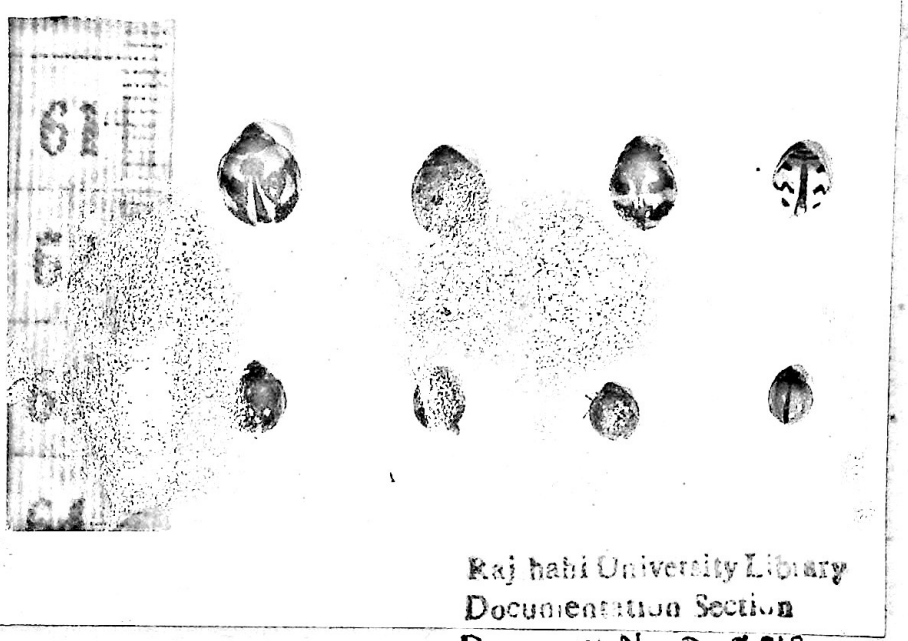
C. septempunctata L., C. septempunctata L., C. repanda Thunb.

M. sexmaculatus Fab.

Below (From left)

M. sexmaculatus Fab., M. sexmaculatus Fab., M. cerocea Fab.

M. discolar Fab.



Mating behaviour

Day light stimulates mating in C. undecimpunctata (Ibrahim, 1955). But mating did not seem to exert any influence on the rate of oocyte development but played an important role in promoting ovulation in C. septempunctata (Wang et al, 1977).

Several workers viz. Ibrahim, 1955; Brettell, 1964; Hodek, 1967; Roy, 1976; Wang et al, 1977 observed mating behaviour of different coccinellids in different parts of the globe.

Materials and Methods:

The coccinellids were collected from cotton fields. The beetles were separately kept in Entomological breeding chambers. At regular intervals of 24 hours, each of the chambers was supplied with aphids on fresh cotton leaves and the mating behaviour was carefully observed.

Observations and Discussion:

The mature male takes initiative in mating and the females, on the other hand, seem to have no interests at the initial stage. At first the male comes close to the female and tries to excite her by knocking with his antennae. Very often she runs away from the male but the male follow the female desperately to mount on her back. During the course of mating, the

male used both the fore and hind legs in embracing the female body from above. The male bends its posterior part ventrally and anteriorly to insert its aedeagus into the female genital opening. The two insects remain at rest quietly for sometimes and from time to time, the male trembles violently and in continuation of such mating the female moves to and fro along with the male on her back and continues its normal feeding.

The male withdraws its aedeagus suddenly after mating is over. Mating takes place more than once either with the same or with other females.

During this observation, the durations of mating of different species were found to be more or less similar. The average mating periods were recorded to be 14.4 $\pm$ 0.92, 14.4 $\pm$ 1.28, 16.2 $\pm$ 0.99, 14.25 $\pm$ 0.79 and 12.0 $\pm$ 0.63 minutes for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar, and M. cerocea respectively. (Table -1).

Ibrahim (1955) observed the mating behaviour of C. undecimpunctata and reported that the average mating period was 6 minutes. Hodek (1967) studied the mating of C. septempunctata and reported that the first mating takes place a few days after emergence and is usually repeated several times during the adult life, even though for most species one copulation is enough to give the female permanent fertility. In C. transversalis the duration of mating was 4 to 5 days (Roy, 1976).

Brettell (1964) observed the mating of D. inconspicuus. But he did not mention the mating period. The present observation on the mating behaviour of different coccinellids was similar to those observed by Ibrahim (1955) and Brettell (1964).

Table - I

The Mating durations of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea (in minutes)

Species	Replication numbers (in minutes)					Total	Average ± S.D.
	1	2	3	4	5		
C. repanda	12	15	16	12	17	72	14.40±0.92
C. septempunctata	10	16	17	12	17	72	14.40±1.28
M. semaculatus	12	18	16	17	18	81	16.20± 0.99
M. discolar	12	16	13	16	16	73	14.25±0.79
M. cerocea	10	13	12	11	14	60	12.00±0.63

Fig. 2. Mating of *C. septempunctata* L

Pre-oviposition period

Pre-oviposition period of C. undecimpunctata aegyptiaca was greatly influenced by temperature (Ibrahim, 1955). Several workers observed the pre-oviposition period of specific coccinellids, viz. C. transversalis (Roy, 1976) C. septempunctata (Wang et al, 1977 and Islam and Nasiruddin, 1978), and C. repanda (Haque and Islam, 1978).

Several experiments were carried out to observe the pre-oviposition period of different coccinellid beetles under different conditions of temperature and mating.

Materials and Methods:

The experiments were split into two parts. For the first part, 25 newly emerged females were equally divided into five groups. Individual female of each group was separated in vials (9.5 x 1 cm) with one male and placed in a fixed, low temperature incubator at 15°C for a daily light exposure of 8 hours. Similar procedure as followed for the other temperatures; viz., 20, 25, 30 and 35°C. A relative humidity of 75 per cent was maintained for all temperatures.

For the second part, 20 newly emerged virgin females were divided into two equal groups. For the first group a single female was placed inside a vial (9.5 x 1 cm) with two

males for continuous mating. The females of the second group were retained singly.

Observations and Discussion:

The pre-oviposition periods varied with temperatures. Longer pre-oviposition periods were recorded at lower temperatures and higher temperatures lowered the pre-oviposition periods of all the coccinellids under observation (Fig. 3).

The statistical analyses showed a significant difference ($P < 0.01$) in the pre-oviposition period of all the species at different temperatures.

Regarding the effect of mating remarkable differences were recorded between the pre-oviposition periods of mated and unmated females (Table - II).

Ibrahim (1955) observed the effect of temperature and mating on the pre-oviposition period of C. undecimpunctata in Egypt. He reported the shortest (always two days) pre-oviposition period at 27°C. He further reported that at 14°C, the average pre-oviposition period was 12 to 14 days whereas, at 29°C, the period came down to 2 to 4 days. He also recorded a remarkable difference in the pre-oviposition period between mated and unmated females of this beetle. He mentioned that the average pre-oviposition period of mated females was about

48 days. The present findings are in close conformity with those of Ibrahim (1955). Roy (1976) studied the pre-oviposition period of C. transversalis and recorded the pre-oviposition period of 5 to 6 days. Wang et al, (1977) reported the pre-oviposition period of C. septempunctata to be about 15 days, while Islam and Nasiruddin (1978), claimed this period to be 10.6 days for the same beetle. According to Haque and Islam (1978) the pre-oviposition period of C. repanda was only 4 days.

Table - II

Effects of mating on the pre-oviposition periods of *C. repanda*, *C. septempunctata*, *M. sexmaculatus* *M. discolar* and *M. cerocea* (in days)

Species	Mated			Unmated		
	Minimum	Maximum	Average ± S.D.	Minimum	Maximum	Average ± S.D.
C. repanda	6	11	8.6±0.93	13	27	19.8 ± 2.73
C. septempunctata	7	11	10.6±0.93	15	22	18.8 ± 1.39
M. sexmaculatus	3	15	8.8±2.01	9	25	16.0 ± 3.06
M. discolar	9	16	12.8±1.39	11	28	20.4 ± 3.66
M. cerocea	5	16	11.8±1.93	19	32	25.4 ± 2.50

FIG.3. Pre-oviposition period of different coccinellids at different temperatures.

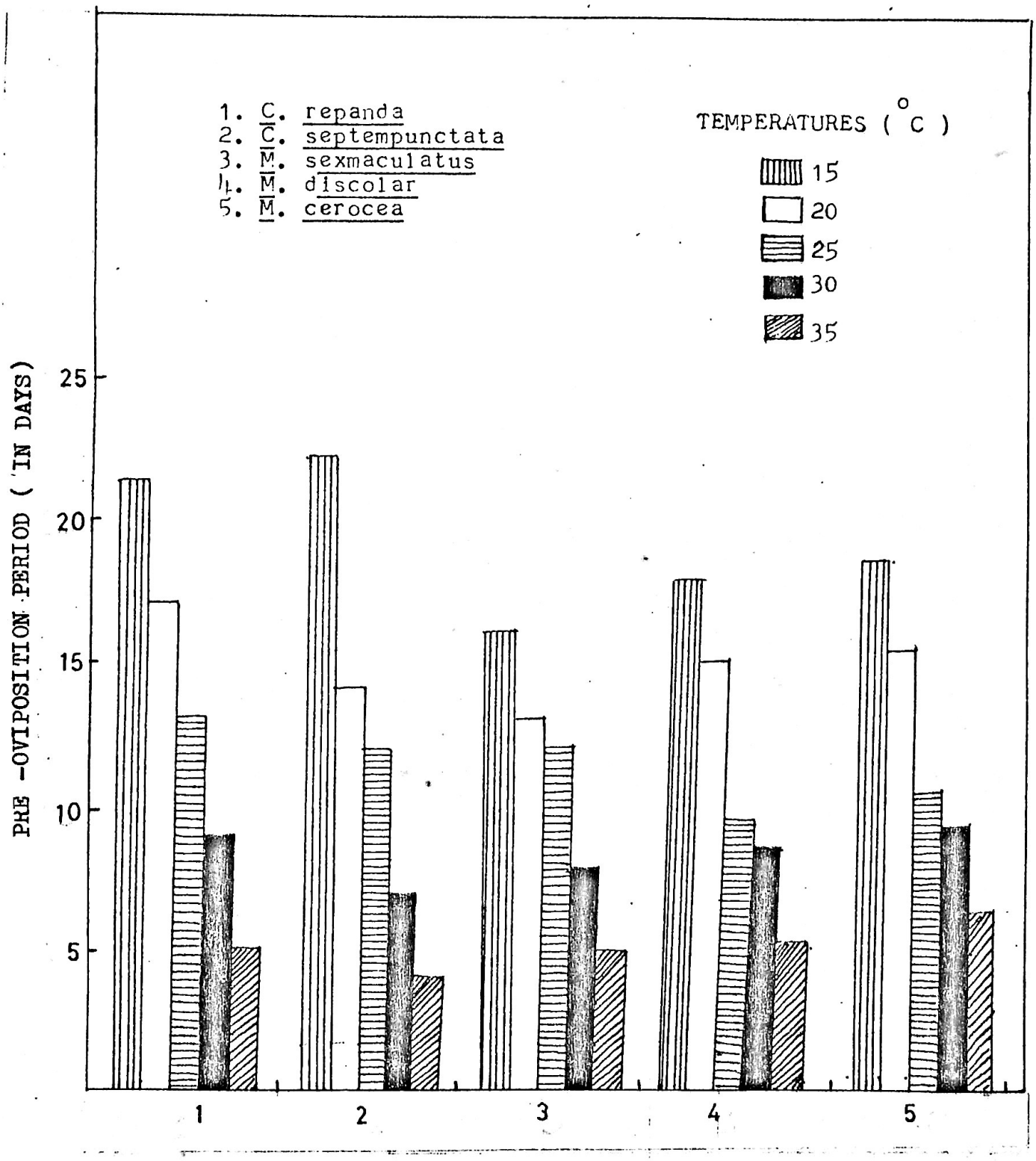
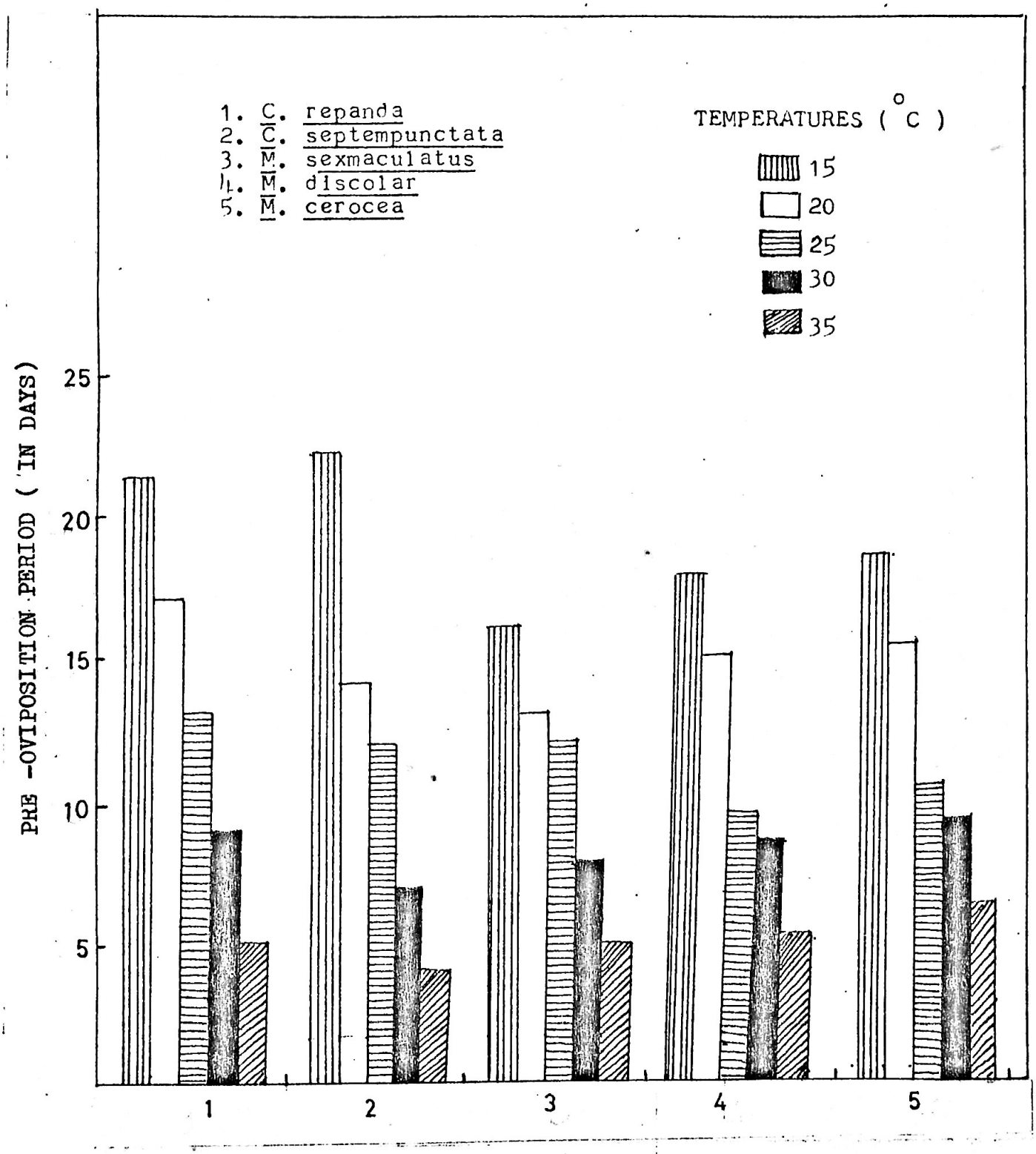

1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
TEMPERATURES (°C)
15
20
25
30
35
PRE -OVIPOSITION PERIOD (IN DAYS)
25
20
15
10
5
1
2
3
4
5

FIG.3. Pre-oviposition period of different coccinellids at different temperatutes.


1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
TEMPERATURES (°C)
15
20
25
30
35
PRE -OVIPOSITION PERIOD (IN DAYS)
25
20
15
10
5
1
2
3
4
5

Oviposition period

Rate of oviposition is often very sensitive to a change in humidity and there may be an effect of mating on it (Zwolfer, 1931). Some workers studied the oviposition periods of different coccinellids, viz. C. sexmaculata (Modawal, 1941), C. undecimpunctata (Ibrahim, 1955), C. transversalis (Roy, 1976), C. septempunctata (Islam and Nasiruddin, 1978), and C. repanda (Haque and Islam, 1978).

The effect of temperature on the oviposition period of coccinellids were studied in the present investigation.

Materials and Methods:

The experimental procedure was same as stated for the pre-oviposition period. After deposition, eggs were transferred to a beaker. The time of deposition of first egg and the time of last egg laying were carefully recorded.

Observations and Discussion:

During the process of oviposition, the last abdominal segment of female was extended until the tip of the abdomen touched the surface of the substratum to lay eggs on it. The interval between the laying of two successive eggs varied from 20 to 30 seconds depending upon species. In the field, eggs were mostly laid on the stem or on the dorsal surface of the

leaves. But in the laboratory eggs were laid on the wall of the beaker, glass vial, cloth or other available substratum in the cage.

The experimental data on the oviposition periods has been shown in the Fig. 4. It is evident that lower the temperature, longer the oviposition period of all the coccinellids under observation but with an increase in temperature, the periods gradually decreased.

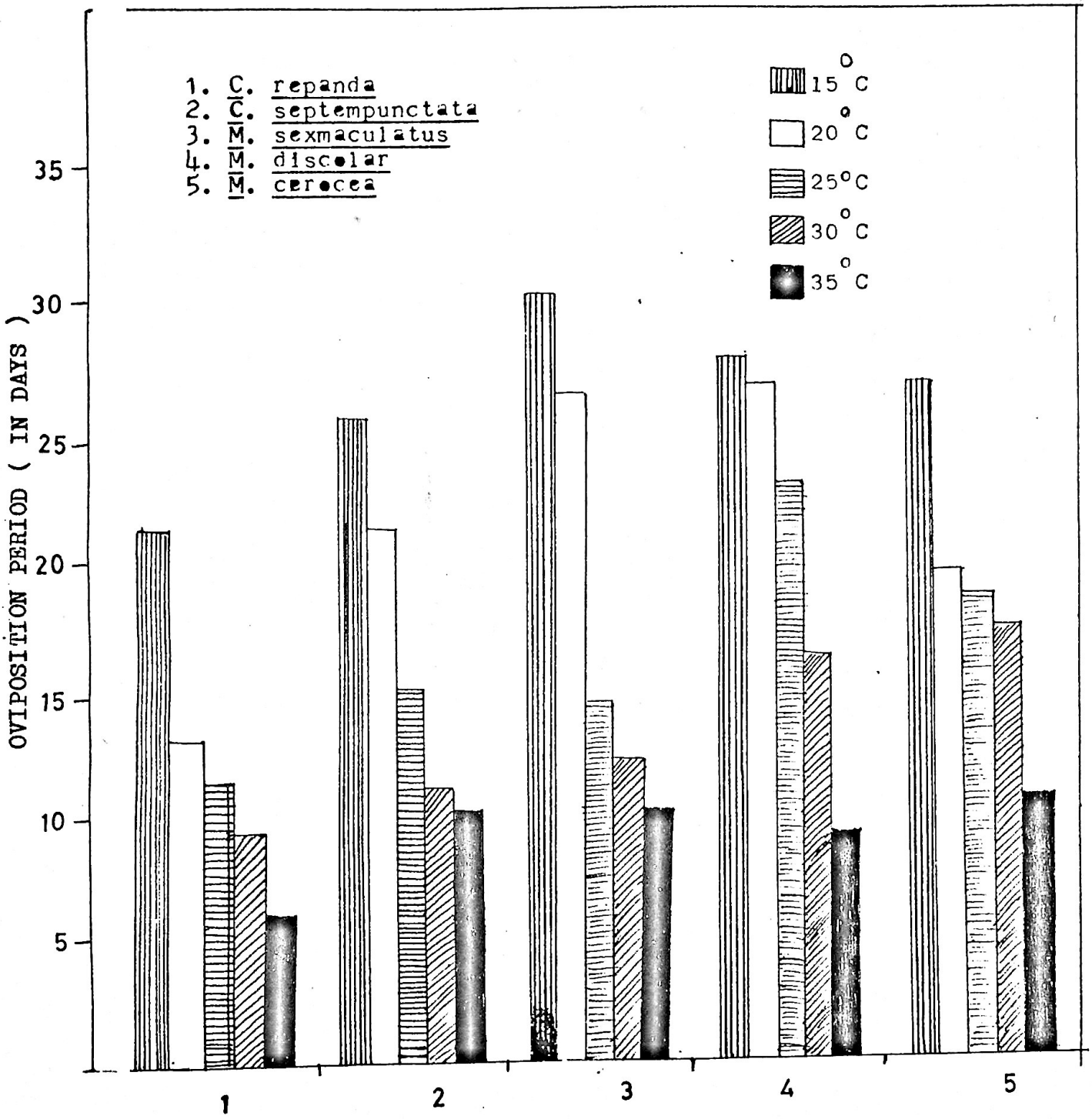
The statistical analyses showed insignificant results.

