DOI:10.6660/TESFE.1993018 台灣昆蟲Formosan Entomol. 13: 187-193 (1993) 研究報告 Research report

Formosan Entomologist
Journal Homepage: entsocjournal.yabee.com.tw

【Research report】

一種瓢蟲 Aiolocaria hexaspilota 對其食餌胡桃金花蟲之功能性反應【研究報告】

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Received: Accepted: 1993/04/15 Available online: 1993/06/01

Abstract

摘要

研究一種瓢蟲 Aiolocaria hexaspilota 對其食餌胡桃金花蟲，Gastrolina depressa, 於不同密度下之功能性反應 (functional response)。以胡桃金花蟲之一齡幼蟲體重為一單位，則A. hexaspilota 之四個齡期幼蟲之每日平均捕食量分別為2.7，21.4，47.3及129.0單位。捕食者之功能性反應基本上呈現Holling 氏第二型曲線形式。 A. hexaspilota 之一齡幼蟲，幾乎無法捕食胡桃金花蟲之三齡幼蟲，在僅有一齡幼蟲之食餌的情況下，捕食者之四齡幼蟲無法取得成長需之足夠食物。最有效的食餌利用是當A. hexaspilota 之若齡 (一，二齡) 及老齡 (三，四齡) 幼蟲，分別捕食若齡 (一，二齡) 及老齡 (三齡，蛹) 之胡桃金花蟲。

Key words:

關鍵詞: Aiolocaria hexaspilota、功能性反應、胡桃金花蟲。

中華昆蟲 13: 187-193(1993)
Chinese J. Entomol. 13: 187-193(1993)

The Functional Response of A Coccinellid Beetle, *Aiolocaria Hexaspilota* to Its Prey, The Walnut Leaf Beetle (*Gastrolina depressa*)

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ABSTRACT

The functional response of a coccinellid beetle, *Aiolocaria hexaspilota*, to various densities and stages of its prey, the walnut leaf beetle (*Gastrolina depressa*), was examined. The average amount of daily prey consumption, in terms of the first instar larval weight of *G. depressa*, by four instar predator larvae was 2.7, 21.4, 47.3 and 129.0 units, respectively. Predator functional responses were essentially of Holling type 2. As the predator developed, the maximum theoretical number of prey consumed per day increased. Although the first to fourth instar predator larvae preyed on first to third instar larvae of *G. depressa*, the first instar predator larvae were almost incapable of catching third instar prey larvae, whereas fourth instar predator larvae, spending a lot of effort in handling and searching, were unable to obtain enough food for growth when the only prey available was in the first instar developmental stage. The efficiency of food utilization was most effective when young (first and second instar) and old (third and fourth instar) larvae of *A. hexaspilota* preyed on young (first and second instar) and old (third instar and pupae) larvae of *G. depressa*, respectively.

Key words: *Aiolocaria hexaspilota*, functional response, *Gastrolina depressa*.

一種瓢蟲 *Aiolocaria hexaspilota* 對其食餌胡桃金花蟲之功能性反應

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摘　要

研究一種瓢蟲 *Aiolocaria hexaspilota* 對其食餌胡桃金花蟲，Gastrolina depressa，於不同密度下之功能性反應(functional response)。以胡桃金花蟲之一齡幼蟲體重為一單位，則 *A. hexaspilota* 之四個齡期幼蟲之每日平均捕食量分別為 2.7, 21.4, 47.3 及 129.0 單位。捕食者之功能性反應基本上呈現 Holling 氏第二型曲線形式。

A. hexaspilota 之一齡幼蟲，幾乎無法捕食胡桃金花蟲之三齡幼蟲，在僅有一齡幼蟲之食餌的情況下，捕食者之四齡幼蟲無法取得成長所需之足夠食物。最有效的食餌利用是當 *A. hexaspilota* 之若齡(一，二齡)及老齡(三，四齡)幼蟲，分別捕食若齡(一，二齡)及老齡(三齡，蛹)之胡桃金花蟲。

關鍵詞：*Aiolocaria hexaspilota*，功能性反應，胡桃金花蟲。

Introduction

Solomon (1949) proposed that the response of predators to prey density can be classified into a functional response, in which the consumption of prey by individual predators changes, and a numerical response. The functional response of various predators was extensively studied by Holling (1959b) and has generated important information concerning the interaction between prey and predator (Collins *et al.*, 1981; Heong and Rubia, 1989; Heong *et al.*, 1991; Hertlein and Thorarinsson, 1987; Holling, 1959a; Hondo, 1979; Mogi, 1969; Shipp and Whitfield, 1991; Treacy *et al.*, 1987).

