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Ecological Studies on *Anagrus incarnatus* Haliday (Hymenoptera : Mymaridae), an Egg Parasitoid of the Rice Planthoppers”

II. Spatial Distribution of Parasitism and Host Eggs in the Paddy Field

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Spatial distribution of parasitism by *Anagrus incarnatus* and that of the rice planthopper eggs were investigated by using Iwao's (1968) method of $\overset{*}{m}$-m relationship. The spatial patterns of the host eggs as well as that of parasitism were found to be overdispersed with an aggregative tendency. The relationship between individual host eggs and egg-masses parasitized by ***A.*** *incarnatus* showed a highly positive correlation. But the intensity of parasitism with respect to the host eggmass size showed a tendency of an inverse density dependent relationship between per cent parasitism and host density per patch.

INTRODUCTION

It has been said that the spatial distribution of an animal species is essential to ecological research for a better understanding of its population dynamics. This study is also said to be useful in analysis of the host-parasitoid or prey-predator systems (Anderson, 1974; Hassell and May, 1974). For the three basic parasitoid responses, the functional responses and the responses to parasitoid density have long been studied. An aggregative response of parasitoids to the host distribution has been currently reported (e.g. Hirose et al., 1976: Hassell, 1982; Morrison and Strong, 1981).

Kuno (1963) studied the spatial distribution of the nymphal populations of *Nilaparvata lugens* (St&l), which is one of the rice planthoppers. For the mymarid *Anagrus incarnatus* Haliday, a dominant egg parasitoid of the rice planthoppers in Japan (Chantarasa-ard et al., 1984a), its behavioural response to the host population has not been reported. Ôtake (1970) studied the dispersal activity of ***Anagrus*** nr. *flaveolus* in the paddy field. However, he did not report

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the spatial distribution of parasitism by this parasitoid.

Chantarasa-ard et al. (1984b) reported the functional response to its host density and the mutual interference between the searching females of ***A. incarnatus***. Therefore, in this paper the spatial distribution of parasitism by this parasitoid in relation to that of its host populations in the paddy field will be discussed.

MATERIALS AND METHODS

To collect the data, a paddy field was selected, the size of which was 825 m^2 (15 x 55 m). This experimental field was located at Hikawa-gun, Shimane Prefecture. Rice variety, Nihon-bare, was transplanted on June **10,** 1983 with spacing 15 x25 cm per hill. Due to the paddy field belonged to the farmer, so insecticides were applied. They were Cartap (granule), MEP (dust), MPP + BPMC (dust) and PAP+BPMC (dust).

The experimental field was divided into 80 strata, of which each stratum was 3 ×3.5 m in size. Stratified random sampling was employed. One rice hill per stratum was sampled and sampling of the rice plants were made 3 times on July 26, August 26 and September 5. On each time, 80 rice hills were collected and then brought back to the laboratory for examining the number of host eggs and parasitized eggs. At the time when host plants were dissected young host eggs were transferred to small vial (1.5×6 cm) providing with moist filter paper. Those eggs were held at room temperature for further development of the insects until parasitized eggs could be recognized. Observation was made under a binocular stereo-microscope.

For analysis of the data, Iwao's (1968) method of $\overset{*}{m}$-m relationship was utilized. The $\overset{*}{m}$ value was based on Lloyd's (1967) method of mean crowding, which is estimated from the equation $\overset{*}{m}=m+(s^2/m-1)$.

The two crucial parameters in Iwao's concept of $\overset{*}{m}$-m relationship are α and β, which he called the "index of contagion" and "density-contagiousness coefficient", respectively. To understand the meaning of α and β, Iwao's concept will be briefly reviewed here (also see Iwao, 1970; Iawo and Kuno, 1981) : The spatial pattern of animal population would be the Poisson distribution, if $\alpha=0$ and $\beta=1$; overdispersion that follows a model of randomly distributed colonies or clumps, if $\alpha>0$ and $\beta=1$; overdispersion that follows a model of negative binomial with a common k, if $\alpha=0$ and $\beta>1$ ($\beta=1+1/k$); the pattern will be overdispersion that follows a model of contagiously distributed colonies or clumps in which the distribution of colonies or clumps are fitted to the negative binomial series with a common k, if $\alpha>0$ and $\beta>1$; and if $\alpha=0$ and $\beta<1$ or $0>\alpha>-1$ and $\beta=1$, the pattern will be underdispersed distribution.

