FIELD AUGMENTATION OF *ORIUS STRIGICOLLIS* (HETEROPTERA: ANTHOCORIDAE) FOR THE CONTROL OF THRIPS IN TAIWAN

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ABSTRACT

Among natural enemies of thrips in Taiwan, the flower bug Orius strigicollis (Poppius) is the most promising biocontrol agent. Large numbers of O. strigicollis can be mass produced in the laboratory, under a constant temperature and photoperiod. They also need to be supplied with bean (Glycine max) sprouts as plant food and as an ovipositional substrate, and with eggs of flour moth (Ephestia cautella Walker) as prey. Field-release tests were conducted on eggplant and adzuki bean grown in open fields in central and southern Taiwan in 1998 and 1999, to evaluate the effect of O. strigicollis as a biological control agent. In the areas where it was released, densities of thrips gradually declined. The number of thrips in the chemical control areas dropped immediately after the application of insecticides, but increased rapidly afterwards. Significant differences between biocontrol areas and chemical control areas appeared 4-6 weeks after the first release. The effect of biocontrol lasted for several weeks. Orius strigicollis released at the proper stage has proven to be a strong natural enemy for the control of thrips on certain crops in open fields.

THRIPS AND THEIR NATURAL ENEMIES

More than ten species of thrips are commonly found on agricultural and horticultural crops in Taiwan (Chang 1991). Thrips usually exist on leaves, new buds, flowers, and young fruits. Their feeding and ovipositing activities directly damage plants. Depending on the species of thrips and their host plants, various degrees of distortion, deformation and defoliation will appear. Injury caused by thrips reduces the growth rate, as well as the quality and quantity of the yield. Moreover, the existence of thrips causes quarantine problems for exported agricultural products. Indirect injury is caused by *Thrips palmi* Karny and *Scirtothrips dorsalis* Hood, as vectors of virus diseases. These cause serious damage to many crops, including watermelon, tomato, cucumber, melon, green pepper and peanut in Taiwan (Yeh *et al.* 1992, Chen and Chiu 1996).

Chemical insecticides are widely applied for the control of thrips. More than 20 insecticides, including formulations for foliar spraying and soil-applied granules, are currently registered for thrips control (Plant Protection Manual 2000). The number of thrips may temporarily be depressed by the spraying of insecticides. However, their short life cycle and strong reproductive abilities cause population densities to recover rapidly. Short generation times and excessive pesticide treatments also contribute to the rapid development of resistance to insecticides.

Thrips with their tiny bodies can hide in

Keywords: *Orius strigicollis*, thrips, biocontrol, eggplant, adzuki bean

flowers, buds, or under the hairs of stems and leaves. Chemical particles may not reach their hiding places, or may not have sufficient contact to be effective. For this mechanical reason, even insecticides highly toxic to thrips sometimes fail to have a satisfactory control effect. Physical control methods, such as mulching with silver PE sheets, the use of UV reflective greenhouses, and colored sticky traps, have been tested (Chu 1987). However, their control effect is both slow and insignificant. To solve the thrips problem, there is a need for effective biological control methods.

Seven species of predators and one species of parasitic wasp have been recorded as natural enemies of thrips in Taiwan (Table 1) (Chiu 1984, Chang 1990, Chang *et al.* 1993, Wang 1994, Wang 1998). The predators include anthocorid bugs, mirid bugs, cecidomyiid flies, and predacious mites. Two predacious thrips and two species of green lacewings are common in Taiwan, and are thought to be possible predators of thrips. Among them, *Orius* flower bugs are an obvious control species. They are already being used in biological control programs (Funderburk *et al.* 2000, Frescata and Mexia 1996, Coll and Ridgeway 1995, Chambers *et al.* 1993, van de Veire and Degheele 1992). In Taiwan, the indigenous *Orius strigicollis,* with its high search ability and high prey consumption (Wang 1994), is being studied as a promising biocontrol agent for thrips.

