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Studies on the Egg Parasites of the Smaller Brown Planthopper, *Laodelphax striatellus* (FALLÉN) (Hemiptera : Delphacidae)

IV. Seasonal Trends in Parasitic and Dispersal Activities, with Special Reference to *Anagrus* nr. *flaveolus* WATERHOUSE (Hymenoptera : Mymaridae)

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Parasitic activity of wasps attacking delphacid eggs on cultivated plots and the intensity of their dispersal were studied by setting in the outdoors flower-pots bearing *Laodelphax striatellus* eggs. *Anagrus* nr. *flaveolus* was an overwhelmingly dominant species. The parasitic activity of the species was ascertained on wheat late in April. It was also clarified that the parasite had already existed on the early-season transplanted rice crops when the adults of *L. striatellus* were about to invade. An increase of parasitic activity in autumn was demonstrated on paddy plots. Dispersal of *Anagrus* to a bare ground on which the research was carried out tended to be continuous all through the season. In autumn, the intensity of dispersal was heightened remarkably. Adaptive significance of the autumn dispersal is discussed in relation to possible ways of hibernation of the parasite. A different species of *Anagrus* and a trichogrammatid belonging to genus *Oligosita* were also recorded occasionally in autumn. The species, however, were mainly obtained on the bare ground and are guessed to be mere facultative inhabitants on rice crops.

INTRODUCTION

Previously, the writer presented a method to investigate the fauna and the relative abundance of insect parasites attacking planthopper eggs in the field (ÔTAKE, 1967). The essential point of this method is to expose young plants bearing planthopper eggs to the attack of parasites inhabiting the field.

After some improvements, the method was used to study seasonal trends in the activity of parasites on cultivated crops and their dispersal on a bare ground. The studies were conducted from 1967 to 1968.

METHODS

Investigations were carried out at the farm belonging to the Shikoku Agricultural Experiment Station, Zentsuji, Kagawa Prefecture, Japan (Fig. 1). In Plot A, rice

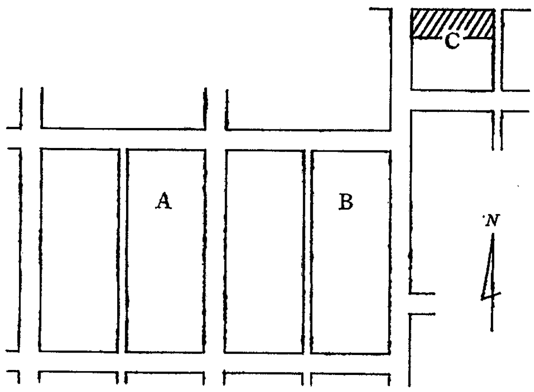

Fig. 1. Map showing plots for investigation. A, B and C are plots with areas of 10, 10 and 5 acres, respectively. Bare ground in Plot C is indicated by oblique lines.

plants were grown on subplots of different dates of transplantation. In 1967, the subplots were of the following 5 different dates of transplantation: May 4, May 15, May 25, June 5 and June 15. In the succeeding year, the number of subplots was decreased in accordance with the readjustment of transplantation to 2 different dates, May 8 and 25. Plot B was investigated during the period of wheat cultivation, from April to June, 1968. The northern one-third of Plot C was left uncultivated for investigating the dispersal of parasites.

Wheat seedlings were used as material to receive the planthopper eggs because of their easiness in handling. Two seedlings planted on a flower-pot were covered with a plastic cylinder, and 15 females and 5 males of *Laodelphax striatellus* were released in the cylinder. The insects were allowed to mate and oviposit for 2 days in an air-conditioned room maintained at 26°C.

Flower-pots thus carrying planthopper eggs were set at points arranged at regular intervals on the plots. In Plot A, 4 setting points were located on each of subplots of transplantation dates of May 4, May 25 and June 15, in 1967, and on each of subplots of both transplantation dates, in 1968. Six points were located on Plot B. In either of Plots A and B, a single flower-pot was set at each setting point. The time intervals of the setting of flower-pots were about two weeks in 1967, and usually one week in 1968. (Until the mid-June of the latter year, however, exceptionally intensive investigations were carried out at intervals of 3 to 4 days in plot A.)

