

PHENOLOGY OF *COCCINELLA SEPTEMPUNCTATA*
(COL.: COCCINELLIDAE) IN CENTRAL GREECE

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Coccinella septempunctata (Coleoptera: Coccinellidae), field collected from central Greece and reared in cages during 1990-1991 and in vials during 1994-1995 outdoors at Kifissia, Athens, developed 4 complete and a 5th partial generations per year. In both cases, only adults of the 1st generation reproduced within the year they emerged; 2nd, 3rd and 4th generation adults reproduced partly in the year they emerged and partly in the following year; 5th generation adults did not reproduce at all in 1990, and eggs/larvae produced by 4th generation females in 1994 died before developing into adults. Adults of the 1st and 5th generations died before winter; those of the 2nd, 3rd and 4th generations overwintered successfully. The greatest numbers of eggs were laid by females of the 1st and 2nd generations.

Visual counts made in the open field at Kopais plain in central Greece (1990-1992) and on the summit of the adjacent Mount Kitheron (1990-1994) indicate that all *C. septempunctata* instars were abundant in the plain between April and June, becoming scarce from July until the end of the warm period of the year following spring. No *C. septempunctata* individuals were found in the plain in winter. On the summit of the mountain, *C. septempunctata* adults were present all year round, singly and in aggregations, except for the month of May. The most numerous arrivals of adults were noticed on the mountain in June. Emigrations of adults from there were noticed from March until the end of April.

KEY-WORDS: lady beetle, phenology, Greece.

Geographical populations of the aphidophagous predator *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) have different voltinism tendencies (Hodek, 1986). In central or western Europe, it is reported with a strong tendency to univoltinism (Jöhnssen, 1930; Hodek, 1959; Hagen, 1962; Bonnemaïson, 1964), and in eastern Europe to bivoltinism (Dobrzhanskii, 1922; Dyadechko, 1954). Around the Mediterranean, *C. septempunctata* from southern and central Spain is reported as bivoltine, since the females reproduced promptly under favorable conditions giving rise to at least a 2nd generation (Hodek, 1986; Hodek & Okuda, 1993). In the coastal plains of Israel, *C. septempunctata* is reported as developing one complete and one partial generation in spring, estivating during July and August, and developing one additional complete and another partial generation in autumn (Bodenheimer, 1943).

Information about the phenology and bionomics of *C. septempunctata* in the Mediterranean region is limited (Hodek *et al.*, 1989). The following studies on voltinism, longevity, reproductive activity and habitats of *C. septempunctata* were carried out in order to obtain more information in Greece.

MATERIALS AND METHODS

EXPERIMENTS

In 1990-1991, *C. septempunctata* was studied using 1st generation adults (recognized by their light colour and soft elytra) and pupae collected on May 10, 1990, from an alfalfa field in the plain of Kopais (ca. 38° 20'-38° 30' N.L.) in central Greece. Forty individuals, 20 of each sex, were reared together in a cylindrical plexiglass cage (30 cm in diameter, 50 cm in length) (Iperti & Brun, 1969) placed outdoors in foliar shadow near the laboratory of the Benaki Institute, Kifissia, Athens. Another 40 individuals, as pupae and late 4th instar larvae, were collected from Kopais on May 8, 1994, and reared in male-female pairs during 1994-1995 in cylindrical plastic vials (5.5 cm in diameter; 6.5 cm in length) similarly placed outdoors. In both cases, the beetles were fed on an abundance of either *Aphis fabae* Scopoli (Homoptera: Aphididae) reared on *Vicia faba* L. (Leguminosae) seedlings or *Dysaphis crataegi* (Kaltenbach) (Homoptera: Aphididae) reared on fruits of *Curcubita maxima* Duch (Cucurbitaceae).

