ENTOMOPHAGA 42 (1/2), 1997, 119-124

FACTORS DETERMINING WINTER SURVIVAL IN *COCCINELLA SEPTEMPUNCTATA* (*COL.: COCCINELLIDAE*)

A. HONĚK

Research Institute of Crop Production, Drnovská 507, 16106 Praha 6 - Ruzyně, Czech Republic

In 1993-1995, adult *Coccinella septempunctata* L. were sampled at several hibernation sites in the western Czech Republic. The beetles were sexed, assorted into three body size classes and exposed in artificial hibernacula to outdoor conditions, from November to April. Average survival rate was 48.4%. Winter survival was not significantly affected by year, gender or body size. However, there were significant differences between adults from different populations (hibernation sites).

KEY-WORDS: body size, male, female, geographic differences, hibernation site, winter survival.

The hibernation biology of *Coccinella septempunctata* L. has been studied in different parts of the species' geographic distribution (Benkevich, 1958; Hodek, 1960, 1962; Adylov, 1965; Mechtiev, 1967.; Alayeva, 1972; Hodek *et al.*, 1977; Semyanov, 1979; Basedow, 1982; Kreiter & Iperti, 1984; Okuda *et al.*, 1986; Honěk, 1989, 1990). The autumn migration, quality of hibernation site, dormancy and post-hibernation dispersal are well understood, whereas mortality during winter is little studied. This is probably due to difficulty of estimating mortality in natural hibernacula or of establishing artificial hibernacula where winter survival can be studied under controlled conditions (cf. Hodek & Honěk, 1996). In 1993, a study of overwintering survival in *C. septempunctata* was begun using artificial hibernacula that were similar to natural wintering sites. Body size was thought to be the most important factor. Earlier studies (Honěk, 1989) had revealed differences in the quality of *C. septempunctata* individuals from hilltop and lowland hibernacula. Gender, annual variation in quality of the beetles and weather may also affect survival. Therefore, the effects of gender, body size, geographic origin of *C. septempunctata* populations, and year on winter survival, in 1993-4, 1994-5 and 1995-6 were analysed.

MATERIAL AND METHODS

Adult *C. septempunctata* were each year sampled from hilltop hibernation sites (Lesní hřeben, 1 480 m a.s.l. at Krkonoše Mountains, 50°44'N 15°45'E; and Raná hill, 400 m a.s.l. at České středohoří Mountains, 50°24'N 13°46'E) and lowland hibernation sites (Jílové, 300 m a.s.l., 49°58'N 14°16'E, and Praha-Ruzyně 360 m a.s.l. and Přední Kopanina, 350 m a.s.l., 50°06'N 14°15'E). The sample from Pomezní boudy (1100 m a.s.l.at Krkonoše Mountains, 50°43'N 15°46'E) was from an hibernaculum situated in a roadside meadow,

TABLE 1

Body size and winter mortality of C. septempunctata *at different geographic localities*

