Species Composition and Seasonal Occurrence of *Orius* spp. (Heteroptera: Anthocoridae), Predacious Natural Enemies of *Thrips palmi* (Thysanoptera: Thripidae), in Eggplant Fields and Surrounding Habitats

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We investigated the species composition of *Orius* spp., predacious natural enemies of *Thrips palmi* KARNY in eggplant fields and surrounding vegetation. At Chikushino, *O. sauteri* (POPPIUS) was dominant on eggplant, followed by *O. minutus* (LINNAEUS) and *O. nagaii* YASUNAGA. *O. sauteri* also dominated the sample on white clover, while the other two species occurred with an extremely low frequency. In contrast, on Gramineae plants such as rice, forage crops and weeds, *O. nagaii* was exclusively dominant, while the other two species were rarely found. These results suggest that the habitats surrounding an agro-ecosystem serve as reservoirs for *Orius* spp. occurring in eggplant fields. The species composition on eggplant varied with sampling date and locality. In the three IPM fields where selective chemicals were applied, the first peak of abundance on leaves was found in early and mid-July, indicating that *Orius* spp. adults begin to immigrate into eggplant fields from early June. From results of direct count on leaves and sticky trap data, *Orius* spp. colonization and subsequent reproduction appeared to be influenced greatly by prey population size.

Key words: *Orius* spp., natural enemy, species composition, reservoir, Integrated Pest Management

INTRODUCTION

The anthocorid bugs, *Orius* spp., have been regarded as promising biological agents in integrated pest management programs (e.g. ISENHOUR and YEARGAN, 1981 a; NAGAI, 1990; ALAUZET et al., 1994; KAWAI, 1995). NAGAI (1991 a) has proved that *Thrips palmi* KARNY, a serious pest of eggplant, can be effectively controlled under an IPM program with a combination of selective chemicals and naturally occurring *Orius* sp. Using this program, complete success has been obtained even in large market gardens (ca. 700 to 1,000 m²) of summer-autumn eggplant (OHNO et al., 1995; TAKEMOTO and OHNO, 1996).

A diversified agro-ecosystem provides *Orius* spp. with different kinds of habitats such as soybean (OKU and KOBAYASHI, 1966), alfalfa (GOODARZY and DAVIS, 1958), and corn (DICKE and JARVIS, 1962). As far as we know, there have been only a few reports on species composition in agricultural fields or specific habitats (e.g., YASUNAGA and KASHIO, 1993), although much literature has dealt with these bugs. Generally, summer-autumn eggplant is grown in open fields following rice cultivation, because of a practical rotation to avoid soil-borne disease. Consequently, the eggplant fields are surrounded by paddy rice and weeds such as white clover and grasses. *Orius* spp. populations colonize the eggplant field following the colonization of innocuous or nonpest Thysanoptera species after transplanting (NAGAI,

1990; OHNO et al., 1995). However, the habitats from which *Orius* spp. migrate into eggplant fields have not been determined as yet. Four species of *Orius*, including *O. sauteri* (POPPIUS), *O. minutus* (LINNAEUS), *O. nagaii* YASUNAGA, and *O. similis* ZHENG, have been typically found in agroecosystems (YASUNAGA, 1993; YASUNAGA and KASHIO, 1993).

In this study, we investigated the species composition of *Orius* spp. in summer-autumn eggplant fields and surrounding habitats such as paddy rice, Gramineae plants (weeds and forage crop), and white clover. In addition, species composition was investigated in relation to the seasonal occurrence of *Orius* spp. in eggplant fields where selective chemicals are mainly applied under the IPM program (OHNO et al., 1995; TAKEMOTO and OHNO, 1996).