The generations of *C. septempunctata* were separated by transferring the earliest eggs and larvae arising from reproducing females into separate cages or vials; the first 20 pairs of adults to develop from these produced the next generation. Eggs from each cage or vial were collected and counted 2-3 times per week. At the same time, mortality and numbers of non-aggregated versus aggregated adults (1990-1991) were recorded, and adults were provided with aphids as prey.

Average fecundity of the females was calculated in the larger cylindrical cages only. For comparison, fecundity was also measured on 20 females reared in male-female pairs in 1991 under controlled laboratory conditions (25° ± 1°C temperature, 65±5% relative humidity and 16h light per day), each couple in a 30 cm × 50 cm cylindrical plexiglass cage. The presence of eggs laid by females reared in the vials was noted for witnessing the period of their reproductive activity.

OBSERVATIONS IN THE FIELD

The phenology of *C. septempunctata* in the field was studied by making timed (30 mins) observations and recording counts of individuals found at two locations in central Greece. The first location was in the plain of Kopais (1990- 1992), and the second (1990-1994) was at the summit of Mount Kitheron (elevation 1 409 m) about 30 km to the southeast of Kopais. The observations were made approximately once every 10 days during late spring and summer and once or twice per month during the other seasons, except when snow was covering the summit of the mountain.

The *C. septempunctata* individuals found on maize, cotton, alfalfa and non-cultivated plants in the plain of Kopais were categorized according to developmental instar. On Mount Kitheron, aggregated versus non-aggregated *C. septempunctata* adults, the number of individuals per aggregation, and a description of the site where the aggregation was found were recorded.

RESULTS AND DISCUSSION

PHENOLOGY IN OUTDOOR EXPERIMENTS

Voltinism. In 1990 (fig. 1) and again in 1994 (fig. 2), *C. septempunctata* developed 4 complete generations between May and November. In addition, a partial 5th generation

appeared in 1990, with adults which did not reproduce and died before winter. In 1994, the partial 5th generation comprised eggs and larvae which died before developing into adults.

In 1990, adults of the 1st, 2nd, 3rd and 4th generations emerged May 10 to 18, June 24 to July 3, July 24 to August 28 and September 2 to 28, respectively. In 1994, they emerged May 20 to 30, June 25 to July 4, August 5 to September 9 and October 17 to 25, respectively.

Adult longevity. Both in 1990 and in 1994, adults of the 1st generation did not overwinter (fig. 1A; fig. 2A; table 1).

Both in 1990-1991 and 1994-1995, adults of the 2nd, 3rd and 4th successfully overwintered (fig. 1 B, C, D; fig. 2 B, C, D; table 1).

TABLE 1

Mortality of Coccinella septempunctata adults reared in outdoor experiments during 1990 and 1994

Generation	Adult emergence (date)		Adult mortality (date)		
			1 st	50%	Last
1 st	1990	10-18/V	4/VII	13/VIII	24/X
	1994	20-20/V	15/VIII	3/X	11/I, 1995
2 nd	1990	24/VI-3/VII	24/VII	15/V, 1991	2/VI, 1991
	1994	25/VI-4/VII	18/VII	2/II, 1995	1/VI, 1995
3 rd	1990	24/VII-28/VIII	7/IX	1/III, 1991	9/VII, 1991
	1994	5/VIII-9/IX	23/IX	23/V, 1995	1/VII, 1995
4 th	1990	2-28/IX	2/X	9/VI, 1991	24/VII, 1991
	1994	17-25/X	7/I, 1995	1/VI, 1995	1/VII, 1995

Reproductive activity and aggregations. Both in 1990 and 1994, females of the 1st generation reproduced, completing their egg laying in the same year, by August 27 in 1990 (fig. 1A) and by November 2 in 1994 (fig. 2A). In 1990, between July 24 and August 18, 20-30% of the adults in plexiglass cages were found in aggregations (fig. 1A). In 1994, 22% of the females in vials stopped the maturation of ovaries before oviposition between July 20 and August 26 (fig. 2A). The tendency of some adults in cages to form aggregations and the marked delay in ovipositing in a part of the 1st generation females in vials, noticed during the same period of the year in both studies, indicate summer dormancy in 20-30% of the 1st generation adults.