On the bare ground of Plot C, a preliminary test was carried out in 1967. Since there was evidence of dispersal of the parasite on the plot, the following regular investigations were designed for the succeeding year: two groups of setting points were arranged on the bare ground; one group was located 5 metres apart and the other 2 metres apart, from the northern edge of the cultivated area within the same plot. Each group consisted of 2 setting points, which were situated on the western and the eastern sides of the ground respectively. As shown in Fig. 2, 4 flower-pots bearing host eggs were placed at each of the points among 5 flower-pots containing densely grown wheat seedlings free from planthopper oviposition. Two reasons can be mentioned for putting together with such densely-planted

Fig. 2. Flower-pots put on the bare ground of Plot C.

flower-pots: first, to make dispersing parasites easy to alight through the formation of a green spot on the bare ground, and secondly, to protect the planthopper egg-bearing seedlings from the injury by sparrow. The effect related to the first item was doubtful but the second reason seemed to be rational. Four flower-pots bearing host eggs were also arranged on a cultivated area along the northern edge of the area. The investigations on Plot C were carried out at intervals of one week during the period from spring to autumn.

The flower-pots were brought back to the laboratory 3 days after their being set in the field. The seedlings with roots were individually put into test tubes and kept in an air-conditioned room at 26°C. The small amount of soil around the roots of the seedlings enabled it to remain alive in the tubes. The number of planthopper nymphs which hatched from a seedling was daily recorded. When the hatching of nymphs was nearly over, the seedling was dissected and host eggs in plant tissues were counted. Parasitized and unparasitized eggs were plainly distinguishable, because, by that time, the parasite pupa became observable through the transparent chorion of the host egg (Ôtake, 1968).

On Plots A and C, trends of appearance of female adult *L. striatellus* in June-July were investigated by counting the insects on randomly sampled rice plants. An investigation of the same sort was also carried out on wheat crops on Plot B, 1968, but it was unsuccessful because of the inadequacy in sampling and scarcity of insects.

RESULTS

All through the investigations, the parasites obtained were nearly exclusively the mymarid, *Anagrus* nr. *flaveolus*.

In autumn, 1968, a different species of *Anagrus* was occasionally recorded on the bare ground. The male of this species is light in colour and the funicle segments of its antenna are nearly of the same length with one another, while in *A.* nr. *flaveolus*, the male is dark and reddish in colour and its first funicle segment is distinctly short. Both species are different from each other also in the arrangement and the number of ciliae on the wing.

In addition to these *Anagrus* species, a trichogrammatid belonging to genus *Oligosita* was found mainly on the bare ground, in autumn. In this species, the males collected were all wingless and some of the females collected were also without wings.

Ordinarily, the intensity of parasitism is expressed by means of the percentage of parasitism. In the present work, however, this method of expression seemed to be rather inadequate because there was a wide variation in the total number of host eggs deposited on the seedlings in a flower-pot (Table 1). As published by the writer in a separate paper, *Anagrus* nr. *flaveolus* tends to oviposit about 20 eggs in rather close successions (Ôtake, 1969). We now assume that 2 flower-pots bearing 100 host eggs, on the one hand, and 200 eggs, on the other hand, were visited by single female parasites, respectively, and each of these parasites deposited all of her egg storage, 20 eggs, on the flower-pot. If percentage parasitisms are calculated in these cases, it becomes realized that two strikingly different values, namely 20 per cent and 10 per cent, are given to the only evidence that either of the flower-pots was visited by a single parasite. It is thus clear that percentage parasitism is inadequate to use in this state of affairs.

Table 1. Frequency Distribution of Host Eggs per Flower-Pot at Respective Setting Points on Plot C

No. of host eggs per flower-pot	Frequency[a]
0 - 13.99	1
14.00- 27.99	1
28.00- 41.99	2
42.00- 55.99	11
56.00- 69.99	18
70.00- 83.99	15
84.00- 97.99	27
98.00-111.99	25
112.00-125.99	16
126.00-139.99	16
140.00-153.99	12
154.00-167.99	4
168.00-181.99	1
	149

[a] All the data for 1968 have been put together.