MASS REARING OF *ORIUS STRIGICOLLIS*

Orius strigicollis (Poppius) and *O. tantillus* (Motschulsky) are found on a range of horticultural crops in Taiwan (Wang 1998). The two species may exist separately, or may occur together on the same plant. Nymphs and adults of both species live and actively search for prey on leaf buds and flowers. *O. strigicollis* is a more aggressive predator than *O. tantillus.* It has a stronger search ability, and reacts more quickly if there is prey nearby. For the purpose of biological control, most effort is being devoted to the study of *O. strigicollis.* Both nymphs and adults of *O. strigicollis* eat large numbers of spider mites (*Tetranychus kanzawai* Kishida) and thrips (*Thrips palmi* Karny) if these are available. A single *O. strigicollis* usually eats more than 200 thrips, or 500-600 spider mites, during its lifetime (including immature and mature stages, and assuming a stable temperature of 25°C) (Table 2 and Table 3) (Wang 1994).

Laboratory-scale mass rearing tests have been carried out since 1997 to establish proper rearing requirements. Bean seedlings (variety "Chin-pe Tou", *Glycine max* L.) are suitable host plants for the laboratory rearing of *O. strigicollis.* The nymphs of *O. strigicollis* on bean seedlings grew faster and survived better than those raised on the leaves of eggplant or snapbean (*Phaseolus vulgaris* L.) or on

Table 1. Natural enemies of thrips in Taiwan

Natural enemy	Order: Family	Role
Recorded species		
Orius strigicollis (Poppius)[5]	Heteroptera: Anthocoridae	Predator
Orius tantillus (Motschulsky)[5]	Heteroptera: Anthocoridae	Predator
Campylomma chinensis Schuh[4]	Heteroptera: Miridae	Predator
Geocoris ochropterus Fabr.[3]	Heteroptera: Lygaeidae	Predator
Anthrocnodax occidentalis Eelt.[3]	Diptera: Cecidomyiidae	Predator
Amblyseius longispinosus (Evans)[3]	Acari: Physeiidae	Predator
Paraphytoseius multidentatus Swirski & Schechter[3]	Acari: Physeiidae	Predator
Ceranisus menes (Walker)[1,2]	Hymenoptera: Eulophidae	Parasitoid
Possible species		
Franklinothrips vespiformis (Crawford)	Thysanoptera: Thripidae	Predator
Scolothrips asura Ramakrishna & Margabandhu	Thysanoptera: Thripidae	Predator
Mallada basalis (Walker)	Homoptera: chrysopidae	Predator
Mallada boninensis (Okamoto)	Homoptera: Chrysopidae	Predator

1. Chiu 1984; 2. Chang 1990; 3. Chang et al. 1993; 4. Wang 1994; 5. Wang 1998.

Table 2. Development time, and total predation capacity, of *Orius strigicollis* nymphs feeding on spider mites and thrips

Prey	Nymph		
	Development (days)	No. of prey consumed	Emergence (%)
Mites	23.0 ± 1.0	126.0 ± 12.2	31.6
Thrips	14.9 ± 0.8	77.9 ± 7.5	65.0

Mites: Nymphs of *Tetranychus kanzawai*. Thrips: Larvae of *Thrips palmi*.
Source: Wang 1994

Table 3. Longevity, and daily predation rate, of *Orius strigicollis* adults feeding on spider mites and thrips

	Adult			
	Female		Male	
Prey	Longevity (day)	No. of prey consumed/day	Longevity (day)	No. of prey consumed/day
Mites	33.5 ± 2.5	11.4 ± 4.2	37.5 ± 0.6	13.5 ± 5.3
Thrips	36.2 ± 3.2	6.3 ± 2.5	25.0 ± 4.1	6.4 ± 2.7

Mites: Nymphs of *Tetranychus kanzawai*. Thrips: Larvae of *Thrips palmi*.
Source: Wang 1994

snapbean pods (Wang *et al.* 1999). Adults lived longer and laid a greater number of eggs. Eggs of fresh *Ephestia cautella* Walker were the best prey, in terms of the growth and reproductive rate of *Orius* flower bugs (Wang *et al.* 1999).

A temperature of 25 - 30°C was the most suitable for the mass rearing of *O. strigicollis.* At only 20°C, both egg incubation and nymph development were retarded. Nymphal stages survived with difficulty at this temperature, while only 37% of nymphs successfully emerged as adults (Table 4). A comparison of populations kept at 25°C with those kept at 30°C found no significant difference in longevity or fecundity of adult females, but the average number of eggs laid per female was about 30% higher at 25°C. Taking into account the best conditions from the viewpoint of both efficient production and the natural ambient temperature, we set the temperature at 27±1°C for *Orius* mass rearing.

