Ecological Entomology (1976) **1**, 201–207

Observations on the biology of *Subcoccinella vigintiquattuor-punctata* (L.) in southern England

AOLA M. RICHARDS, R. D. POPE* AND V. F. EASTOP*

*School of Zoology, University of N.S.W., Sydney, and *Department of Entomology, British Museum (Natural History), London*

Abstract

1. *Subcoccinella 24-punctata* (L.) is exclusively phytophagous, and is widely distributed throughout Britain.
2. Under laboratory conditions the duration of pre-adult instars is about 6 weeks. Adults appear from the end of June onwards. Many enter reproductive diapause at the end of July, but remain active till the end of October.
3. Reproductive diapause is determined by the interaction of photoperiod and temperature.
4. Hibernation is unstable, and there may be high mortality in overwintering adults. These finally die during May and June.
5. The cool temperate climate limits the population size, preventing it from reaching pest proportions.

Introduction

The Coccinellidae are a family of Coleoptera of great economic importance and world-wide distribution. Most are insect predators, but one subfamily, the Epilachninae, are phytophagous and members attack such crops as maize, lucerne, tomatoes, potatoes, beans, wheat and cucurbits. The Epilachninae occur mainly in tropical and semitropical parts of the world, with few species in Europe. This paper is concerned with one of these, *Subcoccinella 24-punctata* (L.), which is widely distributed throughout Europe, Asia Minor, North Africa, Caucasus and U.S.S.R., and is the only epilachnine known to occur in Britain. Although not very common, it is found throughout England, Scotland and Wales.

In southern Europe, *S.24-punctata* is a pest of many plants including lucerne, clover, peas, beans, herbs, potatoes, wheat and lupins (Tanasijevic, 1958). In Britain, it is regarded as harmless, although it has been recorded from lucerne, clover, bladder campion, sea campion, white goosefoot, wheat, scentless mayweed, soapwort, vetch, grasses, nettles, *Phragmites communis* and *Artemisia* (Marriner, 1927; Eastop & Pope, 1966).

In recent years, Tanasijevic (1958) has made a detailed study of the morphology and biology of *S.24-punctata* in Yugoslavia. In Britain, Marriner (1927) recorded some observations on its life history in northern England, and since then it has been neglected. The present study of the species in southern England has led to some interesting comparisons of its biology in these three different localities.

Correspondence: Dr V. F. Eastop, Department of Entomology, British Museum (Natural History), Cromwell Road, London SW7 5BD.

Materials and Methods

During the first 6 months of 1974, weekly visits were made to an area near Kew in Surrey where *Subcoccinella 24-punctata* had been observed over the previous 11 years (Eastop & Pope, 1966, 1969). Specimens of *S.24-punctata* were swept or beaten from low herbage, but were very rare, only one, or at the most two, being taken at any one time. They were used as the basis for a study of the biology of this species.

In the laboratory, beetles were killed with ethyl acetate and dissected under Insect Ringers Solution to study the reproductive system. Live beetles and larvae were kept in specimen tubes with moistened cotton wool stoppers. Some were kept separately so individual progress could be assessed, but others were placed in groups of three or four individuals. They were all kept at room temperature, and fed regularly with leaves of *Melandrium rubrum*. After oviposition all eggs were transferred to a separate container for the duration of the incubation period. Newly emerged adult beetles were kept separate for a few days, and then paired off. They were placed near windows, as warmth and bright light are necessary stimuli for mating in coccinellids.

Taxonomy

Subcoccinella vigintiquattuorpunctata was originally described by Linné in 1758 as *Coccinella.* Since then it has acquired a number of synonyms, and been placed in several different genera (Korschefsky, 1931). It was finally placed in *Subcoccinella.* Incidentally, Agassiz (1846) and not Huber (1842) must be credited with authorship of *Subcoccinella* as he was the first person to latinize the vernacular name applied to the genus by Huber.

The very wide distribution and extensive synonymy suggested that more than one species might be involved, or that subspeciation at least might have occurred. Variability in the number of spots on the elytra occurs in many coccinellids, and is not a good character for separating populations, so a comparative study was made of the male genitalia, female genital plates and spermatheca in a large number of specimens from Turkey, Greece, Spain, Germany, France and England. No differences occurred in the shape of the male genitalia and female genital plates. Small variations were found in the shape of the spermatheca, particularly in France and southern England, but these were not significant and no evidence was found to suggest speciation or clinal distribution leading to subspeciation.

