Biological Control of the Kanzawa Spider Mite, *Tetranychus kanzawai* Kishida, in Tea Fields by the Predacious Mite, *Amblyseius longispinosus* (Evans), which is Resistant to Chemicals (Acarina; Tetranychidae, Phytoseiidae)

By TETSUZO HAMAMURA

Research Planning and Coordination Division, National Research Institute of Vegetables, Ornamental Plants and Tea
(Kanaya, Shizuoka, 428 Japan)

Introduction

The Kanzawa spider mite, *Tetranychus kanzawai* is one of the most harmful pests of tea plants[8]. This species has developed the resistance to acaricides including cyhexatin, and the resistant species has spread over the tea planting districts[3]. Therefore, once the outbreak of this pest occurs, it is difficult to control it by chemicals. However, it is interesting that the occurrence density of this pest tends to decrease recently in tea fields of Shizuoka Prefecture[4].

A predacious mite, *Amblyseius longispinosus* is one of the promising predators to spider mites[2,7]. But it was recognized that this predator did not control effectively the spider mites in the agricultural ecosystem in which many chemicals were used, because of its high susceptibility to insecticides[11].

The resistance to chemicals of the phytoseiid mites[1,6,10] and its utilization to biological control of the spider mites[9,13] have been reported with some species. But the chemical-resistance of the native phytoseiid mite has not been detected in Japan.

This paper reports that the chemical-resistant predacious mite, *Amblyseius longispinosus* is able to work effectively to keep the population density of *T. kanzawai* at a low level, even in the tea fields where chemical control is practiced.

Resistance to chemicals of *A. longispinosus*

1) *Comparison of susceptibility between two strains of A. longispinosus adult females*

Susceptibility of two strains of the predacious mite: one collected from tea plants, *Camellia sinensis*, and the other from a species of Japanese wild glory bower, *Clerodendron trichotomum*, to many chemicals was determined by the spray technique (4 mg/cm^2) in the laboratory.

Susceptibility of the strain collected from tea plants was lower than that from glory bower to most organophosphorus and carbamate insecticides. As shown in Table 1, the resistance ratios (R/S ratios of LC_{50} value) shown for six insecticides were higher than 20, particularly the ratios for methidathion and methomyl were higher than 100. All chemicals tested were classified into three grades by the LC_{50} values of susceptible (Table 2) and resistant (Table 3) strains.

Susceptibility of the R strain to chlorfenvinphos, chlorpyrifos and isoxathion was comparatively high. In both strains, susceptibility to synthetic pyrethroids was high, and these compounds had high repellent effect to the predators.

In both strains, susceptibility to most of acaricides was low, but the susceptibility to polinactin complex and BPMC mixture was comparatively high. Six fungicides tested had no influence on both strains of this predator.

It is possible to select the chemicals that have no or low influence on the predators from Tables 2 and 3.

As the susceptibility to methomyl of *A. longispinosus* collected from some of the tea fields in Shizuoka Prefecture was low, it seemed that the resistance of this species to methomyl had spread throughout Shizuoka Prefecture. However,

Table 1. Resistance to some insecticides of *A. longispinosus* collected from tea plants

Chemicals (Formulation)[a]	Strain[b]	Concentration-mortality regression equation[c]	LC_{50}[d] (ppm)	Resistance ratio
Organophosphorus insecticides				
Methidathion	R	Y=5+1.1588 (X−1.4818)	30.325	118.5
(40%, E.C.)	S	Y=5+2.9739 (X+0.5921)	0.256	1
EPN	R	Y=5+1.1557 (X−2.5668)	368.808	75.8
(45%, E.C.)	S	Y=5+2.0985 (X−0.6631)	4.604	1
Mecarbam	R	Y=5+2.2782 (X−1.7115)	51.464	29.6
(25%, E.C.)	S	Y=5+3.2212 (X−0.2396)	1.736	1
Phenthoate	R	Y=5+2.1289 (X−1.6004)	39.847	29.2
(50%, E.C.)	S	Y=5+2.6427 (X−0.1352)	1.365	1
Carbamate insecticides				
Methomyl	R	Y=5+1.8381 (X−2.0227)	105.366	129.3
(45%, W.P.)	S	Y=5+1.7254 (X+0.0891)	0.815	1
Carbaryl	R	Y=5+1.5695 (X−2.4891)	308.390	23.7
(85%, W.P.)	S	Y=5+2.4605 (X−1.1147)	13.023	1

