EKOLOGIA POLSKA (Ekol. pol.)	35	3–4	755–765	1987

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THE OCCURRENCE OF *ADALIA BIPUNCTATA* (L.) (COLEOPTERA, COCCINELLIDAE) IN APPLE ORCHARDS AND THE EFFECTS OF DIFFERENT FACTORS ON ITS DEVELOPMENT*

ABSTRACT: During five years of field studies (1974–1978) *A. bipunctata* was the most numerous species of ladybirds in apple orchards. The adults occurred in large number during spring especially from green or pink bud stages to the end of May and they averaged about 22% of all coccinellid fauna collected during the period of observations. During the years 1978–1982 laboratory experiments concerning the influence of some biotic and abiotic factors of females fecundity, embryonic and larval development were also conducted.

KEY WORDS: Apple orchards, Coccinellidae, aphid predators, food influence.

1. INTRODUCTION

Adalia bipunctata is a common aphid predator which occurs mainly on different species of trees and bushes (Hodek 1973). According to Iperti (1966) this species prefers the strata of vegetation higher than 2 m. It was also found to occur very often in apple orchards in different parts of Europe (Kanervo 1962, Principi et al. 1967, Evenhuis 1968, Pruszyński and Lipa 1970, Semjanov 1965a, 1965b, 1970, Niemczyk and Olszak 1975/76, Olszak and Niemczyk 1986). Also Asgari (1966) listed *A. bipunctata* as natural enemies of *Aphidula pomi* Deg. in apple orchards around Stuttgart Hohenheim (Federal Republic of Germany). But, he does not state its abundance. Some authors listed *A. bipunctata* as an aphid predator also in the

* This study was partially sponsored by the U.S. Department of Agriculture, Agric. Res. Service Grant FG-Po 362 (JB-31).

nearctic region (Smith 1958, Evenhuis 1960). Some aspects of the biology of this species were described by Hariri (1966), Blackman (1967a, 1967b), Ellingsen (1969a, 1969b), Pruszyński and Lipa (1970), Semjanov (1970). Though coccinellids are polyphagous insects it has been established in many investigations that different aphid species demonstrate a considerable variability in suitability as food for different species of coccinellids (Smith 1965a, 1965b, 1965c, 1966, Blackman 1967a, Olszak 1986a).

The purpose of this work was to ascertain the role of *A. bipunctata,* in apple orchards in Poland and to investigate the influence of some factors on its development. The effect of different aphid foods on the fecundity, survival and development of this predator was particularly interesting.

2. METHODS

Observations on the occurrence of *A. bipunctata* were carried out during the years 1974–1978 in different parts of Poland. It was described in detail by Olszak and Niemczyk (1986).

In the laboratory adult insects were reared in 250 cm^3 glass vials. Oviposition experiments were carried out in 150 cm^3 glass jars covered with clotch gauze. There was one male and one female in each jar. Crumpled pieces of paper were placed in each container as a site for egg laying and eggs were counted usually twice a day. The larvae were reared singly in modified Huffaker's boxes covered with plexiglass with a mesh opening. In experiments on the influence of different prey on *A. bipunctata* development, different species of aphids were used, especially those which occurred on apple trees.

As an alternative food the eggs of angoumois grain moth (*Sitotroga cerealella* Oliv.) were also investigated. The food was always supplied in surplus. The 1st and 2nd instar larvae of ladybirds were given 1st and 2nd instar aphids, while the 3rd and 4th instar ladybirds were given older aphid instars. All laboratory experiments were carried out in rearing chambers with a range of temperature of 20–25°C, about 70% relative humidity and 16 hours long day.

