um 0,06 % abnahm. Ein Teil der überzähligen Parasitennachkommen wurde während des Eistadiums eliminiert. Der Umfang dieser Eliminierung stieg mit der Zunahme der überzähligen Parasiten und umgekehrt.

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Author's address: Dr. Esmat M. Hegazi, Alexandria University, Plant Protection Department, Faculty of Agriculture, Alexandria, Egypt

Laboratory of Entomology, Department of Zoology, University of Gorakhpur, India

Numerical response and area of discovery of a predator, *Coccinella septempunctata* L.

By K. P. Pandey, A. Kumar, R. Singh, S. Shanker and C. P. M. Tripathi

Abstract

The numerical response of the predator *Coccinella septempunctata* shows that the individual predation rate (prey is mustard aphid, *Lipaphis erysimi*) of the grubs decreases with increase of its density. The interference [mutual interference constant (m) = 0.62] between grubs at higher densities was suggested as a cause for this behavioural response and was explained by applying the population model of Hassell and Varley. The data also furnish an insight into the number of predators needed to regulate the estimated prey population and 1 : 50 ratio of predator to prey for the immediate release of *C. septempunctata* was recommended against *L. erysimi*.

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1 Introduction

The ladybird beetle, *Coccinella septempunctata* L. has been reported to be an effective biocontrol agent against the aphid, *Lipaphis erysimi* Kalt., a major pest of the oilseed crop, *Brassica campestris* L. (ATWAL and SETHI 1963; SINHA et al. 1982). The grubs of *C. septempunctata* are voracious feeder and consume more aphids than the adults (HAMALAINEN 1977; RAYCHAUDHARY 1981) and play an important role in suppressing down the aphid population in nature. The numerical response (SOLOMON 1949) of the predator is considered to be an important component in the biocontrol practices and is often responsible for suppressing the prey population (HUFFAKER et al. 1971). In addition, this response also helps in calculation of the number of the predators needed to regulate the estimated prey population (KNIPLING and GILMORE 1971).

The number of prey that a given population of the predator can search and consume in a given area and time period (which is related with the prey finding efficiency of the predator) must also be established. In past, NICHOLSON and BAILEY (1935) were of opinion that the searching efficiency of a predator as measured by its "area of discovery" is constant and thus independent on the prey-predator densities. However, the population model of them (which provides numerical value of the area of discovery (a), viz.,

$$a = \frac{1}{P} \log_e \frac{N}{S}$$

where, N = prey density exposed for predation, P = predator density released for predation and S = number of prey surviving predation) was refuted later on by HASSELL and VARLEY (1969) which have proposed a new model in which the searching efficiency of the predators declines exponentially as their density increases, and incorporated a mutual interference constant (m), deriving an equation

$$a = \frac{Q}{P^m}$$

where, Q = quest constant (the a when only one predator is searching), m = mutual interference constant (the slope of regression of log a on log P). Though this model had been criticised on several grounds (HASSELL 1971; ROYAMA 1971; STINNER and LUCAS 1976), but still widely accepted because of its simplicity.

In view of these informations the laboratory experiments reported herein were designed to examine 1. the effect of various predator densities on the rate of consumption of individuals at a constant prey density and 2. the effect of various predator and prey densities on its area of discovery.

2 Material and methods

L. erysimi were reared in the laboratory on the fresh foliage of *B. campestris* at 20 ± 3 °C, 80 ± 10 % RH and 12:12 photoperiod (PANDEY et al. 1984).

The first set of experiment was designed to study the effect of various predator densities on the rate of consumption of the individuals and its searching efficiency. For this, 4 petridishes were taken and 200 3rd instar nymphs of the aphid (the stage most favoured by the predator, SINHA et al. 1982), placed on the leaf (10 × 6 cm) of the host plant, were put in each one. One, 2, 4, and 8

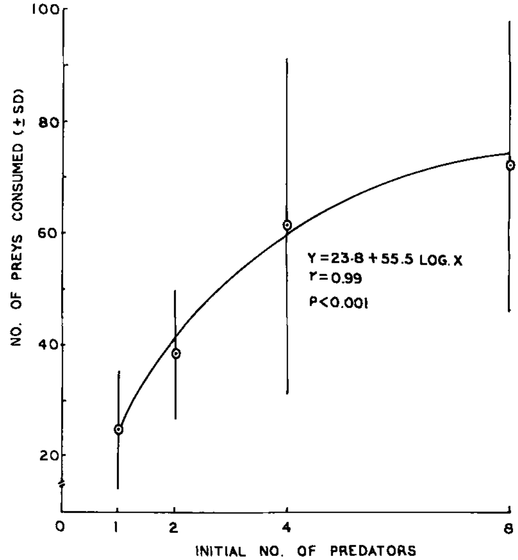

Fig. 1. Relationship between number of preys consumed by different initial numbers of *C. septempunctata* (put with 200 third instar nymphs of *L. erysimi* for 3 h)