Ibrahim (1955) studied the oviposition of C. undecimpunctata in response to temperature and copulation. He reported that both temperature and mating influenced the rates of oviposition. It is observed that at the lowest temperature taken in this experiment i.e. 15°C, the oviposition periods of all species were longest but at 35°C of temperature the periods were shorter (Fig. 4).

Islam and Nasiruddin (1978) reported that the average oviposition period of C. septempunctata was 25 days, while Haque and Islam (1978) studied the same beetle and mentioned that the oviposition period was 19.0 days. However, they did not mention the temperature. Modawal (1941) studied the oviposition of C. sexmaculatus and reported that the female of that beetle did not oviposit at constant temperatures of 10°C and 18°C. The findings support the view of Ibrahim (1955).

FIG. 4. Oviposition period of different coccinellids at different temperatures.

FIG. 4. Oviposition period of different coccinellids at different temperatures.


1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
15°C
20°C
25°C
30°C
35°C
OVIPOSITION PERIOD (IN DAYS)
35
30
25
20
15
10
5
1
2
3
4
5

Fecundity

Fecundity may be strongly influenced by components of the environment other than temperature, notably moisture and food (Andrewartha and Birch, 1954). According to them majority of the insects except a few lepidopterous require a full diet in the adult stage to produce eggs. Several factors such as temperature, amount of food, different artificial (non protein) foods and copulation affected the rate and number of egg production in C. undecimpunctata (Ibrahim, 1955).

The fecundity of coccinellid beetles were studied by Palmer (1911), Hawks (1920), Bagal and Trehan (1945), Smith (1965), Hamalainnen and Markkula (1972), Wang et al (1977), Haque and Islam (1978) and Ali et al (1981).

In the laboratory, experiments were set up to determine the fecundity of coccinellid beetles in response to amount and kind of food, temperature and mating.

Materials and Methods:

Experiment No. 1 (Amount of food)

Hundred) newly emerged females were divided into ten groups of ten females each. Each female was placed separately in a glass vial (9.5 x 1 cm) with a piece of cotton wool soaked with water and provided daily with a certain amount of A. gossypii. Females in group 1 were each allowed daily with 10 aphids,

females in group 2 were each allowed daily with 20 aphids, females in group 3 were each allowed daily with 30 aphids, and so on until females in group 10 were each allowed daily with 100 aphids. From time to time, one male was introduced to each vial containing the female for effective mating. The number of eggs deposited daily by each female was counted and results are shown in Figure.

Experiment No. II (Kind of food)

In this experiment, newly emerged beetles of both sexes of each species were collected and divided into five groups containing five males and five females and transferred to the Tortox Entomological Breeding Chamber (Upper unit 12 x 8 cm and lower unit 12 x 7.5 cm). In this chamber they could mate freely. The insects of the first group was supplied with water. The second group was provided with sufficient number of cotton aphids, A. gossypii. The third group was supplied with fresh pollen dusts of cotton flower. Those of the fourth group was provided with 10 per cent honey solution and fifth group was provided with 10 per cent sucrose solution. Foods were changed daily to avoid fungal or bacterial attack. Five replications with five observations were considered in each case. Deposited eggs were transferred to a beaker and the total number of eggs deposited by each female during her life time was recorded.

Experiment No. III (Temperature)

15 to 35°C constant temperatures were used for this investigation.

Experiment No. IV (Mating)

Regarding the effect of mating, the experimental procedure was same as stated for the pre-oviposition period.

Observations and Discussion:

The results of these experiments have been shown in the tables III, IV and Fig. 5 and 6. From the first experiment it has been observed on dissection that the females fed 10 or less number of aphids daily could not produce any egg in their overies. Daily feeding of 20 or more aphids per female produced eggs in all the cases.

Upto daily allowance of 20 aphids per female, the average number of eggs laid by C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea were 2.2, 3.25, 8.25, 2.5 and 2.75 but gradual increase of aphids from 50 to 100 per female the production of egg gradually increased (Fig. 5).

The second experiment reveals that females only feeding on aphids succeeded in laying eggs but of other types of food failed to produce egg in the overies as revealed by dissection (Table - III).

Within a range of temperature between 20 to 30°C there seems to be a general positive correlation between temperatures and number of eggs laid (Fig. 6).

The statistical analyses showed very high significant difference ($P < 0.01$) in the fecundity of all the species at different temperatures.

The mated females of all species laid more eggs than that of unmated females (Table - IV).

The production of eggs depends on the amount of food and temperature. The coccinellids fed on natural and artificial carbohydrates foods did not lay eggs. Ibrahim (1955) studied the effect of different artificial foods, amount of aphid food and temperature on the fecundity of C. undecimpunctata and reported that no diet other than aphids proved to be either attractive or nutritious enough for the beetle to produce any egg. He also observed that the fecundity was positively correlated with the amount of food consumption and temperature. His observations are in close conformity with those of the present findings. According to Hagen (1962) artificial diets like carbohydrate solution, extra floral nectary secretion or nectar fed upon by many coccinellids were nutritionally deficient for egg production. This view is supported by several workers (Smirnoff, 1958; Hamalainen and Markkula, 1972; Ali

et al, 1981). Sundby (1968) fed seven spotted lady bird on a artificial food containing liver and got no positive results. Smith (1965) studied the fecundity of C. maculata and reported that gravid field collected C. maculata stopped laying eggs after three days of feeding on the diet that contained no protein. He also obtained a complete larval development and oviposition on artificial diets containing protein in case of several coccinellids. Hodek (1967) studied the fecundity of many coccinellids and reported that Coelomegilla maculata with its wide food range was the first coccinellid to be bred on an artificial diet but the present author did not use such protein containing food. In Japan, the artificial diets used for predeceous coccinellids have proved to be only alternative food (Hukusima and Sakurai, 1963 and Tamaka and Maeta, 1965).

Fed on aphids only C. septempunctata laid 400 to 900 eggs. (Wang et al, 1977). According to Bagal and Trehan (1945), the maximum number of eggs laid by a female of the same beetle was 2384. Palmer (1911) found that the number of eggs laid by C. 9-notata varied from 433 to 1047 whereas, A. bipunctata laid an average of 140 with 418 as the maximum 'Hawks, 1920). Ali et al, (1981) studied the fecundity of C. repanda and reported that this beetle laid 75.64 eggs on the average while Haque and Islam (1978) reported that the same beetle laid 208.6 eggs. Hagen's (1962) view that the reproductive potentiality largely depends on the particular type of food, has been confirmed in the present observation.

Table - III

Effects of different foods on the fecundity of C. repanda C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea

Species	Aphids			10% sug. soln.	10% honey soln.	Pollen dust	Water
	Min.	Max.	Ave. ±S.D.				
C. repanda	141	242	204.4±17.31	-	-	-	-
C. septem-punctata	178	275	202.4±13.06	-	-	-	-
M. sexmacu-latus	140	227	175.4±16.85	-	-	-	-
M. discolar	98	200	155.6±17.50	-	-	-	-
M. cerocea	65	127	97.8±10.19	-	-	-	-

Table - IV

Effects of mating on the fecundity of C. repanda, C. septempunctata M. sexmaculatus, M. discolar and M. cerocea

Species	Mated			Unmated		
	Minimum	Maximum	Average ± S.D	Minimum	Maximum	Average ± S.D
C. repanda	141	242	204.4 ± 17.31	40	92	62.2 ± 11.62
C. septempunctata	178	245	202.4 ± 13.06	29	85	54.0 ± 8.11
M. sexmaculatus	140	227	175.4 ± 16.85	27	82	47.0 ± 8.63
M. discolar	98	200	155.6 ± 17.58	12	60	37.0 ± 8.20
M. cerocea	65	127	97.8 ± 10.19	27	58	40.2 ± 4.53

FIG. 5. Fecundity of different species of coccinellids in response to the amount of food.

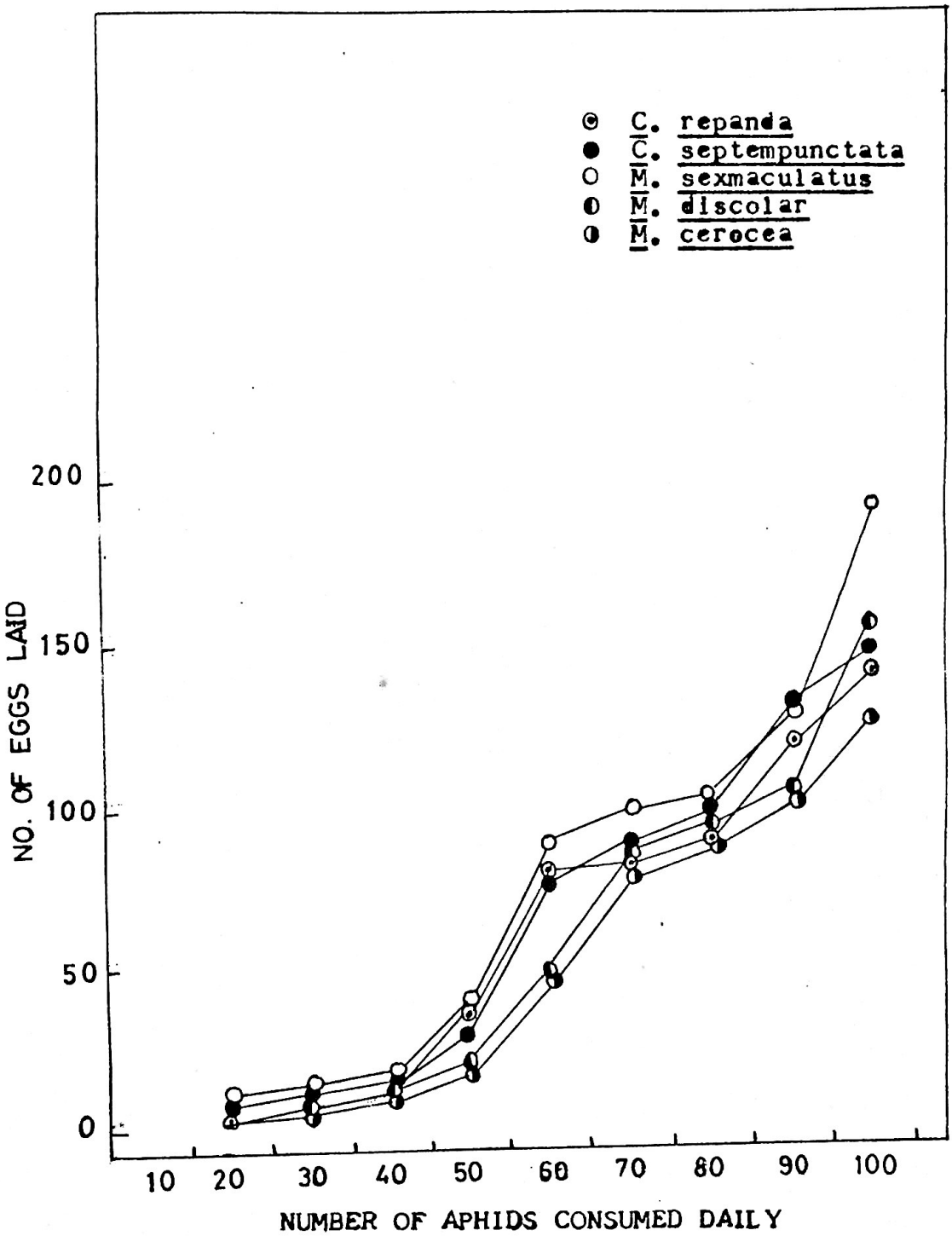
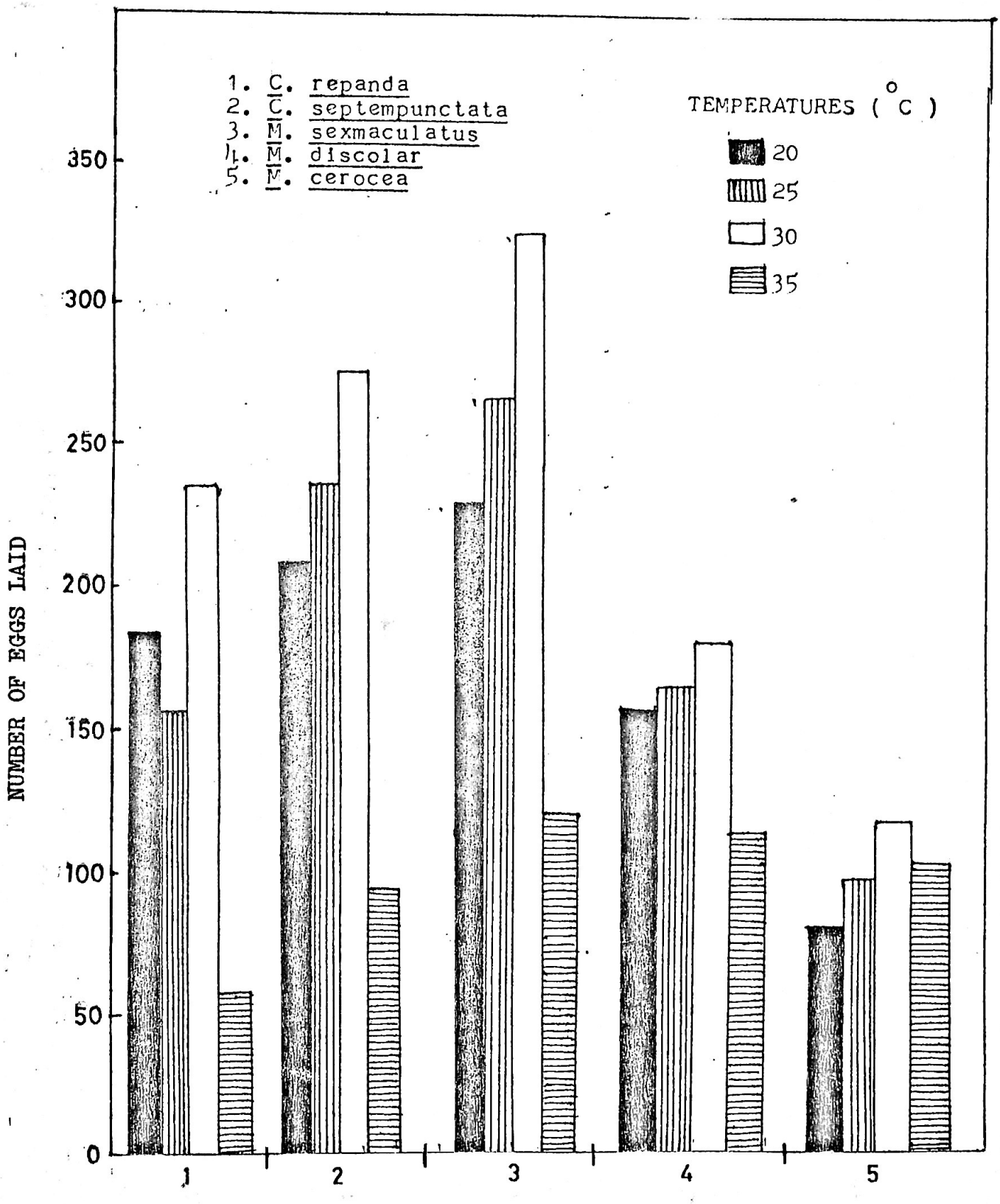

C. repanda
C. septempunctata
M. sexmaculatus
M. discolar
M. cerocea
200
150
100
50
0
NO. OF EGGS LAID
10
20
30
40
50
60
70
80
90
100
NUMBER OF APHIDS CONSUMED DAILY

FIG. 6. Fecundity of different species of coccinellids at different temperatures.


1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
TEMPERATURES (°C)
20
25
30
35
NUMBER OF EGGS LAID
350
300
250
200
150
100
50
0
1
2
3
4
5

Incubation period

The temperature has a pronounced effect on the incubation period of all insects. Barbar (1926) noticed in Pyrausta nubilatis (Hubner) that some eggs failed to hatch during protracted dry periods and he considered that heat and moisture are closely associated in their influence on the incubation of eggs. Several workers, viz. Ibrahim, 1955; Brettell, 1964; Smith, 1964; Roy, 1976; Haque and Islam, 1978 studied the incubation period of different coccinellids in different parts of the world.

In the laboratory, an experiment was carried out to determine the incubation periods of coccinellid beetles under different constant temperatures.

Materials and Methods:

A portion of the leaf containing egg mass of these beetle were cut into pieces and immediately transferred to a low temperature incubator (Cenco model No. 46045-A) to subject them to 15°C for a daily light exposure of 8 hours. In the experiment, each petridish represented a replication and each replication consists of ten observations. Similar procedure was maintained for different temperatures, viz. 20, 25, 30, and 35°C for each constant temperature a constant R.H. of 75 per cent was maintained.

Observations and Discussion:

The experiment reveals that there are slight variation of incubation period between species at different temperatures. The eggs took a longer period to hatch at lower temperature than that of next higher temperature. At 20°C, the eggs took a period of approximately three times greater than that required at 30°C to hatch. But at 35°C, no hatching took place. The development of embryo was enhanced with the increased temperatures and the development was retarded with the decreased temperatures within the limits of effective temperatures. So, it seems that, the temperature played an important role on the variation of incubation period of coccinellids.

Statistical analyses clearly indicated that the incubation periods of different species of coccinellids is dependent on temperatures ($P < 0.01$).

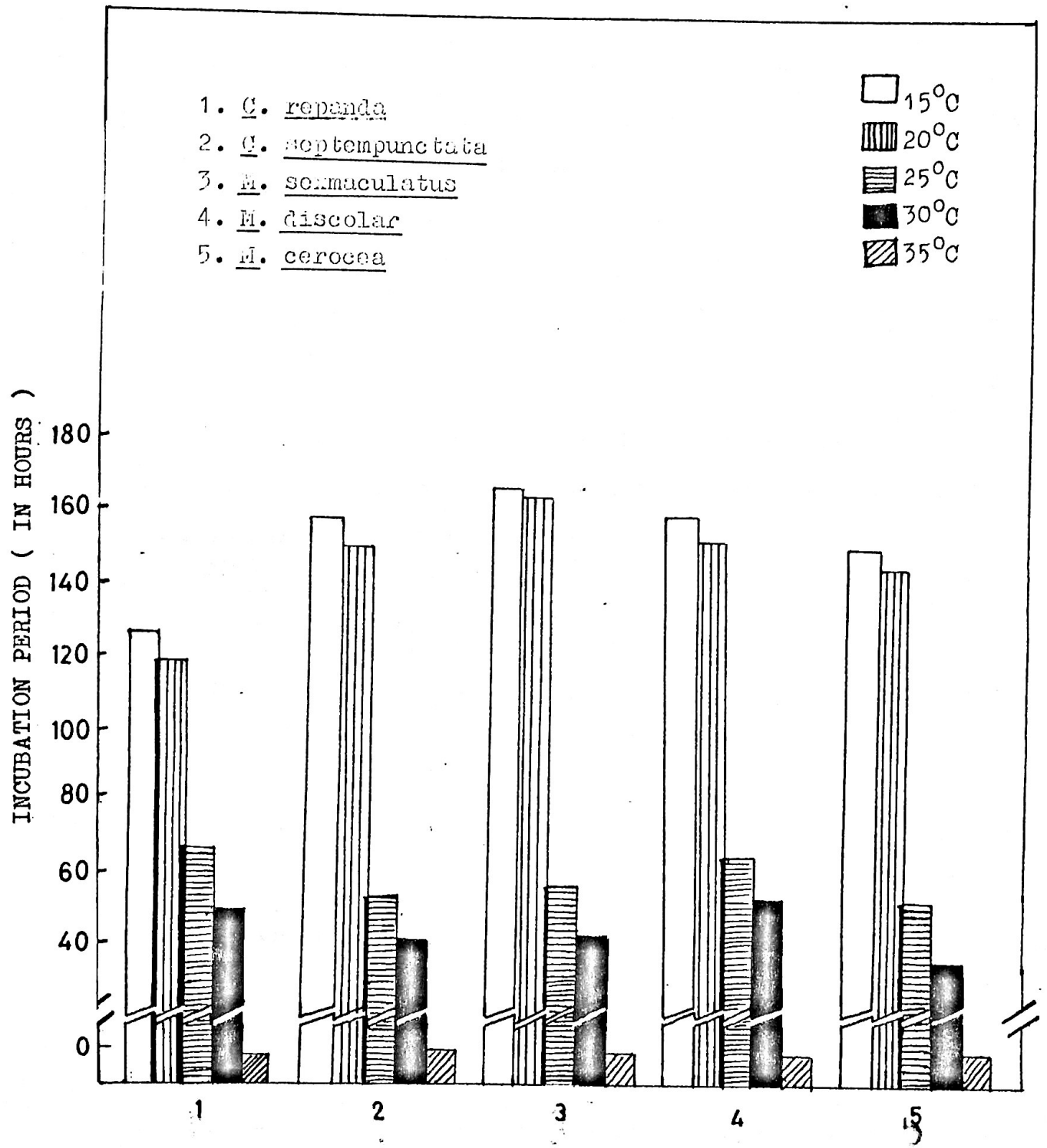
The average incubation period of five species at different temperatures have been graphically represented in Fig. 7.

