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FUNCTIONAL AND NUMERICAL RESPONSE OF *Paederus fuscipes* CURTIS AGAINST *Nilaparvata lugens* STALL AND THEIR SPATIAL DISTRIBUTION IN THE RICE FIELDS

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ABSTRACT

Laboratory experiment and field survey revealed that the rove beetle *Paederus fuscipes* was an aggressive predator of the rice brown plant hopper (RBPH) *Nilaparvata lugens* and to be found at nursery up to vegetative and generative stages in rice fields in Java, Indonesia. As the promising candidate of biological control agent, the rove beetle showed several criteria of desired predator attributes. Functional response of *P. fuscipes* against the RBPH fitted with Type II of Holling, it indicated to cause maximum mortality at low prey density. The expected maximum feeding rates on the RBPH was 16.39 while the actual one was 5.46 individuals/24 hours. Positive and strong coefficient correlation, r = 0.844985, on numerical response of *P. fuscipes* against the RBPH indicated the density-dependent relationship of the predator and prey. Both of *P. fuscipes* and the RBPH exhibited clumped spatial-distribution-pattern. Since paederin causes dermatitis hence an extra careful must be taken into account in handling the rove beetle for controlling pest insects.

Keywords: rice, *Nilaparvata lugens, Paederus fuscipes*, functional response, numerical response, spatial distribution.

INTRODUCTION

A well known of the rove beetle *Paederus fuscipes* Curtis (Coleoptera: Staphylinidae) is due to its hemolymph (paederin) causes dermatitis. Outbreaks of the Paederus dermatitis were reported in several Asia-Pacific countries when the rove beetles are accidentally crushed on the skin, releasing haemolymph paederin. TV One and Kompas News reported the accident in Surabaya, Indonesia, within March 2012. In China, 268 cases of Paederus dermatitis were diagnosed in a total of 316 staff at the toy-building factory. The favorable environment, lighting, humidity, and poor accommodation may have been responsible for the outbreak (Huang, *et al*., 2009). In Malaysia, an outbreak of Paederus dermatitis was reported in a primary school, Terengganu. The school with fluorescent lighting was located next to paddy fields. *P. fuscipes* was easily found in the paddy fields and along the school corridors (Rahmah and Norjaiza, 2008). A total of 360 cases (6.0%) were recorded in the Student Health Center at the residential college in Puncak Alam, Selangor, Malaysia from 1 January to 31 December 2010. The majority of patients stayed at a hostel near an oil palm plantation (Heo *et al*., 2013). On another point of few the rove beetle may be useful for natural control of pest insects in an agroecosystem.

Amongst habitats of the rove beetle are rice fields at which abundant preys are available. The rice brown planthopper, here after is called as RBPH, *Nilaparvata lugens* Stall (Hemiptera: Delphacidae) may be one of the preys. In Indonesia the RBPH is very noxious pest insect and it has highly significant impact on food security. General Directorate of Food Crop (2010) reported that in June 2010, 730 hectares out of 24.664 hectares of infested paddy-areas were failed to harvest. The rove beetle is abundant in the rice fields. It may contribute as mortality factor in natural control of the RBPH and it is believed as a predator on many pest species (Kalshoven, 1981). However, the predatory potency of the rove beetle against the RBPH is not known yet. Several ecological aspects of the predator as potential criteria for biological control agent of the RBPH were described and discussed. Those are functional and numerical response and spatial distribution in the rice fields.

In order to study dynamical predation of the rove beetle on the RBPH, factors that influence the predator abundance are distinguished with factors that influence efficiency of the predator in hunting prey. The responses that relevant to study the predator-prey relationship are functional and numerical response (Solomon, 1949). Functional response is defined as change in the rate of exploitation of prey by an individual predator as a result of a change in prey density. The numerical response in ecology is the change in predator density as a function of change in prey density. Total predation can be expressed as a combination of functional and numerical response (Holling, 1959). Knowledge on spatial distributions of the RBPH and the rove beetle is important for studying predator performance in controlling pest populations. The dependency relationship between predator and prey indicates effectiveness of the predator.

