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FACTORS CAUSING SEASONAL DECLINE IN *CHILOCORUS BIPUSTULATUS* L. [*COCCINELLIDAE*] IN CITRUS GROVES IN ISRAEL (*)

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Dissection of *Chilocorus* females collected in citrus groves at different times of the year reveals a considerable decline in ovogenesis during mid-summer and winter. This decline is not an innate character of the summer or winter generation beetles but is caused by climatic factors, so should not be expressed as aestivation or hibernation. Decreased ovogenesis seems to be the main factor governing *Chilocorus* population decrease during summer. Changes in photoperiod do not hinder egg laying or induce any diapause. *Chilocorus bipustulatus* represents in Israel a potentially multivoltine species whose reproduction during mid-summer or winter is simply slowed down due to unfavorable conditions.

Chilocorus bipustulatus is well known throughout the palearctic region as a polyphagous predator of scale insects (BODENHEIMER, 1951). It is also one of the most frequent and widely distributed Coccinellids in citrus groves in Israel (KEHAT & GREENBERG, 1970). The biology and phenology of this insect have been studied thoroughly in Israel, but the information which has accumulated concerning its field ecology and beneficial value is somewhat contradictory. Early reports concluded that *Chilocorus* is common only in the spring and is extremely scarce throughout the summer, thus being an inefficient predator (HECHT, 1936; BODENHEIMER, 1951). Recent reports stated that though a considerable decline of the population takes place during the second half of the summer, *Chilocorus* may by no means be regarded as extremely scarce throughout the summer and is of considerable value in controlling scale insects (AVIDOV & ROSEN, 1965; AVIDOV & GERSON, 1963; ROSEN & GERSON, 1965; BEN-DOV & ROSEN, 1969; KEHAT, 1968; NADEL & BIRON, 1964). It is a question whether these controversial conclusions are the result of improved physical and ecological conditions in citrus groves (HODEK, 1967) or of misinterpretation of data. However, there is a general agreement

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as to the fact that the *Chilocorus* population declines in the summer (whether in the first or second half) as well as during the winter. The present study was aimed at a better understanding of the factors contributing to population decline of *Chilocorus* during summer and winter.

Materials and Methods

In order to determine the reproductive activity, *Chilocorus* females which had been collected at various times and in different citrus groves were investigated. Insects were left in alcoholic Bouin for 24 hours and then dissected. For each sample, the percentage of females with well-developed ovaries was calculated. Results are presented as the average of monthly percentages obtained from different groves.

Samples of live beetles were brought to the laboratory and supplied with coccids (Florida red scale, *Chrysomphalus aonidum* L. or California red scale, *Aonidiella aurantii* MASK.) and high temperature (28 °C). After 10 days the beetles were dissected and the percentage of ovipositing females was recorded. Thus knowledge was gathered whether any decrease in reproductive activity in the field is due to aestivation or hibernation or simply a quiescence resulting from unfavorable conditions in the grove.

Laboratory studies were conducted to determine the possibilities of inducing diapause in this insect. Groups of larvae and their emerging adults were reared under different photoperiods (white light, T.L. 6 W lamp) and the percentage of ovipositing females in each combination was recorded.

Temperature as a factor contributing to reduction of reproductive activity during summer was examined by caging groups of laboratory-reared adults under controlled temperatures (28°, 32°, 35°C) and humidity conditions (60 % R. H.) for 30 days. The percentage of adults which survived, and the egglaying per female, were recorded. The survival capacity of *Chilocorus* adults under temperature and humidity extremes, as compared to that of two other Coccinellids, was studied by calculating their mortality rates at different combinations of temperature, time exposure and humidity. Similarly, the survival capacity of the different stages of *Chilocorus* was recorded. For further details, see KEHAT, 1967 b.

Results

Dissection of females collected in citrus groves at different times of the year showed that there is a peak of mature females (those with well-developed ovaries) during the spring and early summer followed

by a considerable decline during July. A slight rise in the percentage of mature females was detected during August-September followed by an additional decrease during October-December; from January on this percentage increased gradually (Fig. 1). Oviposition of hibernating field-collected or field-reared adults, caged in the grove during the winter, started in February.