Bretell (1964) observed the incubation period of D. inconspicuus and reported that the period was 12 days with range of 11 to 13 days. But this period was 7 to 10 days in C. transversalis (Roy, 1976) while Smith (1964) reported that the incubation period of the same beetle was approximately 4 days.

In C. repanda, this period was 2.2 days on the average (Haque and Islam, 1978). According to Mountford (1966) the incubation period of most insects decreases with increasing temperatures until the so called peak temperature is reached.

The present findings on the incubation period of five species of coccinellids are in agreement with the above view regarding the temperature effect.

FIG. 7. Incubation period of different species of coccinellids at different temperatures.


1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
15°C
20°C
25°C
30°C
35°C
INCUBATION PERIOD (IN HOURS)
180
160
140
120
100
80
60
40
0
1
2
3
4
5

Hatching and hatchability

The environmental factors such as temperature and humidity have great influence on egg hatching. Many workers studied the effect of temperature and relative humidities on egg hatching of different insects e.g., C. undecimpunctata (Ibrahim, 1955 and Singh and Malhotra, 1979) Rhizopertha dominica (Qayyum, 1968), Tenebrio molitor (Koura [redacted], 1972), C. repanda (Haque and Islam, 1978).

In the laboratory, an experiment was set up to observe the hatching and to determine the effect of temperature on the hatchability of different coccinellids.

Materials and Methods:

The procedure regarding egg deposition was same as that described in the chapter of incubation.

Observations and Discussion:

Hatching:

Few hours before hatching, the uniform yellow colour of egg gradually turn gray. Since the chorion is transparent and the first instar larva can be clearly seen through chorion. After hatching the chorion appears as transparent white empty shells. On hatching the outer pole of chorion ruptured irregularly and so that the prothorax of the first instar larva first appear followed by the head and then the rest of the body.

This process took between 15 to 25 minutes.

Hatchability:

During this experiment the percentage of hatching were recorded to be directly proportional to the rate of increase of temperature between 20°C to 30°C. No hatching took place at 35°C and the eggs underwent shrinkage after 55 to 65 hours.

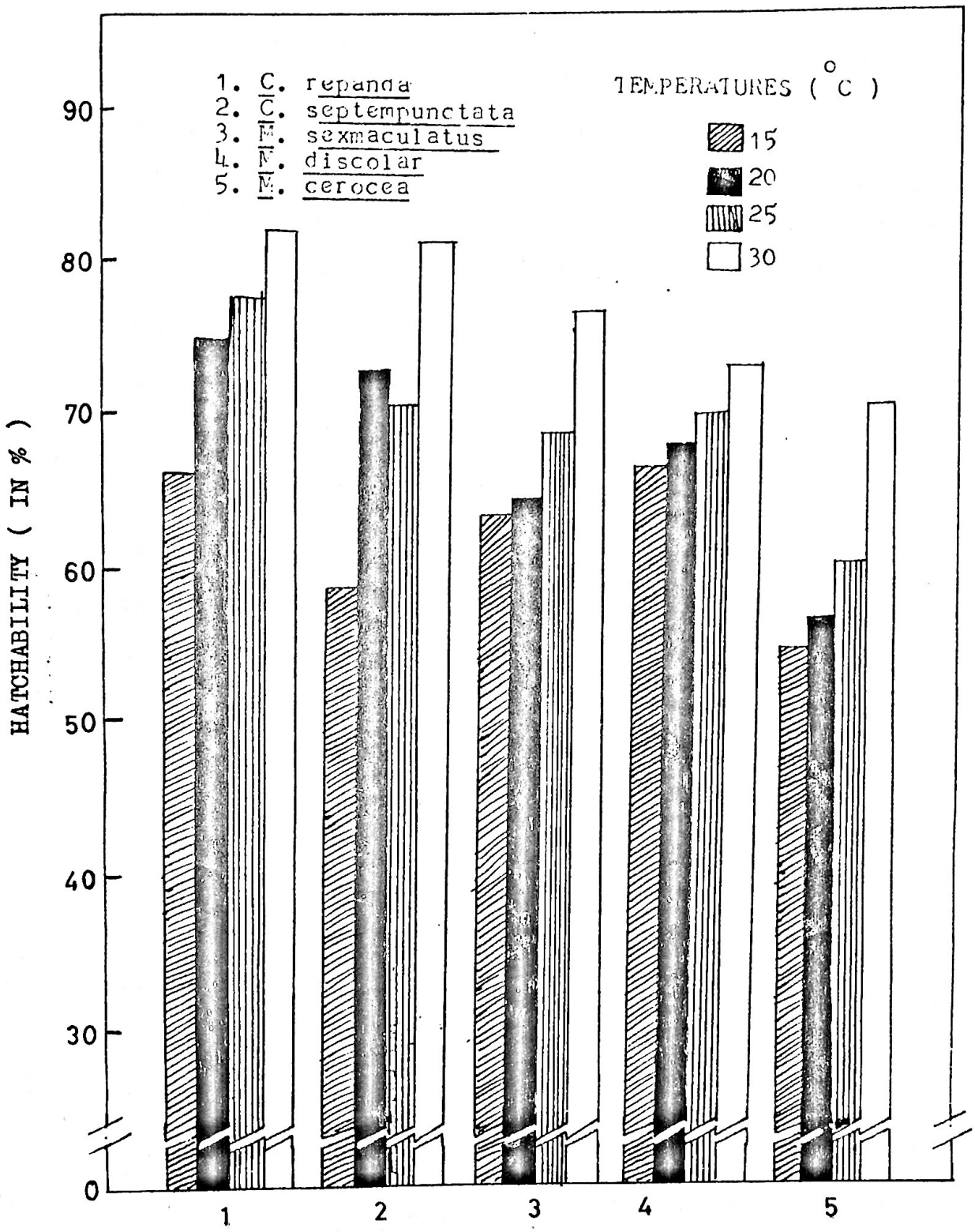
The hatchability of eggs of all five species were highest at 30°C and gradually decreased at higher and similarly at lower temperatures. The average percentage of egg hatching in response to different temperature have been represented in the Fig. 8.

Statistical analysis showed that different degrees of temperature affect egg hatching significantly ($P < 0.01$).

Ibrahim (1955) observed the same process of hatching in C. undecimpunctata. Singh and Malhotra (1979) studied the hatchability of C. undecimpunctata in India and reported that the percentage of hatching being 73 at 30°C. Qayyum (1968) and Koura [redacted] (1972) showed a relatively high percentage of hatching at higher temperature rather than lower temperature. In C. repanda, the average percentage of hatching was 86.1, whereas in C. septempunctata this percentage was 88.0 (Islam and Nasiruddin, 1978). But they did not mention the temperature.

The present findings, however, supports the views of Qayyum (1968) and Koura [redacted] (1972).

FIG. 8. Percentage of hatching of different species of coccinellidæ at different temperatures.


1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
TEMPERATURES (°C)
15
20
25
30
HATCHABILITY (IN %)
90
80
70
60
50
40
30
0
1
2
3
4
5

Larval development

The larval period varies largely at different temperatures. According to Imms (1977) the temperature has an immense influence on the growth, behaviour and metabolic rates of insects and the rate of development is directly related to the optimum range of temperature. Chapman (1973) reported that within the limits of effective temperature, development generally proceeds more rapidly at high level. Cook (1927) has shown that fluctuations of temperature exert an accelerating influence on the rate of development of insects.

Several workers (viz., Gage, 1920; Modawal, 1941; Kamal, 1951; Ibrahim, 1955; Brettell, 1964; Roy, 1976; Notario et al, 1978; Quayum et al, 1982) studied the larvae of different coccinellid species in different parts of the world.

In the laboratory several experiments were set up to determine the effect of food and temperature on larval development.

Materials and Methods:

For the first experiment, ten groups, each with five newly hatched larvae were used. Five larvae of the first group were each allowed daily with 5 aphids, A. gossypii, those of the second group were each allowed daily with 10 aphids, those of the third group were each allowed daily with 15 aphids and so on until those of the 10th group were each provided daily with

50 aphids. Observations were made daily and exuvia as a result of moulting were removed and total periods were counted.

For the second experiment, regarding the effect of temperature on larval development, newly hatched larvae were reared separately in a glass vial (9.5 x 1 cm.) at different temperatures. The experimental temperature viz., 20°C, 25°C, 30°C and 35°C were maintained in a low temperature incubator. In each temperature the larvae were subjected to a daily exposure of 12 hours with a constant relative humidity of 75 per cent.

Observations and Discussion:

The results have been shown in the Table V and Fig. 9 and 10. From the first experiment, it is evident that, the larvae provided each with five aphids daily failed to complete their development. Similarly the larvae of the second group which were provided each with ten aphids daily also failed to complete their development and died at the third and fourth larval instar, however, a few larvae of M. sexmaculatus, M. discolar and M. cerocea survived. The larval periods were influenced by the amount of food consumed during that stage. It was also observed that there was a gradual decrease in the duration of larval stage from 18.5 to 12.0 or 10 days with the increase in the daily amount of food consumed per larva from 15 to 50 aphids. But further increase in the amount of daily food consumed per larva did not produce any further effect (Fig. 9).

The total larval period of all the five species of coccinellids reared at different temperatures decreased gradually with the increase of temperature. The total larval periods with their different larval instars have represented in the Table - V. It is evident from the table that the developmental period of different larval instars at the same temperature differed insignificantly whereas, in each case the variation due to temperature varied much (Table - V).

The statistical analysis showed that the variation is highly significant ($P < 0.01$).

The average period of different larval stages at different temperatures have been represented graphically in Fig. 10.

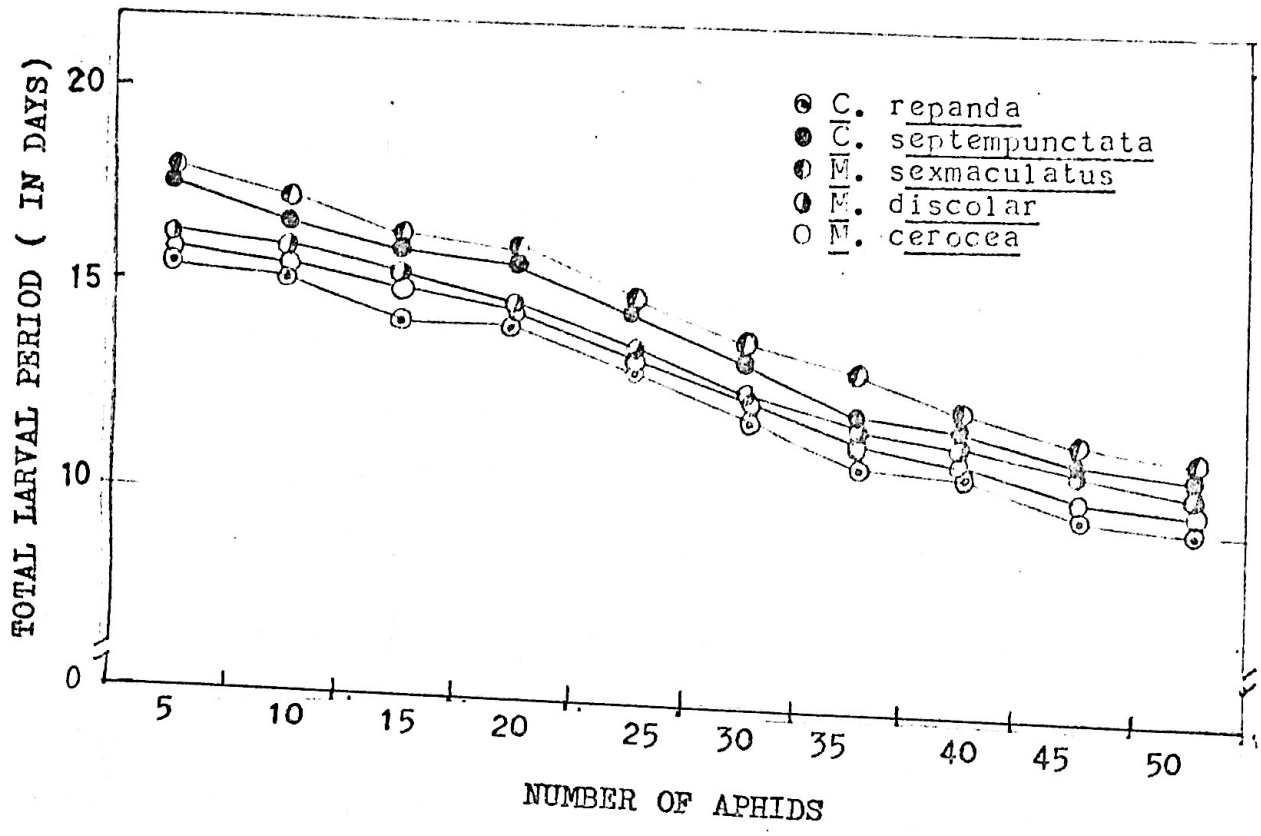
Within the limits of effective temperatures development of insect generally proceeds faster with the increase of temperature (Imms, 1977; Chapman, 1973). The larvae grown at lower temperature took a comparative longer period than that of higher temperature to complete their development (Uvarov, 1931). Ibrahim (1955) recorded that the life cycle of C. undecimpunctata was 49 days at 15°C in winter months whereas, in summer months at 27°C, the life cycle was 11 days. Modawal (1941) observed the larva of C. septempunctata and reported that they did not survive for more than 4-5 days at a temperature below 18°C. According to him there was a gradual decrease in the duration of the larval stage from 18-10 days with the increase

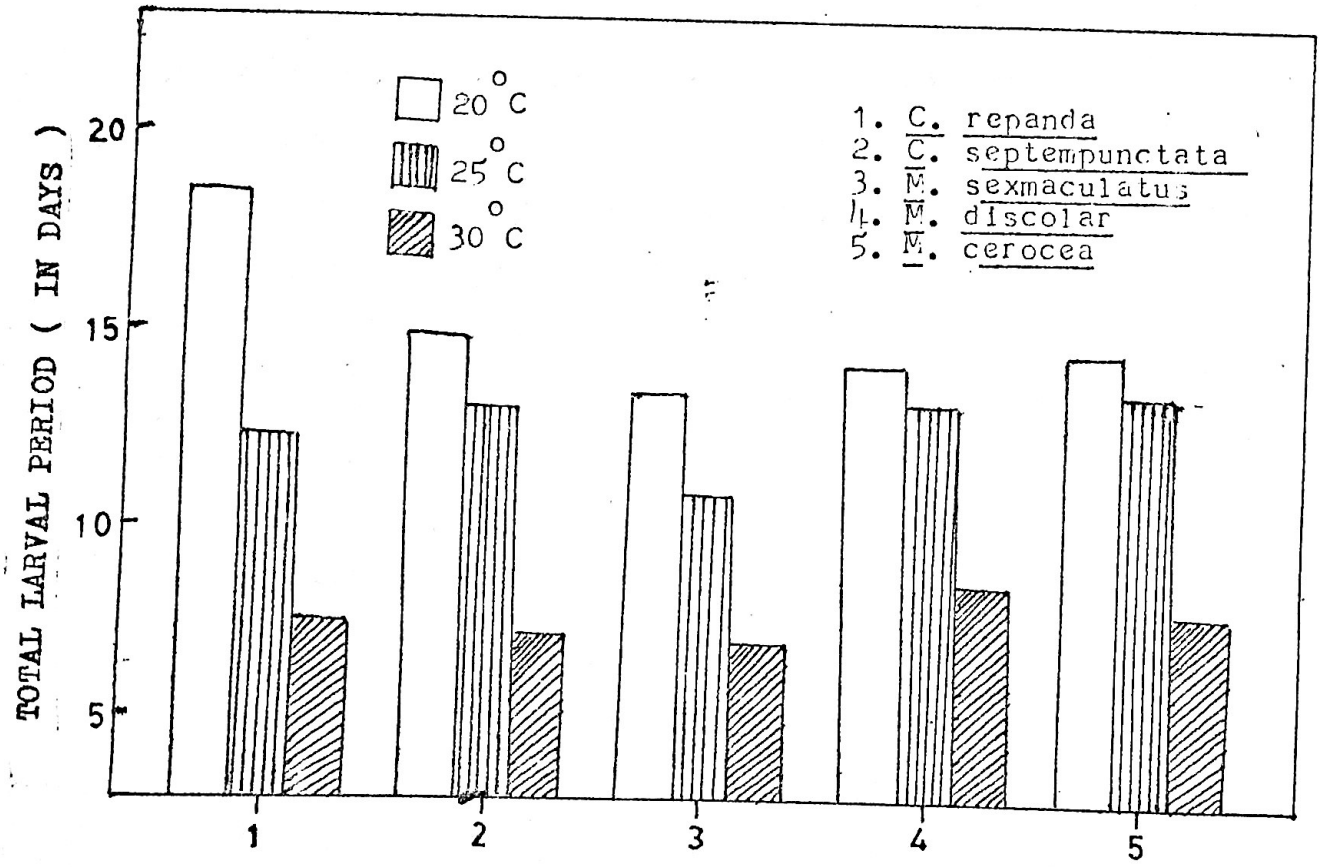
in the daily amount of food consumed per larva from 15-45 aphids. Sethy and Atwal (1963) recorded the speedy development of C. septempunctata at 30°C. However, Notario et al (1978) noted the average larval period of 15 days at 20-23°C and 8 days at 26-29°C of C. septempunctata. Semyanov (1974) observed that the optimum temperature for breeding was 25°C, 12°C being the threshold for the larvae of C. septempunctata. Butler and Dickerson (1972) recorded a shorter duration of total larval period at higher temperature than that of lower temperature, when studied on covergent lady beetle, Hippodamia convergens. Roy (1976) studied the larval period of C. tranversalis and reported that the total larval period was 21-22 days. However, the present findings confirm the effectiveness of both amount of food and temperature as primary factors for larval development. It seems that 30°C, was the most effective temperature for the larval development as mentioned by Chapman (1973) and the duration of larval stages similarly depends on the amount of food consumed during larval period upto a certain limit thus confirm the findings of Ibrahim (1955).

Table - V

The minimum, maximum and average duration of larval instars and total larval period (in hours) of C.repanda, C.Septempunctata, M.sexmaculatus, M.discolar and M. cerocea at different temperatures.

Difft. species	Difft. Temp. (°C)	Duration of larval instars (in hours)														
		1st instar larva			2nd instar larva			3rd instar larva			4th instar larva			Total larval period		
		Min.	Max.	Average ± S.D.	Min.	Max.	Average ± S.D.	Min.	Max.	Average ± S.D.	Min.	Max.	Average ± S.D.	Min.	Max.	Average ± S.D.
C. repanda	20	75.40	96.70	89.38±3.25	64.00	73.00	64.76±1.52	67.30	80.40	73.18± 2.24	232.4	250.2	245.2± 3.19	439.1	500.3	469.38±11.18
	25	46.40	73.20	55.36±4.43	48.40	64.80	57.32±2.32	50.00	60.50	56.26± 1.79	153.4	203.4	176.5± 8.11	338.2	401.9	363.12±12.43
	30	22.20	31.60	26.80±1.70	37.00	56.40	46.57±3.15	52.80	56.00	50.74± 1.79	102.3	111.0	106.2± 1.27	214.3	255.0	237.97± 6.70
C.septem punctata	20	90.48	98.25	95.90±1.34	69.50	82.36	74.40±1.92	72.20	85.25	77.72± 1.95	232.5	255.8	247.1± 3.68	464.7	521.6	494.3± 9.00
	25	46.48	72.55	58.78±4.09	48.50	64.40	55.43±2.66	52.56	63.90	58.74± 1.84	164.2	201.5	191.5± 6.14	311.7	401.8	364.0±15.96
	30	24.50	31.50	28.08±1.29	38.50	55.50	47.60±2.76	48.50	62.50	54.10± 2.78	102.5	115.5	110.5± 2.23	214.0	265.0	244.0± 8.84
M.sex maculatus	20	75.40	84.50	79.41±1.55	66.50	73.40	68.94±1.45	68.40	79.30	75.55± 1.71	233.4	265.5	247.5± 4.39	433.7	502.7	279.9±11.39
	25	39.56	58.96	46.49±2.99	42.56	61.58	51.14±2.88	52.36	61.56	57.92± 1.29	148.9	176.5	162.7± 4.54	283.4	358.6	312.0± 15.71
	30	21.58	27.90	24.82±1.11	37.50	50.56	46.42±2.32	47.56	62.58	54.69± 3.02	102.4	110.6	105.8± 1.52	209.0	251.6	232.8± 8.12
M. discolar	20	83.50	93.50	87.93±1.89	64.50	73.96	69.72±1.47	72.50	82.30	76.38± 1.70	243.4	264.3	252.6± 3.31	463.9	514.6	491.7± 8.83
	25	55.28	78.50	63.04±3.78	49.25	70.50	62.44±3.48	52.38	65.25	60.19± 1.93	172.5	205.5	189.9± 5.20	329.4	419.8	381.9±17.79
	30	27.58	32.50	30.74±0.90	49.25	58.58	53.09±1.78	49.50	65.25	54.87± 2.90	107.5	127.5	131.7±11.96	233.8	283.8	257.3± 9.30
M. cerocea	20	86.50	98.50	91.82±1.97	65.50	75.20	71.20±1.46	69.50	79.26	73.65± 1,52	227.5	256.6	237.6± 4.79	449.0	509.5	483.9± 9.17
	25	56.50	71.58	65.54±2.74	52.50	65.85	59.87±2.29	52.50	62.50	64.14± 1.61	175.2	196.5	184.1± 4.48	336.7	396.4	365.9±10.82
	30	21.56	29.50	24.92±1.52	48.50	56.50	48.67±3.16	48.58	57.56	55.08± 1.66	117.3	137.5	126.7± 3.47	235.9	281.0	262.0± 9.26


TOTAL LARVAL PERIOD (IN DAYS)
20
15
10
0
5
10
15
20
25
30
35
40
45
50
NUMBER OF APHIDS
C. repanda
C. septempunctata
M. sexmaculatus
M. discolar
M. cerocea


TOTAL LARVAL PERIOD (IN DAYS)
20
15
10
5
20° C
25° C
30° C
1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
1
2
3
4
5

Pupal stage

Factors like food, temperature and relative humidities have great influence on the pupal period of insects. Works have been made at different temperatures and relative humidities to determine their influence on the pupal stage of different coccinellid species, viz., C. septempunctata (Notario et al, 1978); C. undecimpunctata (Ibrahim, 1955; Singh and Malhotra, 1979); C. trasversalis (Roy, 1976).