MATERIALS AND METHODS

Functional response

Objectives of the study were to determine type of the functional response of the rove beetle against the RBPH and to determine expected maximum feeding rate of the predator. Method used by Wagiman (1996a) was adopted in this study. Adult colonies of the rove beetle were collected from rice fields. They were then cultured on excess preys i.e. the RBPH under room temperature and RH in the laboratory with 12 hours natural diffuse light and 12 hours dark. Prior to experiments, the unknown age and sex of the predator were starved for 24 hours to

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ensure relative homogeny in their starvation. The RBPH was obtained from Laboratory of Research Center for Management of Biological Resources at University of Gadjah Mada. Fourth-instar nymphs and adults of the RPBH were used in this study as a prey. Preliminary study was done to determine maximum voracity of single predator by culture the predator on excess prey numbers - 20 individuals of the RBPH for each single of the rove beetle - resulting feeding rate ca. 5.46 and it was rounded to be 6 individuals/single predators within 24 hours. Then serial numbers of prey presented (N_t) was made such as follows: 2, 4, 6, 8, 10, 12, and 14 preys, respectively, for each single predator. Arena predation was a glass tube 4 cm in diameter, 20 cm high, five rice-seedlings were placed inside the tube at which roots were kept in wet cotton on the tube mouth. A number of prey and single predator were then placed inside the tube. The predator was allowed to feed on the RBPH during total time (T_t) for 24 hours. At the end of the experiments, total number of actual prey eaten (N_a) were recorded. This experiment was run by five replications.

Holling disc equation (Holling, 1959) was adopted to analyse type of functional response and to determine expectation of maximum feeding rate.

Holling disc equation: $$\mathrm{Ne} = \frac{\mathrm{a'TtNt}}{1 + \mathrm{a'ThNt}}$$

where

N_e = Expected number of prey eaten

N_t = Total number of available prey

T_t = Total time for predator allowed to search, cupture, and feed,

T_h = Handling time, a time period for a single predator catching and feeding a single prey

a' = Feeding rate, number of prey eaten per unit of time

Values of T_h and a'were calculated by developing linear regression of Y=α+βX. N_a/N_t=a'T_t-a'T_hN_a. α=a'T_t. a'=α/Tt. β = -a'T_h. T_h = β/-a'. Ne maximum=T_t/T_h

Numerical response

Objectives of the study were to determine the strength of numerical response of the rove beetle against the RBPH in rice fields. Rice fields infested naturally by the RBPH in Regencies of Sleman and Bantul, Yogyakarta, Indonesia, were selected. Rice variety, and all various treatments for paddy culture such as plant space, irrigation, fertilizing, control of pests and diseases, following to what done by farmers. Population densities of the rove beetle and the RBPH were recorded directly *in situ*. Field observations were conducted at the rice growth stages such as follows: pre planting; nursery; 7, 14, 21, and 30 days after planting, primordial flower, flowering, milky grains. Sampling unit was rice hill, while sampling size was 100 hills. Linear regression was applied to determine numerical response of the rove beetle against the RBPH (Wright and Laing, 1980; Wagiman, 1996b). Prey densities (the RBPH) observed on each of rice-growth stages was plotted against predator densities (the rove beetle) observed on each of rice-growth stages. Due to usually many zeros population-data were observed and variance was much bigger than mean hence for data normalization, prior to analyze the data were transformed into $\log_{10}(x+1)$, where x was observation data.

Spatial distribution

Objectives of the study were to determine spatial distribution patterns of the rove beetle and the RBPH in the rice fields. Data obtained from the study of numerical response of the rove beetle against the RBPH were used to determine the spatial distribution pattern. Patterns of the spatial distribution were determined following procedure of Ludwig and Reynold (1988). Comparison between means ($\bar{x}$) and variance (s^2) of population densities indicate the spatial distribution into categories of regular ($s^2 < \bar{x}$ or variance:mean ratio <1), random ($s^2 = \bar{x}$ or or variance:mean ratio = 0), or clumped ($s^2 > \bar{x}$ or variance:mean ratio >1). The following formula of dispersion index (I_D) is used to determine if the variance:mean ratio value is confirmed with 1, >1 or <1:

$$I_D = \frac{(n-1)s^2}{\bar{x}}$$

where *n* sampling size, s^2 ang $\bar{x}$ are variance and mean, respectively. I_D is distributed refer to chi-squared dispersion (χ^2) with *n-1* degrees of freedom (df). If calculated value of I_D is on preferred confidence interval say (95%) it is confirmed = 1 and it shows random pattern. If calculated value of I_D is less than confidence interval it is confirmed <1 and it shows regular pattern. If calculated value of I_D is more than confidence interval it is confirmed >1 and it shows clumped pattern.

