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ADULT DIAPAUSE IN THE PREDACEOUS COCCINELLID, *CHILOCORUS BIPUSTULATUS*: PHOTOPERIODIC INDUCTION*

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Abstract—Investigations were conducted on the interaction of temperature and photoperiod on the incidence of adult diapause in *Chilocorus bipustulatus*. The threshold of induction in the southern strain investigated is adapted to a shorter photophase and lower temperature than has been reported in the literature for northern strains. A 10 hr photophase at 22°C, or 14 hr photophase at 18°C, prevents diapause induction.

INTRODUCTION

THE ARMOURED-SCALE lady-beetle, *Chilocorus bipustulatus* (L.), recognized throughout the palearctic region as a polyphagous predator of scale insects (AVIDOV and HARPAZ, 1969), is commonly encountered in the citrus groves of Israel. Its biology was first investigated in this area by HECHT (1936) and subsequently by ROSEN and GERSON (1965) and KEHAT (1968).

Reproductive dormancy is characteristic of most coccinellids (HAGEN, 1962) and is manifested by the absence of oögenesis or arrest during its early stages, and by distinct changes in various physiological functions and biochemical activities (BECK, 1968).

Photoperiod was reported to be the primary factor in the induction of adult diapause in a geographical isolate of *C. bipustulatus* from Soviet Central Asia (ZASLAVSKII and BOGDANOVA, 1968). At temperatures below 24°C and under short-day conditions, adult diapause intervened. The maximum photoperiod which afforded total diapause was 14 hr at 20°C. Above 24°C, diapause was averted even under short photoperiods of 9 and 11 hr. The experiments reported herein were designed to assess the response of a geographical isolate from Israel to varying photoperiods and temperatures and to corroborate induction of diapause by respiratory data.

MATERIALS AND METHODS

Maintenance of stock culture

The *C. bipustulatus* larvae and adults were the progeny of beetles collected in citrus groves in the coastal plain of Israel and were reared in plastic cages under

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constant illumination, 28°C and 70% r.h., on the California red scale (*Aonidiella aurantii*). Heavy infestations of these scale insects were separately reared in our laboratory on potatoes at 28°C. An over-abundance of scale insects were presented to the beetles, as inadequate feeding both during the larval development or during adult life, seriously affects fecundity.

Experimental procedure

Newly emerged adults (0 to 24 hr after eclosion) were placed in pairs on single scale-infested potatoes in 0·5 l. glass jars covered with cloth. Strips of white flannel cloth were placed in the jars to facilitate oviposition. The jars were placed in either constant-temperature incubators under various photoperiodic regimens, or in environmental cabinets (Percival; Boon, Iowa) programmed for both photoperiod and thermoperiod. The degree of illumination given in the various experiments (measured with a Gossen light meter) was as follows: 18 and 22°C regimens—60 lux, 8 to 20°C regimens—7600 lux, and the 28°C experiment—190 lux.

Observations were carried out every 1 to 2 days and deposited eggs were removed to ascertain hatching and minimize cannibalism. Biological observations were carried on during 30 to 35 days, after which respiration was determined.

Respiratory studies

Oxygen consumption and carbon dioxide release of individual adult beetles were measured by a gas-chromatographic micromethod (TADMOR *et al.*, 1971) which is based on initial separation of air from CO_2 on a column of Porapak Q and subsequent separation of oxygen from nitrogen on molecular sieve 5A. Respiration was measured for 3 hr at 32°C, and respiratory quotients were calculated from the measurements obtained.

RESULTS AND DISCUSSION

Diapause induction

C. bipustulatus female adults enter into a state of reproductive dormancy at low temperatures and under short-day conditions (Table 1). The temperature of 18°C, in which this dearth of oviposition was induced, is not limiting as a temperature threshold, as a long 14 hr photophase at 18°C does afford a normal level of fecundity. A short photophase of 10 hr at 22°C, which would induce diapause in the northern isolate, had no detrimental effects on the Israeli strain. A programmed thermoperiod (experiment I) under short photophase, affected the level of oviposition more than did a constant temperature regimen (experiment II) but did not significantly affect the incidence of diapause, as expressed in the percentage of ovipositing females.