RESULTS AND DISCUSSION

Spatial distribution of host eggs

Data from the sampling units used for analysis of spatial distribution of individual host eggs and egg-masses are shown in Tables 1 and 2, respectively. From these data, the regression of $\overset{*}{x}$-$\bar{x}$ relationship was drawn following the Iwao's method, and are shown in Figs. 1 and 2 for the individual host egg and egg-mass population, respectively. For the sake of convenience of drawing figures, data of $\overset{*}{x}$ and $\bar{x}$ from Tables 1 and **2** were transformed into log $\overset{*}{x}$ and log $\bar{x}$. Analysis of the data shows that the spatial distribution of individual host eggs is an overdispersion that follows a model of the Poisson distribution of colonies or clumps since $\alpha > 0$ ($\alpha = 0.37$) and $\beta = 1$ (Fig. la). For the egg-mass population, it will be seen from Fig. lb that the spatial pattern is an overdispersion that follows a model of negative binomial distribution with a common k since $\alpha \doteqdot 0, \beta > 1$ ($\alpha =$ -0.08, $\beta = 1.39$).

Table 1. Data used for calculation of a and β of individual host eggs from 80 rice-hill samples.

Date of sampling	Total no. of eggs observed	Mean no. of eggs per hill ($\bar{X}$)	S^2	X*
Jul 26, '83	6,418	80.22	2939.81	115.87
Aug 27, '83	15,334	191.67	70072.32	556.25
Sept 5, '83	5,735	71.69	9560.37	204.05

Table 2. Data used for calculation of α and β of host egg-masses from 80 rice-hill samples,

Date of sampling	Total no. of masses observed	Mean no. of masses per hill (X)	S^2	X*
Jul 26, '83	718	8.97	**40.78**	***12.52***
Aug 27, '83	***1681***	***21.01***	**848.09**	60.37
Sept 5, '83	603	7.54	92.25	18.78

The actual distribution of host eggs based on a set of data sampled on July 26 are mapped in Fig. 2a for the individual host egg population and Fig. 2b for the egg-mass population. It seems to be that the theoretical spatial patterns in Figs. la and lb are in good harmony with the actual distribution.

A little difference in the pattern of distribution between individual host egg population and egg-mass population may be explained by the fact that fundamentally, planthopper eggs in mass are laid in the form of clump or colony, but as the number of masses increase and the variation in mass size the overall of individual egg population turns to be overdispersed with randomly distributed colonies or clumps as will be seen in Fig. 2a. Kuno (1963) has demonstrated that the nymphal populations of N. *lugens* distribute themselves in the pattern of contagiousness with aggregated tendency. This seems to imply that the spatial pattern in nymphal populations of this host species is associated with that of their egg population because it has known that the nymphs and adults of the brown planthopper, particularly brachypterous form, have some restricted nature in dispersal behaviour. It should be noted that

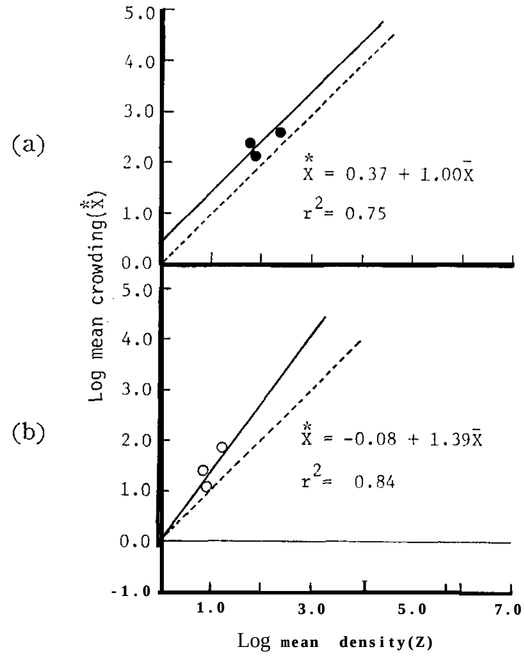

Fig. 1. Relationships between the sample mean density ($\bar{X}$) and mean crowding ($\overset{*}{X}$) of (a) individual egg population; (b) egg-mass population of the rice planthoppers (mainly *Nilaparvata lugens* and *Sogatella furcifera).* Broken line indicates the Poisson distribution.

