BIOLOGICAL CONTROL OF *TETRANYCHUS URTICAE* KOCH (ACARINA: TETRANYCHIDAE) POPULATIONS BY THREE SPECIES OF PHYTOSEIID MITES (ACARINA: PHYTOSEIIDAE)

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Introduction

The two-spotted spider mite *Tetranychus urticae* KOCH is one of the major pests in agricultural crops in the world. Recently predators including phytoseiid mites were considered as effective agents for the biological control of spider mites.

Phytoseiulus persimilis ATHIAS-HENRIOT is regarded as the most vigorous predator of tetranychids on several crops in various countries. *P. persimilis* that originated in Chile was introduced into Japan in 1966 from the Department of Biological Control, University of California (MORI[2]), and was studied by several authors with the view of utilization as a predator (MORI and MORIYAMA[4], MORI and IMABAYASHI[3], MORI and SHINKAJI[5], SHINKAJI and MORI[9]). It has been known that this phytoseiid has no adaptation to weather conditions of winter in high latitudes. Therefore it is thought that the environmental conditions in Hokkaido may affect the efficiency of this predator species. On the other hand, it is also thought that native phytoseiid mites which may be ecological equivalents of *P. persimilis* have influence on the efficiency of the introduced predator.

Thus the experiments of suppression of *T. urticae* populations using three species of predacious mites, *P. persimilis*, *Amblyseius longispinosus* EVANS and *Amblyseius deleoni* MUMA et DENMARK*, were conducted in summer (1975) and autumn (1974) on red clover plants in plastics greenhouses

* This species has long been confused with *A. largoensis* MUMA by many authors in Japan. Recently EHARA[1] examined Florida specimens of *A. deleoni* and *A. largoensis* in comparison with specimens of Japanese "*largoensis*", and he concluded that Japanese "*largoensis*" should be referred to *Amblyseius deleoni* MUMA et DENMARK.

(vinyl-houses). The latter two predator species are native to Japan.

Materials and Methods

The stocks of *P. persimilis* and *A. longispinosus* were reared on *T. urticae* and *A. deleoni* on pollen and *T. urticae* in our insectary by means of the method of McMURTRY and SCRIVEN[7]. The present study deals with 8 predator-prey systems and predator-free system shown in Table 1.

The experiments were carried out in the two seasons; from September 11 to November 2 (autumn), 1974 (systems I, III, VI and IX), and from July 17 to August 27 (summer), 1975 (all systems). Each system consisted of five pots of red clover. Water barriers (water with liquid detergent) surrounding the pots were used to prevent migration and imigration of the predator and prey mites. Adult females of *P. persimilis, A. longispinosus, A. deleoni* and *T. urticae* were released on leaves of each pot plant in densities as shown in Table 1.

During the experiments, the average number of clover leaves per pot was about 150. Random samples of ten leaves per pot were collected at every 7 days intervals. All mites and eggs on the leaf samples were examined under dissective microscope. After that they were replaced in their respective pots to avoid any effects on the prey and predator populations. The leaf damage indices on clover leaves were determined according to MORI and MORIYAMA[4]. During the experimental periods the temperature and

TABLE 1. Initial ratio of predator to prey in the experimental system

System	*P. persimilis* (N*)	*A. longispinosus* (N*)	*A. deleoni* (N*)	*T. urticae* (N*)
I	1 (10)	—	—	10 (100)
II	1 (5)	—	—	20 (100)
III	—	1 (10)	—	10 (100)
IV	—	1 (5)	—	20 (100)
V	—	—	1 (10)	10 (100)
VI	1 (5)	1 (5)	—	20 (100)
VII	1 (5)	—	1 (5)	20 (100)
VIII	—	1 (5)	1 (5)	20 (100)
IX**	—	—	—	(100)

* Number of adult females released
** Control (without predator)

humidity in plastics greenhouses ranged 5°~38°C and 42%~88% RH in summer of 1975, and −4°~34°C and 35%~100% RH in autumn of 1974.

Result and Discussion

Fig. 1 presents the fluctuations of *P. persimilis* and *T. urticae* populations and changes in the mean leaf damage indices (L. D. I.) on predator-released and predator-free clover plants in summer and autumn. On the predator-free plants in summer, *T. urticae* population was increased very sharply with time, also the leaf damage index increased steadily and all host plants were blighted by the 5th week (Fig. 1-A). In the late autumn, however, *T. urticae* population decreased remarkably on the predator-free plants and the L. D. I. curve levelled at about 3.0 and then it gradually declined.