As their rates of egg laying show, some females of the 2nd, 3rd and 4th generations in both studies reproduced partly during the year they emerged and partly during the following spring. In 1994 (fig. 2 B, C, D), 83%, 58% and 28% of the 2nd, 3rd and 4th generation females, respectively, reproduced before overwintering and all survivors reproduced again in the spring of 1995.

Between July 29 and September 12, 1990 (fig. 1B), the great majority of 2nd generation adults in plexiglass cages were found in aggregations. Between July 13 and September 5, 1994 (fig. 2B), 56% of the 2nd generation females in vials remained immature at the not-yet-ovipositing stage. Their reproductive maturation was noticed in the 1st half of September, with up to 83% ovipositing by September 16, 1994 (fig. 2B).

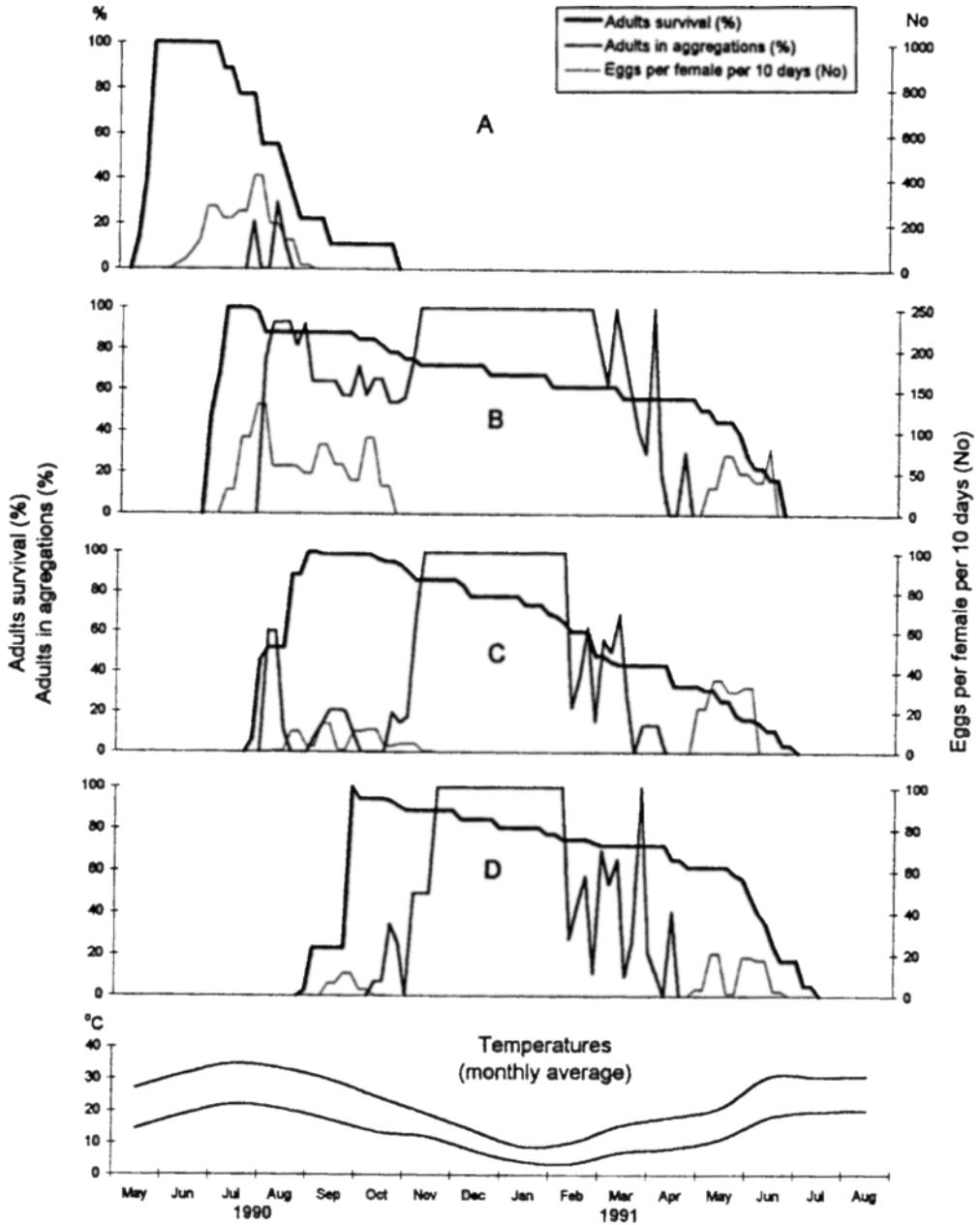


Fig. 1. Voltinism, adult longevity, aggregations formations, and egg production of 40 *Coccinella septempunctata* adults reared in outdoor cages at Kifissia, Athens in 1990-1991.

As in the case of the 1st generation, the tendency of 2nd generation adults in cages to form aggregations and also the observed delay in ovipositing of females in vials occurring during the same period of the year in both studies indicate summer dormancy in more than 50% of the adults of the 2nd generation.

In the 3rd generation, a considerable portion of adults in plexiglass cages (fig. 1C) were found in aggregations during the first half of August 1990. In 1994 (fig. 2C), the observed interval between emergence and the onset of ovipositing was longer than that of the other generations. The question of summer dormancy does not apply to 4th generation adults, which emerged after this season (figs. 1D, 2D).

In 1990 (fig. 1B, C, D), females of the 2nd, 3rd and 4th generations arrested ovipositing on October 22, November 21 and October 22, respectively. In 1994 (fig. 2 B, C, D), they all ceased ovipositing on November 20. All adults in cages (fig. 1 B, C, D) were found in aggregations between November 1990 and February 1991.