An experiment was carried out to observe the duration of pupal stages of coccinellid beetles.

Materials and Methods:

Newly formed pupae of both sexes were collected and immediately transferred to a number of glass vials (2.5 x 1.5 cm). The exact time of formation of pupae were carefully noted. The vials were then transferred to a low temperature incubator i.e. 15°C for a daily exposure of 8 hours. The pupae were checked twice daily and the time of emergence of the adults were carefully noted. The same procedure was repeated at 20°C, 25°C, 30°C and 35°C. For each temperature a constant R.H of 75 per cent was maintained.

Observations and Discussion:

The experiment reveals that the average pupal period of all the described species were more or less same. Longer period was obtained at 15°C. This duration gradually decreases with

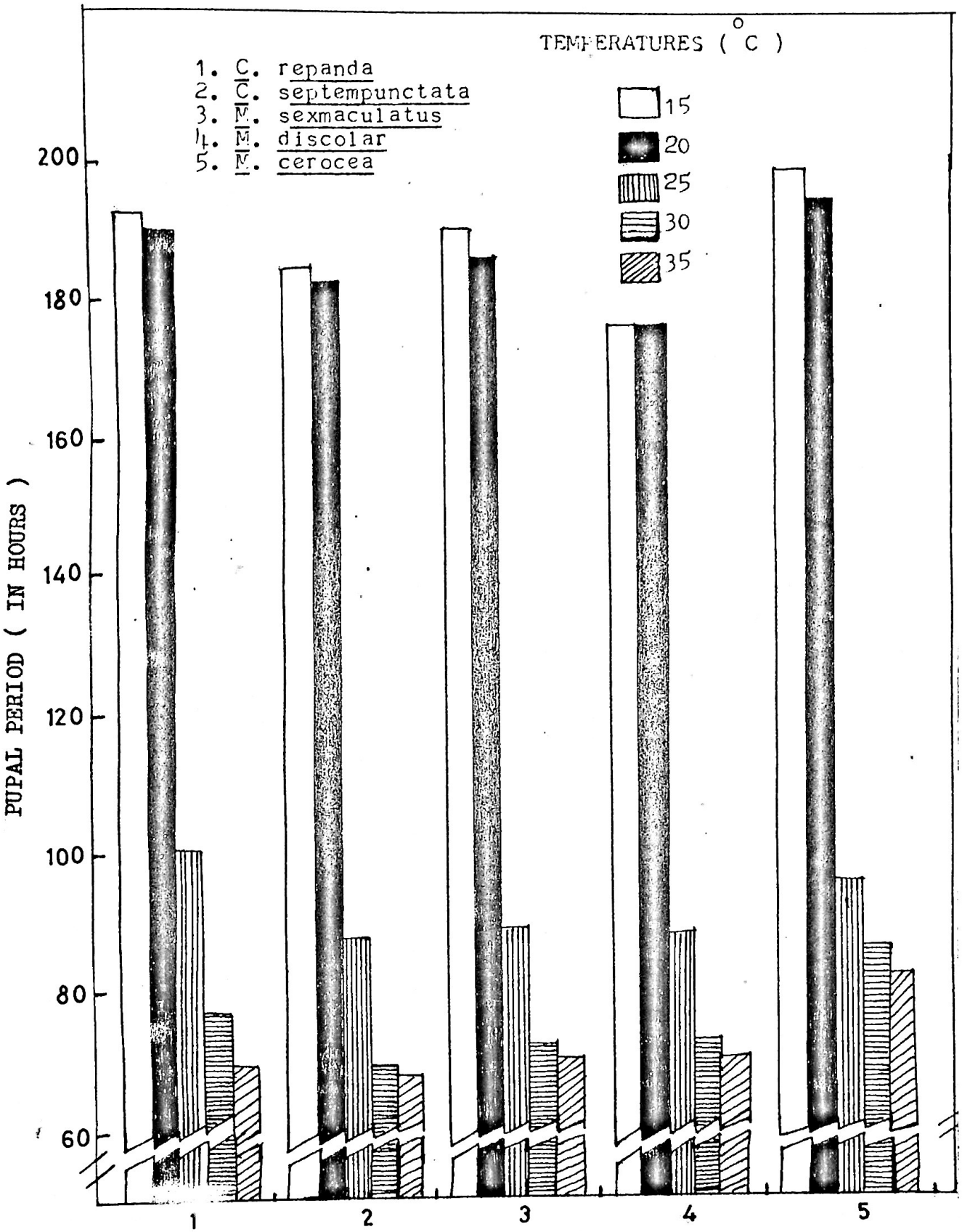
the gradual increase of temperature from 20°C to 35°C. (Fig. 11).

Statistical analysis showed that the pupal period differed significantly ($P < 0.01$) at different temperatures in each species.

Butler and Dickerson (1972) studied the pupal period of convergent lady beetle and reported that the duration increased with the decreasing temperature and decreased with the temperature rises within a upper and lower limit. Notario et al (1978) studied the pupal period of C. septempunctata at different temperatures and reported that the average period was 5.5 days at temperature between 26-29°C and 7 days at 20-23°C respectively. Roy (1976) studied the pupal period of C. transversalis and reported that the period lasted from 7 to 10 days. Islam and Nasiruddin (1978) mentioned that the pupal period of C. repanda and C. septempunctata were 3.2 and 5.1 days respectively. Singh and Malhotra (1979) reported the pupal period of C. undecimpunctata to be 3.3 days.

The present findings are in good agreement with the views of Butler and Dickerson (1972) and Notario et al, (1978) regarding the temperature effect.

FIG. 11. Pupal period of different species of coccinellids at different temperatures.


TEMPERATURES (°C)
1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
15
20
25
30
35
PUPAL PERIOD (IN HOURS)
200
180
160
140
120
100
80
60
1
2
3
4
5

Adult emergence

The process of adult emergence of C. undecimpunctata and the percentage of emergence was studied by Ibrahim (1955). Chapman (1973) reported that the male insect emerges a little before the female although the difference is not great. He further mentioned that apart from the seasonal effect many insect emergence took place at a particular time of a day, more precisely at night or early in the morning.

If an animal exposed to a low or high temperature beyond the limits of the favourable range, it may be killed directly. (Andrewartha and Bireh, 1954). Like developmental stages, the emergence of the adult largely depends on the prevailing temperature. An experiment has been conducted to determine the percentage of emergence in response to different temperatures.

Materials and Methods:

The experimental procedure regarding emergence of adults was same as described in the chapter of pupal period. The pupae were observed daily and the number of emerged adults were counted. Number of unemerged pupae were also counted.

Observations and Discussion:

During emergence, the adult insect forces its way out of the pupal skin through a T-shaped slit at the anterior extremity of the pupa. Through the movement of the legs and wings

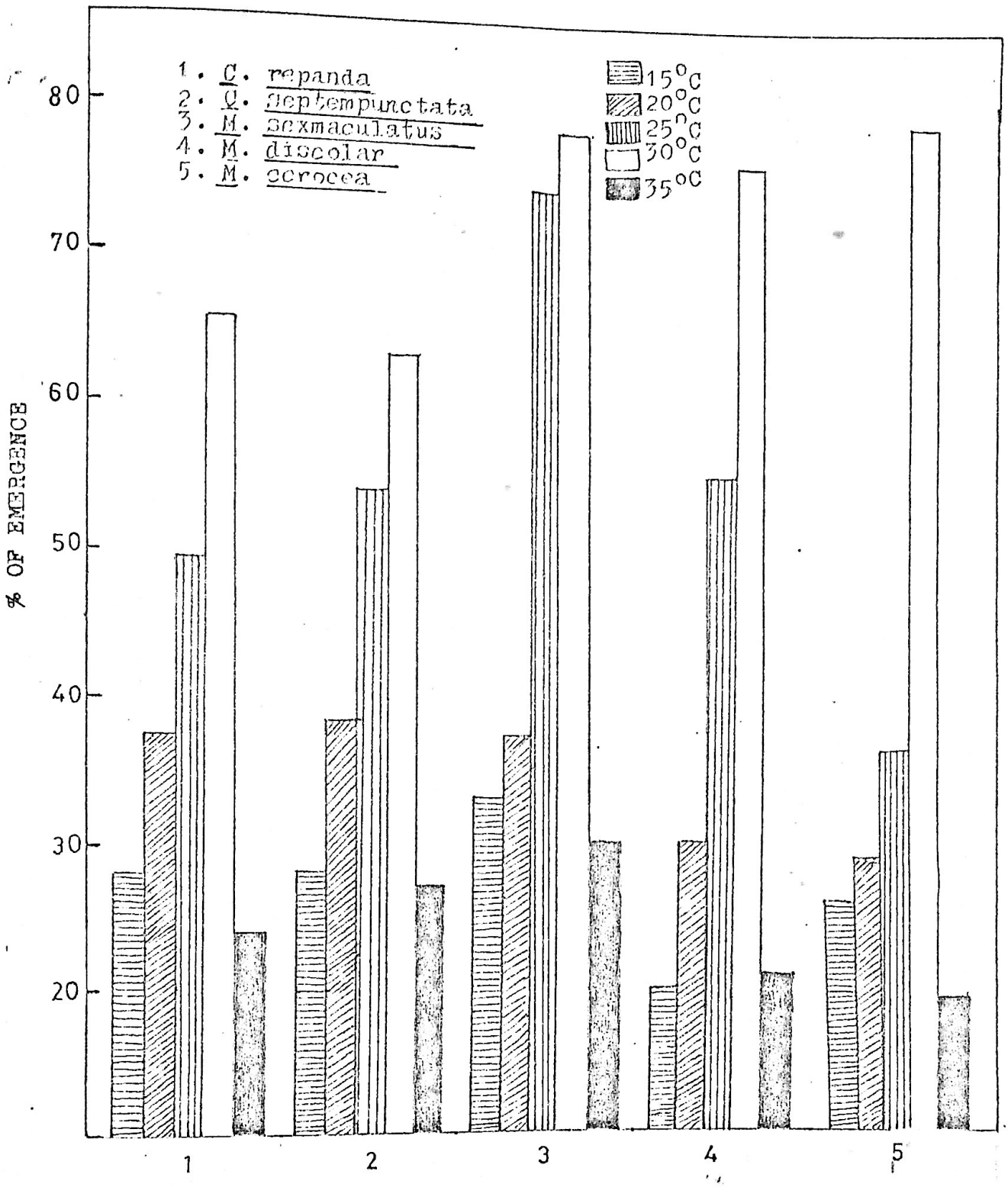
the insect at last succeeds in extricating itself from the pupal skin leaving an empty shell. Immediately after emergence the elytra look light yellow without dotted marks. Regular number of black dots or waves which characterize the elytra of the adult insect starts forming a little after emergence. Then the insects are ready to move and start their activities.

Regarding percentage of emergence, it is evident that within the range of temperature between 15°C to 30°C positive correlation between the temperature and percentage of emergence exists. But at 35°C, the number of percentage decreased. A gradual rise of temperature was more suitable for the emergence of adult. Highest number of adults emerged at 30°C and least number obtained at 15°C and 35°C. 30°C temperature was found to be the limiting factor of emergence as mentioned by Andrewartha and Birch (1954). Majority of emergence took place during day time without any reservation to sexes.

Statistical analysis showed that the percentage of emergence differed significantly ($P < 0.01$) at different temperatures. The effect of temperature on adult emergence has been graphically represented in Fig. 12.

The present findings supports the views of Andrewartha and Birch (1954) regarding temperature effect.

FIG. 12. Percentage of emergence of different species of coccinellids at different temperatures.


1. C. repanda
2. Q. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
15°C
20°C
25°C
30°C
35°C
% OF EMERGENCE
80
70
60
50
40
30
20
1
2
3
4
5

Adult longevity

Adult insects have a normal life span ranging from a few days to many years, depending on the species, and the length of life is correlated with fecundity and mating (Ross, 1965). Factors like crawding, underpopulation, saturation deficit, temperature and also the quality of food have great influence on longevity (Andrewartha and Birch, 1954). Rockstein and Miquel (1973) divide the factors influencing longevity into intrinsic factors including genetic constitution, sex, parental age, fecundity and egg laying and length of metamorphosis, and extrinsic factors, including temperature, ionizing radiation, nutrition and other factors (e.g., light intensity, humidity, etc.)

Several works have been conducted to determine the longevity of different coccinellids (Ibrahim, 1955; Roy, 1976; Haque and Islam 1978; Islam and Nasiruddin, 1978; Ali et al, 1981). Studies on the longevity of coccinellid beetles in response to the amount and kind of food and temperatures are considered essential with a view to increasing the biotic potential of these insects.

Materials and Methods:

Newly emerged beetles of both sexes were collected and their time of emergence was carefully noted. The beetles were separated into five groups, containing ten males and ten females each and

were transferred to the Tortox Entomological Breeding Chambers. In this chamber they could mate freely. The insects of the first group was left without food. The second group was provided with sufficient number of cotton aphids, A. gossypii with cotton leaves. The third group was supplied with fresh pollen dust of cotton flowers. The fourth group was provided with a 10 per cent sugar solution and the fifth group was supplied with a 10 per cent honey solution. The foods were changed daily to avoid fungal or bacterial attack. The beetles were observed daily and the time of their death in each case was noted and the experiment was continued until the death of the last beetle.

To consider the effect of amount of aphid food on longevity, the newly emerged adults were divided into ten groups, ten males and ten females in each. Insects of each group was placed singly in a vial. The insects of the first group was supplied daily with 10 full-grown aphids, A. gossypii; those of the second group with 20 aphids; those of the third group with 30 aphids and so on until those of the tenth group with 100 aphids.

To determine the effect of temperatures on the longevity of the adults the insects were kept at different constant temperatures, viz., 15, 20, 25, 30 and 35°C with a daily a light exposure of 8 hours.

Observations and Discussion:

The results of the experiments have been shown in the tables VI, VII, VIII, IX and Fig. 13. The first experiment reveals that the beetles of all species feeding on aphids, 10 per cent sugar solution, 10 per cent honey solution and pollen dusts of cotton flowers possessed a longer life span than those other foods (Tables VI and VII). The experiments also indicate that the longevity of the female adults were higher than those of the males. The least longevity was obtained when the beetles were starving. The results were statistically significant ($P < 0.01$).

Beetles lived longer when at lower temperatures. It has been observed that at 15°C, the mean longevity of males and females were found to be 48.3 ± 3.35 and 61.0 ± 3.24 days, 51.4 ± 3.40 and 52.3 ± 2.55 days, 47.1 ± 3.57 and 48.7 ± 3.27 days, 46.0 ± 3.11 and 44.7 ± 6.39 and 44.6 ± 3.71 and 51.6 ± 1.89 days respectively for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea. But with a gradual rise of temperatures from 20 to 35°C, the longevity of the beetles came down gradually. At 35°C, the mean longevity of males and females were found to be 13.9 ± 1.55 and 14.8 ± 1.74 days, 20.7 ± 1.22 and 21.6 ± 1.26 days, 15.2 ± 1.88 and 13.4 ± 2.0 days, 21.7 ± 1.82 and 22.7 ± 1.82 days and 19.3 ± 1.82 and 19.6 ± 2.08 days for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea respectively. (Tables VIII and IX).

Temperature had a significant effect on the longevity of the beetles ($P < 0.01$).

Ibrahim (1955) studied the effect of food and temperature on the longevity of C. undecimpunctata in Egypt. He reported that honey and water had an adverse effect on the longevity of this beetle. According to him C. undecimpunctata fed on honey and water took on average longevity five times as long as those fed on aphids, A. durantae. He also reported that the longevity increased with the increase of amount of food consumed and high temperatures showed a negative correlation with the longevity of the adults. But in the present investigation, the pollen dusts of cotton flowers has been observed to increase longevity of the females of all coccinellids studied. Islam and Nasiruddin (1978) studied the longevity of this beetle was 40.7 and 46.3 days for males and females respectively. Haque and Islam (1978) studied the longevity of C. repanda and reported that the male and female lived 17.5 and 24.0 days respectively. Food has a significant influence on the longevity of adults (Norris, 1936: Willcocks and Bahgat, 1936; Wigglesworth, 1955 and Mousa et al., 1960). Smith (1965) observed the effects of different synthetic and protein diets on the longevity of the adult coccinellids and reported that the longevity of both males and females were greater in provision of protein diet. Roy (1976) studied the longevity of C. transversalis and pointed that

the longevity was 20 to 30 days but he did not mention the temperature. The females in all the cases lived a few day more than the males (Ibrahim, 1955; Roy, 1976; Ali *et al.*, 1981). The present findings are in accordance with the findings of Ibrahim (1955).