RESULTS AND DISSCUSSIONS

The studies revealed potency of the rove beetle as a predator of the RBPH, and it is prospective to be exploited for biological control agent against the pest insect. Manley (1977) reported that the rove beetle was found to be an aggressive leafhopper predator in rice field in West Malaysia.

Functional response

Feeding rates of the rove beetle on the RBPH is presented in Table-1. Analyses of linear regression Y=α+βX at which X for N_a and Y for N_a/N_t resulting Y=0.6818-0.0416X. α=0, 6818. β=-0, 0416. a'=α/Tt=0.6818/24=0.0284 preys/h. T_h=β/-a'=-(0.0416)/-(0.0284)=1.4644 h/prey. N_e was calculated with Holling disc equation and the result is presented in Table-1. The actual prey eaten (N_a) and expected prey eaten (N_e) were not significantly different, analyses of $t_{\alpha 0.05}$ resulting P = 0.89672. N_e maximum= T_t/T_h=24/1.4644=16.39 preys within 24 hours. The actual maximum feeding rate was 5.46±1.39 preys within 24 hours. Hence, the expected N_e

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maximum was three folds as compared with the actual one. The actual feeding rate was as biological basic at which during prescribed time - in the study was 24 hours - it was approximately 70% for active moving and feeding (Simanjuntak, 2012), while the expected was mathematical basic with assumption that all the prescribed time for feeding. It implies that for predicting predator potency the actual feeding rate is more appropriate.

Table-1. Number of the RBPH as a prey presented (N_t), number of prey actual eaten (N_a), number of expected prey-eaten referred to Holling disc equation (N_e) by the rove beetle within total time (T_t) 24 hours.

N_t	N_a within 24 hours at replications and means						N_a/N_t	N_e
	1	2	3	4	5	Mean ± S.D.		
2	1	2	1	1	2	1.40 ± 0.55	0.70	1.26
4	2	2	3	2	2	2.20 ± 0.45	0.55	2.34
6	3	2	3	3	4	3.00 ± 0.71	0.50	3.27
8	4	3	5	4	4	4.00 ± 0.71	0.50	4.09
10	5	4	5	5	5	4.80 ± 0.45	0.48	4.81
12	8	6	4	5	5	5.60 ± 1.52	0.47	5.46
14	6	6	7	6	6	6.20 ± 0.45	0.44	6.03

When N_t were plotted against N_e and N_a (Figure-1) the trend line fitted with functional response Type II of Holling. It assumes that a predator spends its time for searching for prey and prey handling which includes: chasing, killing, eating and digesting. At low prey densities, predators spend most of their time on search, whereas at high prey densities, predators spend most of their time on prey handling. Plateau represents predator saturation. Prey mortality declines with prey density. Predators of this type cause maximum mortality at low prey density (Holling, 1959). The rove beetle is an aggressive leafhopper predator in rice field (Manley, 1977) and its functional response fitted with Type II. It implies that the rove beetle may play an important role in preventing the RBPH outbreak by killing macroptera in low density at initial colonization.

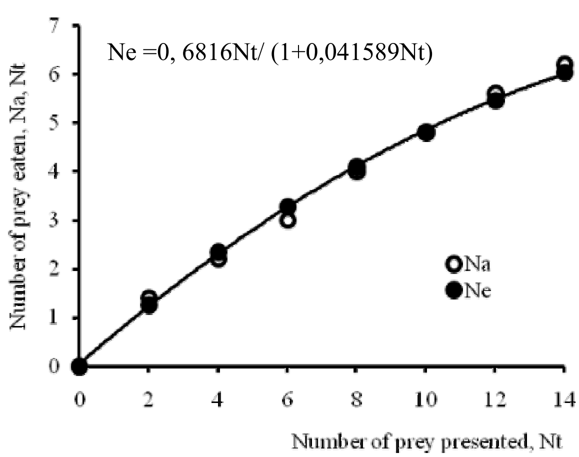

Figure-1. Type II functional response of the rove beetle against the RBPH.