3. RESULTS

3.1. THE OCCURRENCE OF *A. BIPUNCTATA* IN APPLE ORCHARDS

Of the complex of coccinellids occurring in apple orchards *A. bipunctata* is one of the most widespread (Olszak and Niemczyk 1986) and numerous (Fig. 1). This species during the period of observation made up almost 22% of all collected coccinellids with a frequency index 0.41 in 5 orchards and almost 34% of all collected coccinellids with a frequency index 1 in 17 orchards (Fig. 1). One can conclude that these predators have immigrated into the orchards from the surrounding area, since investigations on the overwintering of coccinellids in apple orchards showed that they

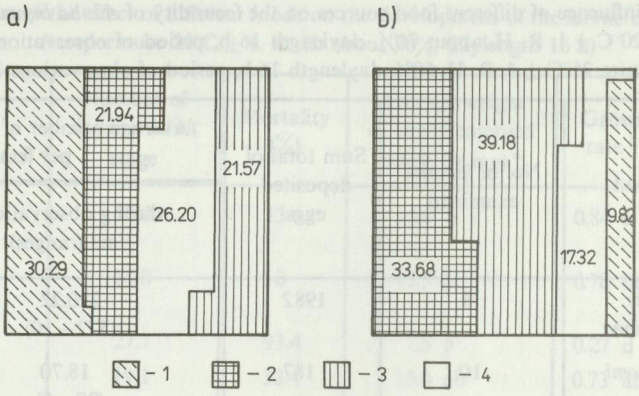

Fig. 1. The participation (in per cent) of *Adalia bipunctata* in coccinellid fauna of apple orchards a – data from 5 orchards over 5-year observations, b – data from 17 orchards over 1-year observations, 1 – *Coccinella septempunctata* L., 2 – *Adalia bipunctata*, 3 – *Propylea quatuordecimpunctata* (L.), 4 – other coccinellids

were almost completely absent under the litter and very scarce under the bark of apple trees (R. W. Olszak – unpublished data).

During five years of investigations a large number of *A. bipunctata* adults occurred in the apple orchard in the spring even if the trees were infested by low numbers of aphids. But detailed studies have shown that coccinellid beetles are able to find and kill aphids which occur at very low densities (O l s z a k 1986b).

Moreover, during flowering they can also find alternative food such as pollen and nectar in the orchard. During May egg masses and larvae were also found, especially on apple trees infested by *Rhopalosiphum insertum* Walk. Later *A. bipunctata* occurred in the apple orchard in rather low numbers, however, they were noticed in adjacent areas on different species of bushes or trees. During the summer time a high number of *A. bipunctata* individuals was observed, e.g., on trees such as birch and weeping willow. In 1976 and 1977 during last ten days of July the *A. bipunctata* population on birch trees infested by aphids was so high that an average of 1 individual per 6–8 leaves occurred. But at the same time in the neighbouring apple orchard which was infested by *Aphis pomi* Deg. they occurred in low numbers, only 1 individual per 1000 leaves. During a period of observation (1974–1978) as many as 1012 specimens in five apple orchards were collected, which made an average of about 22% of all coccinellid fauna.

3.2. INFLUENCE OF DIFFERENT FACTORS ON FECUNDITY, DEVELOPMENT AND SURVIVAL OF *A. BIPUNCTATA* SPECIMENS

3.2.1. Influence of different aphid species supplied as a food on fecundity of *A. bipunctata* females

Five to ten newly hatched pairs of *A. bipunctata* imagines were fed upon the *Dysaphis plantaginea* (Pass.), *Aphis pomi*, and *Phorodon humuli* Schr. aphids. Data on oviposition obtained in two experiments are summarized in Table 1. Both experiments

Table 1. The influence of different food sources on the fecundity of *Adalia bipunctata* females A – temperature 20°C ± 1, R. H. about 70%, daylength 16 h, period of observation – 32 days; B – temperature 25°C ± 4, R. H. 60%, daylength 16 h, period of observations 21 days

Series	Food	No. of females examined	Sum total of deposited eggs	Average number of eggs deposited per female	
				during observation time (ranges)	per day
A	*Dysaphis plantaginea*	9	1982	210.22 (522–10)	6.57
	Aphis pomi	10	187	18.70 (90–0)	0.58
B	*Phorodon humuli*	5	1785	357.0 (570–247)	17.0
	Aphis pomi	5	331	66.2 (176–2)	3.1

show that three species of aphids fed to *A. bipunctata* females had a quite different effect on their fecundity. Females fed on *P. humuli* laid over five times and those fed on *D. plantaginea* over eleven times as many eggs as females fed on *A. pomi* (Table 1).