most of the rice planthopper eggs collected during the course of sampling were **N.** *lugens.*

Spatial distribution of parasitism

The spatial distribution of parasitism by A. *incarnatus* was inferred from the spatial pattern of parasitized host eggs. The data used for calculation of α and β are shown in Tables 3 and 4 for the individual parasitized eggs and parasitized egg-masses. From Fig. 3a, it will be seen that $\alpha > 0, \beta > 1$ ($\alpha =$ 3.71, $\beta = 3.35$) for the individual parasitized egg population. Thus, it indicates that parasitism of individual host eggs distributes in an overdispersed pattern that follows a model of contagiously distributed colonies or clumps. For the parasitism of egg-masses, it will be seen from Fig. 3b that $\alpha \doteqdot 0$ and $\beta > 1$ ($\alpha =$ 0.04, $\beta = 2.92$), so the spatial pattern in parasitized egg-mass population is the same as that of egg-mass population in Fig. lb. Again, when the theoretical spatial pattern of parasitism of individual host egg and egg-mass populations were compared with the actual distribution (Figs. 4 and 5), they are in good harmony each other.

From the results, it may be said that the spatial distribution of parasitism by *A. incarnatus* **is** closely related to its host egg distribution, i.e. the spatial

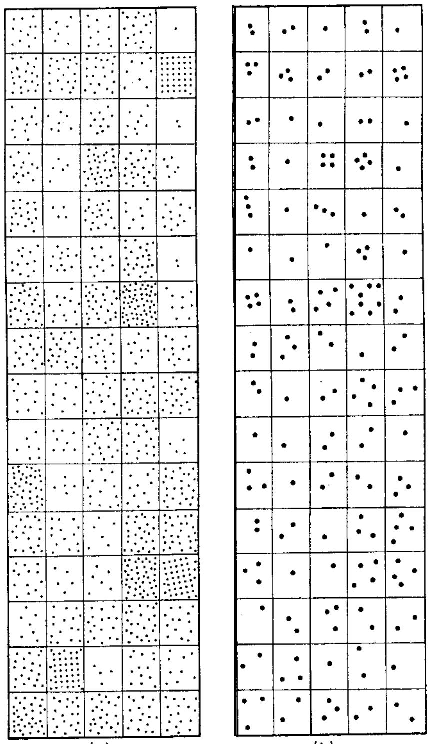

Fig. 2. Mapping of the distribution of (a) individual egg population; (b) egg-mass population of the rice planthoppers (mainly *Nilaparvata lugens* and *Sogatella furcifera*). Data were sampled from the paddy field at Hikawa-gun, Shimane Prefecture, on July 26, 1983.

Table 3. Data used for calculation of α and β of individual parasitized eggs from 80 rice-hill samples.

Date of sampling	Total no. of eggs parasitized	Mean no. of parasitized eggs per hill ($\bar{X}$)	S^2	X*
Jul 26, '83	147	1.84	13.66	6.27
Aug 27, '83	583	7.29	192.92	2.76
Sept 5, '83	814	10.17	260.93	34.76

Table 4. Data used for calculation of α and β of parasitized egg-masses from 80 rice-hill samples.

Date of sampling	Total no. of masses parasitized	Mean no. of parasitized masses per hill (X)	S^2	X*
Jul 26, '83	31	0.39	0.42	0.46
Aug 27, '83	227	2.84	25.93	10.99
Sept 5, '83	285	3.56	20.22	8.24