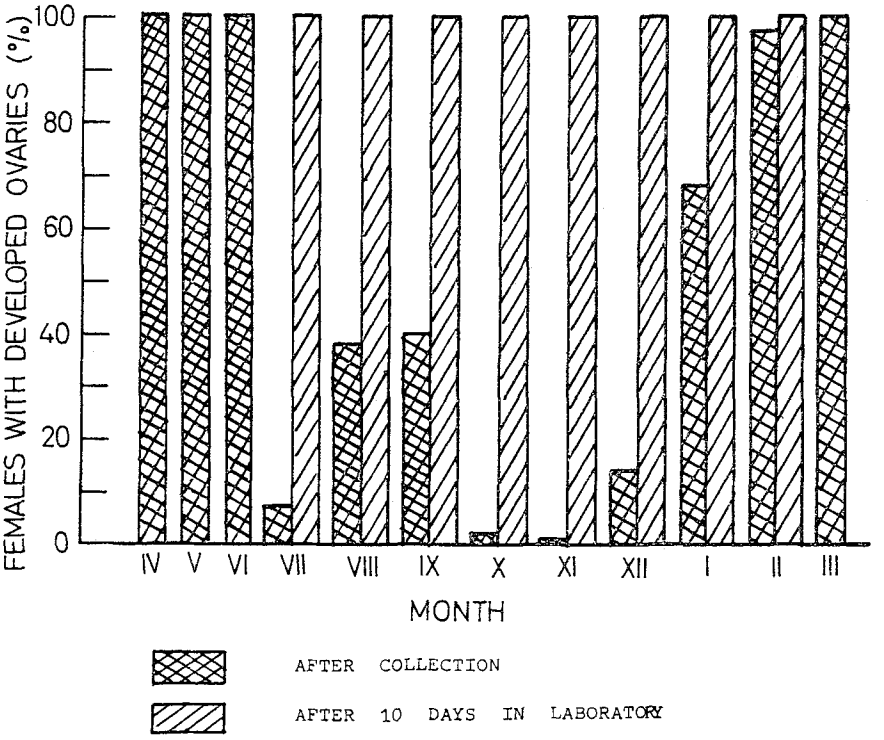

FIG. 1. Monthly average (%) of females of *C. bipustulatus* with developed ovaries.

Beetles which were collected during mid-summer or winter began to lay eggs after they were brought into the laboratory and provided with coccids at a high temperature (28 °C). Dissection of the beetles after 10 days in the laboratory showed a high percentage of mature females as compared to the low percentage occurring originally in the field (Fig. 1). Changes in photoperiod, either at high (28 °C) or low (20 °C) temperatures, did not induce any diapause in laboratory-reared or field-collected females. Darkness, constant light and different combinations of photoperiods and temperatures did not prevent oviposition (Table 1).

TABLE 1

The photoperiods tested, at 28 °C and at 20 °C, which resulted in 100 % oviposition of *C. bipustulatus* (Each photoperiod was tested on 20 individuals; dissection of females was done after 7-8 days at 28 °C, and after 15 days at 20 °C)

Egg to pupa	Adult
darkness	darkness
	8 h light
	16 h light
	24 h light
8 h light	darkness
	8 h light
	16 h light
	24 h light
16 h light	darkness
	8 h light
	16 h light
	24 h light
24 h light	darkness
	8 h light
	16 h light
	24 h light

TABLE 2

The effect of temperature on the survival and egg laying of *C. bipustulatus* during the first 30 days in the laboratory (R. H. 60 %)

Temp. (°C)	No. of beetles examined		Egg laying		Survival (%)	
	Males	Females	Egg/female	Egg/female/day	Males	Females
35	26	15	34	1.1	0	6.6
32	13	12	272	9.0	92.3	83.3
28	17	25	263	8.8	94.1	92.0

Egg production and survival rates dropped considerably at 35 °C (Table 2). The low degree of adaptation of *Chilocorus* adults to temperature and humidity extremes, as compared to two other Coccinellids, is presented in Fig. 2. At extreme high temperatures, which permit only a very short life span (few minutes), survival of the other two Coccinellids examined was greater at low than at high relative humidities (Fig. 2b); at lower temperatures, which permit a longer life span, mortality was higher at low relative humidities (Fig. 2a)

