

Activity and predation of *Coccinella septempunctata* adults in the field (Col., Coccinellidae)

By A. HONĚK

Abstract

Different types of activity of *C. septempunctata* adults, and their dependence on temperature and sunshine were investigated in stands of alfalfa, spring barley and bean. The behaviour was checked in approximately 2 h intervals, between 600 and 1900 h. The activity depended on temperature and degree of satiation. Active movement was observed above 13–15 °C, and its intensity increased with temperature. In non-satiated coccinellid populations (on alfalfa and barley with sparse aphid populations, in May) female and male movement was of equal intensity, being apparently motivated by food searching. In satiated populations (on bean with large aphid colonies, in June) female movement was nearly zero, and male walking activity was motivated by the searching for mates. The frequency of copulations was proportionate to the activity. In satiated populations, predation was observed in individuals sitting on plants near aphid colonies. With temperature > 17 °C, in average 8 % of them were observed when eating aphids. Body temperature may be increased by heat conduction from warm ground surfaces. This thermoregulation behaviour appeared mostly when surface temperatures were < 30 °C and sunshine was diffuse. The flight occurred at (air) temperatures > 21 °C, under bright sunshine. When aphids are abundant, an average individual may eat more than 40 aphids/day.

1 Introduction

When estimating the effect of predators on natural populations of aphids, the behaviour is an important factor. The efficiency of predators depends on the intensity of their searching activity and voracity, which are determined by environmental conditions. The results of laboratory studies of coccinellid behaviour (e.g. BAENSCH 1964; NAKAMUTA 1983; PANDEY et al. 1984) are not easy to apply in the open, as there the conditions are diversified and change with day time and season. In stands of agricultural crops exist usually a range of microclimatic conditions which offer to coccinellids the possibility of active choice and autoregulation of life processes. The differences between laboratory and field make indispensable the direct observation of predator activity in the open. Such studies, although less precise and more laborious than laboratory ones, may provide a realistic picture of predator activities. We started with observations of field activity of *Coccinella septempunctata* adults.

2 Material and methods

Activity of *C. septempunctata* was observed at Praha-Ruzyně (Central Bohemia), in stands of alfalfa (May 15–22, 1984), spring barley (June 11–29, 1982; May 29–June 3, 1984), and bean (June 9–16, 1983; June 4–8 and 15–22, 1984). Particular crop stands were visited usually 5–7 time a day,

between 600–1900 h (Central European Time). Duration of each observation period was 15–40 min. Following activities of *C. septempunctata* adults were recorded: walking activity on the ground and on plants, siting (basking) on the ground and on plants, copulations, eating of aphids, and flight. The adults were classified as siting when they did not move within 20 s of observation, or as actively moving when they walked or flew within this period. All flights within the observation period were counted, repeated very short flights of the same individual were counted as one flight. In dense stands of alfalfa and barley, activities within the plant stands could not be observed, and only the behaviour in the upper stratum of the stands and on bare ground was recorded. The behaviour was checked visually, either during the definite time or at transect of definite length. The stands were inspected in the direction of incident sunrays (see HONĚK 1982). The observations were quantified as numbers of individuals making given activity per unit time of observation, or per unit length of transect. Only a part of individuals present in an investigated space was observed. The number of adults observed per unit time or space depended on weather and changed by a factor of 2. Therefore the observed numbers were usually converted to proportions of individuals making a given activity, from the total of observed adults.

The temperatures were measured for each observation period, with Hg thermometers with the bulb protected from direct insolation but not from IR radiation of surrounding objects. Measurement was made at places whose temperatures represented the whole range of temperatures available to an individual in the particular stand. Measured were (1) T_{OS} -temperature of bare ground surface, usually the highest temperature available within the stand, (2) T_{SS} -temperature of shaded ground surface under the plant cover, usually the lowest temperature in the stand, (3) T_{SA} -temperature of air at shaded place within a plant stand, 15 cm above soil surface, (4) T_{OA} -temperature of air 15 cm above the bare insolated ground surface. The sunshine intensity was classified into three categories: (1) open sky, bright sunshine, (2) partial to total overcast with diffuse sunshine, and (3) total overcast without sunshine.