The estimations of predator efficiency were made in comparison with the curves of prey populations and the L. D. I. on predator-free and predator-released plants. As indicated in Fig. 1-A, a minor peak of the prey density was observed at first week, and then its density decreased to a very low level within three weeks under the influence of the predacious

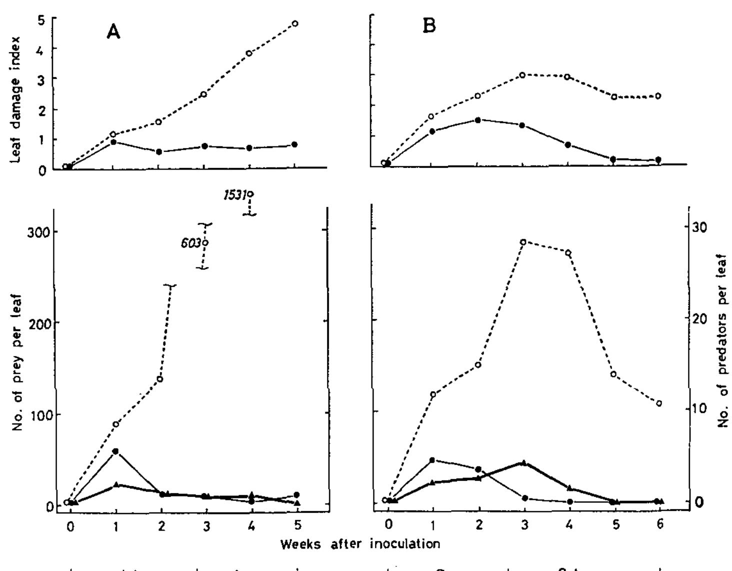

Fig. 1. Population fluctuations of *P. persimilis* and *T. urticae* (system I) and changes in the mean leaf damage indices on predator-released and predator-free plants.

A, summer; B, autumn; ···○···, control (system IX); —●—, *T. urticae*; —▲—, *P. persimilis*.

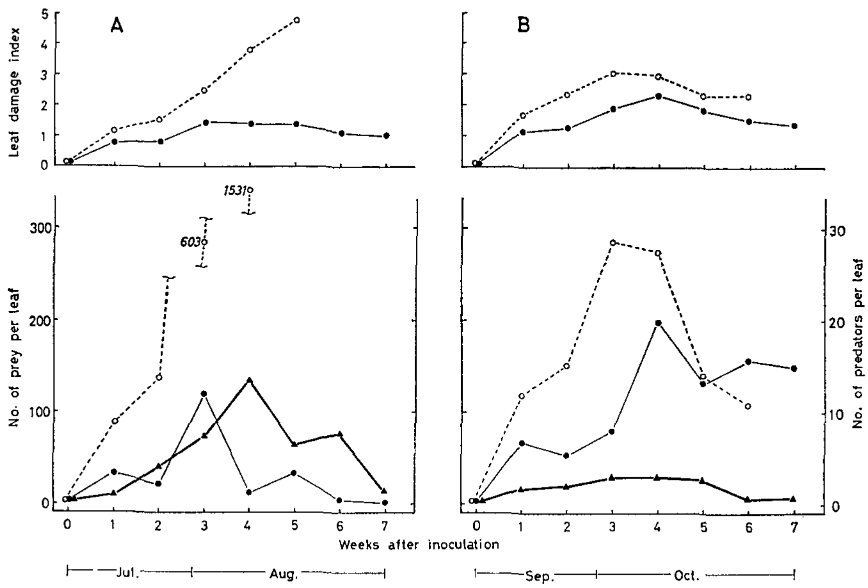

Fig. 2. Population fluctuations of *A. longispinosus* and *T. urticae* (system III) and changes in the mean leaf damage indices on predator-released and predator-free plants.