The photoperiod is another factor influencing egg incubation, nymph development and adult fecundity. Sufficient light is necessary for the proper growth and reproduction of *O. strigicollis.* A photoperiod of 24 hours a day (24L:0D) is unnatural, but is efficient for the rearing of *O. strigicollis.* Compared with other photoperiods tested, nymphs kept in light for 24 hours each day grew stronger and faster, while more than 90% of nymphs emerged as adults within 13 days (Table 5). Adult females lived and oviposited for a longer time, with a shorter previpositional period. The same female might not oviposite continuously every day, but each day an average of 90% of females laid eggs. Hence, a greater number of eggs could accumulate during the entire ovipositional period. A shorter photoperiod slowed down the development of immature *Orius*, while more adult females laid no eggs.

With these improvements in mass rearing techniques for *Orius* flower bugs, large numbers can now be produced in the laboratory. This allows us to study the effect of mass releases of *O. strigicollis* as a biological control agent under field conditions.

Table 4. Effect of temperature on growth and oviposition of *Orius strigicollis*

Temp.	Egg			Nymph			Adult female		
	n	Duration (day)	Hatching (%)	n	Duration (day)	Emergence (%)	n	Longevity (day)	Total eggs/ female
20°C	30	9.3 ± 1.4b	90	27	34.4 ± 0.6b	37	—		
25°C	30	4.9 ± 0.5a	86	24	14.2 ± 0.8a	92	10	27.3 ± 9.1a	54.7 ± 42.3a
30°C	30	4.5 ± 0.5a	93	25	12.4 ± 1.4a	89	10	24.7 ± 9.3a	42.0 ± 47.6a

1. Photoperiod: 14L:10D.
2. Food: *Tetranychus kazawai* and bean seedlings.
3. Data of durations of egg and nymph stages in a column with the same letter are not significantly different by Kruskal-Wallis ANOVA test followed by multiple comparisons ($p<0.05$). Data of adult longevity and total no. of eggs laid were compared by t-test. ($\partial = 0.05$)

Table 5. Effect of photoperiod on growth and oviposition of *Orius strigicollis*

Photo-period L:D	Egg			Nymph			Adult female		
	n	Duration (day)	Hatching (%)	n	Duration (day)	Emergence (%)	n	Longevity (day)	Total eggs/ female
10:14	30	4.5 ± 1.7b	56	17	16.9 ± 1.7b	56.6	7	27.4 ± 6.5a	37.1 ± 52.2a
13:11	30	3.6 ± 0.6a	90	27	12.6 ± 0.9a	88.8	10	25.6 ± 5.6a	50.9 ± 41.2ab
16:8	30	3.2 ± 0.4a	70	21	12.3 ± 1.3a	80.8	10	26.0 ± 9.3a	60.6 ± 27.7b
24:0	30	3.1 ± 0.7a	90	27	12.2 ± 1.7a	90.0	10	36.0 ± 6.6b	82.3 ± 33.6c

1. Temperature: 25°C.
2. Food: *Tetranychus kazawai* and bean seedlings.
3. Data in a column with the same letter are not significantly different by Kruskal-Wallis ANOVA test followed by multiple comparisons ($p \leq 0.05$)

FIELD AUGMENTATION OF *ORIUS STRIGICOLLIS* FOR THE CONTROL OF THRIPS

Summer crop of eggplant

The first field experiment was conducted with eggplant (*Solanum melongena* L.) grown over the summer in an open field in central Taiwan. *Orius* were introduced when the plants were about 1 m high. Each plant was pruned to leave three basal branches, with a total of at least 100 leaves. The biological area occupied 0.1 ha., while 0.4 ha was used for chemical control, and was located next to the biocontrol area. There were three buffer rows of eggplant between the two experimental areas. One hundred to 150 *Orius* nymphs, each 2-3 days old, were released per plant every week for a period of six weeks. In the chemical control area, insecticides such as carbosulfan, carbofuran, and dimethoate were applied. The timing and frequency of insecticide applications were decided by the farmer, according to his experience. Every week, 20 leaves were picked randomly from each experimental area, and the number of pest insects and *O. strigicollis* were counted.