3 Results

3.1 Temperatures within the stands

Local temperatures within crop stands may be very diversified. As an example may serve temperatures in bean stands, June 1983 and 1984 (fig. 1). The diversification of within stand temperatures depended on weather. On overcast days the range of available temperatures did not exceed 1–2°C, and was close to air temperatures measured by standard meteorological methods. On sunny days the range of temperatures simultaneously available in the stands increased. The greatest differentiation of local temperatures was observed between 1200–1500 h, when differences between the lowest and highest temperatures were up to 17°C. The temperatures of insolated ground surface (T_{OS}) exceeded 40°C, but temperatures below 30°C were available somewhere in the stands at every time. Convenient temperatures (25–30°C) were available between 700–1800 h.

3.2 Locomotory activity

The criterion of locomotory activity was the proportion of walking individuals in the population. The intensity of locomotory activity increased with temperature. At temperatures (T_{OA}) above 17°C a fraction of individuals was walking in all cases. Between 13–17°C zero or small (< 10 %) proportion of individuals did move, and the movement ceased below 12–13°C. Thus T_{OA} 15°C may be assumed the average temperature for the start of walking activity.

The increase of the locomotory activity with temperature was greater in populations of stands with low abundance of aphids ("hungry populations"; on alfalfa and barley, in May), than in populations from stands with high abundance of aphids ("satiated populations"; bean with large aphid colonies, in June). The former populations consisted of individuals whose gonads

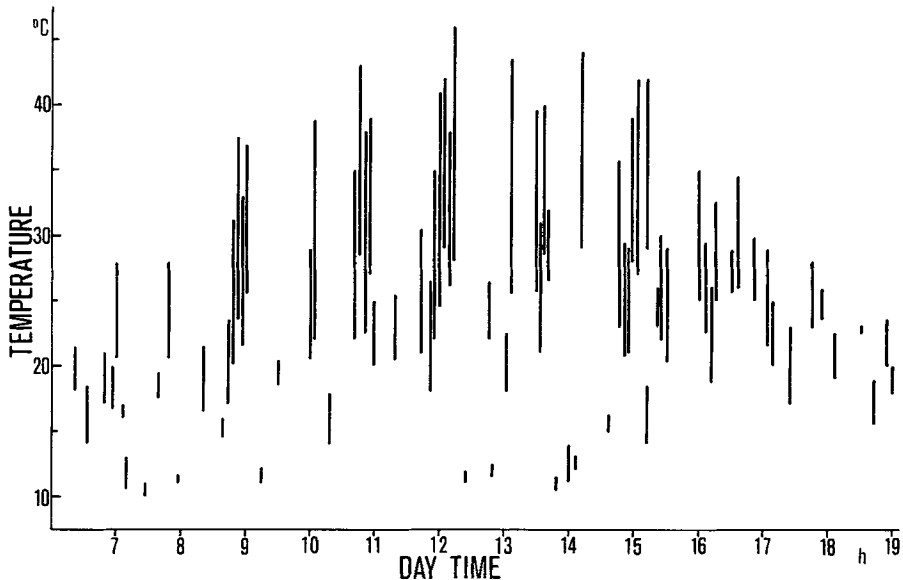


Fig. 1. Diversification of microclimatic temperatures in bean stands in different day time. Measured on June 9–16, 1983, June 4–8 and 15–22, 1984. Every bar represent the range of temperatures available in a stand at a given moment

(female ovaries) were not ripe due to low prey density, while the latter ones were ready to reproduce (cf. HONĚK 1978, 1980). In hungry populations (fig. 2) the intensity of movement increased steeply with temperature (the slope of regression line $b = 3.86$). The walking activity of males was the same as in females, no departure from 1:1 sex ratio was observed among the searching individuals (table). The activity was apparently motivated by the search for food.

In satiated populations (fig. 3) the increase of activity with temperature was less pronounced ($b = 2.43$, statistically different from the former one at $p < 0.01$). The decrease of overall locomotory activity was caused by the fact that a great proportion of females did not walk, even at high temperatures. They preferred sitting on ground (in the morning) or on plants (during warm period of the day). Thus at temperatures (T_{OA}) above 20°C among active individuals there were about 80% of males while among sitting ones 60–70% of females (table). Under low temperatures ($T_{OA} \leq 20^{\circ}\text{C}$) the activity of both sexes was not different. As the food was available without searching (aphid colonies of several thousands of individuals were present on most plants) the locomotory activity of males had apparently a motivation other than search for food, perhaps the search for mates. This assumption was confirmed by the observation that walking males frequently touched aphids but did not attack or eat them; on the other hand, attempts at copulation after encounters with females were frequent.

