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PHENOLOGY OF *HIPPODAMIA UNDECIMNOTATA* (*COL.: COCCINELLIDAE*) IN GREECE

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Hippodamia (Semiadalia) undecimnotata (Coleoptera: Coccinellidae), collected from central Greece and reared in cages during 1993-1994 and in vials during 1994-1995 outdoors at Kifissia, Athens, completed 5 generations per year. In both cases, adults of the 1st, 2nd and 3rd generations reproduced, completing their egg laying in the same year; 4th and 5th generation adults reproduced both in the year they emerged and the following year. In both cases, adults of the 1st and 2nd generations died before winter; in 1993, adults of the 3rd generation died before winter, in 1994, they survived until April 1995. Adults of the 4th and 5th generations overwintered successfully. The greatest numbers of eggs were laid by females of the 1st and 2nd generations.

Field observations and timed counts of specimens (30 minutes per location) made on the tops of Mounts Chlomo and Kitheron and on the neighboring plain of Kopais between 1991 and 1994 revealed that most adults arrived on the mountains between late June and early September and left between the end of March and beginning of May. *H. undecimnotata* were not found on the plain of Kopais during the winter. Overwintered adults arrived between the end of March and beginning of May; 1st generation adults emerged in June. The presence of a few eggs, larvae, pupae and newly-emerged adults observed on the plain during August-September 1993 suggests that at least a portion of the *H. undecimnotata* population in central Greece completes 2 or more overlapping generations per year.

KEY-WORDS: lady beetle, phenology, Greece.

The aphidophagous predator *Hippodamia (Semiadalia) undecimnotata* (Schneider) (Coleoptera: Coccinellidae), is a native of the south-palaearctic, occurring in southern and central Europe (France, Yugoslavia, Greece, Bohemia, Slovakia) (Hodek, 1973; Iperti, 1986; Katsoyannos, 1992; Thalji, 1994) and central Asia (Kazakhstan, Uzbekistan, Turkmenia) (Savoiskaya, 1966; Yakhontov, 1966; Semyanov, 1986). In these areas, *H. undecimnotata* shows the same migratory and aggregational behaviour and the adults enter aestivo-hibernation (Dobzhansky, 1925; Hodek, 1967; Iperti & Buscarlet, 1986). In southeastern France and central Europe (Bohemia, Slovakia), it is univoltine (Iperti, 1966; Hodek, 1966).

There is limited information on the phenology and bionomics of *H. undecimnotata* in the Mediterranean region. The following studies on voltinism, longevity, reproductive activity and habitats of *H. undecimnotata* were carried out in order to obtain such information for this species in Greece.

MATERIALS AND METHODS

In 1993, adults of *H. undecimnotata* were collected on May 3, 1993, from wild plants at the southern edge of 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 near the laboratory of the Benaki Institute, Kifissia, Athens. Another 40 adults, from the same locality were 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 or *Dysaphis crataegi* (Kaltenbach) (Homoptera: Aphididae).

The generations of *H. undecimnotata* were separated from one another by isolating the earliest progeny; the first 20 pairs of emerged adults were considered representative adults of the following generation. Eggs were collected and counted 2-3 times per week. At the same time, mortality was recorded, and adults were provided with aphids as prey.

Average fecundity was only calculated for the females in the cylindrical cages. For comparison, fecundity was also measured on 20 females reared in male-female pairs in 1993 under controlled laboratory conditions (25° ± 1° C temperature, 65 ± 5% relative humidity and 16 h light per day), each couple in a 30 cm × 50 cm cylindrical plexiglass cage. Eggs laid by females reared in the vials were also counted as a record of ovipositing activity, but were not used for fecundity calculations. It was considered that egg cannibalism by the adults occurred in the limited space of the vials.

H. undecimnotata individuals in the field were counted (30 mins) visually at three locations in central Greece: (1) (1990-1994) in the plain of Kopais, (2) (1990-1994) on the summit of Mount Chlomo (elevation 1081 m) about 15 km to the northwest, (3) (1991-1994) on the summit of Mount Kitheron (elevation 1409 m) about 30 km to the southeast. 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 summits of the mountains.

The developmental instars of *H. undecimnotata* were recorded on field crops and wild plants in the plain of Kopais. On the summits of the mountains, aggregated versus non-aggregated *H. undecimnotata* 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 CAGES

Voltinism

In 1993 and again in 1994, *H. undecimnotata* completed 5 generations between June and November.