In the biocontrol area, the number of thrips (*Thrips palmi* Karny) decreased gradually from 50/ leaf to 3/leaf within five weeks. The curve had declined to near zero by the end of the experiment (Fig. 1). In the chemical control area, the number of thrips fell after the plants were sprayed with insecticide, but climbed back shortly afterwards. Chemicals had to be used repeatedly to depress the population of thrips. After the fourth week, the number of thrips in the chemical control area was always higher than in the biocontrol area.

O. strigicollis also gave good control of whitefly. In areas given chemical control, the number of whitefly (*Trialeurodes vaporariorum* (Westwood)) increased to peak in the sixth week.

In contrast, the number of whitefly in the biocontrol area gradually declined to a very low level (Fig. 1).

Both *O. strigicollis* and *Campylomma chinensis* are common predators in eggplant fields in Taiwan. A survey made in a eggplant field where insecticides were not used showed that the natural densities of *O. strigicollis* were much lower than those of *C. chinensis* (Wang 1993). The effect of the releases is shown by the curves in Fig. 2. The number of *O. strigicollis* significantly increased after the first three releases, reaching a peak of 0.6 *O. strigicollis* per leaf. Population densities fell significantly after the releases were halted at the sixth week.

Winter crop of eggplant

The second field experiment was conducted with eggplant grown in central Taiwan over the winter. When the experiment was begun, the young plants were about 30 cm high, and each plant had approximately 15 - 20 leaves. There were five rows in the biocontrol area, each row with 50 plants. The chemical control area had 25 similar rows. These two areas were located side by side, separated by three buffer rows.

Orius nymphs two or three days old were released every week for eight weeks. Twenty *O. strigicollis* per plant were released in the first three weeks. The number increased to 40 nymphs/plant over the next three weeks, and to 80 nymphs/plant in the final two weeks. In the chemical control area, insecticides such as imidacloprid, selecron and mipcide were applied by the farmer. Every week, 20 leaves were picked randomly from each experimental area, and the numbers of pest insects and the *O. strigicollis* were counted.

In the first six weeks, the number of thrips in both areas fluctuated, but showed an overall increase. The highest peak, at 370 thrips/leaf, was found in the chemical control area (Fig. 3). The numbers of thrips in both areas then declined, probably because of the cold weather. However, numbers were lower in the biocontrol area than in the chemical control area after the fourth week (except in the 10th week).

Populations of aphids (*Myzus persicae* Schulzer) were not satisfactorily controlled by the release of *O. strigicollis*. They were always higher in the biocontrol area than in the chemical control area (Fig. 4). *O. strigicollis* did, however, control whitefly. The number of whitefly in the biocontrol area rose in the first two weeks, and then fell in both areas to a low level.

In this experiment, populations of *O. strigicollis* started at a low density. These numbers rose continuously with the artificial releases (Fig. 5), with a peak in the fifth week. The increase in *Orius* flower bugs matches a decrease in thrips and other insects in the same area. The number of *Orius* dropped when the releases stopped in the ninth week.