Coccinellids are known as important predators. A member of this group, *Aiolocaria hexaspilota*, is a rare example of a specific predator, preying only on the walnut leaf beetle, *Gastrolina depressa*. Although Matsura (1976) studied the numerical response of *A. hexaspilota* to its prey, its functional response remains unexamined. As *A. hexaspilota* is monophagous, these laboratory results are expected to reflect actively the predator / prey interaction in the field.

Our project was to examine the

functional response of *A. hexaspilota* to the density of *G. depressa*.

Materials and Methods

In June and July of 1986 and 1987, *A. hexaspilota* and *G. depressa* adults were collected from walnut trees in Ina, Nagano Prefecture, Japan. Each species was kept separately at room temperature under natural daylight conditions (about 20–25°C, 10 h / 14 h photophase / scotophase cycle, and 70–80%RH) and allowed to mate. *G. depressa* larvae hatched from eggs laid by captive adults were reared in plastic dishes (15 cm dia. × 9 cm) containing walnut leaves.

Immediately after hatching or molting, *A. hexaspilota* had access to sufficient prey. The first to third instar larvae of *G. depressa* served as food. The average number of *G. depressa* larvae consumed per day by a single *A. hexaspilota* larva was obtained by dividing the total amount of prey consumed by the duration, in days, of the particular developmental stage in question. The *G. depressa* larval changes in biomass by weight values developed by Matsura (1976) were used, if the weight of the first instar larva was assigned as one unit then that of the second and third instar larvae were 3.4 and 14.6 units, respectively. The average weight of each *A. hexaspilota* larva was also recorded.

In order to measure the functional response of predator to prey, an *A. hexaspilota* larva, newly hatched or molted, was placed in a Petri dish in which the density of *G. depressa* larvae at a particular developmental stage was provided and kept relatively constant. After determining and recording the number consumed, we added *G. depressa* larvae at the same developmental stage to the Petri dish at 18:00 h. every day to keep the density fixed. Various combinations of *G. depressa* larval density and the number of prey consumed by an *A. hexaspilota* larva are shown in Table 1.

Holling type–2 functional responses demonstrated by many predators are described by Holling's disc equation:

$$Y = aNTP / (1 + ahN) \qquad (1)$$

in which Y=total number of prey attacked, a=attack rate, N=total number of prey, P=predator density, h=handling time, the time it takes for a predator to catch, kill, and eat a prey, and T=the total searching time. The way in which a and h are estimated from functional response data is described by Holling (1959a), it is assumed that the number of prey replaced corresponds to the number eaten.

We used the more flexible Royama's model (Royama, 1971) because it allows for removal of prey during the experiment:

$$Y = X_0(1 - e^{-a(PT - hY)}) \qquad (2)$$

in which X_0= initial number of prey, the a, P, T, h and Y terms are analogous to those in Holling's disc equation. According to equation (2),

$$\ln(1 - Y / X_0) = ahY - aPT \qquad (3)$$

The values of a and h were determined from the regression plot of $\ln(1-Y/X_0)$ against Y (Rogers, 1972).

Results and Discussion

The average weight of the first to fourth instar larvae of *A. hexaspilota* were 0.03, 0.08, 0.27 and 0.48 mg, respectively. These predator larvae consumed, respectively, 2.7, 21.4, 47.3 and 129.0 units of prey per day (Table 2).