A, summer; B, autumn; ---o---, control (system IX); —●—, *T. urticae*; —▲—, *A. longispinosus*.

mites. In Fig. 1-B (autumn), the predator density peaked two weeks after the time of the prey peak. This time lag is characteristic of predator-prey system. Prey population decreased to zero at the 4th week, followed by the predator population one week later. By the 3rd or 4th week, predation was so intense that many dead prey were found on the leaves, thereafter no newly killed prey was found and both species approached extinction. During these experiments the L. D. I. on the predator-released plants did not exceed 1.0 and 1.5 in summer and autumn, respectively.

In Fig. 2-A (summer), the numerical response between prey and predator was apparent. Three peaks in the prey population were observed, while the raised populations were elminated by *A. longispinosus*. Both the predator and prey populations decreased to fewer than two mites per leaf by 7th week. The L. D. I. did not exceed 1.5 in summer. There was a seasonal difference in the predator efficiency of *A. longispinosus* between these two seasons. Fig. 2-B shows that *A. longispinosus* appears to be not effective in lowering the prey density in the late autumn. During this time, although the predator still remained in the system, the prey population increased more than that in the predator-free system after the 6th week. This seasonal difference of predator efficiency seems to be due to the fact that *A. longispinosus* was entering diapause during the experimental period in autumn (TAKAHASHI and MORI[10]). The curve of L. D. I. exceeded 2.0 at 4th week, and declined thereafter.

As indicated in Fig. 3, based on prey populations and leaf damage indices there was no evidence that *A. deleoni* suppressed *T. urticae.*

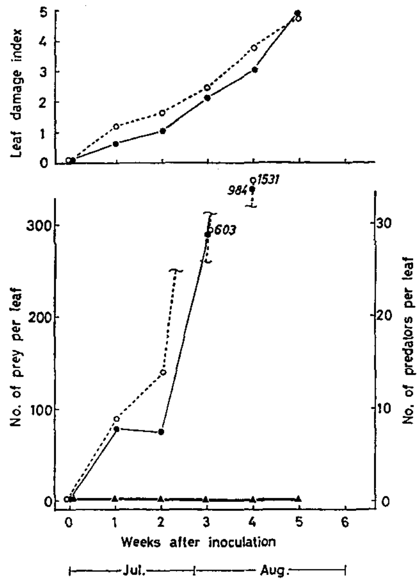

Fig. 3. Population fluctuations of *A. deleoni* and *T. urticae* (system V) and changes in the mean leaf damage indices on predator-released and predator-free plants in summer.

···O···, control (system IX); —●—, *T. urticae*; —▲—, *A. deleoni.*

Fig. 4-A shows that the density of the prey population in summer was suppressed to a very low level by the two predator species, *P. persimilis* and *A. longispinosus* which were introduced simultaneously. It is noted that the density of *P. persimilis* was lower than that of *A. longispinosus* throughout the entire experimental period. Two peaks observed in both of the predator species may correspond to the peaks of prey density respectively, because they lagged behind those of the prey by one week. The damage index did not exceed 1.0. The number of each predator species which was introduced in this system was kept to half as many as the number of predators in the other experiments shown in Figs. 1 and 2 (Table 1). Therefore it is thought to be difficult to compare the result in Fig. 4-A with that in Fig. 1 or Fig. 2. Figs. 7 and 8 show the population changes of prey and predator when one of the two predator species was absent (in this situation, the ratio of predator to prey was 1 to 20). It is suggested from Figs. 4-A, 7 and 8 that the prey population is suppressed more effectively by two predator species which coexist simultaneously than by only a single predator species. Considering the ratio of two predators to prey, i. e. 1 : 10, it is thought from Figs. 1, 2 and 4-A that the coexistence of *A. longispinosus* and *P. persimilis* resulted in the most effective suppression on the two-spotted spider mites in summer.