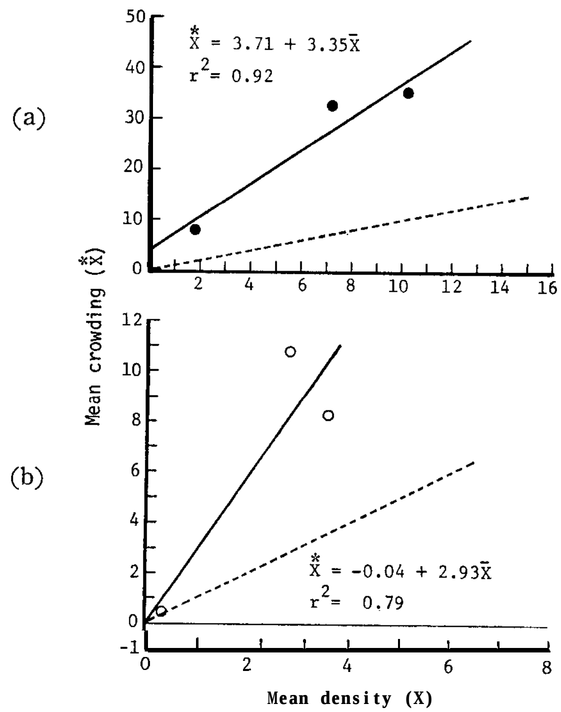

Fig. 3. Relationships between the sample mean density(y) and mean crowding ($\overset{*}{X}$) of (a) individual parasitized eggs; (b) parasitized egg-masses by ***Anagrus incarnatus*** in the paddy field. Broken line indicates the Poisson distribution.

distribution of host eggs is contagiousness with aggregative tendency, and the parasitoid tends to aggregate at the place where the high host egg density is formed.

It is interesting to note that the relationship between per cent parasitism of individual host eggs and egg-masses showed a high positive correlation (r^2=0.78) (Fig. 6). This seems to suggest that A. *incarnatus* has a good dispersal ability in searching for host in the paddy field. However, the intensity of parasitism in relation to the host egg-mass size has a slight negative correlation (r= -0.46). That is per cent parasitism tends to decrease in the larger egg-mass size (Fig. 7).

During the past few years spatial heterogeneity has received the most attention, which has been discussed by several workers (e.g. Beddington et al., 1978; Hassell and May, 1973, 1974; Maynard Smith, 1974). The aggregated response of parasitoids to the spatial heterogeneity of host is called a "selective advantage" (Hassell and May, 1973, 1974). Morrison and Strong (1980) state that searching behaviour of the parasitoids is difficult to be observed in the field, because these insects are often small and relatively fast moving. So they point out that the details and mechanism in searching of parasitoids can

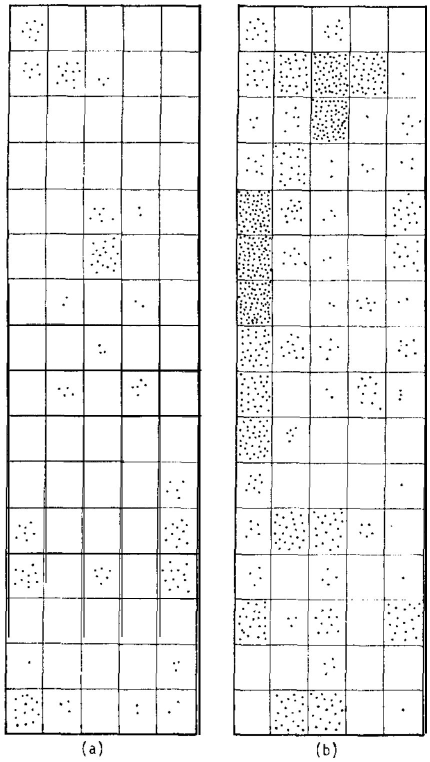

Fig. 4. Mapping of the distribution of parasitism of individual host eggs by *Anagrus incarnatus*. Data were sampled from the paddy field on: (a) July 26; (b) September 5.

only, in most cases, be inferred indirectly from the data of spatial distribution of parasitized hosts and spatial variations in intensity of parasitism.

The spatial parasitism in relation to the host distribution in the field has been found to vary from species to species, of which some show density-dependence ; others show density-independence or inverse density-dependence as reviewed by Hassell and Waage (1984). For *A. incarnatus*, it was likely that this species has a tendency of inverse density-dependence. Hirose et al. (1976) found that if the eggs of *Papilio xuthus* are deposited in clusters, rather than singly, parasitism by *Trichogramma papilionis* will be decreased. Brown and Cameron (1979) found that per cent parasitism by *Ooencyrtus kuwanai* has a strong negative correlation with the gypsy moth egg-mass size. Morrison et al. (1980) also reported that a significant negative correlation between per cent parasitism by *Trichogramma* spp. and eggs of *Heliothis zea* per leaf of soybean plant was observed in the manipulated experimental field. A similar result has also found in *Cephaloleia consanguinea eggs* attacked by eulophid and trichogrammatid parasitoids in the lowland forest of eastern Costa Rica (Morrison and Strong, 1981).