a) E.C.; Emulsifiable concentrate, W.P.; Wettable powder
b) R; Strain collected from tea plants, S; Collected from glory-bower
c) X; Log concentration (ppm), Y; Probit
d) Spraying at the rate of 4 mg of chemical solution per cm^2 was made with a spraying tower.

Table 2. Influence of chemicals on a susceptible strain of *A. longispinosus*

Kind of chemicals	Intensity of influence (ppm)		
	Non~low ($LC_{50}\geqq100$)	Middle ($100>LC_{50}\geqq10$)	High ($10>LC_{50}$)
Organo-phosphorus insecticide	Fenitrothion, DDVP, Salithion, Pirimiphos-methyl	Naled, Prothiophos, Diazinon, Acephate	Methidathion, Chlorpyrifos, Mecarbam, Chlorfenvinphos, EPN, Phenthoate, Isoxathion
Carbamate insecticide	Cartap	Carbaryl, MPMC	Methomyl
Organic chlorine compound	Endosulfan		
Pyrethroid insecticide			Permethrin, Cyhalothrin, Tralomethrin, Cyfluthrin, Fenvalerate, Cypermethrin, Flucythrinate, Fenpropathrin, FMC-54800, Cycloprothrin, Fluvalinate, Ethoproxyfen, Pirethrins
Specific acaricide	Cyhexatin, Propargite, Polynactin complex and CPCBS mixture, Dicofol	Polynactin complex and BPMC mixture, Binapacryl	
Fungicide	Chlorothalonil, Polycarbamate, Basic copper chloride, Captafol, Thiophanate-methyl, Benomyl		

Table 3. Influence of chemicals on a resistant strain of *A. longispinosus*

Kind of chemicals	Intensity of influence (ppm)		
	Non~low ($LC_{50} \geqq 100$)	Middle ($100 > LC_{50} \geqq 10$)	High ($10 > LC_{50}$)
Organo-phosphorus insecticide	Fenitrothion, DDVP, Salithion, Pirimiphos-methyl, Acephate, EPN, Naled	Prothiophos, Phenthoate, Diazinon, Methidathion, Mecarbam, Isoxathion	Chlorpyrifos Chlorfenvinphos
Carbamate insecticide	Cartap, Methomyl, Carbaryl, MPMC		
Organic chlorine compound	Endosulfan		
Pyrethroid insecticide		Fluvalinate, Ethoproxyfen, Cycloprothrin	Permethrin, Cyhalothrin, Tralomethrin, Cyfluthrin, Fenvalerate, Cypermethrin, Flucythrinate, Fenpropathrin, FMC-54800, Pirethrins
Specific acaricide	Cyhexatin, Propargite, Polynactin complex and CPCBS mixture, Dicofol, Binapacryl	Polynactin complex and BPMC mixture	
Fungicide	Chlorothalonil, Polycarbamate, Basic copper chloride, Captafol, Thiophanate-methyl, Benomyl		

Table 4. Changes in mortality and LC_{50} of *A. longispinosus* against methidathion with the advance of selection

Selection pressure concentration times	Date of tests	No. of females used	Mortality (%)	LC_{50} (ppm)	Resistance ratio[a]
	1981 Aug.			30.0	117
80 ppm-1	1983 Jan. 20	111	49.6		
2	Feb. 15	83	44.6		
3	Mar. 8	277	41.9		
4	Apr. 21	105	15.2		
	May 30			181.8	710
200 ppm-1	Jun. 22	84	61.9		
2	Jul. 15	86	51.1		
3	Aug. 4	162	48.2		
4	Aug. 20	99	32.3		
5	Oct. 6	191	24.6		
	Nov. 11			246.7	964
400 ppm-1	Nov. 18	348	86.8		
2	1984 Jan. 7	353	80.7		
3	Feb. 7	345	62.9		
4	Mar. 2	446	70.0		
5	Mar. 28	260	73.5		
6	May 9	173	79.2		
7	Jun. 7	145	80.7		
	Oct. 12			212.2	829

a) LC_{50} of S strain is 0.256 ppm (Table 1).

the susceptibility of the species collected from other prefectures was higher than that observed in Shizuoka Prefecture.