MATERIALS AND METHODS

Species composition in different habitats. *Orius* spp. adults were collected from eggplant fields and surrounding habitats at Fukuoka Agricultural Research Center (FARC) and at home gardens in Chikushino, Fukuoka Prefecture from spring to autumn (1993–1995). All sites were located within a radius of ca. 2 km. Specimens were taken directly from the leaves and fruits of eggplant or from paddy rice and other Gramineae plants by sweeping plants with an insect net (dia. 40 cm). For white clover, specimens were obtained from several hundred flowers brought into the laboratory from the field. In the eggplant and paddy fields, selective chemicals and a few nonselective chemicals were applied. Consequently, the effect of chemicals on the abundance of *Orius* spp. was considered to be minimized.

Changes in the species composition and seasonal occurrence of Orius spp. in eggplant fields. To examine the seasonal changes in the density and species composition of *Orius* spp., three eggplant fields were chosen in Fukuoka Prefecture (TAKEMOTO and OHNO, 1996). At FARC, one experimental field (ca., 2.5 a) was assigned to our eggplant field, around which welsh onion, chrysanthemum and some leaf vegetables were grown. On the other hand, the eggplant field (ca., 10 a) at Maebaru was surrounded by paddy rice fields. Moreover, the eggplant field (ca., 8 a) at Kurogi was located in an agricultural area where paddy rice, corn, and winter-spring eggplants were grown. Naturally occurring white clover was found nearby the eggplant fields. In Maebaru and Kurogi, summer-autumn eggplant is grown primarily for the fresh market. The eggplant fields were made available by the kind cooperation of local growers. In the fields, nursery plants with 4 to 5 leaves were transplanted from early to middle May and only selective chemicals were sprayed to ensure that natural enemies would colonize and reproduce. Contrary to our expectations, in the field at Kurogi broad-spectrum synthetic pesticides were sprayed over eggplants by a grower to control a noctuid moth and aphids. At Chikushino, summer-autumn eggplant was grown in a gothic-type plastic greenhouse of an experimental field (FARC) and only selective chemicals were applied. In the experimental field, summer-autumn eggplant was also grown in a neighboring plastic greenhouse by FARC horticulturists. In accordance with the horticulturist's experimental plan, the plants were cut down in mid August. The destruction of the plants appeared to affect sticky trap catches (see Results).

The populations of *Orius* spp. in three summer-autumn eggplant fields were monitored biweekly in 1994 by counting the number of *Orius* spp. adults and nymphs on 40 to 50 newly expanded leaves in each field. The leaves were chosen by randomly selecting 1 to 2 leaves from the top one-third of each plant. In addition, 5 blue sticky traps (10 × 19 cm) (IT-sheet®, Sankei Kagaku Co., Japan) were evenly placed at least ca. 3 m apart from the perimeter of the eggplant field. Traps were set in a vertical position just below the tops of

the plants and adjusted upward as the plant grew. Specimens collected by the sticky traps were removed with a fine hair brush after soaking the traps in a xylene solution.

Identification of specimens. Specimens collected from the plants and sticky traps were kept in a 75% alcohol solution and a xylene solution, respectively, until identification could be made. Male specimens were identified, based on the morphological character of the genitalia (YASUNAGA, 1993). Hence, species composition was obtained from male adult specimens, since we could not identify female specimens to species. Although the specimens could be collected from May to October in the eggplant fields, sufficient numbers of male specimens were only obtained from July to September because of the small sample size and a female biased sex ratio (see Results). Consequently, species composition in the eggplant fields at different localities was comparable over a period of 2 to 3 months.

RESULTS

Species composition in eggplant fields and surrounding vegetation

A total of 1,543 *Orius* spp. adults were collected and the sex ratio (a proportion of male adults) of the samples varied from 0.196 to 0.896 (Tables 1 to 3). Out of 31 total samples, 15 showed female biased sex ratios that made an analysis of species composition more difficult because there were few male specimens. The overall sex ratio was 0.448.

In the present study, a total of three species were collected from the flowers of white clover (Table 1). Among these, *O. sauteri* dominated, while *O. nagaii* occurred with a lower frequency. On the other hand, *O. minutus* was found in only one sample. Although samples were collected from different kinds of agricultural or nonagricultural fields, there were no obvious differences in the *Orius* species composition on white clover.