In 1993 (fig. 1), adults of the 1st, 2nd, 3rd, 4th and 5th generations emerged June 10 to 14, July 5 to 7, August 1 to 3, September 15 to 18 and October 25 to 29, respectively. In 1994 (fig. 2), they emerged June 5 to 12, July 8 to 18, August 15 to 24, September 25 to October 1 and November 3 to 11, respectively.

Adult longevity

Both in 1993 and 1994, adults of the 1st and 2nd generations did not overwinter (fig. 1A, B; fig. 2A, B; table 1).

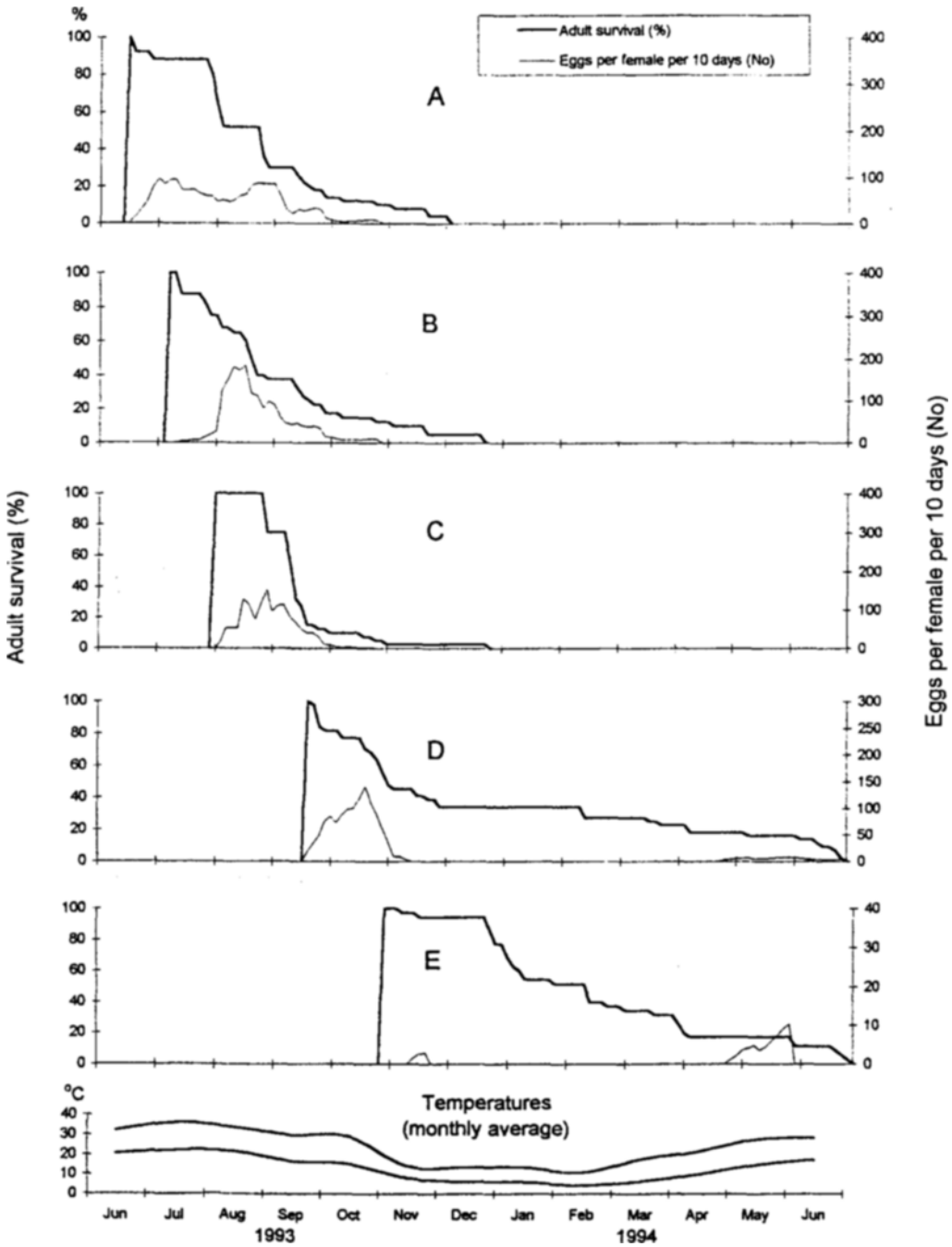

Fig. 1. Voltinism, adult longevity and eggs production of 40 *Hippodamia undecimnotata* adults reared in group cultures in outdoor cages at Kifissia, Athens in 1993-1994.
(A, B, C, D, E: 1st, 2nd, 3rd, 4th and 5th generation).