Origin	Males				Females			
	Average size	Survival % (n)			Average size	Survival % (n)		
		Small	Medium	Large		Small	Medium	Large
1993-4								
Lesní hřeben	3.8 ± 0.2	—	—	—	3.9 ± 0.2	—	—	—
Raná	3.7 ± 0.2	—	—	—	3.8 ± 0.2	—	—	—
Praha-Ruzyně	3.7 ± 0.2	—	—	—	3.8 ± 0.3	—	—	—
Jílové	3.6 ± 0.2	—	—	—	3.8 ± 0.2	—	—	—
Average		45.1 (224)	51.3 (197)	32.5 (40)		47.8 (113)	46.0 (198)	25.3 (198)
1994-5								
Lesní hřeben	3.6 ± 0.2	65.4 (26)	83.3 (60)	88.7 (53)	3.7 ± 0.3	61.9 (42)	86.7 (60)	85.0 (60)
Pomezní boudy	3.4 ± 0.2	0.0 (4)	1.7 (60)	0.0 (17)	3.6 ± 0.3	0.0 (60)	1.7 (60)	8.7 (23)
Jílové	3.6 ± 0.2	62.5 (8)	41.7 (36)	63.3 (30)	3.8 ± 0.2	40.0 (10)	57.1 (49)	38.3 (47)
Praha-Ruzyně	3.5 ± 0.2	36.7 (30)	43.3 (60)	60.0 (25)	3.6 ± 0.3	39.1 (46)	56.7 (60)	50.0 (58)
Average		48.6 (68)	42.6 (120)	64.8 (125)		30.4 (158)	50.2 (229)	53.2 (188)
1995-6								
Lesní hřeben	3.6 ± 0.2	68.8 (16)	33.3 (60)	27.7 (47)	3.7 ± 0.2	25.0 (24)	35.0 (60)	50.0 (60)
Raná	3.4 ± 0.2	73.3 (46)	48.4 (60)	59.5 (19)	3.6 ± 0.3	48.8 (34)	55.7 (60)	60.6 (28)
Praha-Ruzyně	3.4 ± 0.2	66.7 (60)	10.0* (60)	71.0 (31)	3.5 ± 0.3	31.7 (60)	53.3 (60)	56.9 (51)
Přední Kopanina	3.4 ± 0.2	75.0 (48)	71.9 (57)	50.0 (20)	3.6 ± 0.3	53.1 (32)	66.1 (59)	53.5 (43)
Average		76.3 (160)	50.8 (177)	48.1 (117)		39.1 (150)	52.4 (239)	54.4 (182)

* Sample not included in the analysis. Mortality was caused by ice that frozed within the hibernaculum.

i.e. at a high altitude but not on a hilltop. Due to the generally low abundance of *C. septempunctata* in 1993-1995 it was not possible to sample beetles from the same populations each year. The beetles were collected into sterile bottles (to prevent the spread of infection) filled with balls of filter paper and then stored at + 5°C until start of the experiment. Before the beetles were introduced into artificial hibernacula they were sexed and divided into small (hind width of female scutum ≤ 3.36 mm, males ≤ 3.29 mm), medium (females 3.43-3.72 mm, males 3.36-3.65 mm), and large (females ≥ 3.79 mm, males ≥ 3.72 mm) size classes. The beetles were measured under a stereomicroscope to a 0.07 mm accuracy. Groups of ≤ 60 individuals of each gender and size were introduced into artificial hibernacula. In 1993, beetles from all localities were mixed and the sample was divided only by gender and size. The experiments were started on Nov. 3, 1993,

Nov. 1, 1994 and Oct. 26, 1995. Disturbance of the hibernating beetles was avoided. After hibernation, mortality was checked on March 31, 1994, April 5, 1995, and April 10, 1996. Winter periods are designated by the year when the overwintering started, e.g. the 1993-1994 winter as 1993.

Artificial hibernacula consisted of enameled iron sheet cylinders, 30 cm in diameter and length, sunk 5 cm into the soil and covered by nylon fabric. The bottom was covered by 3 cm layer of sand spread over the ground, and several dead oak leaves. The cylinders were placed in the open, in an unshaded area covered by short-cut grass. The data was evaluated by one-way analysis of variance (ANOVA). The data was normally distributed. Average body size is the arithmetic mean of the hind scutum widths of 83-223 males and females from each population.

RESULTS

Average winter survival was 48.4 ± 22.7% and varied from 0.0-88.7% between samples (table 1). The effects of gender, body size, geographic origin, and year were investigated by one-way ANOVA.

There was no significant effect of gender on winter survival either in different years or in the pooled three year data (table 2). In 1993-1995, the effect of gender explained only 3.1, 0.1 and 0.7% the total variance, respectively. In the total sample it explained 1.1% of variance. Body size had a statistically significant effect in 1993. However, winter survival decreased with increasing body size in females and in males, medium sized individuals had the highest survival followed by small and large individuals. In 1994 and 1995 as well as in the pooled data, the effect of body size was not significant and accounted for only 2.7, 1.6 and 0.1% of the variance, respectively.