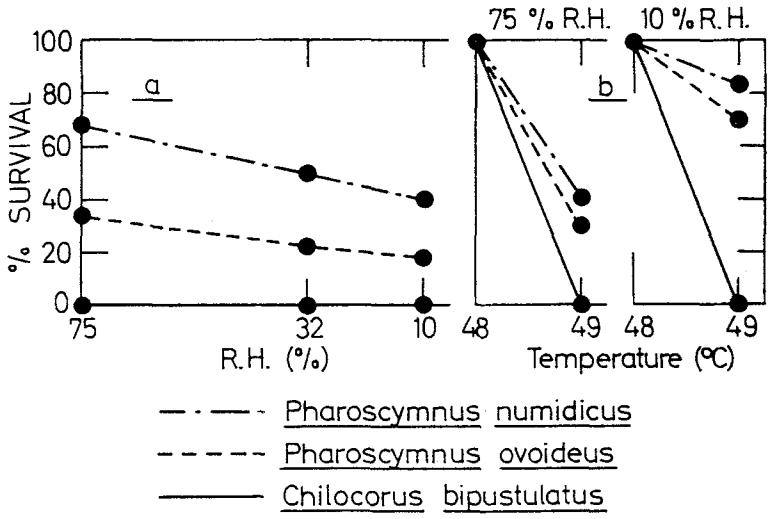

FIG. 2. The effect of extreme temperatures and relative humidities on the survival of adult *C. bipustulatus*, *Ph. numidicus* and *Ph. ovoideus*. (a) 60 minutes' exposure at 47 °C (the line for *C. bipustulatus* being coincident with the abscissa); (b) 10 minutes' exposure at 48 °C and 49 °C. Each dot represents a mean value calculated from four replicates of ten individuals.

The survival capacity of the different stages of *Chilocorus* under temperature and humidity extremes is seen in Fig. 3. Newly hatched larvae, before feeding, were the most susceptible to such extremes; first instar larvae after one day of feeding were more resistant; adults and particularly eggs were the most resistant. All stages survived exposures of 4 hours at 40 °C at all humidity levels.

Discussion

The results of decrease in ovogenesis are in accordance with the field studies showing a decline of *Chilocorus* population (decrease in presence of eggs and larvae) during mid-summer and winter, but are contrary to reports that *Chilocorus* is extremely scarce all summer. The variations in summer in the percentage of mature females in different groves may result from differences in susceptibility of beetles to various macro- and microclimatic conditions prevailing in the groves.

The factors contributing to the summer decline of *Chilocorus* populations have been discussed. Scarcity of scale insects during summer was supposed to be a factor contributing to this decline (BODENHEIMER, 1951). This has been questioned (ROSEN & GERSON, 1965) in view of the fact that most of the trunks and main limbs of citrus trees are heavily infested with live diaspidid populations

throughout the summer. The fungus *Hesperomyces virescens* THAXT., which was found to attack adult *Chilocorus* in Israel, was suspected of being another factor contributing to late summer decline (KAMBUROV, NADEL & KENNETH, 1967). This should also be questioned, in view of the fact that a decrease in *Chilocorus* populations occurred in citrus groves where this fungus was completely absent. The presence of variable populations of natural enemies of *Chilocorus*, as indicated by YINON (1969), also could not be the answer to this decline, in view of their seasonal fluctuations and relatively low population densities. Low fecundity of the summer generations, as pointed out by HECHT (1936) and by BODENHEIMER (1951), and as proved in the present study by dissecting field-collected beetles, seems to give the explanation of the population decline during the summer. The reduction in ovogenesis during the summer is not an innate character of the summer generation beetles but is brought about by climatic factors, and should not be expressed as aestivation but simply as a reduction in reproductive activity.

The low degree of adaptation of *Chilocorus* to temperature extremes is well illustrated in laboratory studies when its survival rates (Figs. 2, 3) and reproductive ability (Table 3) are compared to those of other Coccinellids (KEHAT, 1967 b). The *Chilocorus* population is considerably higher in mature, wellshaded groves of citrus (ROSEN & GERSON, 1965) or date palm (KEHAT, 1967 b) as compared to young, more exposed groves. Moreover, its distribution in citrus groves in the warmer areas is somewhat restricted (KEHAT & GREENBERG, 1970), and it is entirely absent in date palm plantations in the hottest area of the country (KEHAT, 1967 a). These facts agree with the results of the present study. However, further studies should be made to determine whether temperature extremes or scarcity of suitable food is the factor contributing to the decrease in ovogenesis.

Since reproduction of *Chilocorus* during spring and early summer is intensive and results in a considerable adult population increase, the following summer generations — due to a decrease in reproductive activity — do not contribute much to a further increase in the population. The decrease in the adult population in the late summer as pointed out in many reports is therefore probably due to the natural mortality of old age rather than to any damage inflicted upon the existing adult population.