The second parameter of locomotory activity was the velocity of movement. This was measured in a hungry population on barley, 1982. The range of walking speeds was large, 0.17–2.25 cm/s, average of 70 observations was 0.97 ± 0.55 cm/s. Although there was a general increase of walking speed with temperature (fig. 4), this trend was not statistically significant due to large

variation of walking speeds at temperatures (T_{OA}) between 15–20°C. This low dependence on air temperature was caused perhaps by thermoregulation at ground surface which enabled to increase body temperature in morning hours when T_{OA} was still low.

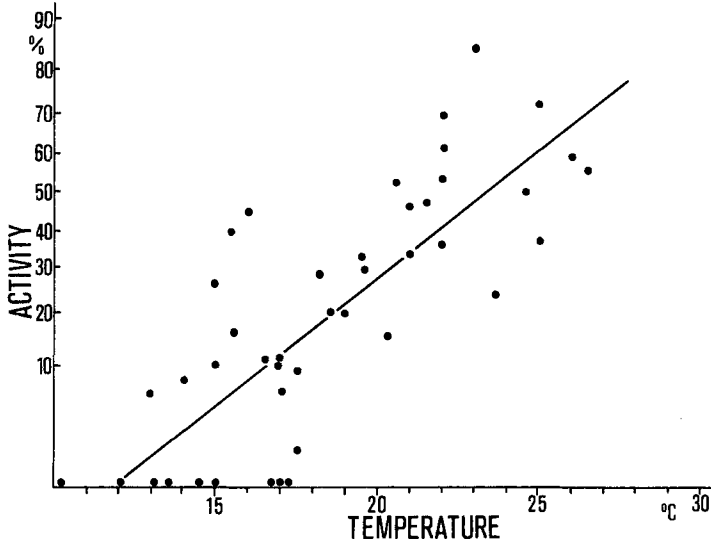


Fig. 2. The relation between temperature (T_{OA}) and proportion of individuals walking on the ground and the plants from total adult population (activity) in "hungry" populations of alfalfa (May 15–22, 1984) and barley (May 29–June 3, 1984). Regression line: $y = 3.86x - 45.24$; $r = 0.769$

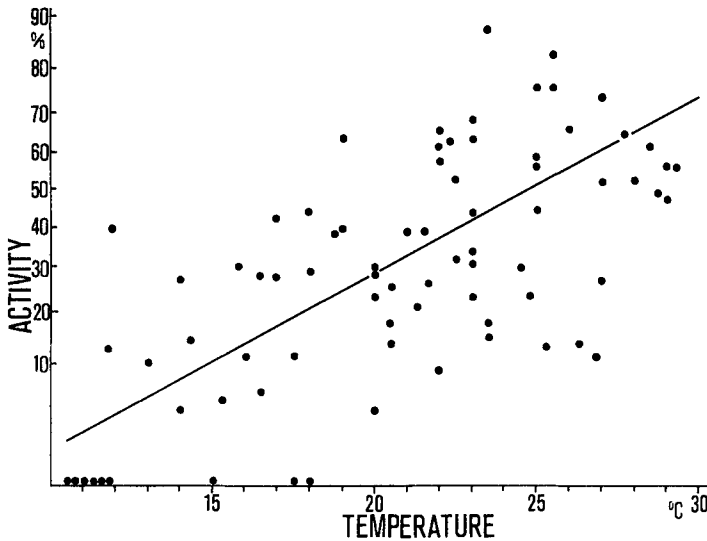


Fig. 3. The relation between temperature (T_{OA}) and proportion of individuals walking on the ground and the plants from total adult population (activity) in "satiated" populations of bean (June 9–16, 1983; June 4–8 and 15–22, 1984). Regression line: $y = 2.43x - 18.09$; $r = 0.692$