The functional response of *A. hexaspilota* larvae to its prey, *G. depressa*, is shown in Table 1 and Fig. 1. The second, third and fourth instar larvae of *A. hexaspilota* preying on first instar larvae of *G. depressa* showed that the predators consumed all prey larvae offered. The fourth instar larvae of *A. hexaspilota* also consumed all the second instar larvae of *G. depressa* offered. The remaining cases demonstrate Holling type–2 predator /

Table 1. Daily stage specific food consumption of *A. hexaspilota* larvae on different stages and densities of *G. depressa*

	Predator stages											
	Larva-1			Larva-2			Larva-3			Larva-4		
Stage of prey	No. of prey offered	No. of prey consumed		No. of prey offered	No. of prey consumed		No. of prey offered	No. of prey consumed		No. of prey offered	No. of prey consumed	
		N	mean		N	mean		N	mean		N	mean
1	5	4	3	5	3	5	5	4	5	50	2	50
1	10	5	5	10	3	10	10	4	10	75	2	75
1	20	3	6.3	15	3	15	15	4	15	100	2	100
1	30	2	6.5	20	3	20	20	3	20	—	—	—
1	—	—	—	30	3	30	30	2	30	—	—	—
1	—	—	—	—	—	—	40	2	40	—	—	—
2	5	5	2.8	5	3	5	5	3	5	40	2	40
2	10	5	2.8	10	3	6.7	10	3	10	60	2	60
2	15	5	3.6	20	3	10	20	3	17.7	80	2	80
2	20	4	3.5	30	3	11.3	30	3	21	—	—	—
2	30	2	4	—	—	—	—	—	—	—	—	—
3	3	3	1	5	4	2.3	5	4	2.5	10	3	10
3	6	3	1	10	4	2	10	3	4.3	20	3	15.7
3	9	3	1	15	4	3.3	15	3	6.8	30	3	23.7
3	—	—	—	20	4	4.3	20	4	4.5	40	3	31.3
3	—	—	—	30	3	5.7	30	4	5.3	50	3	32.7

Table 2. Durations and prey consumption units of each larval stage of *A. hexaspilota* on *G. depressa*

Larva	Duration(days)			Consumption units(units of prey / predator)[1,2]				
	N	x	SD	N	Daily		Total	
					x	SD	x	SD
1	10	2.0	0.3	10	2.7	0.8	5.4	0.5
2	10	2.0	0.5	10	21.4	2.0	42.7	2.7
3	10	2.0	0.2	10	47.3	4.2	94.5	7.8
4	10	4.3	0.5	10	129.0	12.8	554.5	68.4

1) Prey units were estimated by assigning the average weight of larva-1 of *G. depressa* as one unit, the other larval weights were convered into units by their weight ratio to larva-1.

2) Each predator had access to sufficient prey.

prey functional response, which applies to many other predators (Collins *et al.*, 1981; Griffiths, 1969; Heong *et al.*, 1991; Hertlein and Thorarinsson, 1987).

The estimated values of attack rate (a) and handling time (h) for *A. hexaspilota* and the maximum theoretical number of G. depressa consumed per day (1 / h) are shown in Table 3. For stage specific instar of predators, the decre-