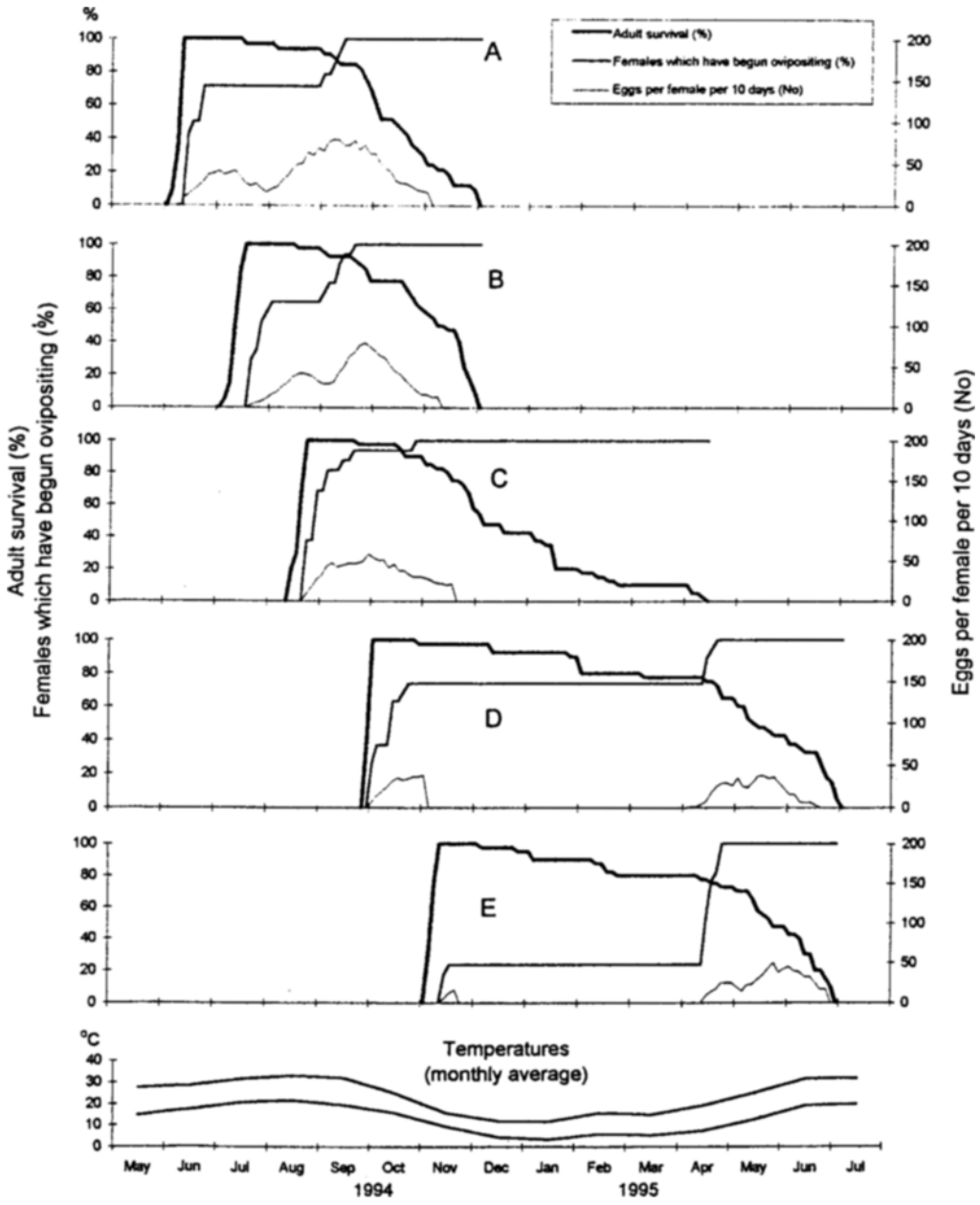

Fig. 2. Voltinism, adult longevity, rate of ovipositing females, and eggs production of 20 pairs of *Hippodamia undecimnotata* adults reared in vials outdoors at Kifissia, Athens in 1994-1995.
(A, B, C, D, E: 1st, 2nd, 3rd, 4th and 5th generation).