Table - VI

Effects of different foods and on control on the longevity of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea (Male)

Species	Food	Longevity in days REPLICATIONS										Average ± S.D.
C. repanda	Aphids	34	33	37	42	52	61	42	42	32	27	40.2 ± 3.04
	10% sug. soln.	22	25	30	20	22	35	18	21	23	25	24.1 ± 1.51
	10% honey soln.	14	25	17	20	21	23	19	18	18	25	20.0 ± 1.06
	Pollendust	22	15	21	23	22	20	21	29	32	16	22.0 ± 1.48
	Control	12	13	14	12	16	9	10	12	16	11	12.5 ± 0.69
C. septem-punctata	Aphids	35	38	45	25	29	21	25	38	46	42	34.4 ± 2.67
	10% Sug. soln.	45	26	36	36	42	40	37	25	23	25	33.5 ± 2.41
	10% honey soln.	18	25	22	16	28	32	30	21	20	25	23.7 ± 1.56
	Pollendust	35	30	38	27	25	23	42	40	35	30	32.5 ± 1.94
	Control	9	12	25	15	8	27	16	12	9	8	14.1 ± 2.06
M. semacu-latus	Aphids	52	35	50	52	42	41	38	40	35	42	42.7 ± 1.94
	10% sug. soln.	46	32	53	50	29	44	37	35	30	46	40.2 ± 2.60
	10% honey soln.	40	45	27	34	37	42	28	27	26	28	33.4 ± 2.14
	Pollendust	36	25	29	42	37	27	25	39	40	42	34.2 ± 2.09
	Control	15	24	26	12	10	11	19	14	14	12	15.7 ± 1.65
M. discolar	Aphids	30	42	40	35	36	27	28	36	23	43	34.0 ± 2.03
	10% sug. soln.	25	28	31	46	40	29	25	27	36	41	32.8 ± 2.23
	10% honey soln.	29	41	52	19	26	28	37	31	25	29	31.7 ± 2.82
	Pollendust	24	39	28	21	35	39	38	44	49	25	34.2 ± 2.79
	Control	13	21	7	12	9	18	25	11	29	7	15.2 ± 2.31
M. cerocea	Aphids	50	27	45	56	62	27	35	48	52	57	45.9 ± 3.71
	10% sug. soln.	45	50	35	38	28	39	49	52	55	37	42.6 ± 2.60
	10% honey soln.	27	25	18	29	35	37	30	25	21	22	25.9 ± 1.80
	Pollendust	48	62	65	35	42	31	35	37	48	57	46.0 ± 3.62
	Control	27	25	19	18	35	30	25	27	29	21	25.6 ± 1.57

Table - VII

Effects of different foods and on control on the longevity of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea (Female)

Species	Food	Longevity in days REPLICATIONS										Average + S.D
C. repanda	Aphids	35	36	64	50	45	47	58	50	42	40	46.7 ± 2.77
	10% sug. soln.	28	37	52	60	42	48	29	42	45	43	42.6 ± 2.92
	10% honey soln.	28	25	26	25	27	19	25	26	18	25	24.4 ± 0.98
	Pollen dusts	45	34	35	38	25	42	20	22	32	19	31.2 ± 2.78
	Control	21	22	20	12	11	9	10	19	21	20	16.5 ± 1.58
C. septem-punctata	Aphids	38	52	42	32	30	35	30	25	45	40	36.9 ± 2.44
	10% sug. soln.	43	45	42	50	52	29	35	27	35	27	38.5 ± 2.77
	10% honey soln.	25	29	27	25	32	32	35	21	25	25	27.6 ± 1.29
	Pollen dusts	35	38	29	37	35	27	29	40	27	40	33.7 ± 1.56
	Control	12	11	15	9	7	12	21	12	18	20	14.0 ± 1.57
M. sexmacu-latus	Aphids	48	47	52	29	38	40	52	47	40	42	43.5 ± 2.13
	10% sug. soln.	48	45	57	26	37	39	50	45	42	43	43.2 ± 2.49
	10% honey soln.	42	52	50	27	29	40	35	37	38	27	37.7 ± 2.63
	Pollen dusts	36	37	42	29	39	40	27	29	36	35	35.0 ± 1.52
	Control	30	25	23	32	19	26	12	15	18	17	21.7 ± 1.97
M. discolar	Aphids	41	39	34	35	23	25	38	41	33	35	34.4 ± 1.85
	10% sug. soln.	32	30	35	24	29	37	48	42	41	21	33.9 ± 2.51
	10% honey soln.	37	29	49	42	47	25	18	21	27	52	34.7 ± 3.69
	Pollen dusts	32	48	50	50	29	19	22	27	37	28	34.2 ± 3.46
	Control	15	18	19	23	12	18	17	19	9	21	17.1 ± 1.24
M. cerocea	Aphids	52	58	62	58	37	27	39	50	38	55	47.6 ± 3.47
	10% sug. soln.	48	49	55	28	29	61	48	55	52	39	46.4 ± 3.31
	10% honey soln.	32	35	38	42	19	21	30	32	35	19	30.3 ± 2.42
	Pollen dusts	50	52	60	65	62	52	61	48	42	45	53.7 ± 2.35
	Control	32	35	39	18	25	21	12	19	16	14	23.1 ± 2.79

Table - VIII

Effects of temperatures on the Longevity of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea (Male)

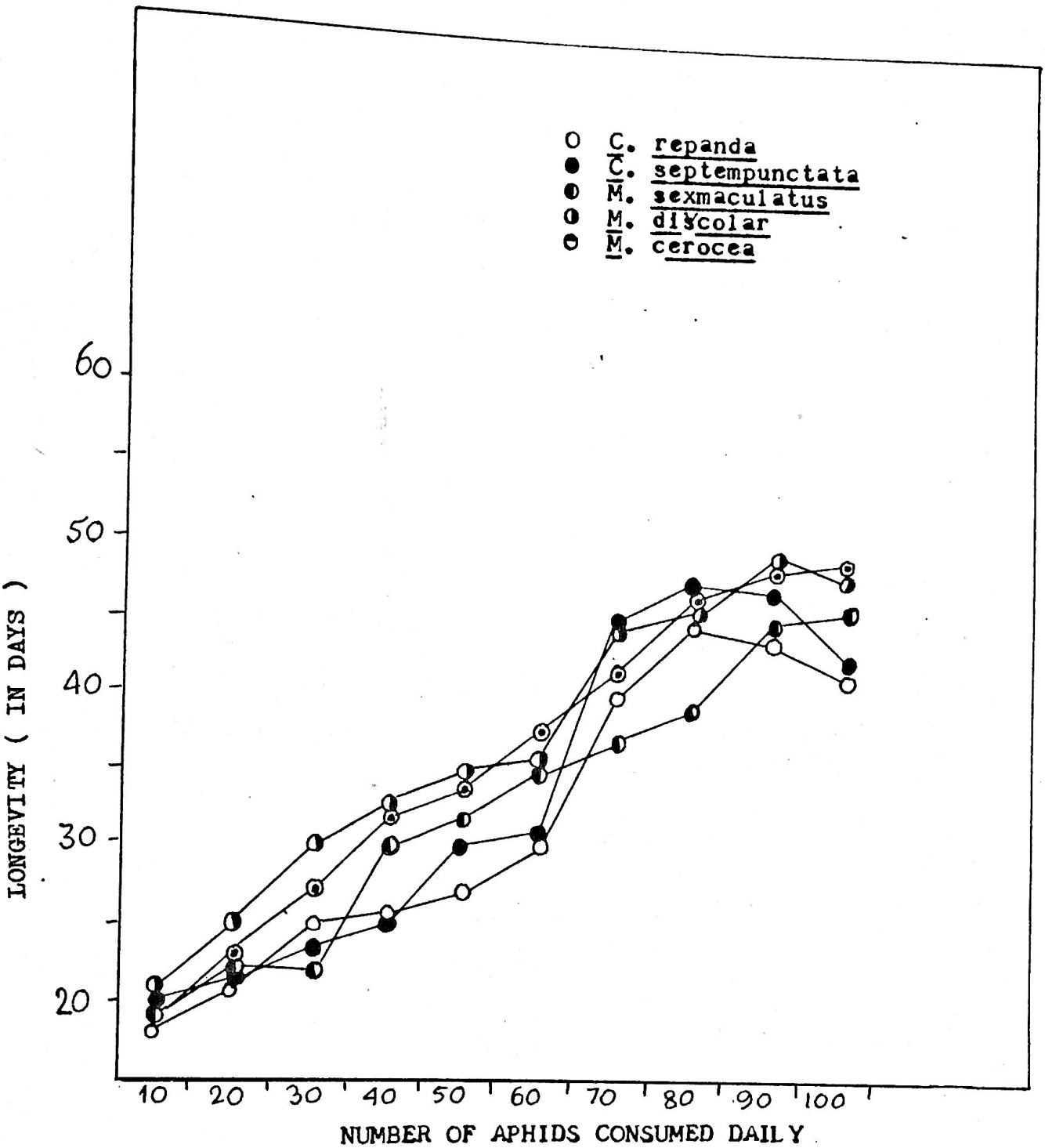
Species	Temp. °C	Longevity in days REPLICATION	Average ± S.D.
C. repanda	15°C	52 65 45 48 35 39 61 55 50 33	48.3 ± 3.35
	20°C	46 57 44 59 61 27 37 49 52 50	48.2 ± 3.29
	25°C	40 52 32 35 45 40 29 52 60 45	43.0 ± 3.09
	30°C	36 45 30 28 42 45 35 37 52 25	37.5 ± 2.70
	35°C	14 9 12 20 22 7 11 12 13 19	13.9 ± 1.55
C. septem-punctata	15	50 57 49 45 65 29 61 59 57 42	51.4 ± 3.40
	20	39 32 35 48 52 58 61 39 39 45	44.8 ± 3.09
	25	42 45 52 36 52 29 35 38 42 39	41.03± 2.31
	30	35 25 45 51 30 35 42 36 39 47	38.5 ± 2.52
	35	18 22 16 29 18 20 18 25 21 20	20.7 ± 1.22
M. sexmacu-latus	15	40 36 57 55 61 62 29 36 45 47	47.1 ± 3.57
	20	42 35 25 61 67 39 45 55 50 39	45.8 ± 4.00
	25	40 45 30 45 50 39 42 29 52 50	42.2 ± 2.58
	30	32 30 36 45 40 25 22 40 42 19	15.2 ± 1.88
	35	10 18 9 20 7 12 20 19 12 25	15·2 ± 1·78
M. discolar	15	45 38 52 42 62 29 58 50 45 39	46.0 ± 3.11
	20	43 51 49 21 38 35 37 50 57 55	43.6 ± 3.49
	25	40 40 21 25 61 42 45 50 52 53	42.9 ± 3.93
	30	39 29 49 29 38 42 48 39 32 35	35.0 ± 3.65
	35	21 25 21 18 18 27 27 19 22 19	21.7 ± 1.11
M. cerocea	15	45 49 35 55 37 62 29 35 38 61	44.6 ± 3.70
	20	45 48 29 61 49 55 49 45 61 45	48.7 ± 2.93
	25	52 45 39 42 50 40 21 56 50 50	44.5 ± 3.14
	30	40 42 28 50 50 42 37 39 40 39	40.7 ± 2.0
	35	19 21 9 10 22 25 27 19 20 21	19.3 ± 1.82

Table - IX.

Effects of temperatures on the longevity of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea (Female)

Species	Tem. $0^{o}C$	Longevity in days REPLICATIONS										Average ± S.D.
C. repanda	15	62	67	56	50	67	72	70	67	60	39	61.0 ± 3.24
	20	50	55	62	68	35	38	37	39	52	41	47.7 ± 3.63
	25	42	45	50	55	49	35	32	48	52	53	35.0 ± 2.28
	30	40	42	38	36	29	27	25	48	33	32	35.0 ± 2.17
	35	18	22	11	19	7	9	12	23	12	15	14.8 ± 1.74
C. septem-punctata	15	52	62	65	55	48	49	58	52	42	40	52.3 ± 2.35
	20	45	45	39	26	55	52	50	55	41	42	45.0 ± 2.78
	25	40	39	42	35	25	42	55	57	39	42	41.6 ± 2.89
	30	38	36	42	29	49	50	36	47	49	36	41.2 ± 2.30
	35	21	22	25	13	27	23	19	19	22	25	21.6 ± 1.26
M. sexmacu-latus	15	42	35	60	62	57	52	36	37	51	55	48.7 ± 3.27
	20	45	35	39	29	56	50	46	44	45	36	42.5 ± 2.49
	25	48	40	56	39	29	52	55	52	46	45	43.2 ± 3.49
	30	35	30	25	28	29	46	47	50	29	36	35.5 ± 2.86
	35	12	20	9	12	29	12	11	10	9	10	13.4 ± 2.00
M. discolar	15	52	55	58	65	61	49	48	39	38	42	44.7 ± 6.39
	20	47	51	47	28	42	47	50	52	50	52	46.6 ± 2.28
	25	45	51	21	40	38	52	55	50	45	35	44.0 ± 2.65
	30	47	45	39	38	45	45	42	40	28	35	41.2 ± 1.98
	35	24	25	23	19	27	22	21	9	28	29	22.7 ± 1.82
M. cerocea	15	55	59	65	57	58	49	52	41	47	50	51.6 ± 1.89
	20	55	45	48	37	38	56	55	45	47	50	47.6 ± 2.12
	25	49	29	55	52	37	42	56	59	52	45	44.0 ± 3.15
	30	42	45	48	37	35	30	42	45	50	38	37.4 ± 4.64
	35	21	21	25	28	13	15	10	12	25	26	19.6 ± 2.08

FIG. 13. Longevity of different species of coccinellids in response to the amount of food.


C. repanda
C. septempunctata
M. sexmaculatus
M. discolar
M. cerocea
LONGEVITY (IN DAYS)
60
50
40
30
20
10
20
30
40
50
60
70
80
90
100
NUMBER OF APHIDS CONSUMED DAILY

Sex-ratio

Animal population consists of both males and females but there is no hard and fast rule of proportionate males and females in any definite number of such population. However, the Mendelian mechanism of sex-determination indicates that the normal sex-ratio would be 1:1. Most species gives birth to equal numbers of males and females. However, some organisms show considerable variability of the sex-ratio. This is due to environmental factors influencing the physiological state of reproducing animals and thus affect the sex-determination of the offspring after conception (Andersen, 1961; Trivers, and Willard, 1973; White, 1973; Charnov and Bull, 1977). The environment has been found to influence the sex-ratio of invertebrates (Clausen, 1939; Flanders, 1939; Ellenby, 1954; Seuge, 1970; Laraichi, 1978).

The record of sex-ratio of the beetles used in the present work is very scanty. However, Ibrahim (1955) observed the sex-ratio of C. undecimpunctata in Egypt.

Materials and Methods:

The total number of eggs laid by individual female during its oviposition period and the emergence of total beetles from those eggs were carefully noted. After hatching, the larvae were reared carefully with necessary precaution. They were daily supplied with aphids with cotton leaves. After emergence

adults were separated according to their sex and were counted separately. The total number of males and females out of the total adults obtained from the total eggs laid per five females in each generation were calculated and finally average percentage of males and females were obtained.

Observation and Discussion:

The experiment reveals that the percentage of females in all coccinellids were slightly greater than that of males. In C. repanda the average percentage of female was 53.3 $\pm$ 1.10 whereas, the percentage of male was found to be 46.69 $\pm$ 1.10. Similarly, the average percentage of females and males of C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea were found to be 53.33 $\pm$ 0.32, and 46.66 $\pm$ 0.32, 54.50 $\pm$ 0.78 and 46.25 $\pm$ 0.51, 53.57 $\pm$ 0.74 and 46.42 $\pm$ 0.74 and 55.58 $\pm$ 0.94 and 44.45 $\pm$ 0.97 respectively. (Table - X).

The Chi square test between the sex ratio of five generation shows that the result is significant ($P < 0.01$).

Ibrahim (1955) collected 1482 adults of C. undecimpunctata among which he observed 687 males and 795 females. He also reported that the ratio of male and female remain same (1:1) in different seasons. It has been observed in the present investigation that the coccinellids strictly follows the Mendelian principles of sex-ratio (viz. 1:1).

Table - X

Sex-ratio of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea

	No. of Eggs	Adult Emerged	No. of Males	No. of females	% of Males	% of females	Average % Males	Average % Females	χ^2 Value
A.	187.50	145.75	67.25	78.50	46.15	58.85	46.69 ± 1.10	53.3 ± 1.10	0.5
	207.25	166.00	70.75	95.25	42.62	57.38			
	156.95	121.00	58.00	63.00	47.93	52.07			
	271.90	250.90	120.50	129.40	48.20	51.80			
	118.25	97.25	47.25	50.00	48.58	51.42			
B.	285.50	229.75	108.50	121.25	47.25	52.75	46.66 ±0.32	53.33 ±0.32	0.42
	218.75	197.25	90.25	107.00	45.75	54.25			
	138.45	112.25	51.70	60.50	46.10	53.90			
	249.75	192.78	90.25	102.53	46.81	53.19			
	210.50	190.25	90.25	100.00	47.43	52.57			
C.	150.50	105.50	45.50	55.00	47.87	52.13	46.25 ± 0.51	54.50 ± 0.78	0.84
	197.00	155.00	70.00	85.00	47.17	54.83			
	175.25	140.25	60.00	80.00	42.96	57.04			
	260.75	185.75	85.50	100.25	46.03	53.97			
	145.00	110.00	50.00	60.00	45.96	54.54			
D.	178.40	132.50	60.25	72.25	45.47	54.53	46.42 ±0.74	53.57 ±0.74	0.41
	168.50	148.50	67.25	81.00	45.28	54.72			
	145.90	121.90	55.45	65.45	45.48	54.52			
	138.70	112.25	55.25	67.00	49.22	50.78			
	197.50	172.50	80.50	92.00	46.66	53.34			
E.	97.25	78.25	35.25	38.00	45.07	54.93	44.45 ± 0.97	55.58 ±0.94	0.87
	182.50	162.50	71.25	81.00	43.84	56.16			
	190.50	170.50	80.50	90.00	47.27	52.93			
	200.56	178.50	80.00	98.50	44.81	55.19			
	122.50	97.50	40.25	52.25	41.28	58.72			

Note: A = C. repanda; B = C. septempunctata; C = M. sexmaculatus; D = M. discolar; E = M. cerocea.

Mortality distribution

The individual in the population will have a mean longevity which is more usefully considered as a distribution of age at which different individuals are subjected to ecological or physiological mortality. "Mortality is the population decline factor and thus, in terms of its effect on the group, is antithetic to natality" (Allee et al, 1949).

Any animal living in a particular environment may be expected to grow at a certain rate, to live for a certain period, and to produce a certain number of offsprings, usually spread over a certain span of its life (Andrewartha and Birch 1954). There will be a mean rate of growth of individuals in the populations and that determined by the environment and by a certain innate quality of the animal itself.

Rapid increase of populations of young organisms i.e., birth rate exceeds the death rate; the stationary population has an intermediate number of young and middle aged and old organisms i.e., the birth rate and death rate are the same; while the declining populations are characterised by a preponderance of the older age groups and thus death rate exceeds death (Andrewartha and Birch, 1954; Odum, 1964).

Materials and Methods:

The number of survivors of each age group (i.e., eggs larvae, pupae and adults) at the beginning of the age interval

and the numbers dying within the respective age intervals were carefully counted. In order to find out the age and mortality distribution for five generations, the estimated average data for each age group have been analysed and arranged in the form of life-table (Table - XI) in accordance with the methods adopted by El-saadany (1973) and El-saadany and Abd-Elfattah (1974).

Observation and Discussion:

In order to depict the mortality distribution of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea the survival and mortality data for each stage have been represented in Table XI. From the table it is observed that the egg stage suffered and highest number of mortality and percentage of mortality in all of five species. The percentage of mortality in egg stage of these insects were 15.51, 32.05, 15.11, 41.63 and 17.62 for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea respectively. The pupa stage suffered the least number of mortality and their apparent and real mortality were 13.80 per cent and 9.49 per cent, 14.36 per cent and 8.33 per cent, 14.11 per cent and 8.00 per cent, 10.86 per cent and 3.89 per cent and 7.40 per cent and 4.48 per cent for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea respectively. The apparent and real mortality of the larvae were 18.63 per cent and 15.74 per cent, 14.62 per cent and 9.93 per cent, 33.24 per cent and 28.22 per cent, 38.66

per cent and 22.56 per cent and 26.45 per cent and 21.79 per cent for the above five species respectively. The mortality rate per age interval which is expressed at the rate per thousand were the highest at the egg stage and lowest at the pupa stage in all of above five species (Table XI).

El-Saadany and Abd-Elfattah (1974) recorded that throughout the population the egg and larval stages represent in greater proportions, while the pupae come next in this respect and the adult counted the least proportion in case of cotton leafworm, Spodoptera littoralis (Boisd). In the present investigation on C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea it was observed that eggs and larval stages were prepondirent throughout the population and the pupae encountered the intermediate number, while the adults were the least (Fig. 14). The present study also showed that the egg stage suffered the greatest mortality both in relative and absolute terms in all of the above five species. The same results were recorded by Sarder (1978) for the Sylepta derogata Fab. Ahmed (1983) for Epilachna. Thus the present findings supports the above views of El-Saadany and Abd-Elfattah (1974), Sarder (1978) and Ahmed (1983).

From the above findings, it can be concluded that all the coccinellids under observation possess a vigorous and expanding population, which is characterised by a preponderance of young

individuals. Nevertheless, it is clear that the larval stages are the most vulnerable to physiological death under optimal conditions, while the egg and pupal stages are the least vulnerable.