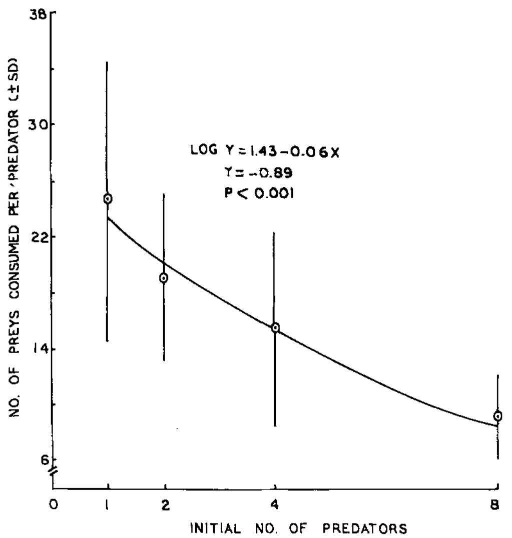

Fig. 2. Relationship between number of preys consumed per *C. septempunctata* at its different initial numbers (put with 200 *L. erysimi* for 3 h)

24 h starved 3rd instar grubs of *C. septempunctata* were introduced in above mentioned 4 petridishes respectively for 3 h for predation.

The second set of the experiment was designed to examine the effect of varying prey densities on the searching efficiency of the predator. For this, 40, 80, 100, 200, 400, and 800 3rd instar nymphs of the aphid were put in 6 petridishes as mentioned above. One predator was introduced in each one for 24 h. At the end of the experiment, the predators were withdrawn from the petridishes and the left over unconsumed aphids were counted. Both the experiments were performed 6 times and the data so obtained were analysed statistically.

3 Results and discussion

Fig. 1 explicits that as the density of the predator increases, the amount of prey consumption increases significantly ($F = 3.94$, $P < 0.025$). The rate of consumption per individual predator is maximum with one predator and decreases linearly with increase of predator density (fig. 2).

The area of discovery of the predator decreases with the increase of both predator as well as prey densities (table).

The increased amount of prey consumption with increase of predator density (fig. 1) clearly indicates that in order to destroy greater number of preys, more predators might be required, however, fig. 1 also represented that when 8 predators were put in, a doubling of prey consumption in comparision to 4 predators did not occur, which might be due to the limited predation-time and the reduction of efficiency of the predators (Ullyett 1949; Burnett 1951). The decreased rate of prey consumption per predator with increase of predator density (fig. 2) explicated the existence of mutual interference amongst the predators (Michelakis 1973; Hassell et al.

Area of discovery of searching grubs of *C. septempunctata* at different *L. erysimi* densities (exposure period 24 h) and at its different densities (exposure period 3h)

Prey densities	Area of discovery	Predator densities	Area of discovery
40	1.743	1	1.13
80	1.386	2	0.85
100	1.204	4	0.55
200	0.916	8	0.35
400	0.798	Mutual inter-	0.62
800	0.496	ference constant	

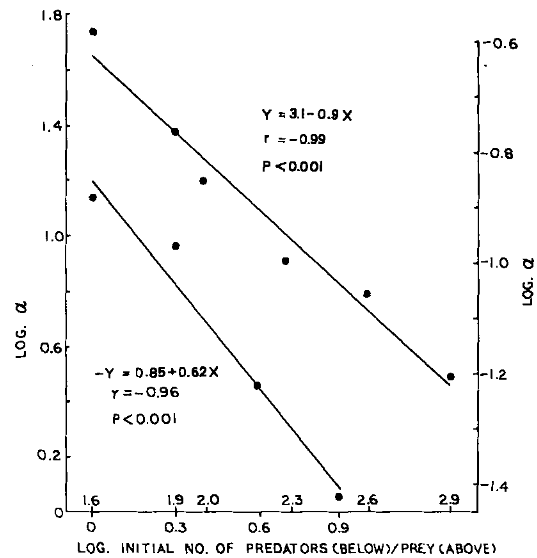

Fig. 3. Relationship between log area of discovery of *C. septempunctata* and log initial numbers of it (X scale mentioned below line and Y scale at right hand) and log initial numbers of *L. erysimi* (X scale mentioned above line and Y scale at left hand)

1976; Hassell 1980; Eveleigh and Chant 1982) which inducts them to scatter (Eveleigh and Chant 1982).

Fig. 3 illustrates that the higher densities of predators as well as prey have an inverse effect on searching efficiency of the predator which is a general phenomenon with predators (Hassell and Varley 1969; Royama 1971; Fernando and Hassell 1980). The cause of inverse effect by the increase of predator density is the enhanced behavioural interactions between predators and preys (mutual interference). The impact of this interference (measured as mutual constant) on the stability of prey predator interactions were explored theoretically in past by Hassell and May (1973), Rogers and Hassell (1974), Beddington (1975). According to them the greater the value of mutual interference constant, the greater would be the tendency of the predator to interact the prey and to become stable in the nature. The strong mutual interference constant (0.62) helps it in its dispersal which favours the spread of the area of interaction.