Numerical response

Relationship between density of the RBPH ($\log_{10}(X+1)$) and density of the rove beetle ($\log_{10}(Y+1)$) performing Y = 0.451X + 0.088 (Figure-2) with r = 0.844985. Intercept = 0.088 indicates that when the RBPH was absent in the rice field, the rove beetle still exists even if it was less than one individual per hill. The high positive correlation is very strong (Sugiyono. 2011) and it indicates density-dependent relationship (Wright and Laing, 1980). This finding supports Manley (1977) that the rove beetle feeding on leafhopper nymphs appears to be density-dependent within certain population levels. Numerical response may due to imigration and reproduction. Biological characteristics of the rove beetle from Malaysia were reported by Bong *et al*. (2012). The total development time of immature stages approximately 17-19 days and short life span was exhibited by adult females and males. The numbers of eggs laid per female varied from 121 to 147 eggs. The beetles compensated

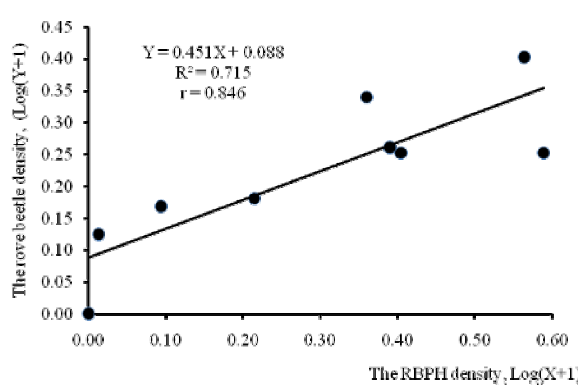

Figure-2. Numerical response of the rove beetle against the RBPH.

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for their shorter life span by increasing their reproductive activity to sustain the progeny in the population. The intrinsic rates of increase (r) were 0.0773 to 0.0873, the net reproduction rates (R_0) were 40.09 to 45.29 offspring. The mean generation time from 43.08 to 48.57 days. This report supports in further studying on developing the rove beetle into biological control agent.

Spatial distribution

Patterns of spatial distribution of the RBPH and the rove beetle on various stages of rice growth varied from regular to clumped (Table-2). When index dispersion (I_D) was compared with X^2 at α 95%, it was confirmed to be <1 (regular) and >1 (clumped). The distribution pattern tended to be clumped when their population density was high and on the other hand it tended to be regular when their population density was low. Index dispersions of the RBPH and the rove beetle were not significantly different as indicated by statistical analyses of $t_{\alpha 0,\ 05}$ and P = 0.1969. It was a good phenomenon meaning that the predator may synchronous with its prey.

Table-2. Pattern of spatial distribution of the RBPH and the rove beetle at rice growth stages.

Rice growth stages	**N**	**The RBPH** (individuals/hill)		**The rove beetle** (individuals/hill)		**Variance/Mean**		**Distribution pattern**				**Chi-Square 95 %**
		Mean	**Variance**	**Mean**	**Variance**	**The RBPH**	**The rove beetle**	**The RBPH**		**The rove beetle**		
								I_D	**≈1**	I_D	**≈1**	
Pre planting	36	0.00	0.00	0.00	0.00	~	~	~	~	~	~	49.80
Nursery	30	0.03	0.03	0.33	0.44	1.00	1.31	29.00	<1	38.00	<1	42.56
7 DAP	100	0.24	0.18	0.47	0.39	0.77	0.84	76.00	<1	82.79	<1	123.22
14 DAP	100	1.29	1.64	1.19	1.39	1.27	1.17	126.04	>1	115.45	>1	123.22
21 DAP	100	0.64	0.52	0.52	0.43	0.81	0.83	79.75	<1	82.62	<1	123.22
30 DP	100	2.66	5.82	1.52	2.13	2.19	1.40	216.71	>1	138.79	>1	123.22
Primordial Flower	100	1.54	1.42	0.79	0.67	0.92	0.85	91.45	<1	84.29	<1	123.22
Flowering	100	1.46	0.86	0.82	0.88	0.59	1.07	58.11	<1	105.81	<1	123.22
Milky grain	100	2.88	7.54	0.79	0.61	2.62	0.77	259.22	>1	76.70	<1	123.22
$t_{\alpha 0,\ 05}$						P = 0.1969						

As a candidate of biological control agent a predator must have strong functional response (Luff, 1983). The strong fungtional response have been showed by the rove beetle against the RBPH, hence, the rove beetle is one of promising natural enemies and it needs to be further studied for controlling the RBPH and other pest insects.

CONCLUSIONS

Existence of the rove beetle in an agroecosystem is meaningful in naturally control of pest insects including the CRBPH. Laboratory experiment and field survey revealed that the rove beetle was a potential predator against the RBPH. The rove beetle exhibited strong functional and numerical response and had relatively similar spatial distribution pattern - clumped - with the RBPH.

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