Fecundity. The average fecundity for the 1st generation adults reared in outdoor cages in 1990 (fig. 1A) was calculated as 1780 eggs per female. The average fecundities for the 2nd, 3rd and 4th generations were determined as 925, 182 and 85 eggs per female, respectively (fig. 1 B, C, D). The relatively low fecundities of 3rd and 4th generation females may be attributed to the combination of limited feeding time available, due to having emerged late in the season under monthly average temperatures below 15°C with day-length less than 11 h 30', and high energy needs for accumulation of reserves for survival overwinter. The average fecundity for adults reared in the laboratory under temperature 25° ± 1°C, relative humidity 65 ± 5% and 16 h light/24 h was 1788 (SD: 576.4) eggs per female.

PHENOLOGY IN THE OPEN FIELD

The plain of Kopais. Overwintered adults were found in the plain of Kopais in the first half of April 1991 and the earliest eggs laid by overwintered females were found in the second half of April 1991 (table 2). During May 1990 and 1991, all developmental instars of *C. septempunctata* were found and adults of the 1st generation had emerged. In June 1991 and again in June 1992, newly emerged adults of the 1st and possibly a 2nd overlapping generation comprised the majority of *C. septempunctata* individuals counted.

Later reproductive activity of *C. septempunctata*, possibly with 3rd or 4th overlapping generations, is indicated by the eggs found in late July, 1992 and the newly emerged adults found in August, 1991 and in September 1992, confirming the results obtained in outdoor cages (fig. 1 B, C, D). However, from July until the end of the warm period of the year, *C. septempunctata* were found in the plain only in very low numbers. This indicates the minor numerical importance of any 3rd or 4th overlapping generation, confirming also the results obtained in outdoor cages (fig. 1 C, D). During the winter months, observations were occasionally made, but no *C. septempunctata* individuals were found in the plain of Kopais.