TABLE 2

One-way ANOVA of the effect of gender, body size, geographic origin and year on winter survival

Source	Effect			Error				
	SS	df	MS	SS	df	MS	F	P
Gender								
1993	16.0	1	16.0	496.2	4	124.1	0.1290	0.7376
1994	18.7	1	18.7	19903.2	22	904.7	0.0207	0.8869
1995	436.0	1	436.0	4591.7	21	218.7	1.9939	0.1725
Total	296.3	1	296.3	26561.4	51	520.8	0.5689	0.4542
Body size								
1993	468.6	2	234.3	43.6	3	14.5	16.1118	0.0248*
1994	532.8	2	266.4	19389.1	21	923.3	0.2885	0.7523
1995	81.7	2	40.9	4946.0	20	247.3	0.1653	0.8488
Total	35.0	2	17.5	26822.6	50	536.5	0.0327	0.9679
Geographic origin								
1994	18036.9	3	6012.3	1885.0	20	94.3	63.7905	0.0000*
1995	1797.7	3	599.2	3230.0	19	170.0	3.5248	0.0349*
Year								
1993-5	1395.8	2	697.9	25461.9	50	509.2	1.3705	0.2634

* Statistically significant results.

Effect of geographic origin could be investigated only in 1994 and 1995 when samples from four localities were kept separately (table 2). In both years geographic origin was by far the most important factor associated with variation in winter survival (90.6 and 35.4% of variance, respectively). Annual variation in winter survival between 1993-1995 was not statistically significant and explained only 5.2% of variance in the pooled three year data set.

In 1994, survival rate (fig. 1) was positively correlated with average body size of the populations from which the samples were taken ($r^2 = 0.668$ in males and 0.412 in females, $df = 10$, $p < 0.05$). In 1995 the correlation was not significant.

DISCUSSION

In a number of insect species, body size is an important correlate of individual fitness. It is positively associated with fecundity (Dixon & Guo, 1993), flight activity and endurance, resistance to starvation and dessiccation, as well as total longevity. Although the data for coccinellids are scarce the effects of body size are probably similar to other insects. Generally, one would expect greater winter survival in large than small *C. septempunctata* individuals. The experiments were designed to test this assumption. The results, however, failed to reveal an important positive effect of increasing body size on winter survival.

One may only speculate about factors affecting the absence of the effect of body size on winter survival. The fact that body size and fat body size, which is correlated with survival capacity (Zhou *et al.*, 1995), are formed at different periods of a coccinellids life may be important. Body size is determined by trophic conditions during larval development, fat is largely accumulated during the teneral and post-teneral life, in the pre-hibernation period. Larval starvation is an important cause of small adult body size. Its intensity is determined by the synchronization between coccinellid development and aphid population development. Larvae from early laid eggs find copious quantities of food while the ones born later may starve. Although there exist mechanisms preventing untimely oviposition (Hemptinne *et al.*, 1992) the synchronization in the field is not perfect, which results in some small individuals (Honek, 1983). However, regardless of body size, young adults face similar trophic conditions. They migrate to plant stands populated by aphids (in the Czech Republic usually alfalfa, umbellifer and composite weeds) where they experience similar trophic conditions. Overall aphid abundance can vary greatly between geographic areas. This makes the overwintering capacity of all the individuals from a particular area similar, regardless of body size.

Thus, local differences in the quality of ladybirds is important. Pre hibernation availability of food and migration probably contribute to differences in the quality of the individuals in local populations. A striking example of this were the populations of Pomezni boudy and Lesni hreben, in 1994. In the population of Pomezni boudy poor trophic conditions (development of *C. septempunctata* larvae in mountain conditions is unusual and was only possible in 1994 because of the warm summer) resulted in small average body size (great proportion of small individuals in the population), starvation during the pre-hibernation period, and inability to disperse before hibernation. Most individuals, even the large ones, were unable to survive the winter. By contrast, the population at Lesni hreben, a nearby high altitude hilltop hibernaculum, was established by migrants from distant localities. These individuals, selected by migration, had generally a high chance of survival. The presence of a large proportion of small individuals not capable of a long migration may indicate poor quality of individuals and be associated with low winter survival. The example of Lesní hřeben and Pomezní boudy populations illustrates why average body size