The number of parasitized eggs per flower-pot will then have to be put as the basis of quantitative analyses of the data obtained.

Fluctuations of these numbers on Plots A and B are shown in Fig. 3. In Plot A, the average of the flower-pots is given for each of the subplots investigated,

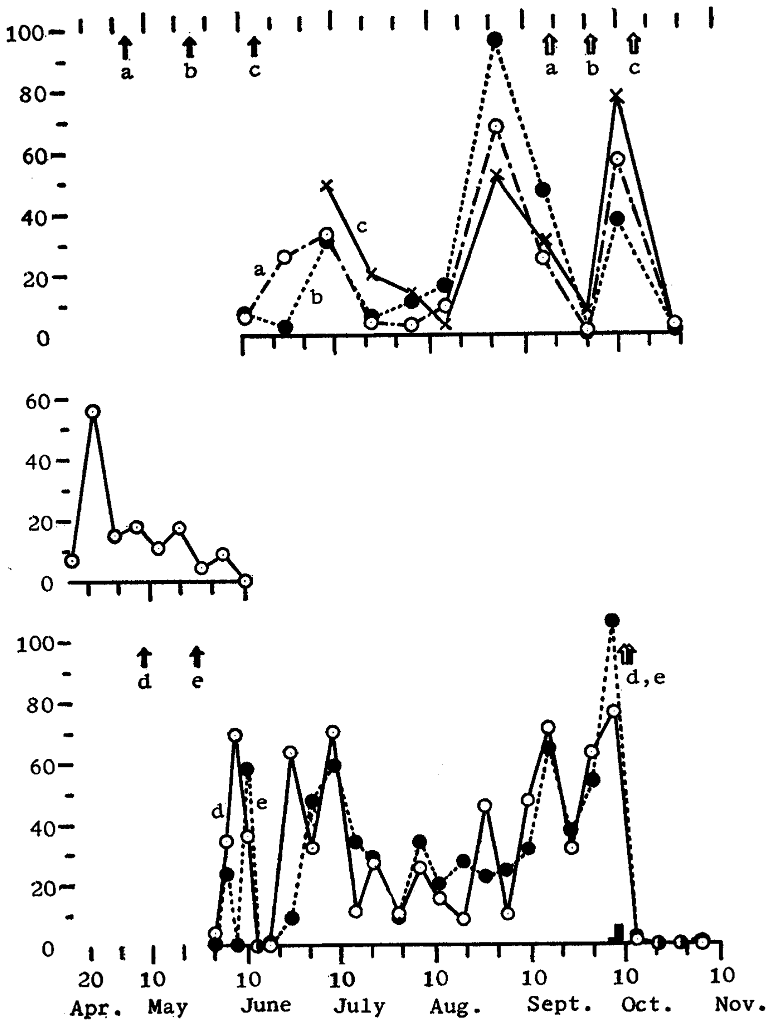

Fig. 3. Seasonal fluctuations in the number of parasitized eggs per flower-pot on Plots A and B. Upper: Plot A in 1967. Letters a, b and c indicate subplots of rice-transplantation dates of May 4, May 25 and June 15, respectively. Middle: Plot B (wheat) in 1968. Lower: Plot A in 1968. Letters d and e indicate subplots of rice-transplantation dates of May 8 and 25. Circles and × represent *Anagrus* nr. *flaveolus*. Vertical bar (the lowest graph alone) represents *Oligosita* sp. Solid and hollow arrows indicate transplantation and harvesting, respectively, on each subplot.

and in Plot B, the average is calculated for the 6 flower-pots arranged in the plot. As in the results obtained in 1966 by the writer (Ôtake, 1967), heavy fluctuations are pointed out in the curves of *Anagrus* in Fig. 3. It is characteristic that trends of fluctuation are similar with one another among the curves on the same paddy plots.