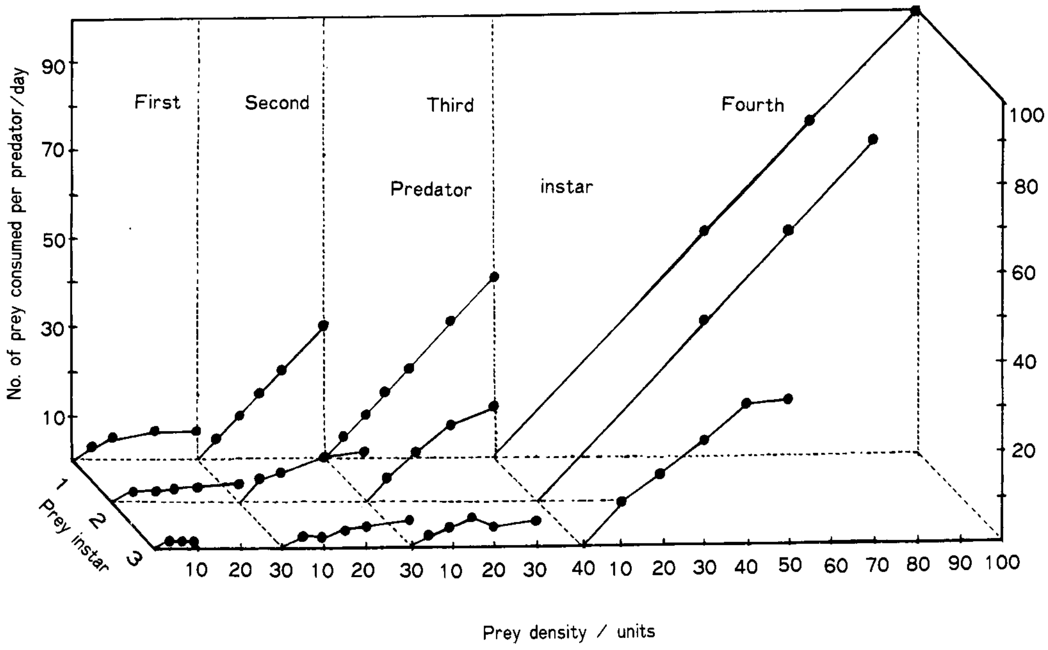

Fig. 1. Functional responses of *A. hexaspilota* larvae to its prey, *G. depressa*.

Table 3. Estimated attack rate (a), handling time (h) and the maximum theoretical prey consumption unit (1 / h) of *A. hexaspilota* on *G. depressa* based on regression analysis results by Rogers model

Predator instar	Attack rate (a)			Handling time (h) and 1 / h		
	Prey instar			Prey instar		
	1	2	3	1 h(1 / h)	2 h(1 / h)	3 h(1 / h)
1	1.508	1.626	—[1)]	0.121(8.26)	0.235(4.26)	—
2	—	2.206	0.498	—	0.067(14.93)	0.108(9.22)
3	—	7.305	0.572	—	0.040(25.14)	0.050(19.87)
4	—	—	1.894	—	—	0.010(103.49)

1) Estimates were unobtainable because all prey were consumed or only one prey was consumed.

mental attack rate was observed when incremental stage of prey was offered, vise versa for handling time of predator. Conversely, while the prey was limited to a particular developmental stage, the values of a and h of the predator increased and decreased respectively, as the predator instar increased. When the predator developed from the first to fourth instar, the incremental unit of the maximum theoretical prey consumption (1 / h) was found.

MacArthur and Pianka (1966) suggested that a prey menu of a predator is limited when its consumption is large, but wide when that is small. The prey menu of *A. hexaspilota* is limited to only one species, *G. depressa*, consistent with its large consumption. Because of the small larval mobility of *A. hexaspilota*, their searching ability is restricted to a small area; hence effective food utilization is an important factor in limiting their population growth. Accordingly, in determining the most effective utilization of food in a small area, we must consider which instar larva of *A. hexaspilota* preys on which instar larva of *G. depressa*.

Although first to fourth instar larvae of *A. hexaspilota* are functionally capable of preying on first to third instar larvae of *G. depressa*, the difficulty for a predator of a particular developmental stage increases as prey develop. This situation is reflected in the attack rate by predators and the duration of handling time (Table 3). Similar results were also reported for other predators (Hassell *et al.*, 1976; Hondo, 1984). Observations of the feeding patterns of *A. hexaspilota* larvae revealed that first instar larvae are almost incapable of catching third instar larvae of *G. depressa*. In order to raise one *A. hexaspilota* to adult, approximately 700 units of *G. depressa* larvae were needed, of which 550 units were consumed by fourth instar larvae. It was suggested that fourth instar larvae of *A. hexaspilota*, spending a lot of effort in handling and searching, were unable to obtain enough food for growth when the only prey available was in the first instar developmental stage. Therefore, the efficiency of utilization of prey food by the predator may be most effective when young (first and second instar) and old (third and fourth instar) larvae of *A. hexaspilota* prey on young (first and second instar) and old (third instar and pupae) larvae of *G. depressa*, respectively.