The summit of Mount Kitheron. Between 1991 and 1994, *C. septempunctata* adults were never found on the summit of the mountain in May. Arrivals occurred in June, the month when the greatest numbers of adults were found on the summit (table 3).

Table 4 gives the total numbers and size of the aggregates of *C. septempunctata* on the summit of Mount Kitheron during 1991. In June, most of the adults were found moving about singly before beginning to form aggregations. By July, the majority of adults were in aggregations; more than half of the population were in groups of 13-60 individuals. Adults of *C. septempunctata* were found at the summit of the mountain for the rest of 1991 and overwintered there. Between late July and November, most commonly they were found in aggregations of 7-24 individuals. No aggregation with more than 60 individuals was observed (table 4).

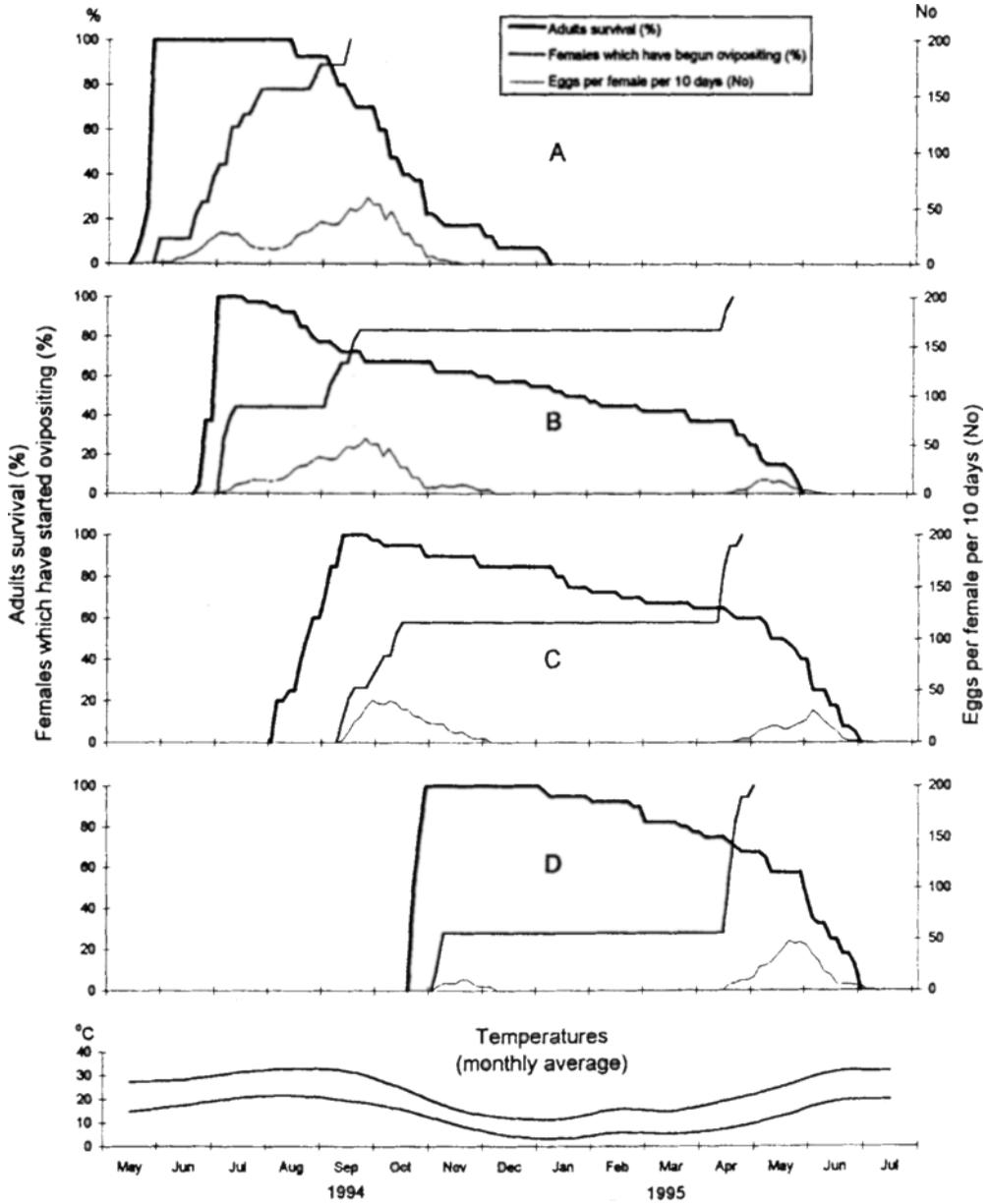


Fig. 2. Voltinism, adult longevity, rate of ovipositing females, and egg production of 20 pairs of *Coccinella septempunctata* adults reared in vials outdoors at Kifissia, Athens in 1994-1995.

The *C. septempunctata* aggregations were usually found under stones of different sizes and occasionally at the bases of shrubs; none were found in the crevices of rocks. Similar

TABLE 2

Coccinella septempunctata recorded on maize, cotton, alfalfa and non-cultivated plants in the plain of Kopais, by 30 minute visual counts during 1990-1992

Date	Number of					
	Eggs	Larvae 1 st , 2 nd instar	Larvae 3 rd , 4 th instar	Pupae	Adults	
1990	May 10	0	0	37	2	16*
	June 27	130	0	0	0	8
	July 13	0	0	8	2	2
	August 23	0	0	0	0	6
	October 10	0	0	0	0	9
1991	April 10	0	0	0	0	67
	April 17	40	0	0	0	32
	May 17	0	7	16	15	42*
	June 11	0	0	0	2	36*
	June 26	0	0	0	3	4*
	July 10	0	0	0	0	4*
	July 24	0	0	0	0	0
	August 12	0	0	0	0	2*
	September 4	0	0	0	0	1
	October 3	0	0	0	0	1
1992	June 10	0	0	18	15	4
	June 23	0	0	0	1	28*
	June 29	0	0	0	0	200*
	July 23	10	0	0	0	3
	August 7	0	0	0	0	2
	September 4	0	0	0	0	6