Life cycle

Oviposition

A female *S.24-punctata* collected in mid May 1974 was kept in captivity for 42 days. During the first 25 days, from 13 May to 6 June, seventy eggs were laid in fourteen batches without further mating taking place. Oviposition usually occurred at night. A single locality was selected on a particular day, and all eggs in that batch were laid close together. They were sometimes laid on the under surface of a *Melandrium rubrum* leaf, but marked preference was shown for the cotton wool stopper. Each egg was laid singly, and deposited in a vertical position with the posterior pole cemented to the substrate.

Egg and eclosion

The egg is yellow, oval, uniformly and finely sculptured all over, and approximately 1·25 mm in length by 0·4 mm in width. The anterior pole is tapered, while the posterior pole is rounded. Shortly before eclosion the chorion turns grey and becomes thin and semi-transparent. The ocelli, mandibles and hatching spines on the head of the embryo become visible through it. A bulge gradually develops on one side of the chorion, caused by pressure of the head and hatching spines. At eclosion the larva emerges head first. Once the head appears, eclosion is completed in from 2 to 10 min. It usually occurred in the early morning. The total mean days incubation was 7·3 days (range 6–11). There is a suggestion (barely significant at the 5% level) that

Table 1. Length of hatching period and percentage hatch in *Subcoccinella* 24-*punctata* (L.)

Date laid	Total eggs laid	Total hatch	Hatch (%)	Range (days)	Mean days incubation		Standard deviation
13.5.74	3	—	—	—	—		
14.5.74	6	2	33	6	6		
21.5.74	9	5	55·5	6–9	7·6		
22.5.74	4	2	50	6	6		
23.5.74	5	2	40	6	6	6·85	1·04
24.5.74	5	3	60	6–7	6·3		
25.5.74	4	3	75	6–7	6·7		
26.5.74	4	3	75	8	8		
27.5.74	5	4	80	6–7	6·5		
31.5.74	3	2	66	6	6		
1.6.74	7	4	57	6–8	7		
2.6.74	7	6	85·7	6–10	8	7·82	1·74
4.6.74	4	4	100	7–11	9·3		
6.6.74	4	2	50	10–11	10·5		
Totals	70	42					
Means			60		7·3		1·52

Period of hatch 20 May to 13 June 1974.

Table 2. Size and duration of preadult instars in *S.24-punctata*

Instar	Length (mm)	No. of specimens	Duration of each instar (days) Range	Mean	Standard deviation
1	1·5	39	4–14	6·7	1·7
2	2·5	37	3–12	5·8	2·2
3	3·5	30	4–9	5·6	1·4
4	6	29	7–16	10·1	2·4
5	4·5	23	4–8	5·7	1·4
Total larval instars		29	21–40	27·8	4·6
Total larval and pupal instars		23	28–47	32·8	4·1
Total egg to adult		23	34–53	40	4·1

the later laid eggs contain a higher proportion of slower developers (Table 1). The percentage hatch was 60%.

Number of preadult instars

The newly emerged larva is 1·5 mm in length by 0·5 mm in width. It either remains on the empty chorion or moves a short distance away, often on to another egg, while waiting for its cuticle to harden and the typical first instar coloration to develop. This may take several hours, and during this time the larva does not feed. At no stage was any attempt made to eat the chorion, and no cannibalism of eggs or other larvae occurred.

Twenty-three specimens were reared from egg to adult. They passed through five instars, four larval and one pupal. Sizes of individuals within each instar varied slightly, so mean values have been given (Table 2). The duration of time spent in these instars varied considerably. The first three larval instars plus the pupal instar averaged 6 days, while the fourth larval instar averaged 10 days, 66% as long again (Table 2). The mean total time from egg to adult was 40 days. A second instar larva collected near Kew on 15 June 1974 fitted into this pattern, becoming adult on 3 July.