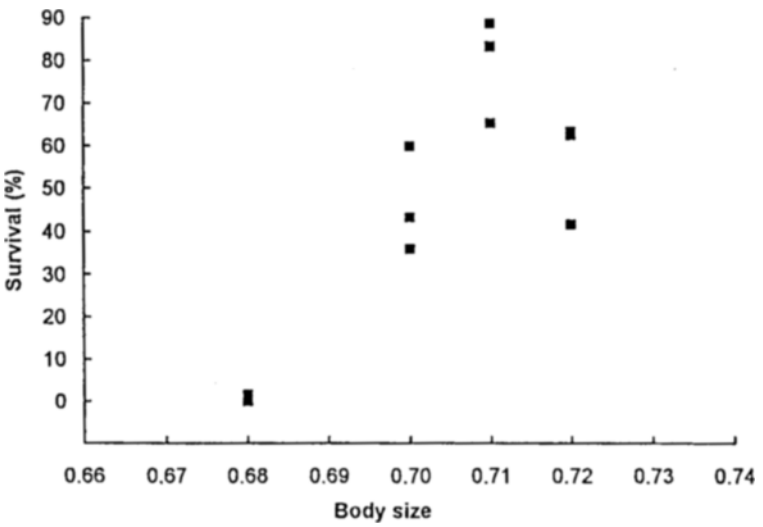

Fig. 1. Survival rate ploted against average body size, arithmetic mean of the breadth of hind margin of the scutum measured on a sample of the original population (n = 83-223). Data for males, 1994. Body size data multiply by 5 to obtain scutum breadth in mm.

may indicate population quality. This situation, however, is only apparent in some years as requires that body size of individuals is very different, e.g. as happens when a partial second generation develops. A second pre-requisite are specific conditions for the pre-hibernation migration, which allows high quality individuals to fly but not poor quality individuals.

Winter survival in these experiments was similar to that observed under natural conditions. For example, in 1976-1987, it was estimated at 30-40% at Raná in the Czech Republic (Honěk, 1989) and somewhat higher, at 67-81% in Poland (Lipa *et al.*, 1975).

ACKNOWLEDGEMENT

The work was partly funded from grant no. 522/97/0271 of the Grant Agency of the Czech Republic. I thank Mrs. L. Kreslová for excellent technical assistance.

RÉSUMÉ

Facteurs déterminant la survie hivernale de *Coccinella septempunctata* (Col. : Coccinellidae)

Entre 1993 et 1995, des adultes de *Coccinella septempunctata* ont été échantillonnés sur différents sites d'hivernation dans l'ouest de la République tchèque. Les individus récoltés étaient classés selon le sexe et répartis en trois classes de taille puis exposés aux conditions extérieures dans des hibernacula artificiels, de novembre à avril. Le taux moyen de survie était de 48,4 %. La survie hivernale n'a pas été significativement affectée par l'année, le sexe ou la taille. Cependant des différences significatives ont été relevées entre adultes provenant de populations (c'est-à-dire de sites d'hivernation) différentes.

REFERENCES

Adylov, Z. K. — 1965. Zimovka khishchnykh kokcinellid v Uzbekistane (Hibernation of predaceous coccinellids in Uzbekistan). — *Tr. Sredneaziat. Nauch. Issl. Inst. Zashch. rast. Tashkent,* 7, 98-102. (In Russian).

Alaeva, M. — 1972. O zimovke nekotorykh kokcinellid na juzhnykh sklonakh Gissarskogo khrebeta i v Gissarskoi doline Tadzhikistana (Hibernation of some coccinellids at southern slopes of Hissar-ridge and Hissar-valley, Tadzhikistan). — *Izv. Akad. Nauk Tadzh. SSR Biol.,* 1972, 63-66. (In Russian).

Basedow, T. — 1982. Untersuchungen zur Populationsdynamik des Siebenpunktmarienkäfers *Coccinella septempunctata* L. (Col., Coccinellidae) auf Getreidefeldern in Schleswig-Holstein von 1976-1979. — *Z. Angew. Entomol.,* 94, 66-82.