Hibernating females did not oviposit during winter, but they started to oviposit when transferred to the laboratory, indicating quiescence but not diapause. Similar results were recorded concerning *C. bipustulatus* L. (HECHT, 1936), *C. stigma* SAY (MUMA, 1955), *C. fraternus* LECONTE (DREA, 1956) and *C. kuwanae* SILVESTRI (NOHARA, 1962). Different photoperiods applied to larvae or adults did not hinder egg laying or induce diapause (Table 2). Thus, *C. bipustulatus*

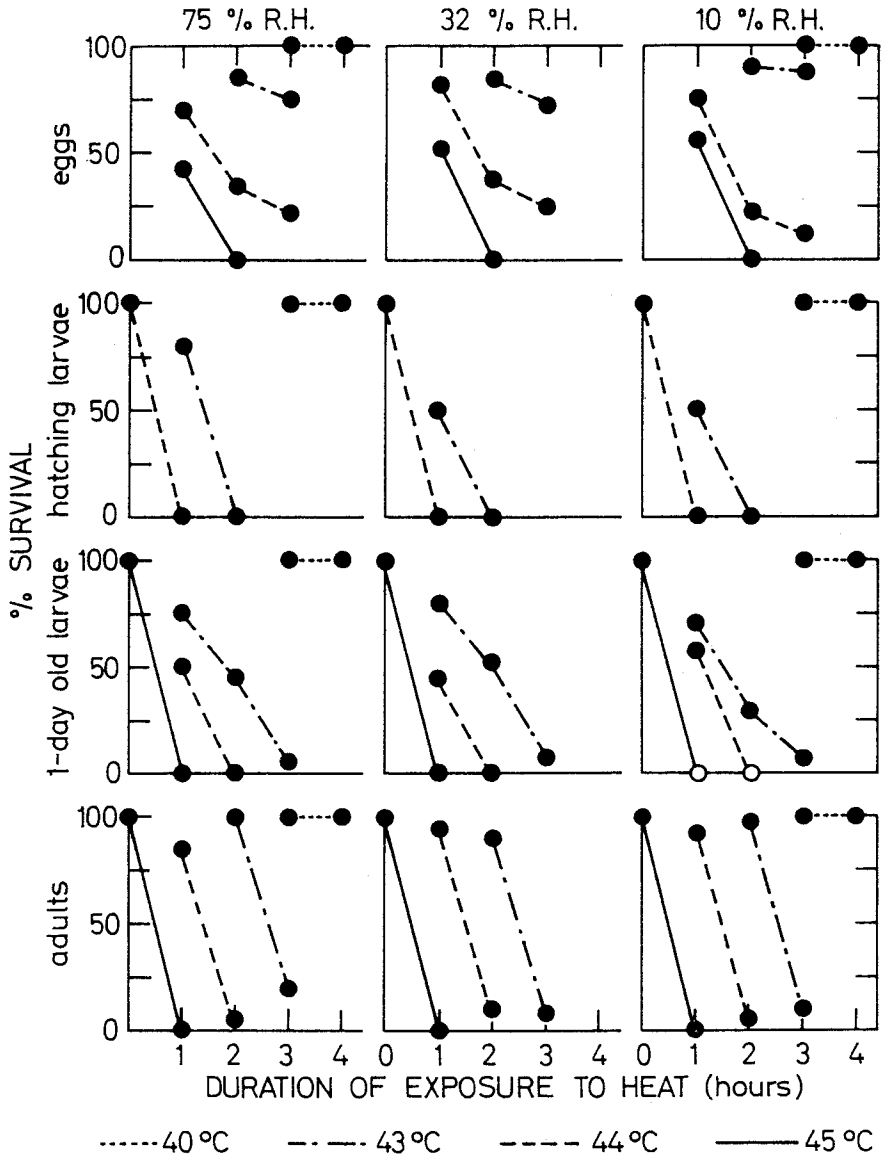

FIG. 3. The effect of high temperatures and of different relative humidities on the survival of different stages of *C. bipustulatus*. Each dot represents a mean value calculated from four replicates of ten individuals.

as many other coccinellids in the temperate zones (HAGEN, 1962), shows a slight tendency toward dormancy but not to diapause. This species thus represents, in Israel, a potentially multivoltine species whose reproduction during midsummer and winter is simply slowed down due to unfavorable conditions.

RÉSUMÉ

Études sur la biologie et le voltinisme de
Chilocorus bipustulatus [*Coccinellidae*]
dans les plantations d'agrumes d'Israël

Des dissections de femelles de *C. bipustulatus* collectionnées au cours de l'année dans des plantations d'agrumes, ont indiqué un déclin de l'ovogenèse au milieu de l'été et durant l'hiver. Ce déclin n'est pas un caractère héréditaire des générations d'été ou d'hiver de ce Coléoptère; il est déclenché par des facteurs climatiques et ne doit pas être considéré comme une estivation ou une hibernation. Des changements dans la photopériode n'empêchent pas l'oviposition et n'induisent pas la diapause. *C. bipustulatus* est une espèce potentiellement multivoltine en Israël dont la reproduction au milieu de l'été ou durant l'hiver est simplement ralentie par des conditions défavorables.

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