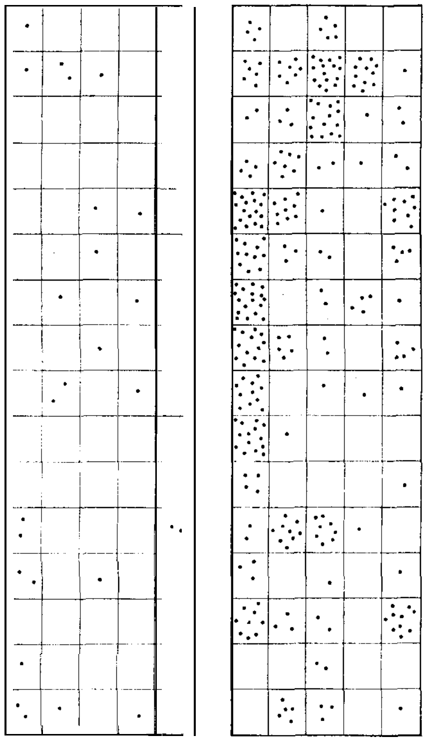

Fig. 5. Mapping of the distribution of parasitism of egg-masses by ***Anagrus incarnatus***. **Data** were sampled from the paddy field on: (a) July 26; (b) September 5.

Hassell and Waage (1984) states that any form of heterogeneity in the distribution of parasitism can have a marked effects on both equilibrium and stability.

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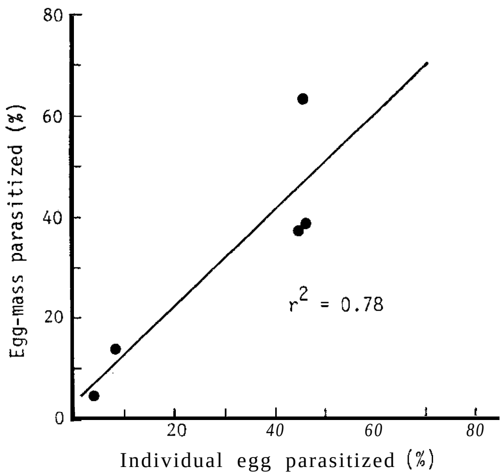

Fig. 6. Relationships of parasitism by *Anagrus incarnatus* between individual eggs and egg-masses of the rice planthoppers in the paddy field. Data were collected 5 times during July-September, 1983, at Hikawa-gun, Shimane Prefecture, and each point in the figure is the mean of each sampling time.

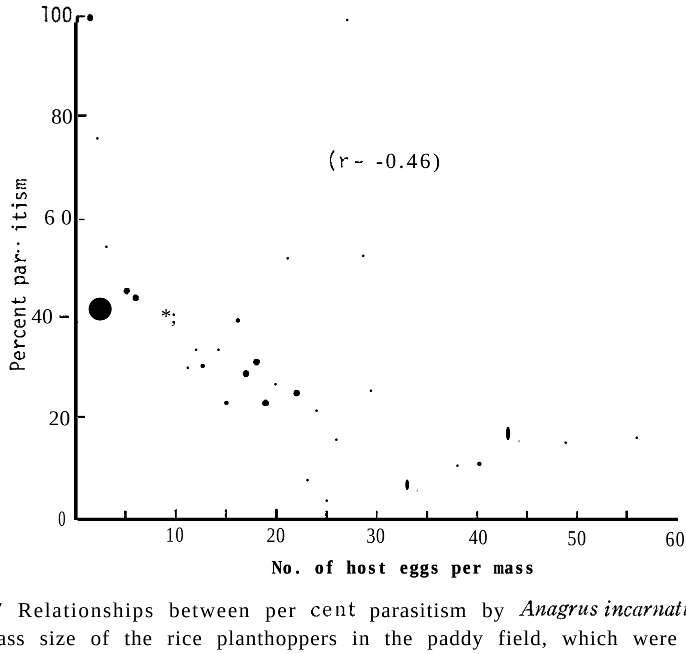

Fig. 7 Relationships between per cent parasitism by *Anagrus incarnatus* and egg-mass size of the rice planthoppers in the paddy field, which were based on the data collected 5 times during July-September, 1983, at Hikawa-gun, Shimane Prefecture.

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