Table 3. Survivors and mortality rates for individuals entering each stage in *S.24-punctata*

Stage	No. of surviving	Mortality	% Mortality
Eggs laid	70	—	—
Eclosion	42	28	40·0
Larva 1	39	3	7·1
Larva 2	37	2	5·1
Larva 3	30	7	18·9
Larva 4	29	1	3·3
Pupa	23	6	20·7
Imago	23	0	0

Mortality

Mortality was fairly high (Table 3), the total percentage mortality being 67%. The greatest mortality of 40·0% occurred in the developing embryo. The mortality rate within the larval instars was 31% of those surviving eclosion, representing 18·6% of eggs laid.

Ecdysis and colour variation

Ecdysis usually occurred late at night or in the early morning. Feeding stopped a few hours beforehand and the integument became very pale. The larva used its anal organ to cement itself to the substrate, usually the under surface of a *Melandrium rubrum* leaf, but occasionally the side of the specimen tube or the cotton wool stopper. Pressure was then exerted to split the cuticle down the ecdysial line from the head capsule to the metanotum or anterior abdominal tergites. The larva slowly pulled itself free leaving the exuvia attached to the substrate. Several hours were required for the cuticle to harden and the typical coloration of the new instar to develop. The exuvia were never eaten. The pupa was always partly enclosed by the fourth instar larval exuvia, which were usually attached to the under surface of a leaf. The developing imago could be seen through the pupal integument shortly before the final ecdysis.

The newly emerged larvae are yellow, and gradually darken as the melanic pattern develops. The numerous setae change from straw colour to black. The first instar larva is the darkest of the four instars, and the fourth instar larva the palest having a basic colour of pale yellow with black markings and setae. The pupa is also yellow.

Of the twenty-three beetles reared, thirteen (56·5%) emerged with the characteristic orange-red colour and black spots. The remaining ten (43·5%) were a uniform pale lemon with red legs and no spots. Over a period varying from 3 to 36 h the colour gradually intensified to the normal coloration. The pronotum and head changed first, with the pale yellow increasing to a deep yellow, orange and finally red. A black spot developed in the centre of the pronotum. Next spots appeared on the elytra, very faintly at first, but gradually increasing in intensity to black. In no instance did the spots fail to develop, although the final intensity of the melanin and orange-red pigment varied. These beetles did not come from special batches of eggs, but were scattered throughout all the eggs. The numerous

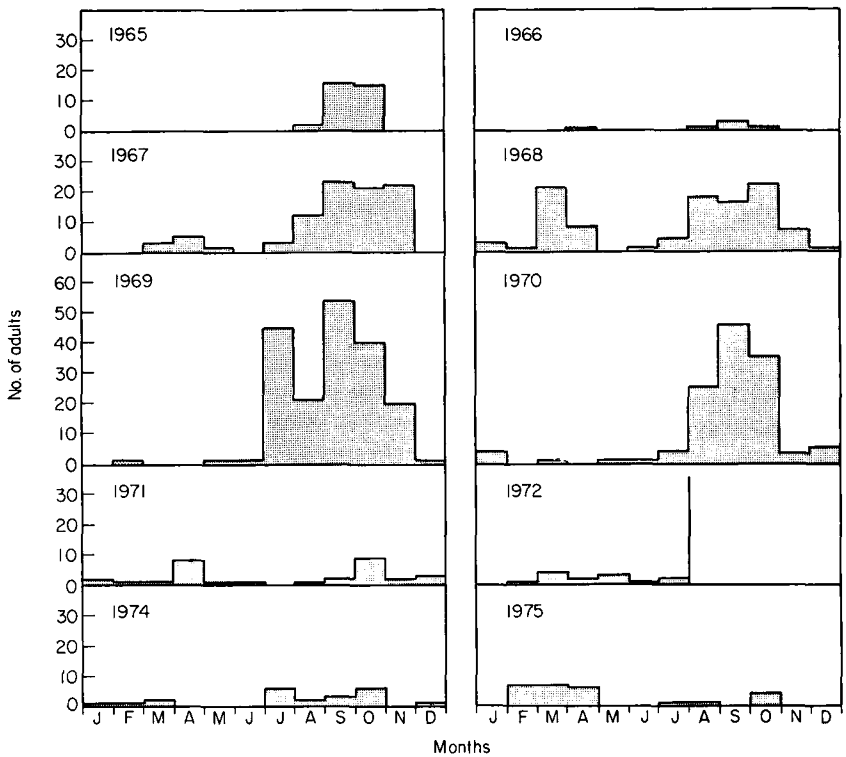

Fig. 1. Total number of *Subcoccinella 24-punctata* (L.) adults recorded near Kew, Surrey, 1965 to August 1972 and 1974–75.

variations in spot patterns that may occur on the elytra are well documented and were not studied.