As shown in Table 2, *O. nagaii* was dominant in the samples collected from rice in paddy fields, followed by *O. sauteri*. *O. minutus* was not recorded. Similar tendencies in species composition were also obtained from Gramineae weeds and Guinea grass.

Among the specimens collected from eggplant, *O. sauteri* was dominant, followed by *O. minutus* and *O. nagaii* (Table 3). Although both *O. sauteri* and *O. minutus* were obtained from most of the samples, *O. nagaii* was found in only 6 out of 13 samples. Moreover, *O. nagaii* was rarely found in the samples collected in August and later in the season. Again, there were no obvious differences in the composition of *Orius* species composition, although eggplant fields

Table 1. Species composition of *Orius* spp. on white clovers at Chikushino

Date	% of individuals			No. of males	Sex ratio (% of males)	Surroundings
	<i>O. sauteri</i>	<i>O. minutus</i>	<i>O. nagaii</i>			
1994 June 29	91.9	0	8.1	34	0.500	Strawberry
July 4	92.9	7.1	0	14	0.583	Vegetable crops
1995 June 9	72.7	0	27.3	22	0.545	Paddy fields
June 16	89.5	0	10.5	19	0.373	Vegetable crops
June 16	100.0	0	0	10	0.259	Strawberry
June 29	100.0	0	0	15	0.357	Paddy fields
July 5	91.1	0	8.9	56	0.514	Vegetable crops
July 7	87.5	0	12.5	32	0.500	Athletic ground
July 13	100.0	0	0	23	0.451	Athletic ground
July 13	100.0	0	0	19	0.302	Paddy fields

Table 2. Species composition of *Orius* spp. on paddy rice and Gramineae plants at Chikushino

Date		% of individuals			No. of males	Sex ratio (% of males)	Surroundings
		<i>O. sauteri</i>	<i>O. minutus</i>	<i>O. nagaii</i>			
On paddy rice							
1993	July 12	0	0	100.0	23	0.622	Paddy fields
	July 28	12.5	0	87.5	8	0.500	„
	Aug. 7	0	0	100.0	20	0.583	„
1994	June 3	0	0	100.0	16	0.327	„
	July 19	24.0	0	76.0	25	0.500	„
On gramineae weeds							
1993	July 16	0	0	100.0	30	0.896	„
	July 13	0	0	100.0	37	0.411	„
On Guinea grass							
1993	May 25	7.7	0	92.3	13	—	„
	July 15	0	0	100.0	37	0.561	„

Table 3. Species composition of *Orius* spp. on eggplants at Chikushino

Date	% of individuals			No. of males	Sex ratio (% of males)	Surroundings
	<i>O. sauteri</i>	<i>O. minutus</i>	<i>O. nagaii</i>			
1993 July 23	50.0	25.0	25.0	8	0.258	Paddy fields
Aug. 19	76.0	24.0	0	25	0.524	„
1994 June 20	80.0	0	20.0	5	0.462	„
July 4	78.9	5.3	15.8	19	0.247	Vegetable crops
July 5	67.7	25.8	6.5	32	0.457	Paddy fields
July 7	80.0	0	20.0	10	0.196	Vegetable crops
July 15	64.7	35.3	0	16	0.654	„
July 22	91.7	8.3	0	32	0.500	„
Aug. 22	80.0	20.0	0	10	0.208	Paddy fields
Sep. 4	70.4	25.9	3.7	27	0.529	„
Sep. 5	44.0	56.0	0	25	0.529	„
Sep. 14	87.5	12.5	0	24	0.444	„
Oct. 3	61.1	38.9	0	18	0.429	„

were located nearby rice paddies and other vegetable crop fields.