In 1993, adults of the 3rd generation did not overwinter (fig. 1C; table 1)). In 1994, about 10% of the adults of the 3rd generation overwintered (fig. 2C; table 1).

Both in 1993-1994 and 1994-1995, adults of the 4th and 5th generations successfully overwintered (fig. 1D, E; fig. 2D, E; table 1).

TABLE 1

Mortality of Hippodamia undecimnotata *adults reared in outdoor cages during 1993 and 1994*

Generation		Adult emergence (date)	Adult mortality (date)		
			1st	50%	Last
1st	1993	10-14/VI	18/VI	10/VIII	6/XII
	1994	5-12/VI	18/VII	3/X	29/XI
2nd	1993	5-7/VII	14/VII	20/VIII	16/XII
	1994	8-18/VII	19/VIII	7/XI	29/XI
3rd	1993	1-3/VIII	26/VIII	10/IX	24/XII
	1994	15-24/VIII	19/IX	5/XII	12/IV, 1995
4th	1993	15-18/IX	21/IX	1/XI	28/VI, 1994
	1994	25-30/IX	29/X	11/V, 1995	1/VII, 1995
5th	1993	25-29/X	8/XI	7/II, 1994	28/VI, 1994
	1994	3-11/XI	5/XII	25/V, 1995	28/VI, 1995

Reproductive activity

Both in 1993 and 1994, females of the 1st and 2nd generations reproduced, completing their egg laying in the same year. The 1st generation females completed egg laying by September 15 in 1993 (fig. 1A) and by November 4 in 1994 (fig. 2A). The 2nd generation completed egg laying by October 29 in 1993 (fig. 1B) and by November 11 in 1994 (fig. 2B). In 1994, 29% of the 1st generation females in vials stopped the maturation of ovaries before oviposition between June 25 and August 31 (fig. 2A); this occurred in 35% of the 2nd generation females arrested at this stage between August 1 and 31 (fig. 2B). The marked delay in ovipositing on the part of 1st and 2nd generation females in vials, noticed during this period of the year, may be evidence of a summer dormancy occurring in about one third of the 1st and 2nd generation adults.

Both in 1993 and 1994, females of the 3rd generation reproduced, completing egg laying in the same year by October 26 in 1993 (fig. 1C) and by November 16 in 1994 (fig. 2C).

As their rates of egg laying show, females of the 4th and 5th generations in both studies (figs. 1D, E; 2D, E) reproduced partly in the year they emerged and partly during the following spring. In 1994 (fig. 2D; E), 74% and 23% of the 4th and 5th generation females, respectively, reproduced before overwintering and all survivors reproduced again in the spring of 1995. The question of summer dormancy does not apply to 4th and 5th generation adults, which emerged after the critical period of the year (figs. 1D, E; 2D, E).

In 1993 (fig. 1D, E), females of the 4th and 5th generations arrested ovipositing on November 12 and 19, respectively. In 1994 (fig. 2D, E), the 4th and 5th generation females ceased ovipositing on November 4 and 19 respectively.

TABLE 2

Hippodamia undecimnotata *recorded on different crops and wild plants in the plain of Kopais, by 30 minute visual counts during 1991-1994*

			No				
	Date	Crop	Eggs	Larvae 1st, 2nd instar	Larvae 3rd, 4th instar	Pupae	Adults
1991	March 27	wild plants					3
	April 10	wild plants					4
	April 17	wild plants					23
	May 3	Wild plants					130
	May 17	wild plants				5	55
	June 11	wild plants				3	34
	June 28	cotton, maize, alfalfa				3	23
	July 10	cotton, alfalfa					1
	July 26	cotton, maize, tomatoes					0
	August 12	maize					2
	September 4	maize					0
	October 3	maize					0
	November 4	alfalfa					0
1992	May 8	wild plants					1
	May 20	wheat, alfalfa					0
	June 10	alfalfa, maize, potatoes			10	12	1
	June 23	alfalfa					2
	June 29	alfalfa					2
	July 8	cotton, maize, onions					4
	July 23	onion, beets, cotton, maize					0
	August 7	squash, cotton, maize					0
	September 4	squash, cotton, maize					90
	September 24	maize					37
	October 12	alfalfa, cotton, maize					94
	October 21	maize					10
1993	April 12	alfalfa					2
	April 26	alfalfa, onion					18
	May 3	maize, alfalfa					6
	June 9	maize, alfalfa					6
	July 2	maize, alfalfa	280				9
	August 4	maize, alfalfa					11
	August 19	tobacco	400		7	3	53
	August 24	tobacco	604	69	29	3	48
	August 31	tobacco			1	15	17
	September 9	maize, wild plants					230
	September 28	maize, wild plants					26
	October 23	wild plants					2
1994	March 30	wild plants					5
	April 6	wild plants					0
	April 26	wild plants					0