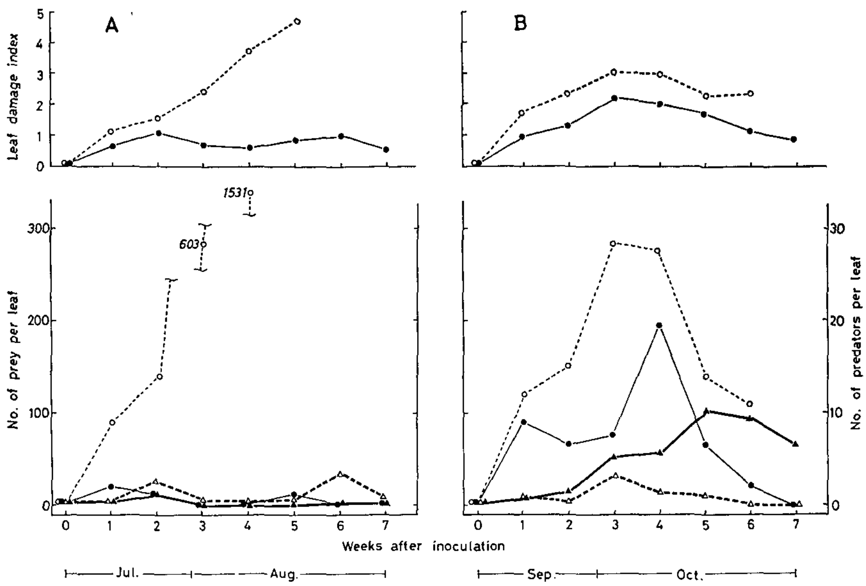

Fig. 4. Population fluctuations of *P. persimilis*, *A. longispinosus* and *T. urticae* (system VI) and changes in the mean leaf damage indices on predator-released and predator-free plants.

A, summer; B, autumn; ····○····, control (system IX); —●—, *T. urticae*; —▲—, *P. persimilis*; ····△····, *A. longispinosus*.

The suppression effect in autumn on the prey population by the two phytoseiid species was relatively lower than that in summer, and it is thought that *P. persimilis* played more effectively than *A. longispinosus* in this season (Fig. 4-B). The host plants recovered from the damage by the prey toward the end of the experiment.

Comparing Fig. 5 with Fig. 7, it is revealed that only *P. persimilis* exerted a remarkable control on *T. urticae* whether *A. deleoni* was present or not, and *A. deleoni* was almost of no effect on *T. urticae* population.

In the case shown in Fig. 6, it seems that *A. longispinosus* was the only control agent on *T. urticae* population, because *A. deleoni* existed at quite low density during the entire experimental period. The evidence that the change of *A. longispinosus* population is apploximately equal to that of the case shown in Fig. 8 may also support this conclusion. It has been pointed out that *A. deleoni* is one of the important predators in citrus orchards of Japan as a natural enemy of *Panonychus citri* (McGregor) (Mori (S)[6], Tanaka and Kashio[11]). This disagreement is probably due to the difference of the prey species and host plants. Saitô[8] stated that each

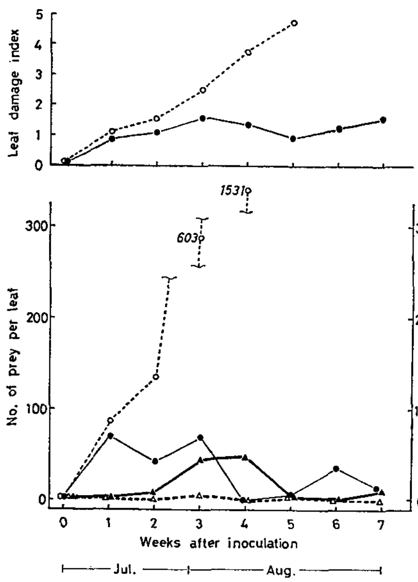

Fig. 5. Population fluctuations of *P. persimilis*, *A. deleoni* and *T. urticae* (system VII) and changes in the mean leaf damage indices on predator-released and predator-free plants in summer.

····○····, control (system IX); —●—, *T. urticae*; —▲—, *P. persimilis*; ·····△·····, *A. deleoni*.

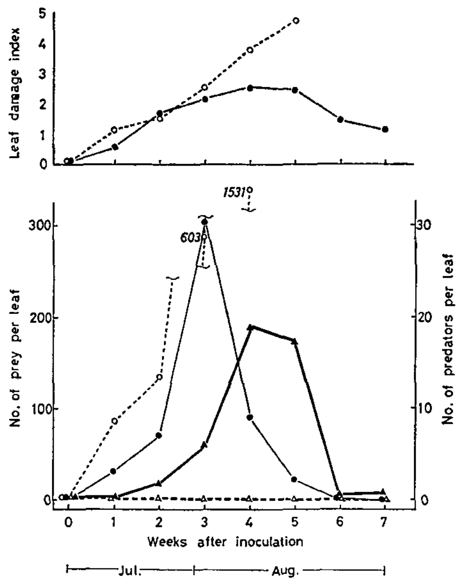

Fig. 6. Population fluctuations of *A. longispinosus*, *A. deleoni* and *T. urticae* (system VIII) and changes in the mean leaf damage indices on predator-released and predator-free plants in summer.