Table - XI

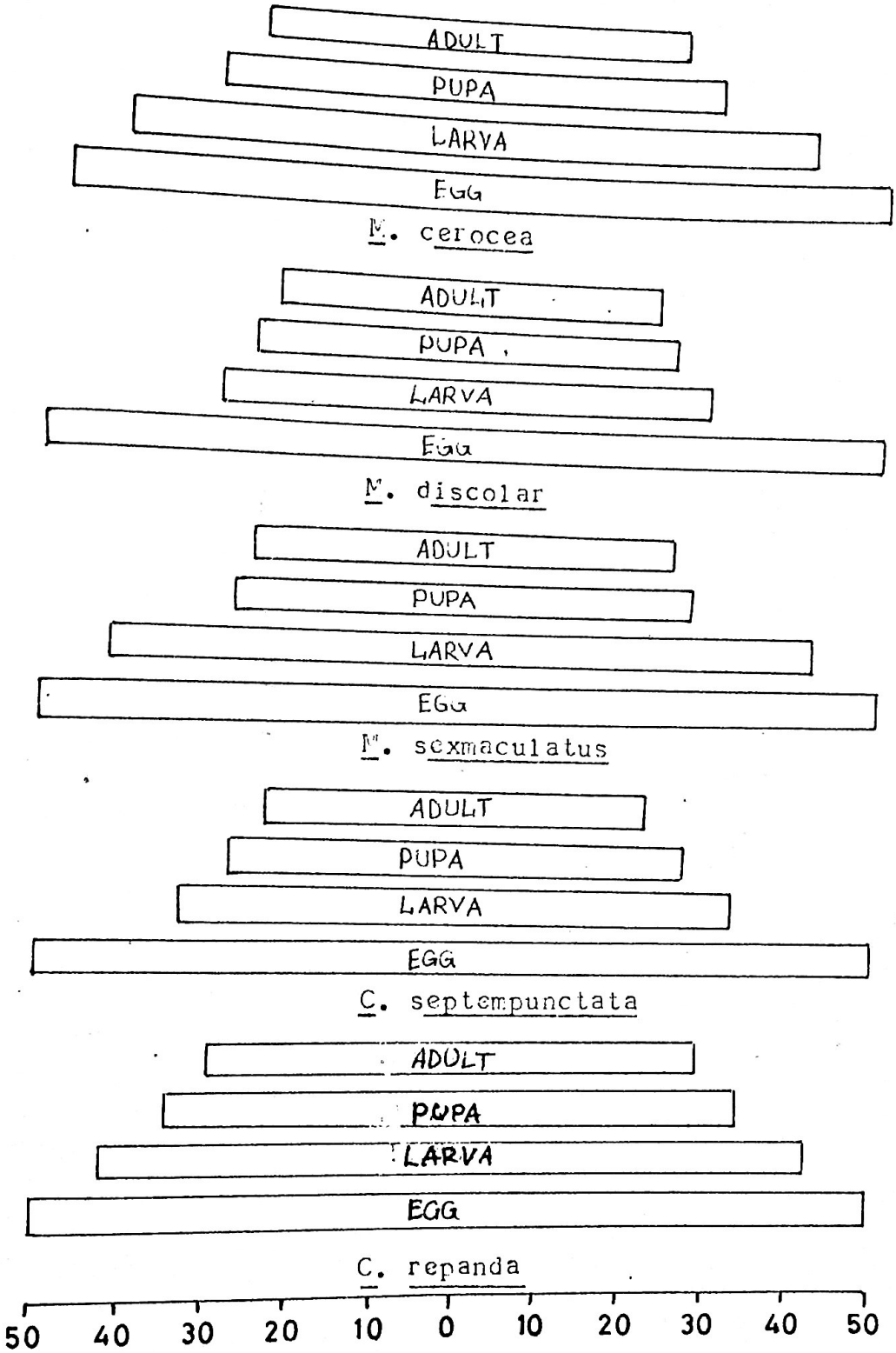
Mortality distribution of C. repanda, C. septem-punctata, M. sexmaculatus, M. discolar and M. cerocea

Age class	X	LX	% of LX (Apparent)	% of LX (Real)	dx	% of AM	% of RM	$1000q_x$
E	A= 2.83	432	100	100	67	15.51	15.51	155.10
	B= 2.39	312	100	100	100	32.05	32.05	320.50
G	C= 2.48	450	100	100	68	15.11	15.11	151.10
G	D= 2.35	257	100	100	107	41.63	41.63	416.30
S	E= 2.41	312	100	100	55	17.62	17.62	176.20
L	A=10.00	365	84.49	84.49	68	18.63	15.74	186.30
A	B= 9.62	212	67.94	67.94	31	14.62	9.93	146.20
R	C=10.70	382	84.88	84.88	127	33.24	28.22	332.40
V	D=10.82	150	58.36	58.36	58	38.66	22.56	386.60
A	E=10.75	257	82.37	82.37	68	26.45	21.79	264.50
E								
P	A= 4.01	297	81.37	68.75	41	13.80	9.49	138.00
U	B= 4.22	181	84.37	58.01	26	14.36	8.33	143.60
P	C= 3.70	255	67.75	56.66	36	14.11	8.00	141.10
A	D= 3.72	92	61.63	55.79	10	10.86	3.89	108.60
E	E= 3.67	186	73.54	60.57	14	7.40	4.48	74.00
A	A=43.07	256	86.19	59.26	256	100	59.26	1000.00
D	B=52.85	143	79.00	45.83	143	100	45.83	1000.00
U	C=61.60	229	89.80	50.88	229	100	22.22	1000.00
L	D=45.75	82	89.13	50.33	82	100	31.90	1000.00
T	E=32.70	165	87.30	52.88	165	100	32.05	1000.00
S								

Note: X = Pivotal age for the age group in unit of days,
LX = Number of surviving at the beginning of age interval X,
dx = Number dying during the age interval X,
AM = Apparent mortality,
RM = Real mortality
$1000q_x$ = Mortality rate per age interval (expressed at the rate per thousand)

A. = C. repanda; B. = C. septempunctata;
C. = M. sexmaculatus; D. = M. discolar;
E. = M. cerocea.

FIG. 14. Age pyramid of different species of coccinellids at different stages.


ADULT
PUPA
LARVA
EGG
M. cerocea
ADULT
PUPA
LARVA
EGG
M. discolar
ADULT
PUPA
LARVA
EGG
M. sexmaculatus
ADULT
PUPA
LARVA
EGG
C. septempunctata
ADULT
PUPA
LARVA
EGG
C. repanda
50 40 30 20 10 0 10 20 30 40 50

Food and feeding

The study of the feeding rate of different coccinellids is important, especially its dependence on abiotic factors. The effectiveness of coccinellids can vary considerably under different meteological conditions (Hodek et al, 1965). Coccinellids are predators feeding on most serious agricultural pests, aphids, coccids etc. Diverge feeding habits found among them vary from monophagy in their choice of prey (Hagen, 1962). This view was also supported by several workers (viz. Bulduf, 1935; Eülmek, 1957; Hodek, 1965). All the species concerned have long been known to feed upon aphids and a number of authors, notably Clausen (1916), Bulduf (1935) have given data on the rate of prey consumption by certain species.

Coccinellids attacked different species of aphids, such as A. Gambuci (Hawks, 1920), A. fabae (Banks, 1955), A. gossypii (Alam et al, 1964), A. craccivora (Bakhetia and Sidhu, 1977).

Besides these, coccinellids feed extra-floral nectary secretion and nectar of different flowers (Dobzhansky, 1922; Volkov, 1938; Kamal, 1951; Rackwood, 1952; Ebrahim, 1955; Putman, 1955, Nishida, 1958; Ewing, 1973). Pollen also has been shown to be essential food for Coelomegilla maculata (Ewert and Chiang, 1946; Putman, 1957; Smith, 1965).

Quantitative feeding rate have been recorded by Carnes (1912); Palmer (1914); Clausen (1915); Cutright (1924); Campbell

(1926); Thomson (1928); Fluke (1929); Sther (1930); Knowlton et al (1938); Ibrahim (1955); Goodargy and Davis (1958); Islam and Nasiruddin (1976); Radke et al (1977); Verma and Chawdhury (1977).

Both larvae and adults extend useful service to us in nourishing harmful aphids and protecting our agricultural crops from the attack of those harmful insects. So, it was felt to make thorough investigation as to how much potentiality they possessed as biotic controlling agents.

Materials and Methods:

Twenty larvae of each species were isolated in a glass vial separately. Each vial was covered with a thin piece of cloth secured with rubber band. The bottom of the vial contained a water soaked blotting paper to avoid drying inside the vial. At regular intervals of 24 hours, each of the larvae in the vial was provided with counted numbers of aphids. After 24 hours the number of aphids present in the vial was determined at the following day. The number of aphids consumed per larva during the preceeding hours was obtained from the difference of aphids supplied and total consumption. Similar procedure was also maintained for the adults. The experiment was carried out under two different room temperatures (viz., 20 and 30°C) and the data obtained were analysed.

Observations and Discussion :

The experimental results have been represented in Fig. 15, 16, 17. From the experiment it is evident that daily feeding rate of these species were more or less same during each of these respective stages of their development. The varying length of stages at different temperatures influenced the total feeding rate.

The experiment reveals that highest number of aphids was consumed by both larvae and adults of C. repanda and lowest number was consumed by M. cerocea (FIG. 16 and 17). Under critical observation it is evident that daily feeding capacity was increased with the increase of their age (Fig. 15). Same result obtained by Ibrahim (1955), Islam and Nasiruddin (1976). In the laboratory the feeding rate of both larvae and adults were found slightly low in degree in comparatively low temperature, at 20°_{C} , whereas, at $30^{\circ}C$ the rate found to be high (Fig. 16 and 17)

During scarcity of food (aphid) both larvae and adults developed cannibalism (Fig. 18)

Hodek (1967) studied the feeding ability of different coccinellids and reported that food consumption is correlated with temperature and the increase in developmenttal rate accompanying a rise in temperature naturally results in a higher daily feeding rate. Total food consumption in fact ,

increase only slightly with rising temperature (Hodek, 1957; Hukusima and Sakurai, 1964) but is, however, very strongly stimulated by an alternation of temperature (Hodek, 1965).

Modawal (1941) stated that the average number of aphids (M. granarium) eaten by one larva of C. sexmaculatus was 465 at 25°C and 310 at 20°C and average number of aphids consumed by the adult of the same beetle was 44 per day. According to Bagal and Trehan (1945) the average number of aphids (B.Brassicae) consumed by one larva during its larval period was 303 and a pair of adult C. sexmaculatus consumed 16321 aphids during its life span and the average feeding rate was 61. Clausen (1915) stated that the number of aphids daily consumed by the larva of A. bipunctata was 14 while in C. californica it was about 20. He also reported that during the entire larval period they consumed 216 to 475 aphids for different species. Roy (1976) mentioned that the 4th instar larva of C. transversalis consumed 50 aphids during each of larval instar. In Semiadalia undecimpunctata Schn., the adult consumed 1276 aphids and the larva consumed 410 aphids in its larval life to complete its development (Yakhontov, 1965). Radke et al (1977) observed the feeding ability of both larva and adult of C. septempunctata and reported that the feeding ability increases with prey densities. Verma and Chowdhury (1977) observed the feeding rate of C. septempunctata in relation to temperature and humidities and showed that in

low temperature the feeding rate was low in comparison to higher temperature. Buldaf (1935) stated that the egg laying female ate more than either virgin females or males.

FIG. 15. Daily food consumption of the larva of C. repanda at two different temperatures.

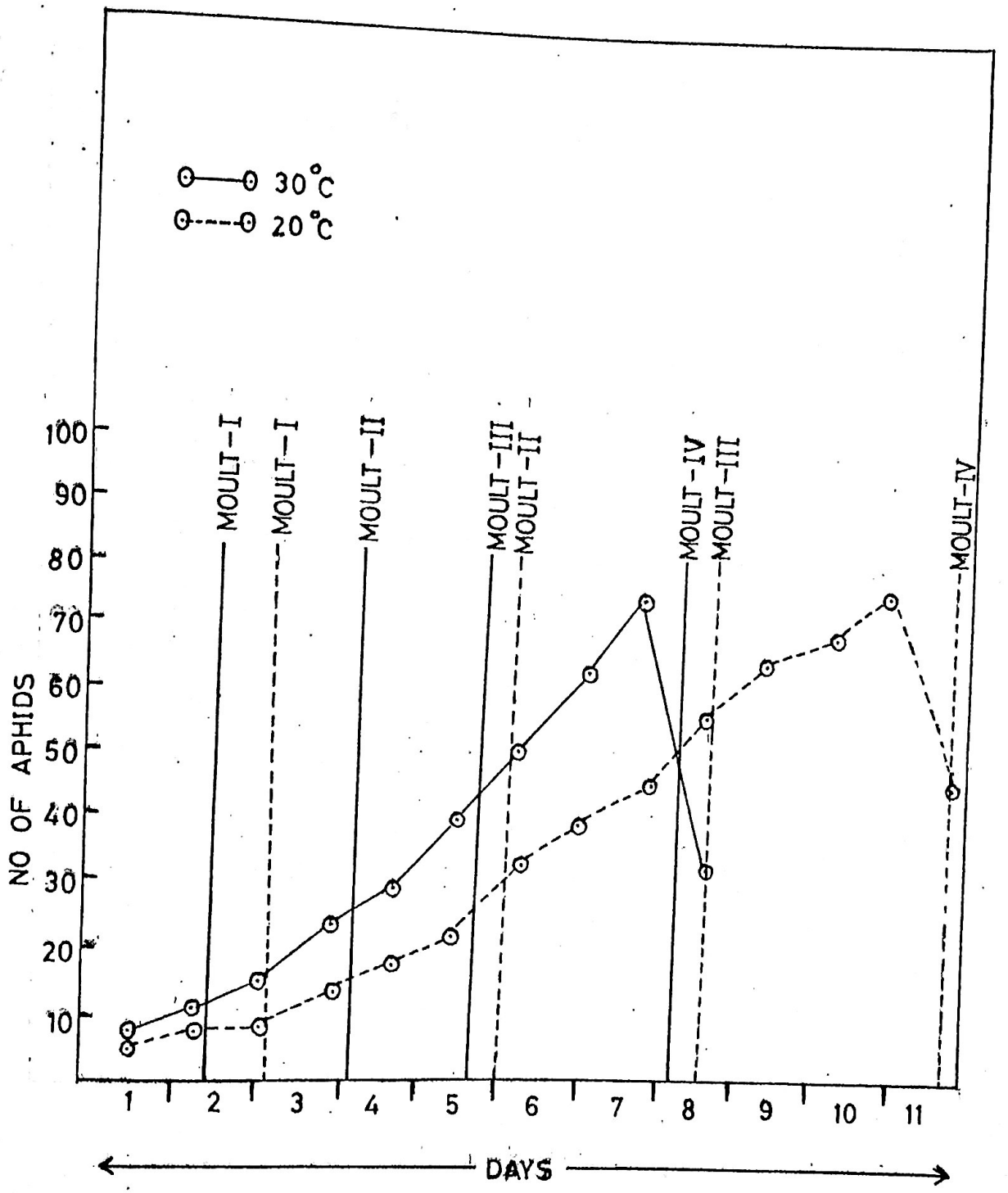
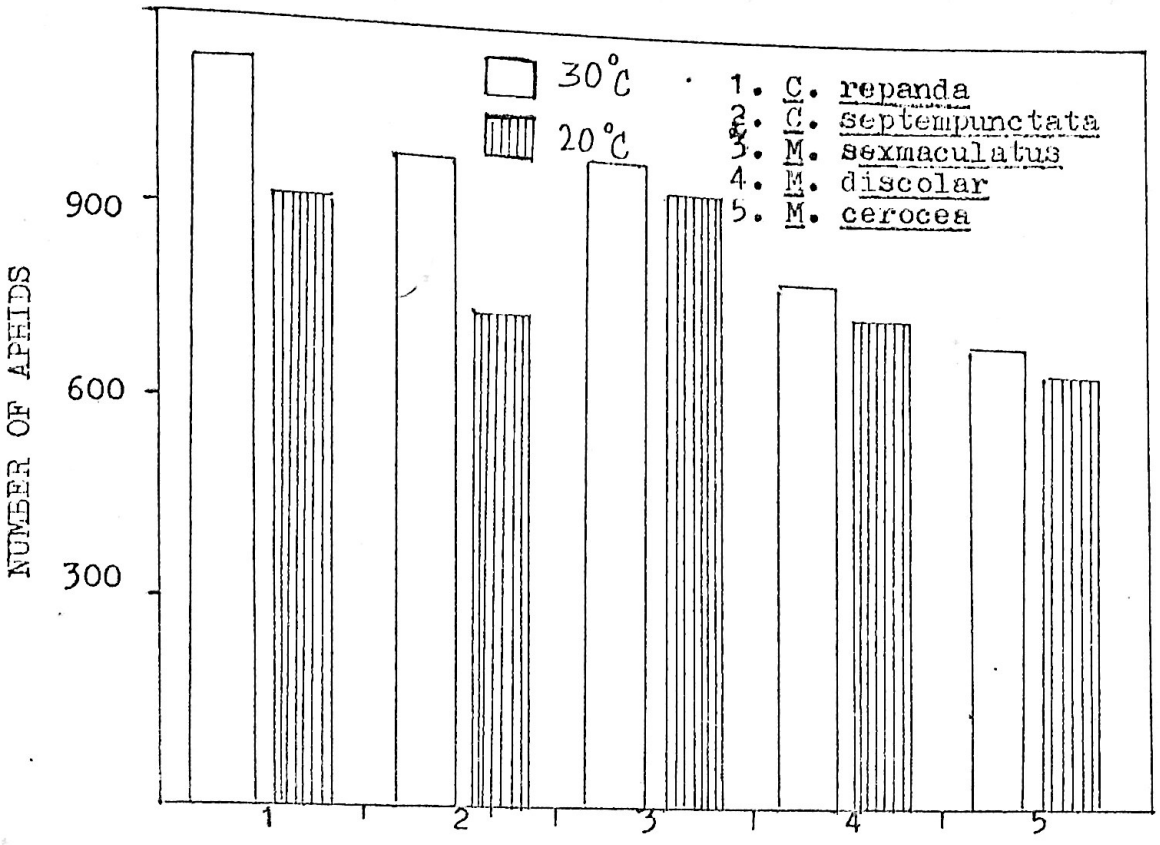

30°C
20°C
MOULT-I
MOULT-I
MOULT-II
MOULT-III
MOULT-II
MOULT-IV
MOULT-III
MOULT-IV
NO OF APHIDS
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
DAYS

FIG. 16. Feeding ability of different species of coccinellids (adult) at two different temperatures.

FIG. 17. Feeding ability of different species of coccinellids (larvae) at two different temperatures.


30°C
20°C
1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
NUMBER OF APHIDS
900
600
300
1
2
3
4
5

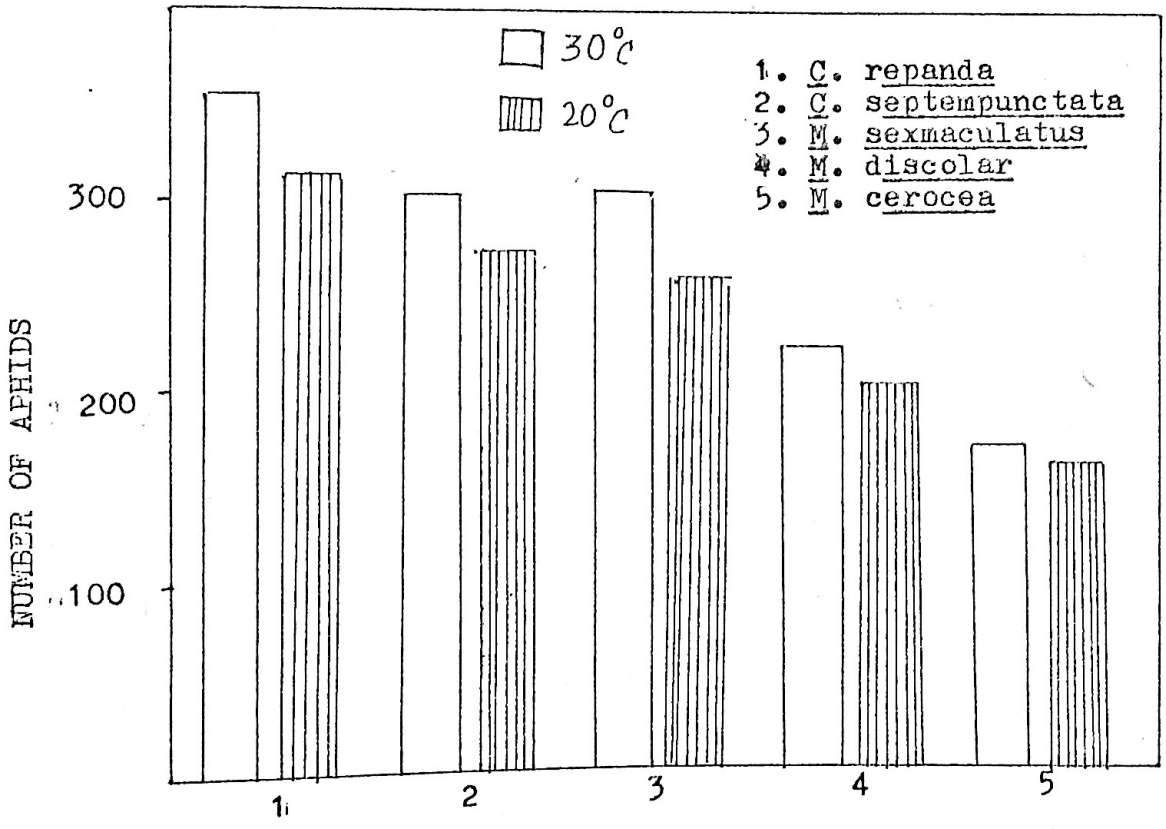
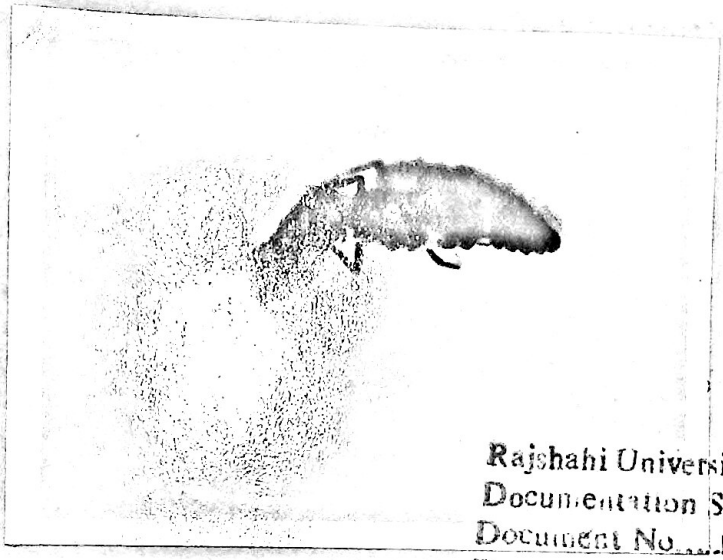

30°C
20°C
1. C. repanda
2. C. septempunctata
3. M. sexmaculatus
4. M. discolar
5. M. cerocea
NUMBER OF APHIDS
300
200
100
1
2
3
4
5

FIG. 18. Showing the cannibalistic habits of C. repanda larva.