2) Laboratory selection and genetic analysis

Females of the resistant strain collected from tea field were further selected for the resistance to methomyl and methidathion, aiming at getting higher resistance. The susceptibility to methomyl was almost unchanged after the selection of 5 times in the laboratory, whereas the resistance ratio for methidathion increased from 117 (LC_{50}, 30 ppm) to about 1000 (LC_{50}, 247 ppm) after the selection of 9 times (Table 4). The highly resistant strain selected was used in examinations of genetic analyses and comparison of fitness between R and S strains.

The methidathion resistance was mainly due to a single completely dominant major gene (Fig. 1). The EPN resistance also depends on a single completely dominant major gene. The degree of dominance[12] was 0.899 in methidathion resistance and 0.876 in EPN resistance. The methomyl resistance was mainly due to a single incompletely dominant major gene (Fig. 2). The degree of dominance was 0.525.

There were no significant differences in the reproductive rate, consumption rate, and diapause nature between R and S strain of *A. longispinosus*.

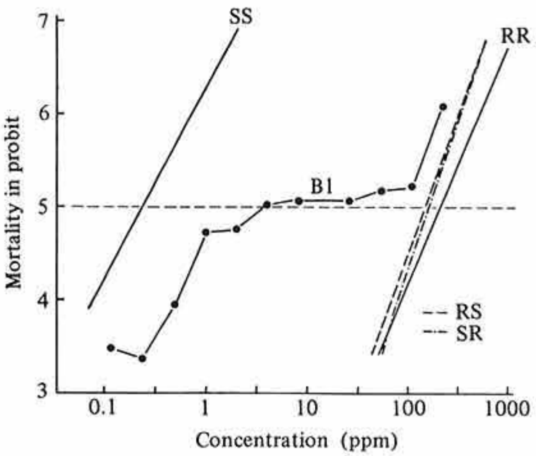

Fig. 1. Methidathion susceptibility of adult females of a resistant strain (RR), a susceptible strain (SS), their hybrids (RS, SR), and backcross progeny (B1) of *A. longispinosus*

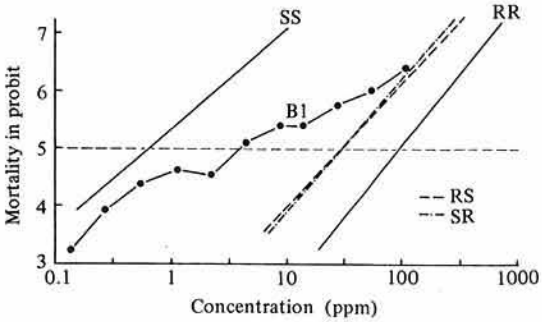

Fig. 2. Methomyl susceptibility of adult females of a resistant strain (RR) a susceptible strain (SS), their hybrids (RS, SR), and backcross progeny (B1) of *A. longispinosus*

Therefore, the fitness of the resistant strain seemed to be almost equal to that of the susceptible strain.

These characters of this predator are of great advantage in utilizing this predator to the biological control of spider mites of various crops.

Role of *A. longispinosus* in the biological control of *T. kanzawai* on tea plants

1) Occurrence and distribution of A. longispinosus in tea fields of Japan

One hundred leaves damaged by *T. kanzawai* were sampled from a tea field and the samples from 3 to 5 fields were sent to our laboratory from main tea-producing prefectures during a period from 1982 to 1984. The results are summarized in Figs. 3 and 4.