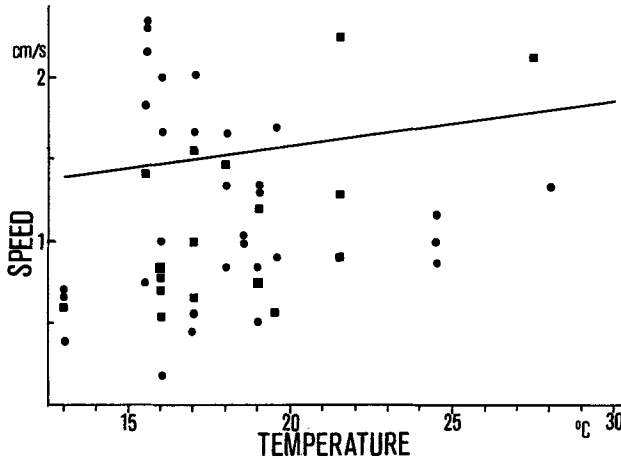


Fig. 4. The velocity of individual movement in relation to air temperature (T_{OA}) in barley, June 11–29, 1982. Regression line: $y = 0.03x + 1.04$; $r = 0.036$. ● males, ■ females

The proportion of walking and sitting individuals in “hungry” and “satiated” populations of *C. septempunctata*

Population	T	walking		sitting	
		males n (%)	females n (%)	males n (%)	females n (%)
hungry ^a	15–27 °C plants	44 (50.0 %)	44 (50.0 %)	107 (47.6 %)	118 (52.4 %)
satiated ^b	≤ 20 °C ground	2 (100.0 %)	0 (0.0 %)	2 (50.0 %)	2 (50.0 %)
	plants	7 (41.2 %)	10 (58.8 %)	82 (52.2 %)	75 (47.8 %)
	> 20 °C ground	111 (84.7 %)	20 (15.3 %)	35 (42.7 %)	47 (57.3 %)
	plants	286 (82.1 %)	62 (17.8 %)	90 (22.5 %)	310 (77.5 %)

^a alfalfa, May 18–19, 1984; ^b bean, June 18–22, 1984.

3.3 Distribution of different activities

A detail picture of the daily distribution of activities on bean (fig. 5) showed that different kinds of activities had not linear distribution with respect to temperature and were asymmetrically distributed with respect to day time (morning activity was not the same as the evening one, even by the same temperature). Locomotory activity at ground surface (fig. 5A) was highest at medium temperatures (T_{OA}), between 1100 and 1700 h. It was low in the morning and in the evening, and both at low and high temperatures. Resting at the open ground (“basking”) (fig. 5B) was highest at low and medium temperatures with sunshine, but its distribution in time was asymmetrical: more individuals basked in the morning (600–1200) than in the afternoon (1500–1900 h). Locomotory activity on plants (fig. 5C) complemented the ground locomotory activity: it was highest in warm days between 900 and 1500 h, and also in the morning and in the afternoon. Resting on plants (fig. 5D) was most frequent in morning and late afternoon. This type of activity had two scopes: the exposition of the body to the sunshine when the elevation of