Benkevich, V. J. — 1958. K biologii semitochechnoi korovki *Coccinella 7-punctata* L. (Biology of Coccinella septempunctata L.). — *Uchen. Zap. Orechovo-Zuevskogo Pedagog. Inst.,* 11, 127-133. (In Russian).

Dixon, A. F. G. & Guo Y. — 1993. Egg and cluster size in ladybird beetles (Coleoptera: Coccinellidae): The direct and indirect effects of aphid abundance. — *Eur. J. Entomol.,* 90, 457-463.

Hemptinne, J. L., Dixon, A. F. G. & Coffin, J. — 1992. Attack strategy of ladybird beetles (Coccinellidae): factors shaping their numerical response. — *Oecologia,* 90, 238-245.

Hodek, I. — 1960. Zimování slunéček (Hibernation-bionomics of Coccinellidae). — *Čas. Čs. Spol. Entomol.,* 57, 1-20. (In Czech, Engl. summary).

Hodek, I. — 1962. Migration of Coccinellids to their hibernation quarters. — Verh. XI Internat. Entomol. Kongr. Wien 1960, 3, 39-40.

Hodek I., Iperti, G., & Roley, F. — 1977. Activation of hibernating *Coccinella septempunctata* (Col.) and *Perilitus coccinellae* (Hym.) and the photoperiodic response after diapause. *Entomol. Exp. Appl.,* 21, 275-286.

Hodek, I. & Honek, A. — 1996. Ecology of Coccinellidae. — *Kluwer,* Dordrecht. The Netherlands.

Honěk, A. — 1983. Factors affecting the distribution of larvae of aphid predators (Col., Coccinellidae and Dipt., Syrphidae) in cereal stands. — *Z. Angew. Entomol.,* 95, 336-343.

Honěk, A. — 1989. Overwintering and annual changes of abundance of *Coccinella septempunctata* in Czechoslovakia (Coleoptera, Coccinellidae). — *Acta Entomol. Bohemoslov.,* 86, 179-192.

Honěk, A. — 1990. Seasonal changes in flight activity of *Coccinella septempunctata* L. (Coleoptera, Coccinellidae). — *Acta Entomol. Bohemoslov.,* 80, 336-341.

Kreiter, S. & Iperti, G. — 1984. Importance des sommets de moyenne altitude dans la survie d'une coccinelle aphidiphage *Semiadalia undecimnotata* (Coleoptera, Coccinellidae). — *Acta. Biol. Mont.,* 1984, 93-98.

Lipa, J. J., Pruszynski, S. & Bartkowski J. — 1975. The parasites and survival of the lady bird beetles (Coccinellidae) during winter. *Acta Parasitol. Pol.,* 23, 453-461.

Mechtiev, A. M. — 1967. O zimovke kokcinellid (Coleoptera: Coccinellidae) v uslovijakh Azerbeidzhana (Hibernation of coccinellids in Azerbeijan). — *Materialy Nauch. Teor. Konf. Molodykh Uchenykh Baku.,* p. 208. (In Russian).

Okuda, T., Hodková, M. & Hodek, I. — 1986. Flight tendency in *Coccinella septempunctata* in relation to changes in flight muscles, ovaries and corpus allatum. — In: Ecology of Aphidophaga. **Hodek I.** (ed.) *Academia-Dr. W. Junk.* pp. 217-223.

Semyanov, V. P. — 1979. Migracii i migracionnoe sostoyanie u semitochechnoi bozhei korovki (Coccinella septempunctata L.) (Migration and migration behaviour in Coccinella septempunctata L.). — In: Morfologia, sistematika i evolyucija zhivotnykh. p. 75-76. (In Russian).

Zhou, X., Honek, A., Powell, W. & Carter, N. — 1995: Variations in body length, weight, fat content and survival in *Coccinella septempunctata* at different hibernation sites. — *Entomol.Exp. Appl.,* 75, 99-107.