Species composition in eggplant fields in relation to the seasonal occurrence

In the FARC experimental field at Chikushino, the density of *Orius* spp. per leaf increased rapidly and reached a peak in early July (Fig. 1). During the survey, most of the individuals in the direct count on leaves were nymphs. A similar tendency was obtained in two other IPM fields at Kurogi and Maebaru. The density dropped to a mean of <0.2 per leaf in mid July. From early September, no individuals were found on the leaves. The maximum number of adult *Orius* spp. caught by blue sticky traps was seen in mid July, followed by a 2nd peak in mid August. Despite the 2nd peak of *Orius* spp. adults caught by sticky traps, there was no distinct peak in the direct counts of *Orius* spp. on eggplant leaves. This discrepancy between the densities was attributed to the massive immigration of *Orius*

Fig. 1. Seasonal occurrence (above) and species composition (below) of *Orius* spp. in the eggplant field at Chikushino. Solid and broken lines show the number of individuals of *Orius* spp. per leaf and per trap/day, respectively. Vertical lines show the standard error of the mean.

spp. adults resulting from the destruction of eggplants in a neighboring plastic greenhouse. In terms of species composition, *O. sauteri* dominated all of the samples. Although the frequency of *O. minutus* was low, it was also found in all of the samples. In contrast, *O. nagaii* was only obtained from the sample in mid July.

At Kurogi, the density of *Orius* spp. per leaf reached a peak in July (Fig. 2). After the 1st peak of abundance, nonselective chemicals were sprayed because of the increased density of noctuid moths and aphids. Consequently, the populations of *Orius* spp. fluctuated with two peaks. A similar tendency was found with a time lag for the sticky traps. A maximum number of *Orius* spp. adults was captured with sticky traps in mid July, with another well defined peak in middle August. Throughout the eggplant growing season, *O. sauteri* was predominant in the sample, while *O. minutus* and *O. nagaii* occurred in low frequencies. Although *O. minutus* was found in extremely low frequencies in most of the samples, it was present in all samples. *O. nagaii*, however, was found only in mid July and early August samples.

At Maebaru, the peak abundance of *Orius* spp. per leaf was found in mid July and then the density decreased in late July. The number of *Orius* spp. adults on sticky traps remained high from early to late July without a significant peak of abundance and declined slowly thereafter (Fig. 3). In species composition, *O. sauteri* dominated the sample from early July to early August, but remained in low frequency, compared to that at Chikushino and Kurogi. *O. minutus* occurred with a lower frequency than did *O. sauteri*. On the other hand, *O. nagaii* became dominant in September, although it was rarely found in early August.

Fig. 2. Seasonal occurrence (above) and species composition (below) of *Orius* spp. in the eggplant field at Kurogi. See legend to Fig. 1 for explanation.

Fig. 3. Seasonal occurrence (above) and species composition (below) of *Orius* spp. in the eggplant field at Maebaru. See legend to Fig. 1 for explanation.

DISCUSSION

Among four species collected from agricultural fields in Japan (YASUNAGA and KASHIO, 1993), we recorded 3 species, i.e., *O. sauteri*, *O. minutus*, and *O. nagaii*, in this study. Only two specimens of *O. similis* were collected from an eggplant field at Maebaru in our preliminary

survey (OHNO and TAKEMOTO, unpublished data). Judging from the species composition of *Orius* spp. in eggplant fields, it appears that *O. sauteri* plays a key role in controlling *Thrips palmi* in an IPM program.