Annual cycle

Between 1963 and 1972 and between 1974 and 1975 weekly records were kept of the number of *S.24-punctata* observed near Kew in Surrey. Over the whole period 624 were seen. Beetles were active throughout the year, although numbers fluctuated markedly (Fig. 1). Few were seen between November and February, but hibernation was not total as some beetles were active during spells of milder weather. In early February 1974 dissection of a female's abdomen revealed large masses of white fat body, an empty alimentary tract, and ovaries consisting of small, white germaria, all characteristic of diapausing coccinellids. No further beetles were seen till mid March, when a pair were taken *in cop.* In both beetles much of the fat body had turned from white to yellow, and the alimentary tract was full. The ovarian follicles, although still white, had increased in size, and one oocyte was almost fully developed. Another female dissected at the end of March had yellow fat body, the abdomen contained droplets of fat, and two oocytes were vitellinized. All beetles dissected in March had emerged from hibernation. In 1975, two beetles were observed *in cop.* in late April. Overwintering adults die off during May and June. The larvae emerging from eggs laid from April to June became adult from June to August, and adults reached a peak in early autumn (Fig. 1). The twenty-three beetles which emerged from pupae between 18 June and 19 July 1974 were paired off so that mating behaviour could be studied. Although large quantities of *Melandrium rubrum* were eaten, mating was not observed, nor were any eggs laid. At the end of July, three females were killed and dissected. The quantity of food in the alimentary tract varied, as did the amount of fat body, but in all cases the ovaries consisted of small white germaria characteristic of diapausing coccinellids. Ovaries from two more females dissected in mid August were in a similar stage of immaturity. Another female collected in Essex in late August 1975 was also in reproductive diapause.

Beetles continue feeding and remain active through September and October till the onset of cooler temperatures. It is not certain whether the low numbers observed in spring reflect a high winter mortality or a low level of activity during cool weather. Mating occurs in spring before the beetles disperse. No experimental evidence was obtained for the existence of a second generation. Between 1967 and 1970 inclusive, a period of warm autumns, *S.24-punctata* was observed more frequently than in 1963–66 or 1971–75. Again it is not clear whether this represents greater activity due to higher temperatures at the time of maximum population, or an increase in population due to more favourable weather conditions.

Food preferences

S.24-punctata is primarily phytophagous, and normally feeds on leaves. In captivity larvae and adults were fed regularly on leaves of *Melandrium rubrum*. They appeared to be host specific in their food preferences, as clovers and nettles on which the species is known to feed, were rejected. Large quantities of food were consumed. Both beetles and larvae fed on the under surface of leaves, eating the lower epidermis and palisade cells, but leaving the upper epidermis intact. As a result, leaves gradually became etiolated with yellowish brown blotches.

Female beetles sometimes ate their own eggs, but there was no other evidence of cannibalism.

Discussion

Although *Subcoccinella 24-punctata* is widespread throughout Europe, and in many countries is regarded as a pest, the main interest in it has centred on its taxonomy. Over the last 200 years, descriptions of variations and aberrations have led to a massive literature about it. It is only comparatively recently that a thorough study has been made of its biology. Tanasijevic (1958) has studied *S.24-punctata* in Yugoslavia, where it is a major pest of lucerne. Because very little is known about its biology in northern Europe, Tanasijevic's work has been used as the basis for a study of its biology in England, in an attempt to explain why it has not become a pest in Britain.

S.24-punctata has mandibles highly specialized for feeding on plant tissues, so is well equipped to cause considerable damage to crops. Although many of the plants attacked in southern Europe also occur in England, there both larvae and adults appear to be very selective in the choice of food plant. The specimens reared in London during 1974, fed exclusively on *Melandrium rubrum* throughout the whole of their life cycle. It was significant that this plant was not common in the west London area. Host plant specificity is generally greater at moderate temperatures than at very high or very low temperatures.