	September 24	0	0	0	0	3*

* Newly emerged adults with light coloured and soft elytra comprising more than 50% of individuals counted.

habitats used as dormancy sites by *C. septempunctata* are reported from different parts of central and eastern Europe (Hodek, 1973). On warm and sunny days (table 4, November) many adults were found singly on stones or on the upper surfaces of plant leaves.

In 1991, emigration of adults from the summit of the mountain started in March (tables 3 and 4). Until the end of April, most of the remaining *C. septempunctata* adults were found singly or in small aggregations of 2-6 individuals (table 4).

CONCLUSION

The results of the outdoor experiments show that even with the optimum reproductive activity obtained by an acceleration of generations (only the earliest eggs and/or adults were isolated) and an abundance of aphids offered at times when they would usually be scarce in the field, only part of the *C. septempunctata* females reproduced and developed 4 to 5 overlapping generations per year. The rest of the females remained immature, either in summer dormancy (1st and 2nd generation) or in winter quiescence (3rd and 4th generation). As fecundity results show, the greatest numbers of eggs per female are produced by females of the 1st and 2nd generations.

TABLE 3

Coccinella septempunctata recorded at the summit of Mount Kitheron, by 30 minute visual counts during 1991-1994

Date	Adults No.	Date	Adults No.	Date	Adults No.	Date	Adults No.
1991		1992		1993		1994	
March 7	443	May 8	0	March 26	0	March 30	0
March 27	68	June 19	19	April 12	0	April 6	0
April 10	43	June 29	20	May 3	0	July 8	308
April 26	11	July 10	22	June 9	5000		
May 5	0	August 7	19	August 4	340		
June 26	2000	August 20	2	August 19	300		
July 2	900	August 28	2	September 9	105		
July 26	621	September 10	2	September 28	90		
August 21	580	October 9	0	October 23	40		
September 19	353	October 19	0				
October 10	325	November 20	0				
November 20	280	December 21	0				