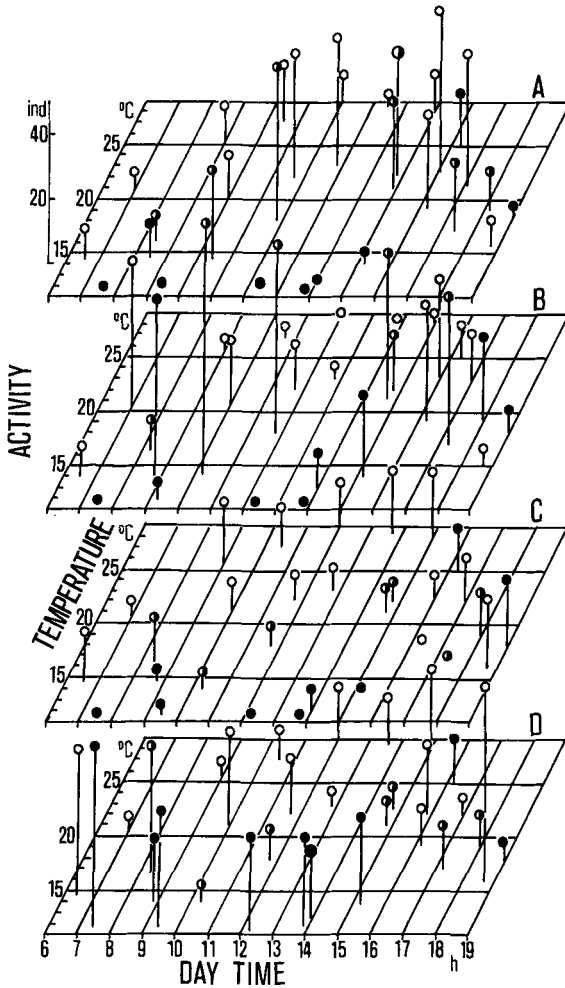


Fig. 5. Different types of adult activity in relation to day time and temperature (T_{OA}). The no. of individuals observed per 100 m transect by visual counting, bean, June 4–8, 1984. A = walking at the ground surface, B = sitting at the ground surface, C = walking on plants, D = sitting on plants. For explanation of \circ symbols, see fig. 6

the sun was low (i.e. “basking”), and sheltering within plant structures during bad weather or extremely high temperatures. With extremely high temperatures, the plants, due to transpirative cooling, were perhaps the coolest objects available in the stand.

3.4 Thermoregulation

The exposition of body on warm ground surfaces (thermoregulative “basking”) enabled to increase the body temperature by heat conduction from surfaces of appropriate temperature. The proportion of

basking individuals in total population (fig. 6) depended on temperature of ground surface (T_{OS}) and intensity of sunshine. The basking was highest at T_{OS} between 17 and 28 °C, decreased sharply between 29–38 °C, and ceased above 39 °C. Also at T_{OS} 17 °C and overcast sky the ground surface was not warmer than other places in the stand, and no basking was observed. The proportion of basking individuals was greater when the sky was slightly clouded and the sunshine was diffuse than under bright sunshine. Heat conduction from ground surface was then the only way how to increase body temperature since the sunshine was not sufficiently intensive to enable the increase of body temperature by exposition to sun radiation. As the basking activity was largely reduced at T_{OS} above 30 °C, we may assume this temperature as an upper limit of preferred body temperatures.

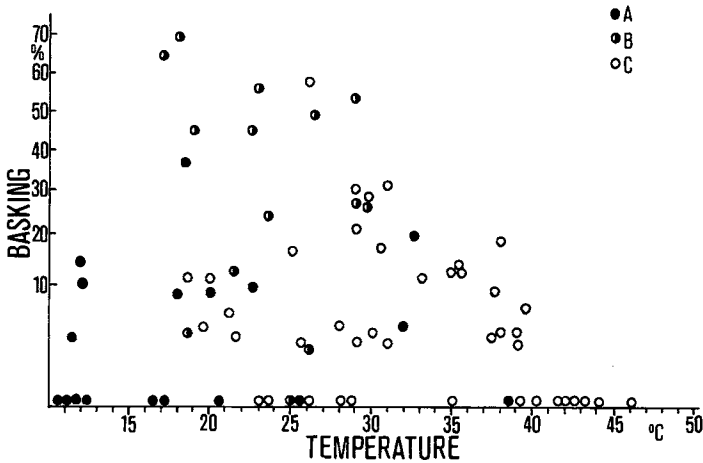


Fig. 6. Thermoregulation activity. Proportion of adults siting at sun-exposed ground surface in relation to temperature of this surface (T_{OS}), bean, June 4–8, 1984. A = overcast, B = partial overcast, diffuse sunshine, C = bright sunshine

3.5 Predation

In stands with low aphid abundance the encounters between coccinellids and aphids were rare, even when the walking activity of hungry coccinellid populations was high. In 1982 barley, after ca 150 minutes of continuous observation of different searching individuals, only two encounters followed by a successful attack on aphid were observed.

In satiated coccinellid populations, eating of aphids was frequently observed among individuals siting on plants, near or within dense aphid colonies (fig. 7). The eating of prey was observed at temperatures (T_{OA}) above 17°C, and the proportion of individuals eating prey in the population did not significantly increase with temperature. It also did not depend on the intensity of sunshine. In 1983 barley, in average 8% of individuals siting on plants was observed when eating aphid. As the females prevailed among siting individuals (table), the rate of predation in females was apparently higher than in males. The latter spent more time in movement and searching for mates. In observed cases, the mean time for capture and eating prey was 1.37 min.