3.2.2. The effect of different food on the development of *A. bipunctata* larvae

First instar larvae of *A. bipunctata* were divided into six groups each of 30 larvae immediately after hatching from eggs. Each group was given one of the following combinations of food: *Rhopalosiphum insertum, Dysaphis plantaginea, Aphis pomi, Acyrtosipon pisum* Harris, *A. pisum* + *Sitotroga cerealella* eggs or *Sitotroga* eggs only. The relative suitability of the different foods for the development of the larvae was tested by measuring the parameters listed in Table 2. Of the six diets tested all had a different influence on the development of the larvae tested. But, considering mortality, the average weight of newly emerged adults, the growth rate and food value index one can conclude that three species were almost equally suitable: *R. insertum, D. plantaginea* and *A. pisum*. The larvae of *A. bipunctata* accepted also *Sitotroga* eggs, but less than 10% of them reached the adult stage.

The observations suggest that the young larvae of *A. bipunctata* had more difficulty breaking through the horion of *Sitotroga* eggs than larvae of *Propylea quatuordecim-punctata* (L.) (O l s z a k 1986a). All parameters improved in the test in which 1st instar larvae were fed *A. pisum* and the older instars *Sitotroga* eggs (Table 2).

The worst results were obtained with *A. pomi*. In comparison with larvae fed *D. plantaginea, A. pisum* and *R. insertum* the speed of the development of larvae fed *A. pomi* was decreased by 47.3, 45.0 and 38.5% whereas survival was decreased by about 93, 60

Table 2. Comparison of the effect of different foods on the development of the larvae of *Adalia bipunctata* (temperature 20°C ± 1, R. H. about 70%, daylength 16 h)

Prey	Number of days to adult stage	Mortality (%)	Average weight of newly emerged adult (in mg) [4]	Growth rate [1,4]	Food value index [2,4]
Rhopalosiphum insertum	20.0	13.4	15.8 b	0.84 c	0.27 b
Dysaphis plantaginea	18.8	0	15.3 b	0.78 bc	0.21 a
Aphis pomi	27.7	93.4	7.5 c	0.27 d	0.03 c
Acyrthosiphon pisum	19.1	33.4	15.0 ab	0.73 ab	0.16 a
Sitotroga cerealella – eggs	25.0	93.4	9.7 c	0.38 b	–
S. cerealella eggs + *A. pisum* [3]	18.9	33.4	12.8 a	0.66 a	–

[1] It was evaluated as: $\frac{\text{weight of newly emerged adults}}{\text{length of development (in days)}}$. [2] It was evaluated as: $\frac{\text{weight of aphids consumed}}{\text{weight of newly emerged adults}}$. [3] The 1st instar larvae were fed *A. pisum* and the older stages *Sitotroga* eggs. [4] Means not followed by the same letter are significantly different at the 5% level of probability as determined by Student *t*-test.

and 80%, respectively. Also, other attributes such as the average weight of newly emerged adults, the growth rate and food value index were much worse when *A. bipunctata* larvae were fed *A. pomi* than in combination with other aphids (Table 2).

3.2.3. The effect of different amounts of food on the development of *A. bipunctata* larvae

First instar larvae of *A. bipunctata,* immediately after hatching from eggs, were divided into three groups and a different feeding rate was imposed on each group: 2 aphids per day, 5 aphids per day and more than 20 aphids per day per one larva. Several characteristics of development listed in Table 3 have been examined.

It was found that *A. bipunctata* larvae were able reach adulthood even if they consumed only 2 aphids per day during whole larval stage. But such low daily feeding rate induced a higher mortality of the preimaginal stages and less than 50% of the individuals reached the adult stage. In comparison with other daily feeding rates characteristics such as: larval stage duration, weight of newly emerged adults and growth rate were worse and the differences between them were statistically significant (Table 3).