It was anticipated that a southern strain of *C. bipustulatus*, endemic to the eastern Mediterranean area, might differ in its response to photoperiod and thermoperiod from the more northern isolate of this beetle investigated in Soviet Central Asia (ZASLAVSKII and BOGDANOVA, 1968). Indeed, the results presented

herein indicate that the local *C. bipustulatus* population enters diapause only at much lower temperatures and photophases than has been reported for the northern strain. This is consistent with the view that geographical strains adapt their threshold of response to local climatic conditions (DANILEVSKII, 1965).

TABLE 1—EFFECT OF PHOTOPERIOD AND THERMOPERIOD ON OVIPOSITION OF *C. bipustulatus* BEETLES

Experiment	Thermo- and photoperiodic regimen		No. of replicates	Average No. of eggs/female	Females oviposition (%)	Average preoviposition period (days)
	Larva	Adult				
I	24 L; 28°C	14 D; 8°C 10 L; 20°C	11	1·4	45·5	21†
II	24 L; 28°C	14 D; 18°C 10 L; 18°C	10	5·6	60·0	17
III	14 D; 18°C 10 L; 18°C	14 D; 18°C 10 L; 18°C	11	0·9	0·9	21†
IV	24 L; 28°C	10 D; 18°C 14 L; 18°C	14	61·3*	92·8	14
V	24 L; 28°C	14 D; 22°C 10 L; 22°C	7	72·5*	100	10

D = Scotophase. L = Photophase.
* Significantly different from experiments I, II, III ($P<0·01$).
† Significantly different from experiments IV, V ($P<0·01$).

C. bipustulatus exhibits cumulative sensitivity to diapause induction during its development and the incidence of diapause is almost total in adults which had been reared throughout their larval and pupal development under short-day and low temperature conditions (experiment III).

Preoviposition is lengthened under conditions which induce diapause.

Similar trends are evident with larval diapause of *Pectinophora gossypiella* (ANKERSMIT and ADKISSON, 1967) and adult diapause of the coccinellid *Chilocorus renipustulatus* (PANTYUKHOV, 1968).

Respiration studies

The respiratory rates and quotients of beetles in a state of adult diapause were compared to similar values obtained and calculated for non-diapausing individuals (Table 2). No significant differences were noted in the respiration of male beetles. This is consistent with the stated absence of diapause in adult males (BECK, 1968).

TABLE 2—RESPIRATION OF ADULT *C. bipustulatus* UNDER VARIOUS PHOTOPERIODIC REGIMENS

Thermo- and photo-periodic regimen*	Males					Females				
	No. of replicates	Average weight (mg)	μl/mg weight per hr		RQ	No. of replicates	Average weight (mg)	μl/mg weight per hr		RQ
			O_2	CO_2				O_2	CO_2	
I	13	8·0	1·14 ± 0·14†	0·91 ± 0·12	0·80 ± 0·13	14	9·0	1·22 ± 0·27	0·92 ± 0·09	0·75 ± 0·16
II	10	5·6	1·42 ± 0·30	0·94 ± 0·12	0·66 ± 0·08	9	6·9	1·25 ± 0·35	0·89 ± 0·18	0·71 ± 0·08
IV	13	7·2	1·49 ± 0·11	1·04 ± 0·10	0·69 ± 0·04	13	8·5	2·04 ± 0·32 ‡	1·36 ± 0·25 §	0·67 ± 0·05

* Details of coded thermo- and photoperiodic regimens are same as in Table 1.

† ± Standard deviation.

‡ Significantly different from O_2 consumption of females in experiments I and II ($P < 0·01$).

§ Significantly different from CO_2 release of females in experiments I and II ($P < 0·01$).

The respiratory rate is significantly lower in diapausing females than in non-diapausing ones. The low RQ (0·7) suggests that fat reserves serve in these female beetles as sole substrate for energy production.

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