3.6 Copulation

Copulating pairs were observed both on ground surface and on plants. The copulations occurred mostly after an encounter of two walking individuals or a walking male with a siting female. The frequency of copulations was therefore proportionate to the intensity of locomotory activity in the population (fig. 8A). Below certain level of activity (about 30% of active individuals) virtually no copulation was observed. As in satiated populations walking individuals were largely males (table), the frequency of copulations depended apparently on male activity. By contrast, copulation activity was not correlated with T_{OA} air temperature (fig. 8B). This was perhaps due to thermoregulative basking on insulated ground surfaces, which enabled activity even at low air temperatures.

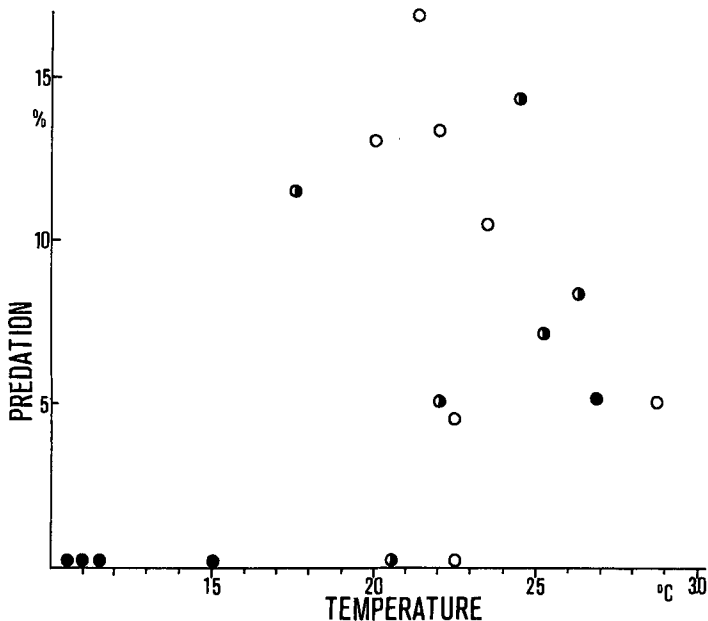
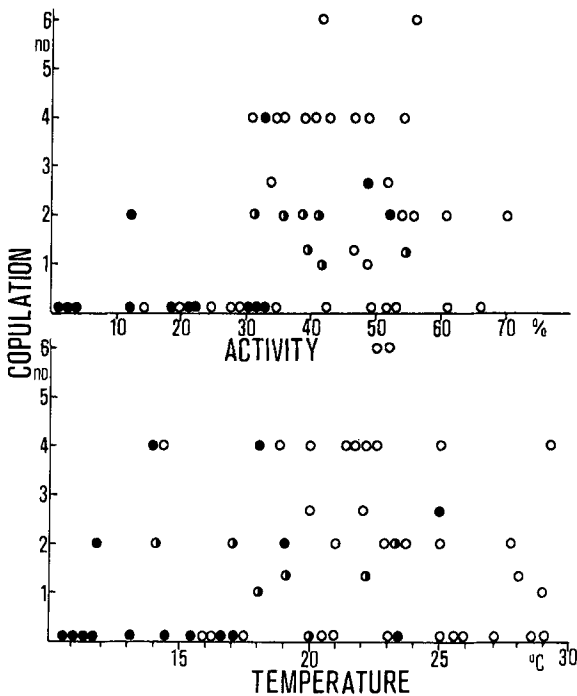


Fig. 7. The proportion of individuals observed when eating aphids among individuals siting on plants (predation). Bean, June 9-16, 1983. For explanation of \circ symbols, see fig. 6



The copulations at low temperatures were also longer and the probability to observe them greater.