As for the bare ground of plot C, the numbers of parasitized eggs on the flower-pots were averaged for each setting point (Fig. 4). In the figure, no distinction is made between the two *Anagrus* species. For the prupose of comparison, the averages of the flower-pots set on the cultivated area of the same plot

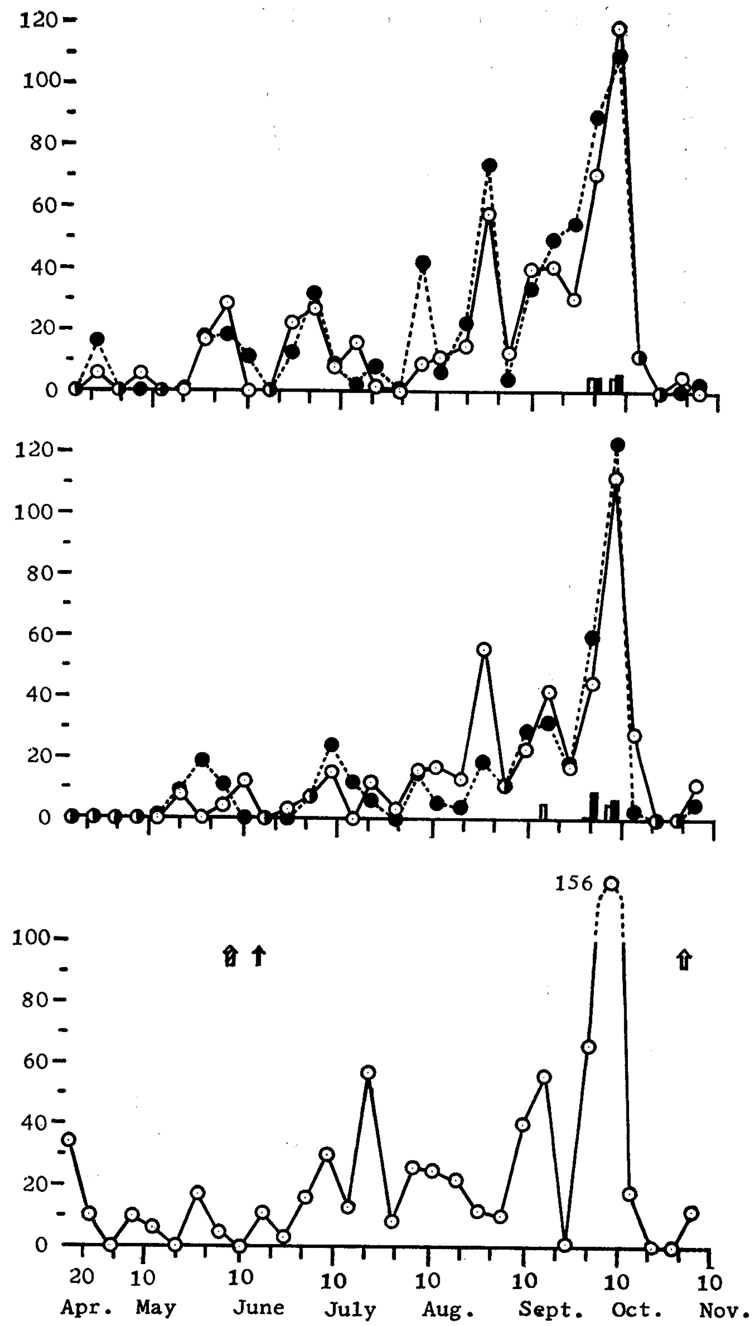

Fig. 4. Seasonal fluctuations in the number of parasitized eggs per flower-pot on Plot C. Upper: setting points 5 metres apart from the cultivated area. Circle and vertical bar represent *Anagrus* and *Oligosita,* respectively. Solid and hollow symbols indicate the points on the eastern and western sides, respectively. Semi-solid circle is used to show that eggs parasitized by *Anagrus* at one point were equal to those at the other point. Middle: setting points 2 metres apart from the cultivated area. Symbols are the same as the above. Lower: the cultivated area. *Anagrus* alone was recorded. Arrow with oblique lines indicates the date of wheat harvesting. Solid and hollow arrows are the same as in Fig. 3.

are also demonstrated. It is noteworthy that in each of the upper two graphs, similar trend curves are drawn between the eastern and western sides of the bare ground.