Three species of phytoseiid mites i.e. *A. longispinosus, A. eharai*, and *A. liturivorus* were detected in tea fields of Japan. But in tea fields where chemicals are sprayed, only *A. longispinosus* was detected. The occurrence of *A. longispinosus* was confirmed in many of the surveyed prefectures except Saitama, Gifu, Shiga and Nara (Fig. 3). In all of the surveyed 32 fields of Shizuoka Prefecture the occurrence of *A. longispinosus* was found in June 1982. The population density of *A. longispinosus* was high in tea fields of Shizuoka and Fukuoka.

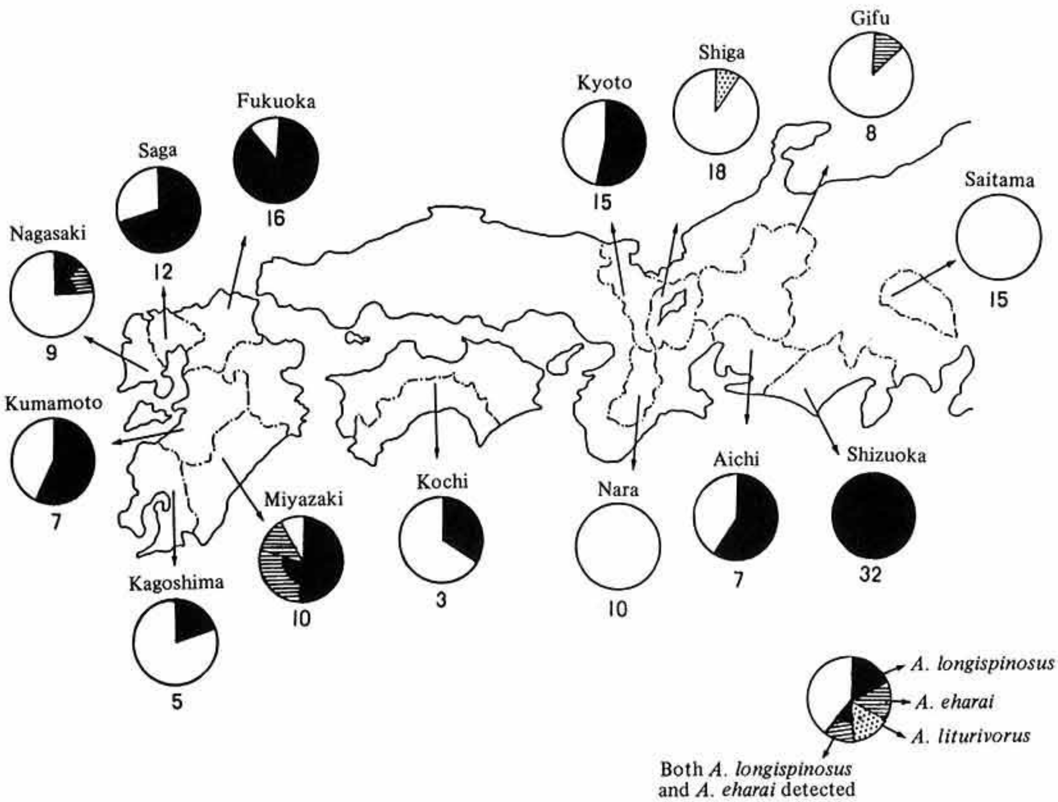

Fig. 3. Percentage of tea fields where the phytoseiid mites were detected to the total number of tea fields surveyed (shown by numerals) in each prefecture from 1982 to 1984