It was also found that in two other feeding rate combinations the per cent of larvae that reached adult stages was the same and length of the postembryonic stages was very

Table 3. Effect of food intake on the development of *A. bipunctata* larvae (temperature 20°C ± 1, R. H. about 70%, daylength 16 h)

Amount of food (aphids per 1 larva per day) [1]	Duration of larval stages (in days)					Duration of pupal stages (in days)	No. of larvae reached adult stages (in %)	Average weight of newly emerged adult (in mg) [3]	Growth rate [2,3]
	L_1	L_2	L_3	L_4	$\sum$ [3]				
2	3.1	3.2	4.4	8.1	18.8 b	7.8	46.6	6.64 a	0.25 a
5	2.7	2.5	3.1	4.8	13.1 a	7.7	66.6	9.54 b	0.45 b
in surplus	3.2	2.7	2.0	3.9	11.8 a	7.3	66.6	15.02 c	0.77 c

[1] *Acyrthosiphon pisum* was served. [2] See footnote 1 in Table 2. [3] See footnote 4 in Table 2.

similar. Significant differences occurred only between the weight of newly emerged adults and growth rate (Table 3).

3.2.4. Survival of *A. bipunctata* larvae without food

Newly hatched larvae were kept without food and water or without food but with a water supply at three different temperatures. The results are shown in Figure 2. It is obvious that survival was greatly influenced by temperature. The greatest differences occurred between 15 and 25°C and indicated that periods of cool temperature may prolong the survival of larvae. Also, water accessibility had an influence on the prolongation of the survival of some larvae. These results indicate that even if the eggs are placed relatively far from the food source the newly hatched larvae have enough time to find them.

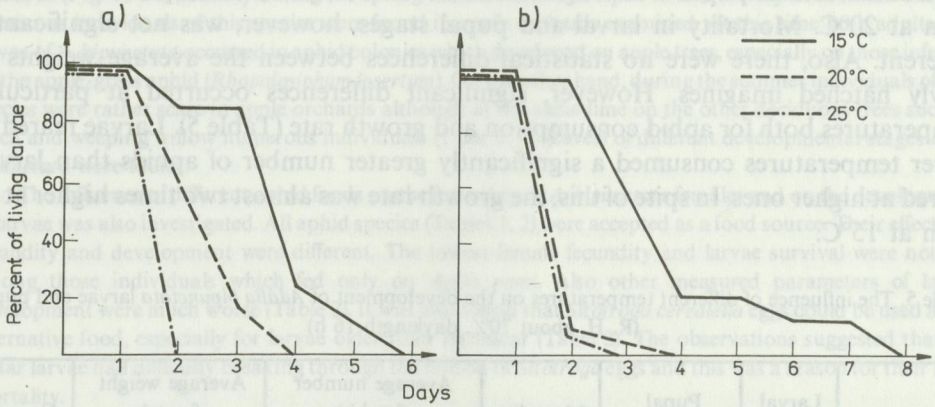

Fig. 2. Survival of *A. bipunctata* larvae without food (R. H. about 70%, daylength 16 h)
a – without water, b – with water

3.2.5. Influence of temperature on the length of *A. bipunctata* embryonic development

Newly layed batches of eggs were placed in a rearing cabinet at different constant temperatures (Table 4). To protect the eggs against the cannibalistic behaviour of newly hatched larvae, they were removed from the batches immediately after emerging.

Table 4. The influence of different temperatures on the length of the embryonic development of *Adalia bipunctata* (R. H. about 70%, daylength 16 h)

Temperature (in °C)	Number of eggs observed	Embryonic development (in days)		Percentage of eggs hatched during first day	Percentage of all eggs hatched
		average	ranges		
15	81	9.5	8–11	66.6	76.5
20	74	4.0	3–5	87.8	89.1
25	78	2.0	2	58.9	58.9

Embryonic development was shortest at temperature of 25°C and it lasted only 2 days. But at 15°C it varied from 8 to 11 days. Most of larvae emerged during the first day of eclosion but some of them hatched one or two days later. The highest per cent of emerged larvae was observed at 20°C (Table 4).