3.7 Flight

The flight activity depended on temperature (fig. 9). Flight appeared at temperatures (T_{OA}) above 21°C; this temperature may be

Fig. 8. Number of copulating pairs observed visually per 100 m transect (copulation) in relation to: A = proportion of walking individuals in total adult population (activity); B = temperature (T_{OA}). Bean, June 4-8 and 15-22, 1984. For explanation of \circ symbols see fig. 6

considered a threshold for flight. At above threshold temperatures flight activity varied largely and did not significantly increase with temperature. Flight was observed only on sunny days, while on days when the sky was completely overcast or sunshine was diffuse flight activity was near zero, even when air temperatures were favourable. Among 99 flying individuals investigated on June 19–21, 1984 in bean, 97 % were males. Of three flying females at least one had unripe ovarioles and belonged apparently to the new generation. Flight activity of females was dramatically reduced with sexual maturation.

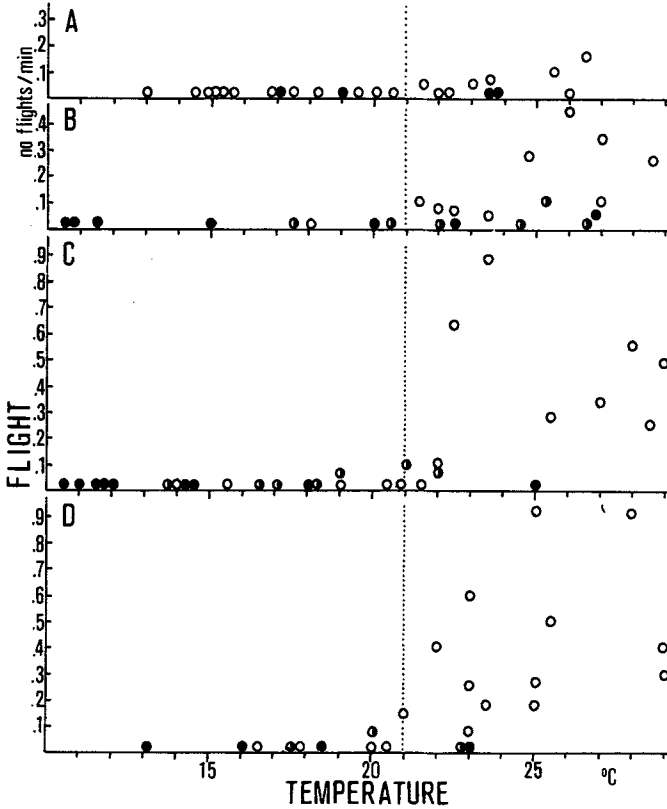


Fig. 9. The number of flights observed per 1 min (flight activity) in relation to temperature (T_{OA}). Dotted line - threshold temperature for flight. A = alfalfa, May 15–18, 1984, B = bean, June 8–16, 1983, C = bean, June 4–6, 1984, D = bean, June 15–22, 1984. For explanation of \circ symbols see fig. 6

4 Discussion

As the coccinellid activity depended on satiation, the predation in hungry and satiated coccinellid populations should be considered separately.

According to the theory (HODEK 1973), it is the initiation phase of growth of aphid populations, when coccinellid populations may effectively control their growth. In this period non-satiated coccinellid adults were motivated by search for food, and searching activity in both sexes depended on temperature.

If the aphids were found after a random encounter with searching coccinellids, the effectiveness of predation could be calculated from our data. As an example of sparse aphid populations we took the re-evaluated data from HONĚK (1980) for alfalfa stands at the time of coccinellid ovariole maturation, May 15–25, 1978. Aphid population density was 0.02–0.08 aphids per alfalfa stem; the length of the trajectory needed for complete investigation of the whole stem surface (calculated as $2 \times$ length of the twigs + sum of perimeters of all leaves) was 3.6–4.8 m per stem. We assumed that (1) it was no perception of prey at distance > 1 cm (STUBBS 1980; NAKAMUTA 1984) and (2) no repeated search at the same leaf or twig (this is a simplification, cf. HODEK 1973). Then the mean distance which should be run by a coccinellid before encountering an aphid was 70.7 m. With mean velocity 0.58 m/min, an encounter would be expected after 2.03 h of searching activity. With continuous movement during some 9 h available for predation per day (from 900 when the dew ceased to 1800 h), about 4.4 aphids per day would be captured. Such consumption would be certainly too low to maintain even basic vital functions. Therefore the above premisses lead evidently to underestimation of coccinellid predation capacity. Assumption of a modified searching strategy (repeated search on some portions of plants and omission of others, cf. HODEK 1973) would hardly alter the results of our calculations substantially. A logical conclusion is that coccinellid search cannot be completely random and some kind of prey perception at distance is to be assumed. With our incomplete information we are not able to calculate real predation rates in stands with sparse aphid populations.