Fecundity

The average fecundity of the 1st, 2nd, 3rd, 4th and 5th generation adults reared in outdoor cages in 1993 (fig. 1) was calculated as 405, 376, 293, 284 and 51 eggs per female, respectively. The relatively low fecundities of 4th and 5th generation females maybe 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 of adults reared in the laboratory under temperature 25° ± 1°C, relative humidity 65 ± 5% and 16 h light per day was 907 (SD: 235.2) eggs per female.

PHENOLOGY IN THE OPEN FIELD

The plain of Kopais

Overwintered adults were found in the plain of Kopais between end of March and beginning of May in 1991 and 1994 (table 2). During June 1991 and 1992, larvae and pupae of *H. undecimnotata* were found and adults of the 1st generation emerged. Later reproductive activity of *H. undecimnotata,* with 2nd, 3rd or 4th overlapping generations, is indicated by the eggs found in early July and again in late August 1993, the larvae, pupae and newly emerged adults found in late August 1993 and the newly emerged adults found in September-October 1992 and 1993, confirming the results obtained in outdoor cages (fig. 1B, C, D). During the winter months, observations were occasionally made, but no *H. undecimnotata* individuals were found in the plain of Kopais.

The summits of Mounts Chlomo and Kitheron

Between 1991 and 1994, *H. undecimnotata* adults were never found on the summits of the mountains between early May and early June (table 3). In all years, migration to both summits began in June. The greatest numbers of adults were found on the summit of Mount Chlomo: in 1991 on September 4, in 1992 on September 10 and in 1993 on August 4. On the summit of Mount Kitheron, maxima were found: in 1991 on September 19, in 1992 on August 28 and in 1993 on August 19.

Table 4 gives the total numbers and the size of the aggregates of *H. undecimnotata* on the summits of Mounts Chlomo and Kitheron during 1992-1993. In the period of *H. undecimnotata* migration (June-September 1992 and 1993), at both summits, the great majority of adults were in aggregations. Few individuals were found moving about singly. This indicates that adults of *H. undecimnotata* form aggregations soon after their arrival on the summits. From June, more than half of the population were in groups of hundreds or thousands of individuals. Adults of *H. undecimnotata* were found at the summits of the mountains for the rest of 1992 and overwintered there. Between June and December, most commonly there were found aggregations of 1-3 thousands individuals at the top of Mount Chlomo and of 3-10 hundred at the top of Mount Kitheron.

The *H. undecimnotata* aggregations were usually found in ventilated crevices of rocks, often located near the most prominent spots on the summits, as reported by Hodek (1973) and Iperti and Buscarlet (1986).

In 1993, emigration of adults from the summits of the mountains started in April (tables 3 and 4). On May 3, 1993, on Mount Chlomo, most of the *H. undecimnotata* adults were found singly or in small aggregations of 2-100 individuals (table 3).

TABLE 3

Hippodamia undecimnotata *recorded at the summits of Mounts Chlomo and Kitheron by 30 minute visual counts during 1991-1994*