TABLE 4

Coccinella septempunctata adults found singly and in aggregations, during 30 minute visual counts at the summit of Mount Kitheron in 1991

Date	Adults total No.	%					
		Singly	In aggregations				
			2-6 individuals	7-12 individuals	13-24 individuals	25-48 individuals	48-60 individuals
March 27	68	54.4	45.6	0	0	0	0
April 10	43	72.1	27.9	0	0	0	0
April 26	11	36.4	63.6	0	0	0	3
June 26	2000	86.2	0.6	3.2	3.5	6.5	0
July 2	900	28.1	2.9	3.1	12.0	18.3	35.6
July 26	621	48.7	3.6	7.3	25.0	5.8	9.6
August 21	580						
September 19	336	1.2	22.9	27.7	39.3	8.9	0
October 10	325						
November 20	280	37.5	21.2	26.9	14.4	0	0
Total	4259	57.8	5.8	7.2	11.9	8.5	8.9

The phenology of *C. septempunctata* in the Kopais plain shows that, from early July onwards, *C. septempunctata* in different developmental instars can be found on vegetation with aphids, until the end of the warm period of the year. This indicates bivoltinism or possible multivoltinism of *C. septempunctata* in the field.

The findings at the summit of Mount Kitheron show the migratory ("hypso-tactic") behaviour of *C. septempunctata*. Such behaviour is not reported from central and eastern

Europe, where *C. septempunctata* often hibernates near its breeding habitats at dormancy sites situated at forest edges, clearings or wind breaks (Hodek, 1973).

The observed migratory behaviour of *C. septempunctata* in this study may be due to factors such as those favoring the "hypsolectism" of *Hippodamia undecimnotata* (Schneider), including hot and dry weather conditions and scarcity of aphids (Iperti, 1978; Iperti & Hodek, 1974). These are environmental conditions which are met in central Greece from mid-late June onwards.

RÉSUMÉ

Phénologie de *Coccinella septempunctata* (Col. Coccinellidae) en Grèce

Coccinella septempunctata (Coleoptera : Coccinellidae) récoltée dans les champs en Grèce centrale et élevée dans des cages de 1990 à 1991 et dans des tubes en 1994 et 1995 hors du laboratoire à Kiphissia, Athènes, a développé 4 générations complètes et une 5^e génération partielle par an. Dans les deux cas, seuls les adultes de la 1^{re} génération se sont reproduits spontanément. Les adultes de la 2^e, 3^e et 4^e génération se sont reproduits d'une part l'année de leur émergence et d'autre part l'année suivante. Les adultes de la 5^e génération, en 1990, ne se sont pas reproduits ; les œufs et les larves produits par les femelles de la 4^e génération, en 1994, sont morts avant de compléter leur développement jusqu'au stade d'adulte. Les adultes de la première génération meurent avant l'hiver. Les adultes des 2^e, 3^e et 4^e générations hivernent avec succès. Le plus grand nombre d'œufs a été pondu par les femelles des 1^{re} et 2^e générations.

Les dénombrements réalisés par observation visuelle sur le terrain dans la plaine de Kopais en Grèce centrale (1990-1992) et sur le sommet de la montagne Kitheron voisine (1990-1994) ont montré que, dans la plaine, on a trouvé en abondance *C. septempunctata*, à tous les stades de développement, au cours de la période qui s'étend d'avril à juin et rarement à partir du mois de juillet jusqu'au printemps suivant. Sur le sommet de la montagne, les adultes de *C. septempunctata* ont été trouvés, individuellement ou en agrégations, tout au long de l'année, à l'exception du mois de mai. La plus forte migration des adultes vers la montagne, a été notée au mois de juin. L'émigration des adultes de la montagne s'observe à partir du mois de mars jusqu'à la fin du mois d'avril.

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