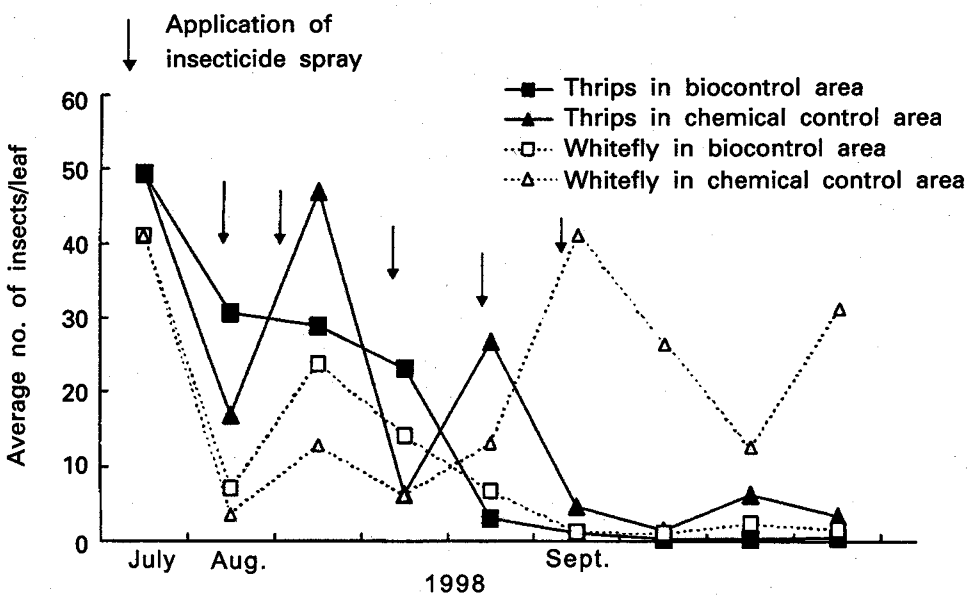

Fig. 1. Numbers of thrips and whitefly in an experimental eggplant field in Taiwan.

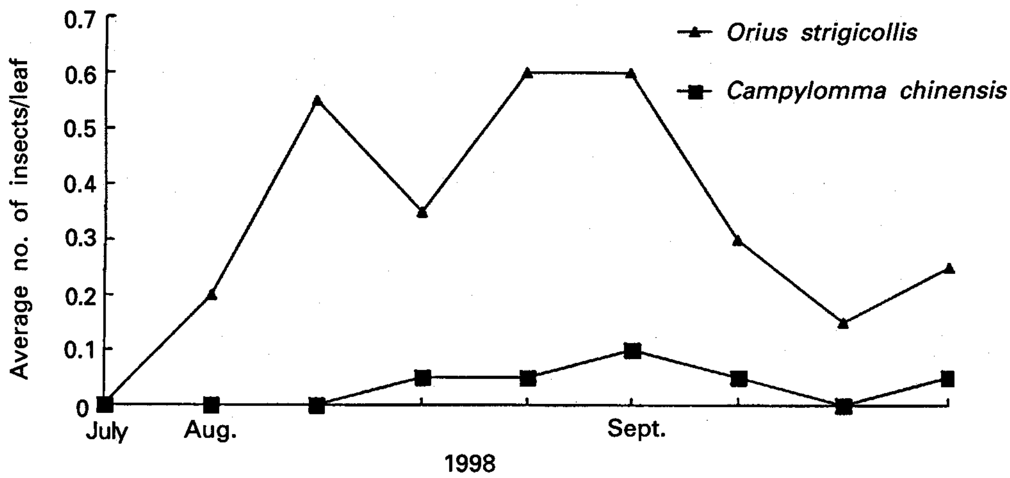

Fig. 2. Numbers of *Orius strigicollis* and *Campylomma chinensis* in the biocontrol area of an experimental eggplant field in Taiwan.

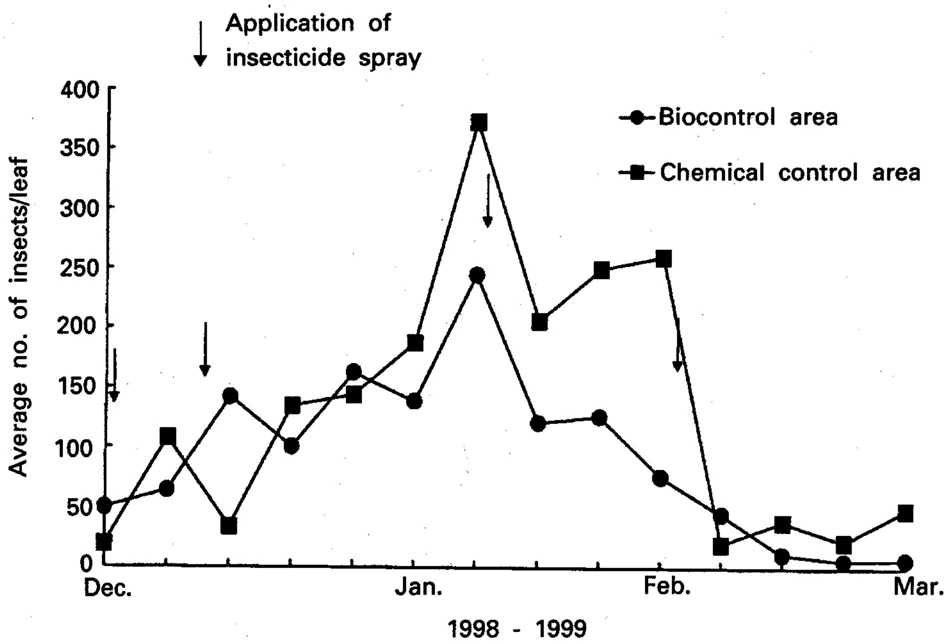

Fig. 3. Numbers of thrips in an experimental eggplant field in Taiwan.