DISCUSSION

It is known that *L. striatellus* overwinter among forage crops and weeds at the nymphal stage. The first dispersal of the adults takes place in spring, and wheat crops are one of their main destinations. It is therefore meaningful that in April, *Anagrus* were already active on wheat crops in Plots B and C (Fig. 3 and the lower graph in Fig. 4).

The period of the second emergence of adults of the planthopper is mainly from late May to mid-June. The dispersing adults alight on early-season transplanted rice crops by preference. This may be recognizable from the continuous increase in planthopper density which was observed on the early-season transplanted subplots of Plot A in the first half of June as seen in Fig. 5. (There were no delphacids other than *L. striatellus* that inhabited abundantly the paddy plots in June.)

Comparing Fig. 3 with Fig. 5 we are conscious of a marked fact that *Anagrus* had already existed on rice crops when the invasion of *L. striatellus* was about to be intensified. Since all living plants had been removed from the plot by

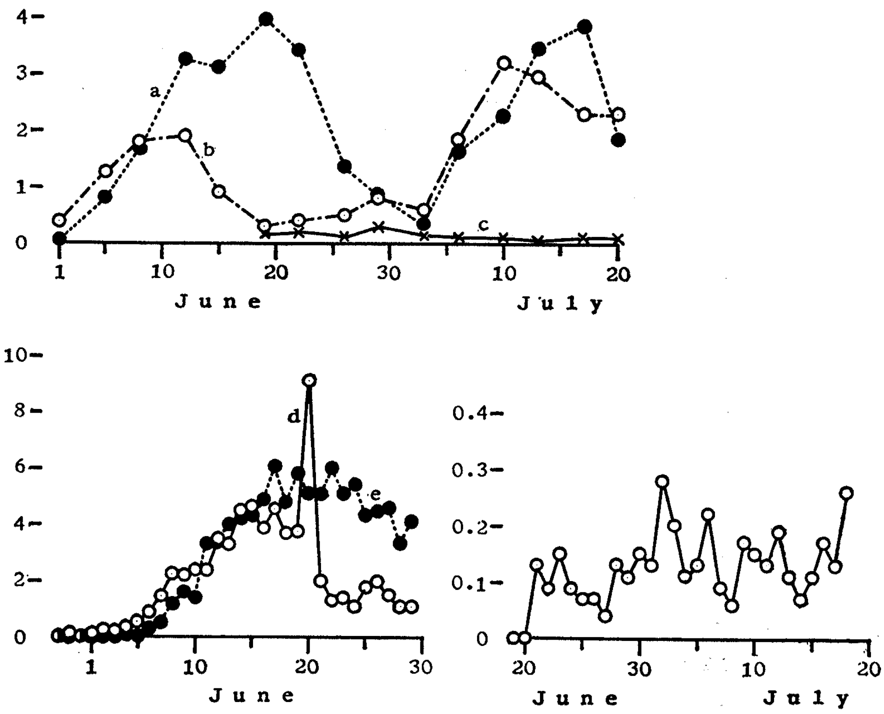

Fig. 5. Fluctuations in the number of female adults of *Laodelphax striatellus* per hill of rice plants. Upper: Plot A in 1967. Letters a, b and c indicate the same as in Fig. 3. Lower: Plot A (left) and Plot C (right) in 1968. Letters d and e indicate the same as in Fig. 3.

ploughing and puddling in advance of transplantation, it is certain that parasitism resulted from the activity of wasps which had come flying from the neighbouring wheat crops, weeds, etc.