Some *Orius* species are known to show prey preference (NAGAI, 1991 b), and have different prey suitability (BUSH et al., 1993), and searching strategies (ISENHOUR and YEARGAN, 1981 b). Moreover, for *O. tristicolor*, the colonization pattern appears to be affected by the attractiveness of the mixed-crop habitat (LETOURNEAU and ALTIERI, 1983). The cues or factors causing *Orius* spp. to choose a habitat remain uncertain. On eggplant, *O. sauteri* was dominant in most of the samples and consisted of three *Orius* species; the relative frequency of *O. sauteri* varied with sampling date and locality. In contrast, *O. sauteri* and *O. nagaii* were clearly dominant on white clover and rice plant, respectively. From the viewpoint of prey selection, it is interesting to refer to thrips species composition in each habitat. On paddy rice plants, *Anaphothrips obscurus* (MULLER) and *Stenchaetothrips biformis* (BAGNALL) are dominant (UMEYA et al., 1988). On white clover, *Frankliniella intonsa* (TRYBOM) is clearly dominant (MURAI, 1988). On the other hand, at least 8 thrips species are observed on eggplant, although the relative frequency of each thrips species varies with the year, season, and locality (TAKEMOTO and OHNO, 1996). Among these species *A. obscurus* is less abundant in eggplant fields, while *F. intonsa*, *T. palmi*, *Mycterothrips glycines*, and *T. tabaci* are dominant (TAKEMOTO and OHNO, 1996, unpublished data). Such differences in thrips species composition appear to explain why *Orius* species composition is so stable on both paddy rice plants and white clover, and why congeneric species coexisting varying frequencies on eggplant. Further study is needed to clarify the relationships between the *Orius* species and thrips communities.

In light of the effective control of *T. palmi* in eggplant fields, the indigenous thrips community has an important role in eggplant fields during the early growing season (OHNO et al., 1995; TAKEMOTO and OHNO, 1996). After colonization of these indigenous thrips, *Orius* spp. populations will migrate into the fields and colonize, so that by the time *T. palmi* migrates into the eggplant fields from greenhouses of winter-spring eggplant, the predator density will be sufficiently high to suppress the *T. palmi* population. However, if broad spectrum chemicals are applied to control other pests, indigenous thrips can not colonize eggplant fields prior to the colonization of *Orius* spp. (OHNO et al., 1995). Consequently, delayed colonization of *Orius* spp. may lead to the failure of IPM programs. Similarly, early immigration into habitats without sufficient prey populations could also lead to the rapid extinction or emigration of the predator population (LETOURNEAU and ALTIERI, 1983).

The peak abundance of direct counts (most individuals were nymphs) followed by a peak abundance of sticky traps (adults) indicates that *Orius* spp. adults began to colonize eggplant fields from early June and the subsequent generation occurred with a peak abundance in July, as found in our previous study (OHNO et al., 1995). Moreover, sticky trap data show a second peak of abundance in eggplant fields at Chikushino and Kurogi. At Chikushino, the second peak was not preceded by that of direct counts. Hence, the second peak is attributable to immigration from the neighboring eggplant field where eggplants were cut down, although most of the *Orius* spp. adults appear to emigrate soon from the eggplant greenhouse without reproducing. In contrast, the second peak in abundance of sticky traps was preceded by that of direct counts at Kurogi. The differences in prey population size may account for this discrepancy between Chikushino and Kurogi. The *T. palmi* population reached peak abundance during the period at Kurogi, while thrips densities were extremely low at Chikushino (TAKEMOTO and OHNO, 1996). These results indicate

that the colonization rate of *Orius* spp. adults is not associated with the population size of thrips species but subsequent reproduction of *Orius* spp. is greatly influenced by the population size of thrips species.

From the perspective of IPM in summer-autumn eggplant fields, it is worth focusing on the role of paddy fields and white clover. Summer-autumn eggplants are grown in open fields following the paddy rice harvest of the preceding year. Hence, eggplant fields are located nearby paddy fields, along which white clover grows as weeds. Therefore, it is expected that paddy fields and their surroundings serve as reservoirs that harbor *Orius* spp. populations which migrate into eggplant fields. However, if chemicals are applied in paddy fields, *Orius* species occurring on rice plants and white clover could be affected.

In conclusion, it is necessary to consider the role of the agro-ecosystem and thus, carefully plan control strategies involving selective chemicals to ensure the colonization and reproduction of innocuous or nonpest prey populations in eggplant, paddy fields, and surrounding habitats to serve as reservoirs for *Orius* spp.

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