Acknowledgments

We thank Professor T. Yoshida, Faculty of Agriculture, Okayama University, Japan, and Dr. T. Matsura, Department of Biology, Kyoto Kyoiku University, Japan for their valuable suggestions and Professor C. I. Shih, Department of Entomology, Chung Hsing University, Taiwan, and Dr. H. Yasuda, Faculty of agriculture, Yamagata University, Japan, for reviewing this manuscript.

References

Collins, M. D., S. A. Ward, and A. F. G. Dixon. 1981. Handling time and the functional response of *Aphelinus thomsoni*, a predator and parasite of the aphid *Drepanosiphum platanoidis*. J. Anim. Ecol. 50: 479–487.

Griffiths, K. J. 1969. The importance of coincidence in the functional and numerical responses of two parasites of the European pine sawfly, *Neodiprion sertifer*. Can. Entomol. 101: 673–713.

Hassell, M. P., J. H. Lawton, and J. R. Beddington. 1976. The components of arthropod predation. I. The prey death-rate. J. Anim. Ecol. 45: 135–164.

Heong, K. L. and E. G. Rubia, 1989. Functional response of *Lycosa pseudoannulata* on brown planthopper (BPH) and green leafhopper (GLH). Int. Rice Res. Newsl. 14: 29–30.

Heong, K. L., S. Bleih, and E. G. Rubia. 1991. Prey preference of the wolf spider, *Pardosa pseudoannulata* (Boesenberg et Strand). Res. Popul. Ecol. 33: 179–186.

Hertlein, M. B. and K. Thorarinsson. 1987. Variable patch times and the functional response of *Leptopilina boulardi* (Hymenoptera: Eucoilidae). Environ. Entomol. 16: 593–598.

Holling, C. S. 1959a. The components of predation as revealed by a study of small mammal predation of the European pine sawfly. Can. Entomol. 91: 293–320.

Holling, C. S. 1959b. Some characteristics of simple type of predation and parasitism. Can. Entomol. 91: 385–398.

Hondo, M. 1979. Natural enemies of mulberry tiger moth, *Spilarctia imparilis* (Lepidoptera: Arctiidae). centering around the interaction between natural populations of *S. imparilis* and its predator, *Parena perforata* (Coleoptera: Carabidae). New Entomol. 28: 21–30.

Hondo, M. 1984. Foraging strategy of *Parena perforata* Bates (Coleoptera: Carabidae), the predator of the mulberry tiger moth, *Spilarctia imparilis* Butler (Lepidoptera: Arctiidae): Responses to prey density and relationships between prey consumption and growth rate. Jap. J. Ecol. 34: 457–466.

MacArthur, R. H., and E. R. Pianka. 1966. On optimal use of a patchy environment. Amer. Natur. 100: 603–609.

Matsura, T. 1976. Ecological studies of a coccinellid, *Aiolocaria hexaspilota* Hope I. Interaction between field populations of *A. hexaspilota* and its prey, the walnut leaf beetle (*Gastrolina depressa* Baly). Jap. J. Ecol. 26: 147–156.

Mogi, M. 1969. Predation response of the larvae of *Harmonia axyridis* Pallas (Coccinellidae) to the different prey density. Jap. J. Ent. Zool. 13: 9–16.

Rogers, D. J. 1972. Random search and insect population models. J. Anim. Ecol. 41: 369–383.

Royama, T. 1971. A comparative study of models for predation and parasitism. Res. Popul. Ecol. Supplement 1: 1–91.

Shipp, J. L. and G. H. Whitfield. 1991. Functional response of the predatory mite, *Amblyseius cucumeris* (Acari: Phytoseiidae), on western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae). Environ. Entomol. 20: 694–699.

Solomon, M. E. 1949. The natural control of animal populations. J. Anim. Ecol. 18: 1–35.

Treacy, M. F., J. H. Benedict, J. D. Lopez, and R. K. Morrison. 1987. Functional response of a predator (Neuroptera: Chrysopidae) to bollworm (Lepidoptera: Noctuidae) eggs on smoothleaf, hirsute and pilose cottons. J. Econ. Entomol. 80: 376–379.

Received for publication September 8, 1992; revised manuscript accepted April 15, 1993.