····○····control (system IX); —●—, *T. urticae*; —▲—, *A. longispinosus*; ·····△·····, *A. deleoni*.

species of tetranychid mite has a characteristic life style peculiar to its habitat. It may be thought that a phytoseiid mite species also has an adaptation to the mode of life of limited prey species and their host plants. To use the phytoseiid mites as control agents of tetranychids, it will be necessary to make clear the relationship between the characteristics of the predator and prey in the sense of their mode of life in their natural habitats.

It may be said that the native phytoseiid mite species such as *A. deleoni* and *A. longispinosus* did not at least reduce the efficiency of *P. persimilis* as the pest control agent under present experimental conditions. It is also indicated that the coexistence of *P. persimilis* and *A. longispinosus* resulted in the most effective suppression on the two-spotted spider mite. Because the systems of these experiments are small and time scale so short, this

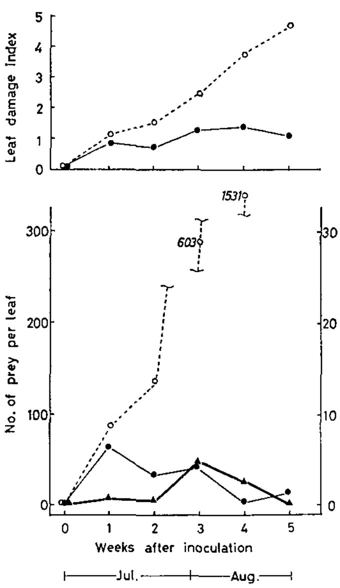

Fig. 7. Population fluctuations of *P. persimilis* and *T. urticae* (system II) and changes in the mean leaf damage indices on predator-released and predator-free plants in summer.

----○----, control (system IX); —●—, *T. urticae*; —▲—, *P. persimilis*.

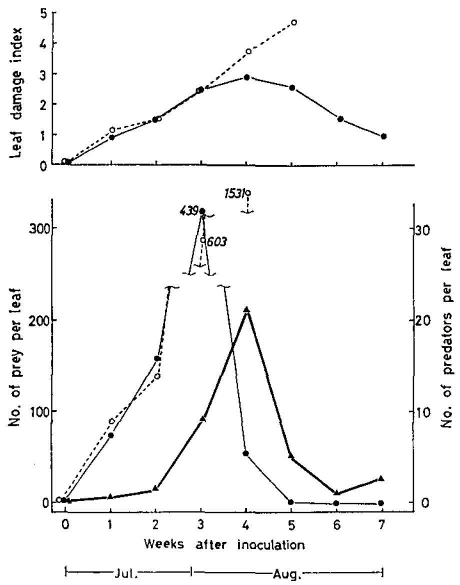

Fig. 8. Population fluctuations of *A. longispinosus* and *T. urticae* (system IV) and changes in the mean leaf damage indices on predator-released and predator-free plants in summer.

----○----, control (system IX); —●—, *T. urticae*; —▲—, *A. longispinosus*.

phenomenon has been left unexplained. The competition between these two predacious mite species is the subject for future study.

Summary

The predator efficiency was estimated through a comparative study on the population changes of three predator species (*Phytoseiulus persimilis* ATHIAS-HENRIOT, *Amblyseius longispinosus* EVANS and *A. deleoni* MUMA et DENMARK) and prey (*Tetranychus urticae* KOCH), as well as the changes of the mean leaf damage indices on predator-released and predator-free clover plants.

Both *P. persimilis* and *A. longispinosus* suppressed effectively *T. urticae* population in summer, but *A. longispinosus* could not control the prey in autumn.

There was no evidence that *A. deleoni* suppressed *T. urticae* population in the present system.

An excellent control on *T. urticae* was observed in summer in the system in which *P. persimilis* and *A. longispinosus* coexisted.

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