The importance of synchronization of the occurrence of natural enemies with that of their prey is often emphasized. It is needless to say that synchronization should be in space as well as in time. We have frequently been informed that the dispersal habit or ability of a parasite or a predator does not match well with that of its prey. For example, it was demonstrated at Rothamsted by BANKS (1955) that coccinellids were ineffective as predators of a bean-infesting aphid, *Aphis fabae* SCOP., because the overwintered ladybirds and their progeny attacked first *Microlophium evansi* (THEO.) on nettles and when many coccinellids arrived on bean plots, the infestation of *A. fabae* there had already reached their maximum numbers. KIRITANI (1964) observed that in Wakayama Prefecture, Japan, parasitisms of the southern green stink bug, *Nezara viridula* L., by egg parasites, mainly *Asolcus mitsukurii* (ASHMEAD) and *Telenomus nakagawai* WATANABE, were significantly lowered on paddy fields, compared with remarkably high parasitisms attained on potatoes to which the overwintered bugs had been attracted first prior to invasion into the paddy fields. According to him, that the parasites did not have a high ability for dispersal as that of the bug would be primarily responsible for the observed restraint in parasitism on the paddy fields.

Compared with the cases mentioned above, the synchronized appearances of *Anagrus* and *Laodelphax* both on wheat and on early-season transplanted rice crops would be said to be notable.

In a previous paper, the writer expressed doubts as to whether the results of the trapping of parasites with artificially set host eggs can possibly be considered to bear a direct relation to the abundance of the parasite species therein (ÔTAKE, 1967). Unfortunately, the question is still unsolved. It will therefore be rather unwise to analyze the results obtained from the cultivated plots in the present research in great detail. Nevertheless, we are strongly impressed with the evidence that in autumn, the number of parasitized eggs increased remarkably in every paddy plot. It was also observed in the autumn of 1966 that a very high percentage of parasitism was reached on one of the paddy fields studied, and the writer thought that this might be attributable to a vast multiplication of an alternative host, *Nilaparvata lugens* (STÅL), in that year (ÔTAKE, 1967). In 1967, *N. lugens* again attained a considerably high density, but in the succeeding year, they hardly increased and *Sogatella furcifera* (HORVÁTH), another important delphacid infesting rice plants, too, was not abundant. The relationships between *Anagrus* and rice-inhabiting delphacids seems, therefore, to be more complex in actuality than those which the writer assumed previously.

It is moreover noteworthy that in 1967, a considerable number of parasitized eggs were recorded on subplots after harvesting (the upper graph in Fig. 3).

As seen in Fig. 4, throughout the season it was seldom that any flower-pot placed on the bare ground was not attacked by *Anagrus*. There was no significant difference in the seasonal trends of parasitization between the setting points kept 5 metres apart from the cultivated area and those 2 metres apart. It is guessed from these facts that the dispersal of this parasite from cultivated plots to the neighbourhood is rather habitual and is often made on a fairly broad scale. Though very minute and delicate, the wasps may be able to disperse to a considerable distance on an air current. A similar behaviour of dispersal has been discussed by KUWAYAMA (1935) concerning another mymarid, *Anaphes nipponicus* KUWAYAMA, which attacks the egg of the rice leaf-beetle, *Lema oryzae* KUWAYAMA.

An autumn increase in the number of host eggs parasitized by *Anagrus* was remarkable on the bare ground. It is interesting that a lot of parasitized eggs were nearly simultaneously recorded also on the rice-ripening area within the same plot (the lower graph in Fig. 4). Although we have to be prudent in drawing any decisive conclusion from the results of an investigation conducted for only one year, nevertheless, the parasite may have acquired a habit of active dispersal in autumn as a character adapted for seeking hibernation places. Actually no information has yet been obtained on the hibernation of this species. Through the writer's short experiments, however, the diapause of the parasite was demonstrated to be facultative as long as the egg of *L. striatellus* is given as host. This seems to be also supported by the evidence that parasitized eggs, though small in number, were still obtainable even in early November (Fig. 4). Two possibilities for hibernation are then considered: hibernation in the adult form and the other by means of parasitizing upon delphacid species which hibernate under the diapause at the egg stage. According to KISIMOTO (personal communication), the following delphacids are known to overwinter at the egg stage in and around Zentsuji: *Nilaparvata muiri* CHINA on *Leersia japonica* MAKINO, *Saccharosydne procerus* MATSUMURA on *Zizania latifolia* TURCZ., etc.

In autumn, a fair number of *Oligosita* sp. were obtained on the bare ground (Fig. 4). Since the species was scarcely recorded from rice crops (cf. Fig. 3), however, it is regarded as a mere facultative resident in the paddy field.

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