CHAPTER II SEASONAL DISTRIBUTION

SEASONAL ABUNDANCE OF COCCINELLIDS

Seasonal distribution of predaceous insect is one of the important part of the biological study. The size of insect population is considered to be the most important factor among all the factors involved in ecological studies (Southwood, 1971).

The study of fluctuation in population is concerned with basic food supplies, conditions for reproduction, relation between predator and prey, climate, parasites, diseases, balances, successions and other factors (Pearse, 1939). Depending upon their reproductive pattern, population fluctuation in insects must follow any one of the general ways: certain species consists of individuals present in all stages of development and belonging to different generations - 'complete overlapping generations'; other species are dominated at particular phenological intervals by individuals in essentially the same stage of development - 'Incomplete overlapping generations' (Davidson, 1944). The study of the population may be divided very broadly into extensive and intensive (Morris, 1960). Extensive studies are carried out over a large area and are normally concerned with the distribution of insect species or with the relation of insect pest population to crop damage or with the prediction of damage and the application of control measures (Strickland, 1961).

Intensive studies involve the continual observation of the population of an animal in the same area. Usually information is required on the size of the population of successive developmental stages so that a life table or budget may be constructed and an attempt may be made to determine the factors that cause the major fluctuation in population size and those that govern to regulate it. (Morris, 1960; Richards, 1961).

To estimate the density of population several methods have been followed from time to time. Salt et al (1948) estimated the number of orthoptera in a acre of soil, each sample being four inches in diameter and 12 inches in depth. Madge (1954) used quadrat one foot square to estimate the density of the population of Oncopera fascienlata. Lloyd (1941) was able to trap the small fly, Metriocenmus hirticollis by placing a funnel-like frame of one foot square on the surface of the fitter - bed which led the flies upward into a jar in which they were trapped.

Coccinellid feed on aphid of different species and are often encountered in large numbers on the plants infested with aphid and the usual random sampling was encountered in this case.

The distribution of different species of coccinellids were observed by many workers in different parts of the world (viz. Willcocks, 1925; Bishara, 1934; Kamal, 1951; Ibrahim, 1955;

Venugopal [redacted], 1977; Bishop and Blood, 1977; Pope, 1978; Bournoville, 1978; Quayum et al, 1979). An efforts was, therefore, made to study the population abundance of predaceous coccinellid in the aphid infested crop field as to find out the prey-predator relationship in response to temperature.

Materials and Methods:

To study their seasonal distribution several aphid infested crop fields (viz. cotton, egg plant, mustard and wheat) were selected. During the observation from September, 1979 to September 1981, ten plots were made in each of the crop field for simultaneous observation. Each of the ten plots of cotton and egg plant (3 feet x 3 feet) contained four aphid infested plants whereas each plot of mustard and wheat contained fifty plants. Richard's (1940) sampling methods were followed here. Three leaves, one from top, one from middle and one from lower part of the plant were selected randomly from each plant and tapped with number cards to observe the aphid population. During the observation the coccinellid population (both larva and adult) associated with aphid colonies within the selected plots were counted every alternate day. The sampling continued in the same manner for the consecutive months. Daily field temperature were also recorded.

Observations and Discussion:

The result of the experiment have been graphically represented in the Fig. 19. The population fluctuation of aphid in the experimental plots was found to be very much dependent on temperature. It was also observed that the population of coccinellids also fluctuated with the factors related to aphid population. During summer months from March to July, when field temperature ranged between 25 to 30°C both coccinellids and aphids disappeared from the selected crop field but at the advent of winter from the months of November to February under temperature range of 17 to 25°C they reappeared in the field (Fig. 19).

The collected data showed that a relationship exists between the aphid population and their coccinellid predators. The equation for the regression of aphid (Y) and coccinellid (X) was obtained as follows.

(Larvae) $Y = 63.357 + 0.0013X$ $(r = 0.5432)$

(Adults) $Y = 54.150 + 0.0012X$ $(r = 0.6265)$

The values of the regression co-efficient are significant in both the cases (Fig. 20).

During the present investigation it was observed that with the increase of temperature the aphid population decreased and the population of coccinellid decreased with the decrease of

aphid population. It was amply clear that the lack of aphid populations in the selected fields during summer months is positively correlated with the absence of coccinellid.

Willcocks (1925) and Bishara (1934) studied the seasonal abundance of C. undecimpunctata but they did not discuss the problem clearly. Kamal (1951) claimed that the beetle is most commonly met with in Egypt from March till the end of October. He also claimed that the beetle has two distinct generations per year, the first one beginning in March in upper Egypt and the second one occurring in the latter half of September in lower Egypt but they did not mention any temperature related with their distribution.

Ibrahim (1955) observed the seasonal distribution of C. undecimpunctata in Egypt and reported that the generation periods were not always constant. Several factors, including variation of temperature and frequency of aphid population influence the exact period of each generation. Patnaik et al (1977) conducted a survey work on aphidophagus insects in Orissa from August 1975 to July 1976 and found a number of several aphidophagus coccinellid in aphid infested sorghum, maize, egg plant, pulse etc. Bishop and Blood (1977) observed that the population abundance of six coccinellids were very much dependent on the distribution of A. gossypii in the cotton field in South eastern Queensland. Venugopal [redacted] (1977) observed the population dynamics of A. gossypii Glov. and its coccinellid predators on okra (bhendi).

According to their report the predator migrated in response to increased number of prey. Pope (1978) observed the population distribution of coccinellid predators and mentioned that the most potent regulator of the population was the food supply. He, further, noted that fluctuation of aphid and their migratory habits usually lead to the dispersal of the lady bird beetles. In summer, the aphid was rare in the lucerni (France) field and the predator of aphid, coccinellids also decrease but they were not well adapted to change the aphid population (Bournville, 1978) Quayum et al (1979) studied the incidence of C. repanda and reported that the lack of aphid population in cotton field during summer months is positively correlated with absence of coccinellid. The present investigation confirms that immensity and scarcity of coccinellid are mainly dependent on the variation of temperature and availability of their preys and thus agree with the views of Bishop and Blood (1977), Pope (1978) and Quayum et al (1979).

FIG. 19. Showing the distribution of different species of coccinellids in relation to aphid population and temperature.

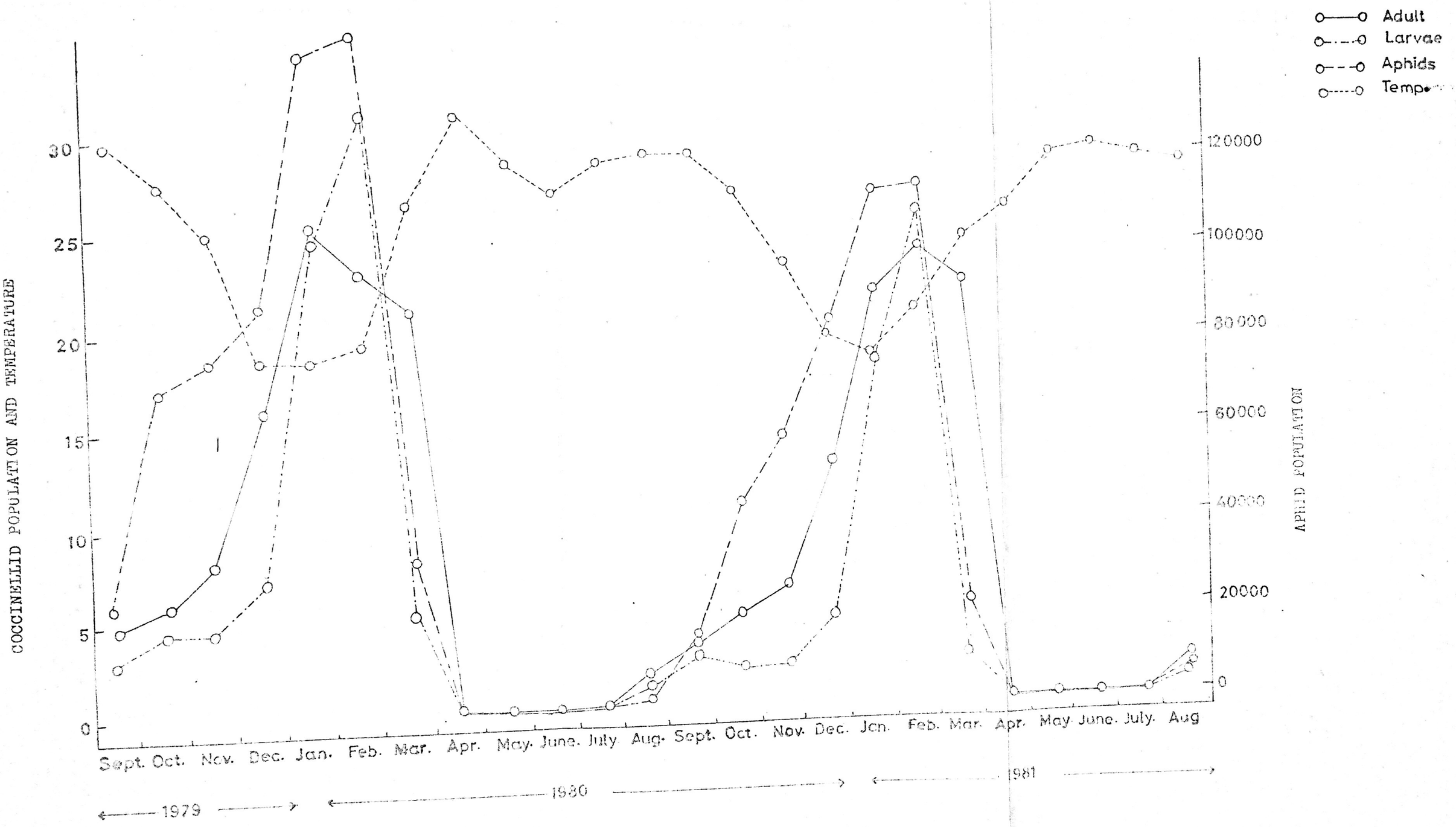
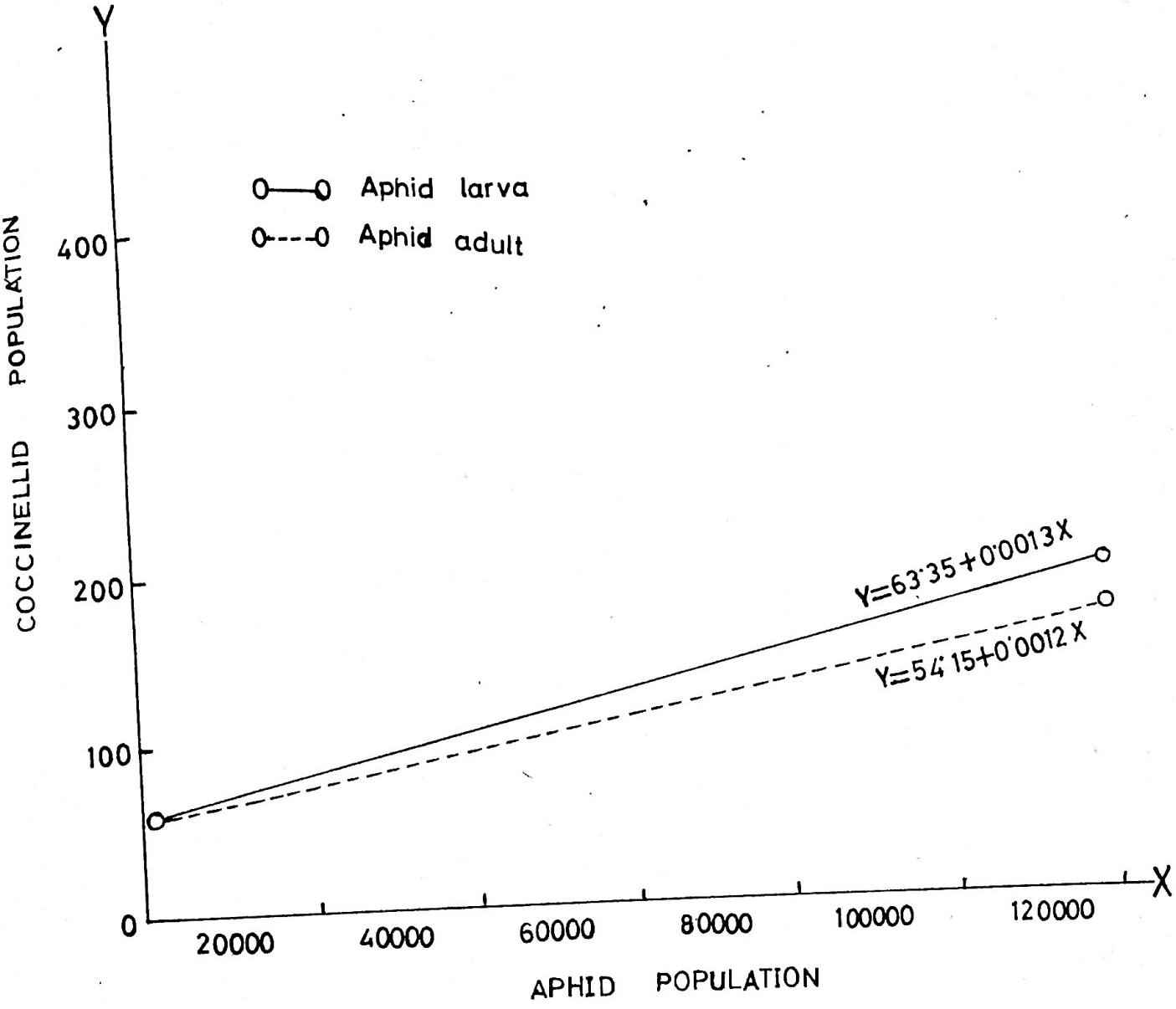

Adult
Larvae
Aphids
Temp
COCCINELLID POPULATION AND TEMPERATURE
APHID POPULATION
30
25
20
15
10
5
0
120000
100000
80000
60000
40000
20000
0
Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May. June. July. Aug
1979
1980
1981

FIG. 20. Regression lines for aphid and coccinellid population.


Y
O—O Aphid larva
O---O Aphid adult
COCCINELLID POPULATION
400
300
200
100
0
Y=63·35+0·0013X
Y=54·15+0·0012X
20000
40000
60000
80000
100000
120000
X
APHID POPULATION

CHAPTER- III SUMMARY

LITERATURE CITED

SUMMARY

An investigation on the biology, ecology and seasonal distribution of predaceous coccinellids, viz., Coccinella repanda Thunb., C. septempunctata L., Menochilus sexmaculatus F., M. discolar Fab., M. cerocea Fab. have been carried out.

The mean mating periods were 14.4 ± 0.92, 14.4 ± 1.82, 16.2 ± 0.99, 14.25 ± 0.79 and 12.0 ± 0.63 minutes respectively for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea.

The effects of temperatures and matings on pre-oviposition periods were observed. Longer pre-oviposition periods were recorded at lower temperatures and higher temperatures lowered the pre-oviposition periods of all the species studied. The mean pre-oviposition periods of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar, and M. cerocea were 21.74 ± 2.46, 22.07 ± 1.93, 16.45 ± 1.64, 18.45 ± 1.32 and 18.95 ± 1.20 and 5.35 ± 0.85, 4.20 ± 0.61, 5.60 ± 1.07, 7.66 ± 0.79 and 7.66 ± 0.78 days at 15°C and 35°C respectively. Temperature had a significant effect on pre-oviposition period of these beetles ($P < 0.01$). On the other hand, short pre-oviposition periods were recorded in the mated females. The periods were 8.6 ± 0.93, 10.6 ± 0.98, 8.8 ± 2.01, 12.8 ± 1.93 and 11.8 ± 1.93 days for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea respectively. And this periods of the virgin females

were 19.8 ± 2.73, 18.8 ± 1.39, 16.0 ± 3.06, 20.4 ± 3.66 and 25.4 ± 2.5 days respectively for these beetles.

The mean oviposition periods of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea were 21.2 ± 5.16 ± 26.2 ± 2.90, 30.8 ± 5.02, 29.9 ± 2.83 and 27.5 ± 2.87 days at 15°C respectively. The oviposition periods came down to 6.80 ± 1.37, 10.0 ± 1.35, 10.0 ± 1.14, 9.3 ± 0.97 and 10.2 ± 1.17 days at 35°C respectively for the same beetles. Temperatures had no effect on oviposition period.

The eggs were laid in clusters and remained attached to the substratum. A cluster contained from 5 to 50 eggs. The effect of amount of food indicated that fecundity was positively correlated with the amount of food consumed. Non protein natural and artificial food did not seem to be either attractive or nutritious enough for the beetles to produce eggs. The mean ovipositions were 235.2 ± 30.22, 275.0 ± 38.83, 323.6 ± 42.18, 180.2 ± 10.61 and 114.2 ± 25.3 at 30°C, and 57.8 ± 12.10, 93.2 ± 13.64, 119.0 ± 17.64, 112.8 ± 14.95 and 101.2 ± 28.78 at 35°C for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea respectively. The effect of temperature on oviposition was significant. ($P < 0.01$).

The mated females of C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea laid 185 ± 30.21, 178.99 ± 21.86, 229.96 ± 24.06, 161.04 ± 13.11 and 90.08 ± 14.53

eggs respective whereas, the virgin females of the same beetles laid 57.98 ± 13.8, 51.88 ± 10.85, 65.9 ± 11.04, 41.2 ± 8.59 and 37.26 ± 8.97 eggs respectively.

The incubation periods were 130.05 ± 5.36, 147.43 ± 7.11, 170.64 ± 18.77, 165.94 ± 5.32 and 151.25 ± 7.69 hours for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea respectively at 15°C. The periods were 44.5.5 ± 2.45, 46.26 ± 2.17, 45.75 ± 2.84, 44.68 ± 2.20 and 39.36 ± 1.25 hours respectively at 30°C for the same beetles. The effect of temperature on incubation periods was significant ($P < 0.01$).

The mean percentages of hatchability were 65.44 ± 2.23, 59.03 ± 4.52, 65.96 ± 4.33, 67.13 ± 2.80 and 55.95 ± 3.36 respectively for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea at 15°C. At 30°C, the percentages were 82.74 ± 1.63, 81.51 ± 4.15, 82.53 ± 2.23, 73.99 ± 2.39, and 71.29 ± 2.65 respectively for the same beetles. Temperatures had a significant effect on the hatchability of eggs of these beetles ($P < 0.01$).

The durations of different immature stages at five different temperatures (viz., 15°C, 20°C, 25°C, 20°C and 35°C) were determined in the laboratory. No development occurred at 15 and 35°C. A partial development, however, took place at 32°C. Four larval instars were observed. The durations of larval and pupal periods decreased with the increase of temperatures ($P < 0.01$).

Emergence of the adults varied directly with temperatures. At 15°C, the percentages of emergence were 28.2 ± 2.18, 28.49 ± 2.71, 33.69 ± 3.17, 20.24 ± 1.95, and 26.9 ± 1.90 respectively for C. repanda, C. septempunctata, M. sexmaculatus, M. discolar and M. cerocea. At 30°C, the percentages increased to 65.06 ± 5.56, 63.8 ± 4.54, 79.10 ± 2.06, 76.4 ± 1.32 and 81.79 ± 3.09 respectively for the same beetles, while at 35°C, the percentages reduced to 24.34 ± 2.70, 27.58 ± 4.32, 30.93 ± 2.28, 21.8 ± 1.76 and 19.66 ± 2.63 respectively. Temperature had a significant effect on the adult emergence ($P < 0.01$).

Longevity of the adults in response to food and temperature was observed. Aphids served as the best food for adult longevity, whereas, 10 per cent sugar solution, and pollen dust were next in the order. In case of females of all species, pollen dusts of cotton flowers was one of the effective foods for longevity. The effect of food on longevity was significant ($P < 0.01$). Long life spans were recorded at 15°C. With the rise of temperature from 20 to 35°C longevity was reduced. The variation of longevity at different temperatures was significant ($P < 0.01$).

Male and females sex-ratios followed the typical Mendelian sex-ratio of 1:1.

Feeding habits of both larvae and adults were observe at two different temperatures, viz., 20 and 30°C. Both larvae and adults of C. repanda consumed the maximum number of aphids and

the minimum number of aphids was consumed by the larvae and adults was obtained in M. cerocea.

Seasonal distributions of both larvae and adult coccinellids were observed in the field. The population of coccinellids fluctuated with the factors related to aphid populations. During summer (March to July) when field temperature ranged from 25 - 30°C, both coccinellids and aphids disappeared from the field but during winter (September to February) with field temperatures ranging from 17-25°C reappearance of both the aphids and coccinellids occurred.

LITERATURE CITED

Abraham, C.C., K.P. Mathew., N.M. Das. 1973. New record of Coccinella arcuata Fabs. as a predator of Nilaparvata lugens Stal. in Kerala. Agril. Res. J. 11(1) 75.