S.24-punctata is usually exclusively phytophagous, but if the food supply is inadequate, female beetles may occasionally lay eggs and eat them. Marriner (1927) records the first meal of all his newly hatched *S.24-punctata* larvae as consisting of part of the chorion, after which other larvae were attacked and eaten. This behaviour is characteristic of aphidophagous coccinellids. None of the forty-two larvae in the present experiments attempted to eat their egg shells or each other.

The position and shape of the spines used as egg bursters in *S.24-punctata* have been variously interpreted. Strouhal (1927) regards two short, blunt, stellate clusters of setae, from each of which a long slender spine protrudes, as the egg bursters. They occur on either side of the pronotum in the first instar larva, and are shed at the first ecdysis. Tanasijevic (1958) interprets six long spines with serrated truncate tips, three on either side of the head, as the hatching spines. Both groups of spines were present on all first instar larvae examined during our experiments, but it was difficult to decide which ones were used by the larva.

Intraspecific variation in colour pattern is a common phenomenon in coccinellids. Two types may occur—variations in the amount of melanin present leading to numerous patterns and taxonomic aberrations within species, and variations in the intensity of pigmentation in newly emerged adults. In the latter case, the time required for development of the normal colour pattern may vary from hours to weeks or even months. Both types of colour variation occur in *S.24-punctata.* Variations in the amount of melanin lead to the development of numerous patterns around the normal twenty-four spots on the elytra, and range from total absence of melanin to coalescence of spots, and finally to a totally melanic form. Tanasijevic (1958) illustrates fifteen different variations, while Hodek (1973) features yet another. The gradual and dramatic

Table 4. Duration of preadult stages of life cycle in *S.24-punctata*

	Duration of each instar (days)			
	London	Carlisle (Marriner, 1927)	Yugoslavia (Tanasijevic, 1958)	
	May–June	June–July	April–June	July–August
Developing embryo	6–11	3–6	8·8–18·6	4·5–6·4
Instar 1	4–14	2	22·7–49	14–18
Instar 2	3–12	3		
Instar 3	4–9	—		
Instar 4	7–16	—		
Pupa	4–8	7–8	6–13·5	4–4
Total larval instars	27·8 (21–40)	22·5 (21–24)	35·9 (22·7–49)	15·9 (14–18)
Total egg to adult	40 (34–53)	34	59·3 (37·5–81)	24·6 (22–28)

changes in coloration from uniform pale lemon to orange-red, accompanied by the gradual development of black spots, have not previously been recorded in newly emerged adult *S.24-punctata*. However, they have been noted in other coccinellids. Hodek (1973) records them in *Hippodamia tredecimpunctata* (L.), and considers that they are usual in all coccinellids. Eastop (1969) records them in *Coccinella septempunctata* L., but notes that in *Adalia bipunctata* (L.) melanin appears early in the development of the adult inside the pupa. In the London specimens of *S.24-punctata* more than half the adults reared emerged with a colour pattern very close to normal.

S.24-punctata has four larval instars. Marriner (1927) recorded only three, as he failed to separate the third and fourth instars. Tanasijevic (1958) observed four larval instars and a prepupal stage. In comparing the duration of generations of *S. 24-punctata* in England and Yugoslavia (Table 4), the prepupal stage has been incorporated into the larval instars.

The number of generations per year that *S. 24-punctata* may pass through varies in different parts of Europe, as differences in latitude and seasonal temperatures influence its biology. Warmer climates enable more generations to be completed. Tanasijevic (1958) lists two to three generations in Italy, two and perhaps a partial third in Yugoslavia, and two in Hungary. Marriner (1927) records two generations in Carlisle reared in glass fronted or gauze cages. Although summer temperatures in Carlisle are rather lower than in London, the longer mid-summer photoperiod at Carlisle may be the factor which permits two generations of *S. 24-punctata* while only one was observed in London. Hämäläinen & Martii (1972) describe how the interaction of photoperiod and temperature influence the number of generations of *Coccinella septempunctata*.

The mean number of eggs per batch laid by individual females in May and June was lower in London than in Yugoslavia. In London this consisted of 5 eggs (range 3–9) from fourteen batches, and in Yugoslavia 12·6 eggs (range 8·6–21) from twenty-three batches (range 5–38). Marriner's (1927) observations are not comparable with these figures, as only four egg batches were recorded, and it is not known how many females laid the eggs. The total egg laying capacity of females in England is not known, but these figures suggest that it is very much lower than the normal range of 200–300 eggs in Yugoslavia.