Chlomo			Kitheron		
	Date	Adults No		Date	Adults No
1991	February 19	4275	1991	March 7	3312
	February 27	2899		March 27	1666
	April 3	1376		April 10	629
	April 17	1232		April 26	63
	May 3	2		May 3	0
	June 28	3331		June 28	632
	July 10	3247		July 2	575
	July 26	3972		July 26	1151
	August 12	5575		August 21	2000
	September 4	10000		September 19	2322
	October 3	8815		October 18	2300
	November 4	5557		November 20	3914
1992	January 22	3500	1992	May 8	0
	May 8	0		May 20	0
	May 20	0		June 10	0
	June 10	11		June 19	2
	June 19	0		June 29	2150
	June 29	4205		July 10	1700
	July 10	3547		July 13	2557
	July 20	2475		July 20	1667
	July 29	6550		July 29	1300
	August 10	6150		August 10	1430
	August 20 .	4750		August 20	810
	August 28	6100		August 28	3500
	September 10	10000		September 10	1000
	September 24	6750		September 24	1645
	October 9	7600		October 9	1380
	October 19	8300		October 19	1220
	November 20	6850		November 20	1250
	December 21	6100		December 21	850
1993	January 20	8500	1993		
	March 5	7000			
	March 26	7500		March 26	1280
	April 12	7000		April 12	420
	May 3	633		May 3	75
	May 17	0		May 17	0
	June 9	1000		June 9	0
	August 4	7500		August 4	2250
	August 19	5500		August 19	4800
	September 9	4000		September 9	2500
	September 28	2800		September 28	1000
	October 23	2600		October 23	1300
1994	March 30	6470	1994	March 30	390
	April 6	5700			
	May 5	0		May 5	0
	July 8	9400		July 8	720

TABLE 4

Hippodamia undecimnotata *adults found singly and in aggregations, during 30 minutes visual counts at the summits of Mounts Chlomo and Kitheron (1992-1993)*

	Date	Chlomo									Kitheron							
			%							Adults total	%							
			A	B	C	D	E	F	G	H	No	A	B	C	D	E	F	G	H
1992	May 8	0									0								
	May 20	0									0								
	June 10	11	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0								
	June 19	0									2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	June 29	4205	0.1	0.1	0.0	1.1	5.9	9.5	83.2	0.0	2150	0.0	0.0	0.0	0.0	0.0	39.5	60.5	0.0
	July 10	3547	0.6	0.0	1.3	5.0	0.0	36.7	56.4	0.0	1700	0.6	0.0	0.0	5.3	17.6	76.5	0.0	0.0
	July 13										2557	0.0	0.3	0.8	9.0	0.0	39.1	50.8	0.0
	July 20	2475	0.0	0.0	2.6	4.4	12.1	80.8	0.0	0.0	1667	0.0	0.1	0.9	3.0	9.0	21.0	66.0	0.0
	July 29	6550	0.0	0.0	0.8	1.5	18.3	18.3	61.1	0.0	1300	0.0	0.4	3.5	0.0	38.5	57.7	0.0	0.0
	August 10	6150	0.5	0.0	1.6	2.8	13.8	48.8	32.5	0.0	1430	0.1	0.3	1.6	5.6	50.3	42.0	0.0	0.0
	August 20	4750	0.0	0.0	0.0	0.0	9.5	48.4	42.1	0.0	810	0.0	0.0	3.7	34.6	61.7	0.0	0.0	0.0
	August 28	6100	0.0	0.0	0.0	1.6	4.9	36.1	57.4	0.0	3500	0.0	0.0	2.9	20.0	34.3	42.9	0.0	0.0
	September 10	10000	0.0	0.0	0.0	0.0	0.0	20.0	30.0	50.0	1000	0.0	0.0	0.0	20.0	30.0	50.0	0.0	0.0
	September 24	6750	0.0	0.0	1.5	3.0	8.1	13.3	74.1	0.0	1645	0.0	0.9	1.8	0.0	36.5	60.8	0.0	0.0
	October 9	7600	0.0	0.3	0.4	2.6	6.6	4.6	85.5	0.0	1380	0.0	0.0	2.2	7.2	36.2	54.3	0.0	0.0
	October 19	8300	0.0	0.5	0.7	2.4	12.0	12.0	72.3	0.0	1220	0.0	0.0	4.1	5.7	32.8	57.4	0.0	0.0
	November 20	6850	0.0	0.0	0.7	0.7	13.9	33.6	51.1	0.0	1250	0.0	0.0	4.0	0.0	40.0	56.0	0.0	0.0
	December 21	6100	0.0	0.8	1.6	4.1	11.5	32.8	49.2	0.0	850	0.0	0.0	5.9	11.8	0.0	82.4	0.0	0.0
1993	January 20	8500	0.6	0.0	0.0	6.5	10.6	35.3	47.1	0.0									
	March 5	7000	0.0	0.0	0.0	2.9	11.4	35.7	50.0	0.0									
	March 26	7500	0.0	0.0	0.0	5.3	8.0	40.0	46.7	0.0	1280	0.0	0.0	2.3	0.0	39.1	58.6	0.0	0.0
	April 12	7000	0.2	0.2	1.0	1.4	4.3	35.7	57.1	0.0	420	3.6	6.0	9.5	33.3	47.6	0.0	0.0	0.0
	May 3	633	24.5	4.4	23.7	47.4	0.0	0.0	0.0	0.0	75	0.0	6.7	40.0	53.3	0.0	0.0	0.0	0.0
	May 17	0									0								
	June 9	1000	5.0	35.0	60.0	0.0	0.0	0.0	0.0	0.0	0								
	August 4	7500	0.0	0.0	0.0	0.0	0.0	6.7	93.3	0.0	2250	0.0	0.0	0.0	0.0	11.1	22.2	66.7	0.0
	August 19	5500	0.0	0.0	0.0	0.0	0.0	9.1	90.9	0.0	4800	0.0	0.0	0.0	0.0	6.3	10.4	0.0	83.3
	September 9	4000	0.5	0.0	0.0	0.0	0.0	24.5	75.0	0.0	2500	0.0	0.0	0.0	0.0	0.0	40.0	60.0	0.0
	September 28	2800	0.0	0.0	0.0	0.0	0.0	28.6	71.4	0.0	1000	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
	October 23	2600	3.8	0.0	0.0	0.0	0.0	19.2	76.9	0.0	1300	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
	Total	133421	0.3	0.4	1.1	2.4	7.2	26.4	58.5	3.7	36086	0.1	0.2	1.5	5.8	19.2	43.6	18.6	11.1