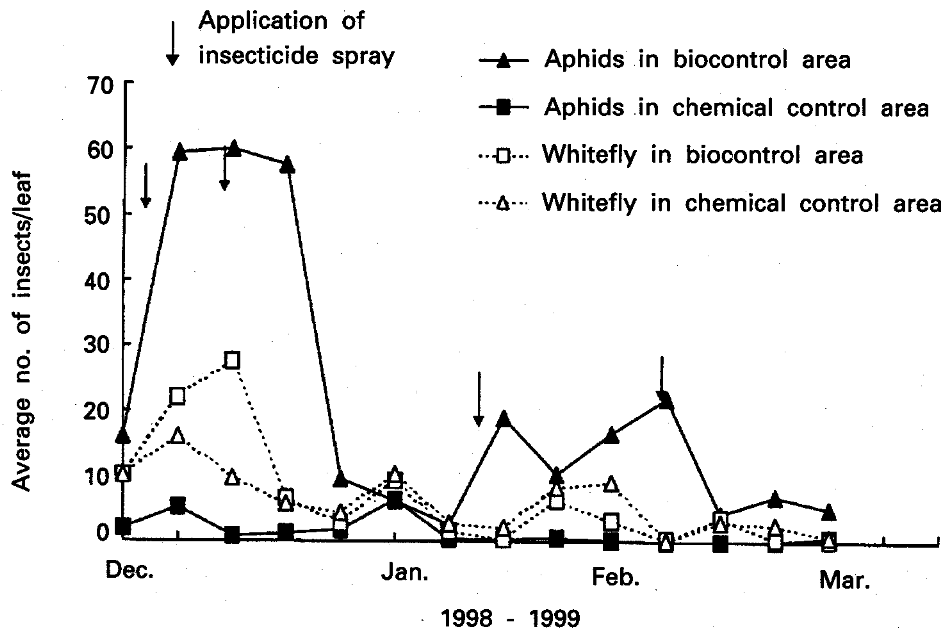

Fig. 4. Number of aphids and whitefly in an experimental eggplant field in Taiwan.

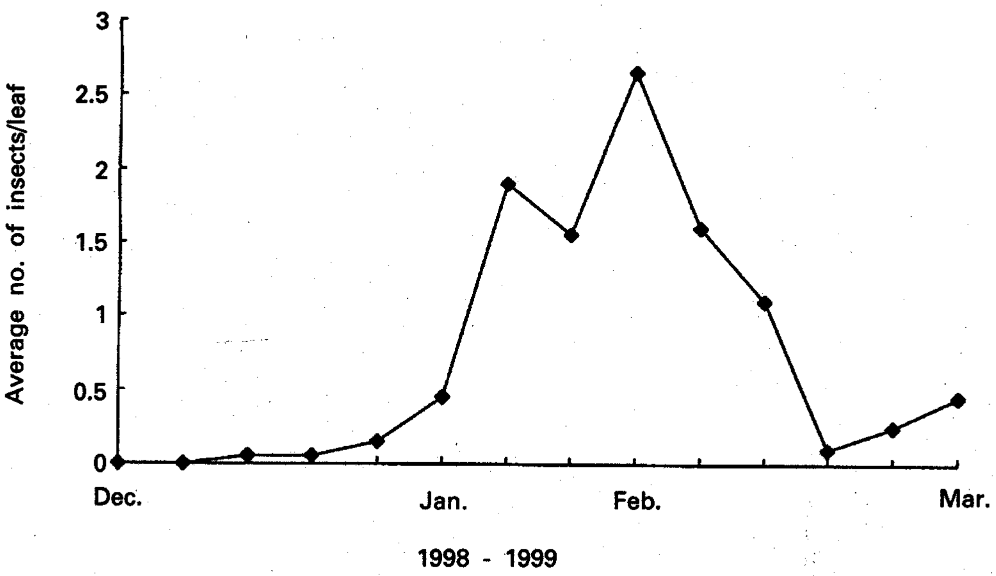

Fig. 5. Number of *Orius strigicollis* in the biocontrol area of an experimental eggplant field in Taiwan.