3.2.6. The influence of different temperature on the development of *A. bipunctata* larvae and pupae

Thirty individuals were kept for observation from the time of hatching until they reached adult stage at two different constant temperatures (15 and 20°C). Data on the larval and pupal stages, mortality, aphid consumption, weight of newly hatched adult and growth rate are summarized in Table 5. It was shown that time of the development of both larvae and pupae was longer for about 7–8 day at the temperature of 15°C than at 20°C. Mortality in larval and pupal stages, however, was not significantly different. Also, there were no statistical differences between the average weights of newly hatched imagines. However, significant differences occurred at particular temperatures both for aphid consumption and growth rate (Table 5). Larvae reared at lower temperatures consumed a significantly greater number of aphids than larvae reared at higher ones. In spite of this, the growth rate was almost two times higher at 20 than at 15°C.

Table 5. The influence of different temperatures on the development of *Adalia bipunctata* larvae and pupae (R. H. about 70%, daylength 16 h)

Temperature (°C)	Larval period (in days)	Pupal period (in days) [1]	Mortality (%)	Average number of aphids consumed during the larval stage [2]	Average weight of newly emerged adults [3,5]	Growth rate [4,5]
15	18.3	15.8	26.7	239.8	13.9 a	0.40 a
20	11.8	7.3	33.4	131.4	15.2 a	0.79 b

[1] The prepupa stage was included. [2] *Acyrthosiphon pisum* was served. [3] Mean weight of adults immediately after emerging from pupa. [4] See footnote 1 in Table 2. [5] See footnote 4 in Table 2.

4. CONCLUSIONS

(1) Different aphid food sources significantly affected the fecundity of the females and the development of *A. bipunctata* larvae. *A. pomi* had the most unfavourable effect.

(2) The use of the eggs of *Sitotroga cerealella* as food for the larvae showed that it may be used as a supplementary or an alternate food, especially for the older larvae of *A. bipunctata*. First instar larvae had difficulty breaking through the horion of *Sitotroga* eggs and this influenced their high mortality.

(3) Newly hatched larvae kept without food were able to survive 2–7 days. Temperature played an essential role in this. Lower temperature together with water accessibility distinctly prolonged the survival of the larve.

(4) Temperature significantly affected the rate of embryonic and larval development and mortality.

(5) Temperature had a great influence on the rate of food consumption during the larval stage.

5. SUMMARY

During the investigations of coccinellid fauna in apple orchard it was found that *Adalia bipunctata* was one of the most abundant species. This species averaged 22% of all coccinellid fauna which occurred in apple orchards (Fig. 1). Particularly during the spring time, from end of April to end of May or first half of June, numerous individuals of this species were found in apple orchards examined. At this time both adults and larvae of *A. bipunctata* occurred in aphid colonies which developed on apple trees, especially on those infested by the apple-grass aphid (*Rhopalosiphum insertum*). On the other hand, during the summer individuals of this species were rather scare in apple orchards although at the same time on the other deciduous trees such as birch and weeping willow numerous individuals (1 per 6–8 leaves) of different developmental stages of *A. bipunctata* were found.

The influence of different aphid foods on the fecundity of *A. bipunctata* females and on the development of larvae was also investigated. All aphid species (Tables 1, 2) were accepted as a food source. Their effects on fecundity and development were different. The lowest female fecundity and larvae survival were noticed among those individuals which fed only on *Aphis pomi*. Also other measured parameters of larval development were much worse (Table 2). It was also found that *Sitotroga cerealella* eggs could be used as an alternative food, especially for larvae older than 1st instar (Table 2). The observations suggested that 1st instar larvae had difficulty breaking through the horion of *Sitotroga* eggs and this was a reason for their high mortality.

The quantity of food also had a significant influence on the speed of larval development (Table 3). It was found that *A. bipunctata* larvae were able to reach adulthood even if they consumed only 2 aphids per day during whole larval stage. But such a low daily feeding rate made the larval mortality higher than 50%.