Ahmed, A. 1983. Bionomics and ecology and control of Epilachna beetles of Rajshahi University Campus and adjacent areas. M.Phil. thesis. Dept. of Zoology. Rajshahi University, pp. 117.

Alam, M.A., A. Ahmed., S. Alam., M.A. Islam. 1964. A review of research division of Entomology (1947-64). Agril. Res. Inst. Dacca. 76p.

*Alee, W.C., A.E. Park., T. Emerson and K. Pschmidt. 1949. Principles of animal ecology. W.B. Saunders Company, Philadelphia. pp. 837.

Ali, M.S., M.A. Quayum and A.S.M.S. Rahman. 1981. Effect of food on longevity and fecundity of Coccinella repanda Thunb. (Coleopatera: Coccinellidae). Bangladesh J. Zool. 9(2): 125-129.

*Andersen, F.W. 1961. Effect of density on animal sex-ratio. Oikos, 12, 1-16.

Andrewartha, H.C. and L.C. Birch. 1954. The distribution and abundance of animals. Univ. Chicago press. Chicago, pp. 782.

Bagal, S.R. and K.N. Trehan. 1945. Life history and bionomics of two predaceous and one microphagous species of Coccinellidae. J. Bombay Nat. Hist. 45(4): 566-574.

*Bakhetia, D.R.C. and A.S. Sidhu 1977. Biology and seasonal activity of the ground nut aphid, Aphis craccivora Koch. J. Res. Punjab Agric. Univ. 14(3) 299-303.

Balduf, W.V. 1935. The bionomics of Entomophagous Coleoptera. J.S. Swift Co., Inc., pp. 220.

*Banks, C.J. 1955. An ecological study of Coccinellidae with Aphis fabae on Vicia faba Bull. Entomol. Res., 46, 561-87.

*Barber, G.W. 1926. Some factors responsible for the decrease of the European corn borer in New England during 1923 and 1924. Ecology 7, 143-162.

*Bishop, A.L. and P.R.B. Blood., 1978. Temporal distribution and abundance of coccinellid complex as related to aphid population on cotton in S. East Queensland. Aust. J. Zool.

*Bishara, I. 1934. The cotton worm, Prodenia litura, in Egypt (Bull. Soc. Roy. Entom.) Egypte. XVIII, pp. 288-420.

Bournoville, R. 1978. Study of the seasonal dynamics of a population of the pea aphid, Acyrthosipham pisum Harris. in lucerne fields. Annals. de Zoologic. Ecologic Animals, 10(1), 1-27.

Brettell, W.V. 1964. Biology of Diloponis insconspicuus Pope. a predator of citrus red scale, with noted on the feeding behaviour of other scale predators. J. Entomol Soc. Africa, 17-28.

Butler, G.D. and A. Dickerson. 1972. Life cycle of convergent lady beetles in relation to temperature. J. Econ. Ent. 65(5): 1508 - 1509.

*Campbell, R.E. 1926. The pea aphids in California. J. Agric. Res. 32(9): 861-881.

*Carnes, E.K. 1912. Collecting ladybird (Coccinellidae) by by the ton. Mon. Bull. Calif. Comm. Hort. Monthly Bull., 1, 71-81.

Chapman, R.F. 1973. The insects: Structure and function ELBS. Low priced edition pp. 819.

*Charnov, E.L. and J. Bull. 1977. When sex is environmentally determined? Nature. Lond., 266, 828-830.

Clausen, C.P. 1915. A comparative study of a series of aphid feeding Coccinellidae. J. Econ. Ent. 8: 487-491.

_____ 1916. Life history and feeding records of a series of Californian Coccinellidae. Calif. Univ. Pub. Entomol., 251-38.

_____ 1939. The effect of host size upon sex-ratio of hymenopterous parasites and its relation to methods of rearing and colonization. J.N.Y. Ent. Soc., 47, 1-9.

_____ 1956. Biological control of insect pests in continental United States. U.S.D. Tech. Bull., 1139, 151 pp.

*Cook, M.C. 1927. Some effects of alternating temperatures on the growth and metabolism of cutworm larva. J. econ. Ent. 20: 769-782.

*Cutright, C.R. 1924. Bionomics of Hippodamia teredecimpunctata L. Ann. Entomol. Soc. Am., 17, 188-92.

*Davidson, J. 1944. On the relationship between temperature and the rate of development of insects at constant temperature. J. Anim. Ecol. 13: 26-38.

Dieke, G.H. 1947. Lady beetles of the genus Epilachna (Sens: Lat) in Asia, Europe and Australia. Simthson Misc. Coll. 106(15): 1-183.

Dobzhansky, T. 1922. Massings and migrations of Coccinellidae. Imag. diapause. Rept. Bur. Appl. Entomol. Agr. Sci. Comm. 2. 103-24, 229-34.

*Ellenby, C. 1954. Environmental determination of sex ratio of plant parasitic nematodes. Nature. Lond., 174, 1016-1017.

El-Saadany, G.B. 1973. Comparison of mortality factor within a generation of the cotton leafworm, Spodoptera littoralis (Boisd). Z. Angew. Ent. 74(4): 370-372.

_____ and ABD Elfattah, 1974. Age and mortality distribution for the cotton leafworm, Spodoptera littoralis (Boisd.) Ibid. 75(1): 79-81.

*Ewert, M.A. and H.C. Chiang. 1946. Effects of some environmental factors on the distribution of three species of Coccinellidae in their micro habitat. Proc. Symp. Ecol. Aphidoph Inst., Praha 1965.

Ewing, H.E. 1973. Notes on oregon Coccinellidae. J. Econ. Entomol. , 6, 404-7.

Flanders, S.E. 1939. Environmental control of sex in hymenopterous insects Ann. ent. Soc. A., 32, 11-26.

Fletcher, T.B. 1914. Some South Indian Insects and other animals of importance considered especially from an economic point of view. Govt. Press, Madras, pp. 546.

*Fluke, C.L. 1929. The known predaceous and parasitic enemies of the pea aphids in North America. Wisconsin Agr. Exp. Sta. Res. Bull. 93: 1-47.

Fulmek, L. 1957. Insecten als B; attlausfeinde. Amm. Natur. Museum Wien, 61, 110-227.

*Gage, G.W. 1920. The larvae of coccinellidae (Illinois Biol. Monogr.) 233-294.

*Goodarzy, K. and D.W. Davis. 1958. Natural enemies of the spotted alfalfa aphids in Utha. J. Econ. Ent. 51(5): 612-616.

Hagen, K.S. 1962. Biology and ecology of predaceous Coccinellidae. Dept. Biol. Cont. Univ. of Calif. 289-362.

Hamalainen, M. and A.M. Markkula. 1972. Effect of type of food on fecundity in Coccinella septempunctata L. (Col: Coccinellidae). Ann. Ent. Fenn. 38, 195-199.

Hawks, O.A.M. 1920. Observation on the life history, biology and genetics of the ladybird beetle, Adalia bipunctata (Muls) Proc. Zool. Soc. London., 475-90.

Haque, I. and M.A. Islam. 1978. Effect of different food on the longevity and fecundity of Coccinella repanda Thunb. (Coleoptera: Coccinallidae). Bangladesh J. Agril. Sci. 5(2): 233-288.

Hodek, I. 1957. The larval food consumption of Coccinella 7-punctata L. Folia Zool., 6, 3-11.

_____. 1958. Influence of temperature, rel. humidity and photoperiodicity on the speed of development of Coccinella septempunctata L. Acta Soc. Entomol. Ceskoslov., 55, 121-41.

_____. 1965. Several types of induction and completion of adult diapause. Proc. Intern. Congr. Entomol., 12th, London, 1964, 431-32.

*_____., Holman, J., Novak, K., Skuhravy, V., P. Stary., L. Welsmann. and J. Zekeny, 1956. The present possibilities and prospects of integrated control of Aphis fabae Scop. Proc. Symp. Liblice near Praha.

Hodek, I. 1967. Bionomics and ecology of predaceous Coccinellidae. Ann. Rev. Ent. 12, 79-104.

*Hukusima, S. and H. Sakurai. 1963. Comparison of physiological natures between predaceous Coccinellidae reared on artificial diet and aphid alone. Rept. Tokai Branch Entomol. Soc. Japan, 15, 12-21.

*_____. 1964. Aphid consumption by adult Coccinella septempunctata L. (Coleoptera: Coccinellidae) in relation to temperature. Ann. Rept. Soc. Plant Protect. N. Japan, 15, 126-28.

Ibrahim, M.M. 1955. Studies on Coccinella undecimpunctata aegyptiaca Reiche. I. Preliminary notes and morphology of the early stages. Bull. Soc. Fouad I er d. Entomol., 38, 251-74.

Ibrahim. 1955. Studies on Coccinella undecimpunctata aegyptiaca Reche. II. Biology and life history. Bull. Soc. Entomol. Egypte. 39, 395-423.

IMMs, A.D. 1977. Recent advances in Entomology. Methuen and Co. London. pp. 886.

Islam, M.A. and M. Nasiruddin. 1976. Comparative efficacy of two insect predators, Menoichilus sexmaculatus F. and Coccinalla repanda Thunb. Bangladesh J. Zool (4): 128-130.

_____. 1978. Life history and feeding habit of Coccinella repanda Thunb. (Coleoptera: Coccinellidae), Bangladesh J. Agril. Sci. 5(1): 53-55.

_____. 1978. Life history and feeding habit of Coccinalla septempunctata L. (Coleoptera: Coccinellidae) Ibid. 5(1): 119-123.

Kamal, M. 1951. The biological control of the cotton leaf-worm, Prodenia litura F., in Egypt. Bull. Soc. Fouad I Entomol., 35, 221-70.

Knowlton, G.F., C.F. Harison, E.C. Harmston. 1938. Pea aphid investigations. Proc. Utah. Acad. Sci. Arts and letters. 15: 71-80.

*Korschefsky, R. 1931. Coleopterarum catalogus, part 118 (Coccinallidae) Junk. Berlin, Germany, 224 pp.

Koura, A.,1972 . On the biology of Tenebrio molitor in Egypt. Bull. Soc. Entomol. Egypte., 56: 297-300.

*Latereille, 1807. Cited from M.Sc. (Ag) Thesis, 1976. Bangladesh Agril. Univ. Mymensingh. Studies on the Life history of Epilachna 12-punctata Muls. in relation to the host plant preference.

*Laraichi, M. 1978. An effect de hautes temperatures sur le taux sexual de Ooencyrtus fecundus (Hymenoptera: Encyrtidae.) Entomologia exp. appl., 23, 237-242.

Lefroy, H.M. 1909. Indian insects life. Jhacter, Spink & Co., Calcutta 308-309.

Lloyd, N. C. 1941. The Cherry aphid in the orange. Agril. Gaz. N. 51061, 149-52.

*Madge, P.E. 1954. Control of underground caterpillar J. Dept. Agric. S. Australia, 171pp.

Mousa, M.A., E.A. Nasr and A.S. Hassan, 1960. Factor affecting longevity and reproductive potentials of moths of the cotton leaf worm, Prodonia litura F. Bull. Soc. Ent. Egypte XLIV: 383.

*Mountford, M.D. 1966. Relationships of temperature to the duration of the development of insects. Rev. Appl. Ent. 56-61.

Morris, R.F. 1960. Sampling of insect populations. Rev. Ent. 5: 243-64.

Modawal, C.N. 1941. A biological note on Chilomonis sexmaculatus Fab. Indian J. Entomol. 3: 139-140.

Nielson, M.W., and W.E. Qurrie. 1960. Biology of the convergent lady beetle when fed a spotted alfalfa aphids diet. J. Econ. Entomol. 53: 257-59.

*Nishida, T. 1958. Extra floral glandular secretions, a food source for certain insects. Proc. Hawaiian Entomol. Soc., 16, 379-86.

Norris, M.Y. 1936. The feeding habits of adult lepidoptera (Trans. R. Soc. London.), 61-90.

*Notario, A., C. Estrada, I. Gonzalez. 1978. Contribution to Study of the biology of Coccinella septempunctata L. (Coleoptera: Coccinellidae), Ann. del. Inst. Nat. Aq. Sereis. protect.

Odum, E.P. 1964. Fundamentals of ecology. W.B. Saunders Co., London.

Okamoto, H. 1974. Laboratory studies on the food ecology of aphidophagous coccinellids. Tech. Bull. Kagawa Univ. 25(2): 219-224.

Palmer, M.A. 1911. Some notes on heredity in the coccinellid genus Adalia (Muls). Ann. Entomol. Soc. Am., 4, 283-302.

_____. 1914, Some notes on life history of lady beetles. Ibid. 7, 213-38.

Patnaik, N.C., J.M. Satpathy., K.C. Bhagat. 1977. Note in the occurrence of aphidophagous insect predators in Puri district and their predation on the Sorghum aphid, Longiunquis saccjari. Indian J. Agric. Sci. 47(11): 585-586.

*Pearse, A.S. 1939. Animal Ecology Graw Hill Book Co. Inc. London, pp. 642.

Pope, R. 1978. Lady bird. lady bird, The international wildlife magazine, pp. 55.

Putman, W.L. 1955. Bionomics of Stethorus punctillum in Ontario. Can. Entomologists, 87, 9-33.

_____. 1957. Laboratory studies on the food of some coccinellids found in Ontario peach orchards. Ibid., 89, 572-79.

Qayyum, H.A. 1968. Ecological studies on egg hatching and on the larval instars of Rhizopertha domonica (E) Pak J. Sci. Res. 20: 74-76.

Quayum, M.A., M.S. Ali, A.S.M.S. Rahman. 1979. Incidence of Coccinella repanda Thunb. (Coleoptera: Coccinellidae) in response to aphid population and temperature. Bangladesh J. Asiatic Soc. (Sc) 5(2): 43-46.

_____. 1982. Morphological studies on the larvae of Coccinella repanda Thunb. (Coleoptera: Coccinellidae). Univ. J. Zool. Rajshahi University. 1: 51-56.

*Rakke, H.E., Y.S. Huang., G.C. Liu. 1977. Influence of age of predators, Coccinella septempunctata and population density of the host, Rhopalosiphum maides on the rate of predation. Indian J. Agric. Sci. Punjab

Rahman, A.S.M.S., M.S. Ali, M.A. Quayum, A. Ahmed, N. Islam. 1983. A priliminary reports on the coccinellid beetles of Rajshahi. Asiatic Soc. Bang. (Sc) IX(2): 137-139.

*Richards, O.W., 1940. The biology of the small white butterfly, (Pieres rapae) with special reference to the factors controlling abundance, J. Animal Ecol. 9: 243-288.

_____. 1961. The theoretical and Practical study of natural populations. Annl. Rev. Entomol. 6: 147-162.

Ross, H.H. 1965. A text book of Entomology. John. Willey & Sons. Inc. U.S.A., pp. 182.

Roache, L.C. 1960. Lady bug, lady bug; Whats in a name Coleopterists. Bull., 14, 21-25.

Rockstein, M. and J. Miquel., 1973. Aging in insects. In "The physiology in insects", Vol. 1, 371-478.

Rockwood, L.P. 1952. Notes on coccinellids in Pacific Northwest pan-pacific Entomol., 28, 139-47.

Roy, P. 1976. Life history and feeding behaviour of Coccinella transversalis Fabs. (Coleoptera: Coccinellidae), a predator mustard aphid, Lipaphis erysimi (Kalt). Indian biol. VII, 122: 59-61.

Salt, G., F.S.J. Hollic and M.V. Brial, 1948. The arthropod population of posture soil. J. Anim. ecol. 17:139-50, 171.

Sarder, M.S. 1978. Biology and ecology of cotton leaf roller, Sylepta derogata Fab. (Lepidoptera: Pyralidae). M. Sc. thesis, Dept. of Zool. Rajshahi University, pp. 94.

*Sasaji, H. 1971. Fauna of Japonica Coccinellidae (Insecta: Coleoptera) Academic press of Japan. IX. 340.

*Savoiskaya, G.I. 1974. Insect as predator of crop. Nasekomye Zashchiniki, Crozhacya. Alma- Ata, USSR. 121.

Semyanov, V.P. 1974. A method of breeding Coccinella septempunctata in the laboratory. Zashchita Rastenii, 64-32.

Sethy, S.L. and A.S. Atwal. 1963. Influence of temperature and humidity on the development stages of lady bird beetles, Coccinella septempunctata. Indian J. Agric. Soc. 34(3): 166-171.

*Seuge, J. 1970. Influence of rearing conditions on sex determination in Pseudaulacaspis pentagona (Tagr.), Acad. Sci. Paris Ser. D. 270, 1258-1260.

Singh, R., and R.K. Malhotra. 1979. Some studies on the biology of Coccinella undecimpunctata memetriesi Muls. a predator of mustard aphid. Current Science 48(20): 904-904.

Smith, B.C. 1964. Effects of foods on some aphidophagous Coccinellidae. Proc. Symp. Liblice near praha 1965. 75-81

_____. 1965. Effects of food on the longevity, fecundity and development of adult coccinellids (Coleoptera: Coccinellidae). Can. Ent. 97: 910-919.

*Smirnoff, W.A. 1958. An artificial diet for rearing coccinellid beetles. Can. Entomol., 90, 563-65.

Southwood, T.R.E. 1971. Ecological methods. Chapman & Hall, London.

*Stehr, W.C. 1930. The Coccinellidae of Mennesota Univ. Minn. Agr. Sta. Tech. Bull. 75, pp. 54.

*Strickland, A.H. 1961. Sampling crop pests and their hosts. Rev. Ent. 6: 201-20.

Sundby, R.A. 1968. Some factors influencing the reproduction and longevity of Coccinella septempunctata L. (Coleoptera: Coccinellidae). Entomophaga. 13, 197-202.

Sweetman, H. L. 1936. The biological control of insects. (Comstock, Ihca, N.Y., 461 pp).

_____. 1958. The principles of biological control (W.C. Brown Co., Dubuque, Iowa, 560 pp.)

Tamaka, M., and Y. Maeta., 1965 rearing of some predaceous coccinellid beetles by the artificial diets (In Japanese, with English sum.) Bull. Hort. Res. Sta. Japan, Ser. D., No. 3, 17-35.

_____ and D. Olsen., 1977. Feeding potential of predatore M. persicae. J. Ent. Soc. of British, Columbia, 74, 23-26.

Thomson, W.R. 1928. The seasonal and ecological distribution of the common aphids predators of central Florida. Florida Entomol., 11, 49-52.

_____ and F. J. Simmond. 1965. A catalogue of the parasites and predators of insect pests. Section 4, Host predator catalogue. Commonwealth Agril. Bur. Comm. Ins. Biol. Cont. 67 pp.

*Timberlake, P.H. 1943. The coccinellidae or lady beetles of the Koebele collection, part I. The Hawaiian plantens Res., 47, 1-67.

*Trivers, R.L. and D. E. Willard. 1973. Natural selection of parental ability to vary sex ratio of offspring Science N.Y. 179, 90-92.

Uvarov, B.P. 1931. Insects and climate, Trans. R. Soc. London 79: 1-247.

Verma, K.L. and A.N. Chawdhury., 1977. Predation on Peach leaf curl aphids, Brachycaudus helichrysi (Kalt.) by Coccinellia Septempunctata. Indian J. Ent. 37(3): 315-316.

Venugopal, M.S. 1977. Some observations on the natural population of A. gossypii Glov. on bhendi and its coccinellids predators. Labdev. J. Sc. Tech. 13(3/4):237-239.

*Volkov, V.F., 1938. C. septempunctata and Adonia variegata. Plant protection, U.S.S.R., 14, 99-101, Rev. Appl. Entomol., 26, 353-54.

*Wang, T.S., H.C. Zhong., Chau. Ck., CY, OUO, F. 1977. Observations and reproduction of Coccinella septempunctata. Acta, Entomol. Kenking, Inst. Zool., Academic Sinika. China.

*Watson, W.Y. 1956. A study of the phylogeny of genera of the tribe Coccinellidae (Col) Contrib. Roy, Ontario Museum, Div. Zool. Paleontol., 42, 52 pp.

*White, M.J.D. 1973. Animal cytology and evolution 3rd. edn. Cambridge Univ. Press, Cambridge and London 961 pp.

Wigglesworth, V.B. 1955. The principles of insect physiology ELBS ed. of 7th Ed. Chapman and Hall Ltd. 827 pp.

Willcocks, F.C. 1925. The insects and related pests of Egypt (Cairo).

_____ and S. Bhagat. 1936. The insects and related pests of Egypt. Insects and mites injurous to the cotton plant. Royal Agric. Soc. 1(11):791.

Wolcott, N. 1960. Efficiency of lady beetles (Coccinellidae: Coleoptera) in insect control. J. Agric. Univ. P. Rico, 165-172.

*Yakhontov, V.V. 1965. Diapause in Coccinellidae of Central Asia. Proc. Symp. Liblice near Praha.

*Zwolfer, W. 1931. Studies Zur Oekologie and Epidemiologie der Insecten. I Die kieferneule Panolis flamea, Schiff., Zfacjr. f. angew. Ent., 17:475-562.

*Not seen in original