Adzuki bean

The third field experiment was conducted in a field of adzuki bean (*Vigna angularis*) in Southern Taiwan. The crop of adzuki bean was planted in the middle of September (early autumn). The experimental field was 0.3 ha, and was divided evenly into three areas, one for biocontrol and two for chemical control. Thousands of young *Orius* nymphs were released in the biocontrol area every week for five weeks. The release times were: before flowering; at initiation of flowering; during flowering; during early pod formation; and at the end of the flowering stage.

For the control of leaf-feeders and pod borers, insecticides were applied twice in the biocontrol area, and six or eight times in the two chemical control areas. During the flowering period, 20 inflorescences were picked randomly every week from each experimental area, and the number of thrips were counted. The yield of adzuki beans from each area was recorded.

Bean thrips (*Megalurothrips usitatus* (Bagnall)) is the most important insect pest of adzuki bean in Taiwan. In the chemical control areas, the density of bean thrips increased rapidly during the flowering stage, and was always higher than in the biocontrol area (Table 6). By the late flowering stage, thrips populations were much higher in both chemical control areas than in the biocontrol area. It is difficult to spray enough insecticide onto flowers growing under leaves. Damage by thrips to the flowers prevented the plants from producing healthy pods.

The frequency of insecticide sprays, and the yields of adzuki beans given chemical control, are typical of bean fields in the area. It should be noted that the yield of adzuki beans from the biocontrol area was 1.2 - 1.7 times higher than those from the chemical control areas.

SOME FACTORS INFLUENCING PEST CONTROL BY *ORIUS STRIGICOLLIS*

Because of Taiwan's relatively warm climate, most crops are grown in the open field, although some high-value crops may be grown under structures to protect them from strong sunshine, strong winds, and heavy rain.

The successful augmentation of natural enemies requires that the released creatures stay and reproduce in the field. *Orius* flower bugs consume a greater number of prey as adults than during immature stages, but adults also tend to disperse from the target field within a short period of time. Hatching of eggs and the survival of newly hatched nymphs may vary in the fluctuating temperatures found in the natural environment. Therefore, we selected 2-3-day old nymphs for release. These nymphs are strong enough to survive in the natural environment, and their populations are more stable than those at the flying stage.

For the augmentation of natural enemies, large numbers of natural enemies must be released repeatedly to achieve a significant control effect. The price of natural enemies, and the cost of releasing them, must be low enough to make this control method economical. Our efficient mass production of *O. strigicollis* makes their cost compatible with that of chemical or other control methods. This greatly improves the possibility that farmers will adopt this control method.

The selection of the right crop is also essential for the efficient use of *O. strigicollis*. Species of

Table 6. Results of biocontrol and chemical control in adzuki bean fields, Kaohsiung, 1999

	Biocontrol	Chemical control	
		I	II
	No. of thrips/inflorescence		
Flowering stage	2.9	1.7	13.2
Flowering and podding stage	18.8	12.8	28.4
End of flowering stage	13.5	46.4	41.7
	No. of insecticide sprays		
	2	6	8
	Yield (kg/ha)		
	262	223	150

Orius do not adapt well to all crops. As well as feeding on prey, *Orius* flower bugs need to take some juice from plants as part of their food. Preferred plants vary, according to the species of *Orius*. *O. strigicollis* favors plants belonging to the families Leguminosae, Cucurbitaceae, and Solanaceae. Utilization of *O. strigicollis* on these crops usually gives better results than on other crops.

FUTURE PROSPECTS

Orius strigicollis is an indigenous species in Taiwan, and well adapted to the local environment. Although natural densities are low, field augmentation has proven to be an effective method of biological control. *Orius* was shown to take a large number of pest insects as prey in fields of eggplant and adzuki bean. The control effect was shown on thrips as well as on other small insects and mites. Futher progress in techniques of mass production and utilization of these flower bugs is expected to improve their utilization in biocontrol programs in Taiwan.

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