Newly hatched larvae were also able to survive a relatively long period of time without food (Fig. 2), but this was greatly influenced by temperature. At lower temperature (15°C) they lived much longer than at higher one (25°C). The temperature also had an essential influence on the speed of the embryonic development. It lasted dependently on temperature from 2 to 8 or even 11 days. Other parameters were also differentiated (Table 4).

Temperature also significantly influenced larval development. It was shown that the time of development was two times longer at 15 than at 20°C (Table 5). However, larvae reared at a lower temperature consumed a significantly greater number of aphids than larvae reared at a higher one. But in spite of this, the growth rate was almost two times higher at 20 than at 15°C (Table 5).

6. POLISH SUMMARY

W trakcie badań nad fauną biedronek sadów jabłoniowych stwierdzono, że jednym z najliczniej występujących gatunków była *Adalia bipunctata*. Udział osobników tego gatunku wynosił średnio 22% występującej w sadach fauny biedronek (rys. 1). Szczególnie licznie gatunek ten występował w badanych sadach w okresie wiosennym od końca kwietnia do końca maja lub pierwszej połowy czerwca. W okresie tym w koloniach mszyc rozwijających się na jabłoniach zarówno owady dorosłe jak i larwy tego gatunku

występowały szczególnie licznie na drzewach porażonych przez mszycę jabłoniowo-zbożową (*Rhopalosiphum insertum*). W miesiącach letnich natomiast osobniki tego gatunku w sadach jabłoniowych występowały raczej nielicznie, mimo że w tym czasie różne stadia rozwojowe *A. bipunctata* znajdowano w znacznych liczebnościach (1 osobnik na 6–8 liści) na innych drzewach liściastych, np. na brzozie i wierzbie.

Przeprowadzono również badania nad wpływem różnych gatunków mszyc, podawanych jako pokarm, na płodność samic i rozwój larw *A. bipunctata*. Wszystkie badane gatunki mszyc (tab. 1, 2) były akceptowane jako pokarm, ale ich wpływ na płodność i rozwój był różny. Najniższą płodność samic i przeżywalność larw zanotowano w przypadku karmienia ich mszycą jabłoniową (*Aphis pomi*). W tej kombinacji pokarmowej również wszystkie inne badane parametry rozwoju larw były znacznie gorsze niż w kombinacji, gdzie jako pokarm podawano inne gatunki mszyc.

Stwierdzono również, że jako zastępczy pokarm w hodowli biedronek *A. bipunctata* można stosować jaja skośnika zbożowiaczka (*Sitotroga cerealella*). Przy tym znacznie lepsze efekty uzyskano karmiąc nimi larwy biedronki dopiero od II stadium rozwojowego. Larwy I stadium rozwojowego mają bowiem trudności w przegryzieniu horionu jaj skośnika i stąd ich znaczna śmiertelność (tab. 2). Znaczny wpływ na szybkość rozwoju larw miała również ilość dostępnego pokarmu (tab. 3). Stwierdzono, że larwy *A. bipunctata* osiągnęły stadium imagines zjadając tylko 2 mszyce dziennie. Tak niska racja pokarmowa powodowała jednak ponad 50% śmiertelności badanych larw.

Stwierdzono również, że larwy I stadium pozbawione pożywienia w ogóle żyły stosunkowo długo (rys. 2), a na długość ich przeżywania zasadniczy wpływ wywierała temperatura. W temp. niższej (15°C) przeżywały znacznie dłużej niż w wysokiej (25 C). Temperatura miała również istotny wpływ na długość rozwoju embrionalnego, który w zależności od warunków termicznych trwał od 2 do 8, a nawet 11 dni; zróżnicowane były także inne badane parametry (tab. 4).

Temperatura miała również istotny wpływ na długość rozwoju larwalnego, który w temp. 15°C był dwukrotnie dłuższy niż w temp. 20°C. Jednocześnie larwy hodowane w temp. 15°C zjadały w okresie swojego rozwoju o ponad 80% mszyc więcej niż larwy hodowane w temp. 20°C. Mimo to stopień wzrostu larw był prawie dwukrotnie wyższy w temp. 20°C niż w temp. 15°C (tab. 5).

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(*Received 22 October 1986*)