Predation on dense aphid populations in sparse stands (bean) was observed more directly. With a simplification, hourly consumption of an individual sitting on plant near an aphid colony (C) may be estimated from the mean time needed for prey eating ($HT = 1.37$ min), and proportion of individuals observed when eating aphids ($P = 8\%$), as $C = 0.6 P HT^{-1}$. The individual consumption is then 3.5 aphids/h. With 12 h available in days of good weather for predation (600–1800 h), about 42 aphids/day may be eaten by a coccinellid adult, less than the consumption reported in literature (HODEK 1973). In calculating the effectivity of population, one must consider the fraction of total population resting on plants, which is likely to be prepared for predation. In bean stands it was in the average about 50%.

Further observations of *C. septempunctata* behaviour may increase the precision of the quantitative results. However, they should be completed by other methods of investigation of predation effectiveness in the open.

Zusammenfassung

Aktivität und Prädation von Coccinella septempunctata im Freiland (Col., Coccinellidae)

Die Abhängigkeit des verschiedenen Verhaltens der Imagines von *Coccinella septempunctata* von der Temperatur und Sonnenstrahlungsintensität wurde im Freiland in Luzerne-, Sommergerste- und Bohnenbeständen untersucht. Die Beobachtungen wurden am Tage (zwischen 6.00 und 19.00 Uhr) unternommen, und zwar alle 2 Stunden mit einer Beobachtungsperiode von 15–40 Minuten.

Die Aktivität der Marienkäfer wurde durch die Temperatur und den Grad der Sättigung beeinflusst. Die Aktivität begann bei Temperaturen zwischen 13–15°C und nahm an Intensität mit steigender Temperatur zu. In den nichtgesättigten Marienkäferpopulationen war die Laufaktivität der Männchen und Weibchen gleich stark (in Luzerne- und Sommergerstebeständen mit schwachen Blattlauspopulationen im Mai). Sie wurde vornehmlich durch das Aufsuchen der Beute motiviert. Bei den gesättigten Marienkäfern (in Bohnenbeständen mit starken Blattlauskolonien im Juni) wurde Laufaktivität vorwiegend nur bei Männchen beobachtet, während die Weibchen meistens an den Pflanzen in der Nähe von Blattlauskolonien ruhig saßen. Die Aktivität der

Männchen wurde dabei offensichtlich durch die Suche nach einer Kopulationsmöglichkeit motiviert, denn die Anzahl der beobachteten Paarungen stand mit dieser Aktivität in proportionalem Zusammenhang. Ein Beutefangverhalten gesättigter Marienkäfer wurde meistens bei Individuen festgestellt, die sich in der Nähe von Blattlauskolonien befanden. Bei Temperaturen über 17°C wurden durchschnittlich 8% dieser Individuen beim Beutefraß angetroffen. Die Körpertemperatur der Marienkäfer könnte hierbei von der warmen Grundoberfläche gesteigert worden sein. Ein solches thermoregulatorisches Verhalten zeigte sich meist bei Grundoberflächentemperaturen unter 30°C und diffuser Sonnenstrahlung. Der Flug der Käfer wurde bei Lufttemperaturen über 21°C und Sonnenschein beobachtet. Ein durchschnittlich aktives Individuum konnte in Bohnenbeständen mehr als 40 Blattläuse pro Tag verzehren.

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Sterilization induced by precocenes on females of *Blattella germanica* (L.): Short- and long-term effects

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Abstract

The induction of antgonadotropic effects by topical application of title compounds on virgin female adults of *Blattella germanica* is reported. Concerning the short-term effects, natural precocenes (P1 and P2) and the related analogue EP2 inhibited oöcyte growth and colleterial glands development, and in all cases EP2 was the most active compound followed by P2 and P1. However, the recovery of the reproductive capability observed in most cases during long-term experiments suggested that, in this species, damage caused to CA as a consequence of precocene activity does not appear to be irreversible.