The present findings thus suggest that the ratio of predator and prey should not exceed 1 : 50 for controlling the estimated prey population at any immediate release site.

Acknowledgement

CSIR New Delhi is acknowledged for providing financial support.

Zusammenfassung

Dichtereaktionen und Jagdareal von Coccinella septempunctata L.

Die numerische Reaktion des Prädators *C. septempunctata* zeigte, daß die individuelle Prädationsquote (Beute: Senfblattlaus, *Lipaphis erysimi*) der Käferlarven mit der Dichte anstieg. Die Beziehungen (Beziehungskonstante m = 0,62) zwischen den Larven bei höherer Dichte wurden als Ursache für diese Reaktion angesehen und unter Anwendung des Populationsmodells von HASSELL und VARLEY näher betrachtet. Die Ergebnisse ergaben auch einen Einblick in die Zahl der Prädatoren, welche notwendig sind, die geschätzte Beute-Population zu reduzieren. Hierfür wird eine Freilassungsquote von 1 *C. septempunctata* auf 50 *L. erysimi*-Individuen empfohlen.

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Address of the last named author: Dr. C. P. M. TRIPATHI, Department of Zoology, University of Gorakhpur, Gorakhpur-273001, India

BUCHBESPRECHUNGEN

CRAWLEY, M. J.: Herbivory. **The dynamics of animal-plant interactions.** Studies in ecology, vol. 10. Oxford-London-Edinburgh-Boston-Melbourne: Blackwell Scientific Publ., 437 pp. many fig. and tab. ISBN 0-623-00808-3. £ 25.50.

This book reviews the population dynamics of plants and the animals that feed on them, bringing together the results of research by botanists and zoologists. It thus reviews much literature which entomologists would not ordinarily read. Successive chapters summarise the dynamics of plant and animal populations and then the interactions between the two at both species and community levels. It ends with a series of challenging statements intended to stimulate thought and experimentation and a reference list of over 50 pages which provides the reader with the means to study more deeply those aspects of particular interest. Throughout, the author draws examples from the applied literature and shows how theoretical studies assist understanding of practical problems in plant protection and suggests new approaches to their solution. In particular, he discusses such important topics as the effects of different kinds of insect feeding on plant growth, effects of crop area on pest attack, mixed cropping as a pest management strategy and the differences in the outcome of herbivore interactions with annual and perennial plants. Thus, for the applied entomologist, the book is both stimulating and enlightening and should lead to new insights into the management of insect pests of crops and strategies in the biological control of weeds.

The book is, therefore, strongly recommended to entomologists seeking a fresh approach to their research and those wishing to improve their understanding of plant population dynamics and the important ways in which they differ from those of animals. D. J. GREATHEAD, Ascot, Berks.

SCHAEFER, M.; TISCHLER, W.: **Ökologie.** Mit engl.-dt. Register. Wörterbücher der Biologie. 2., überarb. und erw. Aufl. Stuttgart, New York: G. Fischer 1983. 354 S., 38 Abb. und 6 Tab. Kart. 26,80 DM. ISBN 3-437-20308-8 (Lizenzausg.). UTB Nr. 430.

Seit der Erstauflage 1975 (von W. TISCHLER) hat das übergreifende Gebiet der Ökologie in zahlreichen Bereichen der Wissenschaft, Wirtschaft und Politik eine starke Erweiterung erfahren. So ist es zu begrüßen, daß die hier vorgelegte 2. Auflage (unter Mitarbeit von M. SCHAEFER) dieser Erweiterung Rechnung trägt. Das Hauptproblem eines Lexikons für Ökologie bleibt immer die Auswahl der Stichwörter. Es ist nicht möglich, alle interessierten Kreise voll zufriedenzustellen, zumal unter „Ökologie" oft sehr Verschiedenes verstanden wird. Die beiden Autoren erweitern das Wörterbuch auf mehr als 4000 Begriffe und berücksichtigen dabei vor allem die Allgemeine Ökologie, Pflanzenökologie, Tierökologie, Limnologie, Meeresökologie, Bodenökologie und Grundlagen der Angewandten Ökologie. Die Zahl der Stichwörter aus der speziellen Parasitologie wurde eingeschränkt. Das englisch-deutsche Register fördert die Verbreitung und erleichtert den Zugang zur englisch-sprachigen Fachliteratur. Das Wörterbuch ist nicht nur für alle in Ausbildung, Lehre und Praxis stehenden Biologen und Ökologen eine gute Arbeitsgrundlage, sondern vermittelt allen an Fragen der Umwelt Interessierten präzise Informationen.

W. SCHWENKE, München