A: Adults found singly; B: Adults found in aggregrations of 2-10 individuals; C: of 11-30 individuals; D: of 31-100 individuals; E: of 101-300 individuals; F: of 301-1000 individuals; G: of 1001-3000 individuals; H: of > 3000 individuals.

Factors favoring the "hypsotactic" and aggregational behavior of *H. undecimnotata* (Hodek, 1960; 1967) include hot and dry weather conditions (Iperti, 1978), wind currents (Iperti and Buscarlet, 1986), scarcity of aphids (Iperti and Hodek, 1974) as well as aphid quality affected by aged host plants (Rolley *et al.*, 1974). These conditions seem to be met in central Greece from mid-late June onward. The completion of 5 annual generations by *H. undecimnotata* reared in outdoor cages represents an optimum obtained by accelaration of generations (only the earliest eggs and/or adults were isolated) and by providing aphids in abundance at times when they would usually be scarce in the field.

RÉSUMÉ

Phénologie d'*Hippodamia undecimnotata* (Col.: Coccinellidae) en Grèce

Hippodamia (Semiadalia) undecimnotata (Col.: Coccinellidae), récoltée en Grèce centrale puis mise en élevage dans des cages pendant les années 1993-1994 et en tubes en 1994-1995, à l'extérieur à Kifissia (Athènes), a présenté 5 générations par an. Dans les deux cas, des adultes de première, deuxième et troisième générations se sont reproduits, et ont pondu au cours de la même année ; les adultes des quatrième et cinquième générations se sont reproduits à la fois l'année de leur émergence et l'année suivante. Dans les deux cas, les adultes de première et deuxième générations sont morts avant l'hiver; en 1993, les adultes de troisième génération sont eux-aussi morts avant l'hiver alors qu'en 1994 ils ont survécu jusqu'en avril 1995. Les adultes de quatrième et cinquième générations ont hiverné avec succès. Le plus grand nombre d'œufs a été pondu par les femelles de première et deuxième générations.

Des observations sur le terrain ainsi que des comptages réguliers d'individus (30 mn par site) effectués sur le sommet des Monts Chlomo et Kitheron et dans la plaine voisine de Kopais, entre 1991 et 1994, ont révélé que la plupart des adultes arrivaient sur les montagnes entre la fin juin et le début septembre et quittaient ces zones entre la fin mars et le début mai. *H. undecimnotata* n'a pas été trouvée dans la plaine de Kopais pendant l'hiver. Les adultes ayant hiverné arrivaient entre la fin mars et le début mai; la première génération d'adultes émergeait en juin. La présence de quelques œufs, larves, nymphes et adultes nouvellement sortis observée dans la plaine en août-septembre 1993 suggère qu'au moins une partie de la population de *H. undecimnotata* en Grèce centrale présente deux générations ou plus qui se chevauchent dans une même année.

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