The duration of preadult instars in *S.24-punctata* is variable, and appears to be directly related to temperature. Marriner (1927) found that each stage of the life cycle could be hastened or retarded by changing the temperature, but that both the June–July and July–August generations reared in cages in Carlisle were of similar length. The duration of the west London instars is slightly longer than in Carlisle, and is about half way between those in the spring and summer generations in Yugoslavia (Table 4). Marriner's overwintering beetles laid their eggs in early June, thus overlapping in time with the later egg batches of the London female. The differences in the rate of preadult development in Carlisle and London may be due to temperature variation, but no night temperatures are available from the Carlisle and London cages for comparison. Probably development is even slower in the field due to lower temperatures, especially at night. This may be why large numbers of adults are not usually observed in west London until August or September (Fig. 1). As a small number of this population are adult by the latter part of June, it is possible that in warm seasons they may give rise to a partial second generation overlapping with the protracted first generation; but so far there is no experimental evidence for this.

In both England and Yugoslavia, reproductive diapause commences in some individuals of *S.24-punctata* as early as July. Although in reproductive diapause, the beetles remain active throughout the autumn. Hibernation is often unstable, allowing beetles to become active for short periods on mild winter days. In a variable climate there is likely to be strong selection for unstable diapause, because the inability to return to dormancy after a spell of mild weather in January could be fatal. There is more likely to be a balanced genetic mechanism allowing diapausing individuals to contribute some non-diapausing individuals to the next generation and vice versa, than to have distinct strains with diapausing and non-diapausing genotypes. This applies both to reproductive diapause and to hibernation. The low numbers observed in spring may indicate a high mortality in the overwintering population in southern England.

The cool climate may be the most important influence limiting the population size of *S.24-punctata* in England. The shorter, cooler summers inhibit the accelerated rate of development of preadult instars which occurs in Yugoslavia and favour reproductive diapause, while mortality during the variable winter also prevents the species from building up to pest proportions in England.

Acknowledgments

We should like to thank our colleague P. M. Hammond for collecting the female beetle in May 1974. One of us, A. M. Richards, wishes to thank Dr P. Freeman, Keeper of Entomology, British Museum (Natural History), for permission to carry out part of this study in the Department of Entomology whilst the recipient of an Imperial Relations Trust Travel Grant.

References

Agassiz, L. (1846) Coleoptera. In: *Nomenclator Zoologicus*, Fasc. XI. Solod.

Eastop, V.F. (1969) An apparently undescribed structure in the Coccinellidae (Coleoptera). *Proc. R. ent. Soc. Lond.* A, **44** (7–9), 111–112.

Eastop, V.F. & Pope, R.D. (1966) Notes on the ecology and phenology of some British Coccinellidae. *Entomologist*, **99**, 287–289.

Eastop, V.F. & Pope, R.D. (1969) Notes on the biology of some British Coccinellidae. *Entomologist*, **102**, 162–164.

Hämalainen, M. & Martii, M. (1972) Possibility of producing *Coccinella septempunctata* L. (Col., Coccinellidae) without a diapause. *Ann. ent. Fenn.* **38** (4), 193–194.

Hodek, I. (1973) *Biology of Coccinellidae*. Junk, The Hague.

Huber, P. (1842) Mémoire pour servir à l'histoire de la coccinelle de la saponaire. *Mém. Soc. Phys. H.N. Genève*, **IX** (2), 363–378.

Korschefsky, R. (1931) Coccinellidae. In: *Coleopterorum Catalogus*, partes 118 + 120, 659 pp. Berlin.

Marriner, T.F. (1927) Observations on the life history of *Subcoccinella 24-punctata*. *Entomologist's mon. Mag.* **63**, 118–123.

Strouhal, H. (1927) Die larven der palaearktischen Coccinellini und Psylloborini. *Arch. Naturgesch.* **92** (A), **3**, 1–62.

Tanasijevic, N. (1958) Zur morphologie und biologie des luzernemarienkafers *Subcoccinella vigintiquatuorpunctata* L. (Coleoptera:Coccinellidae). *Beitr. Ent.* **8** (1/2), 23–78.

Received 14 February 1976