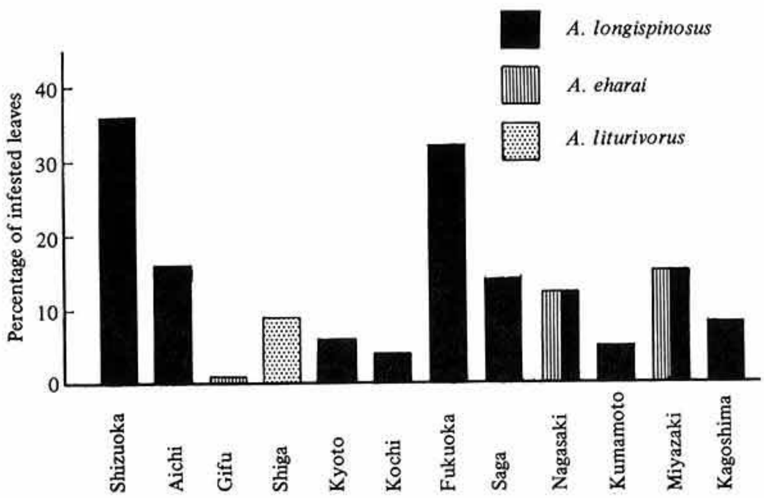

Fig. 4. Average percentage of infested leaves by the phytoseiid mites in tea fields where they were detected

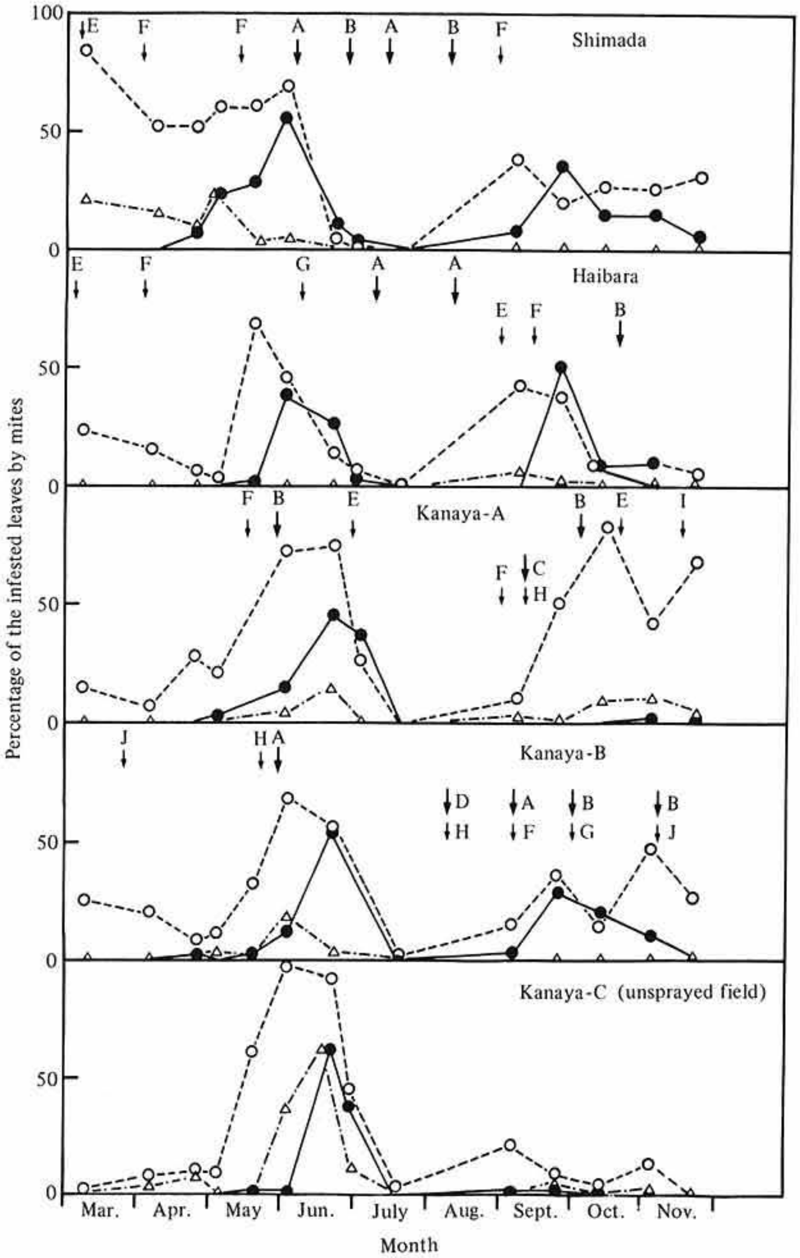

Fig. 5. Seasonal occurrence (expressed by percentage of infested leaves) of *T. kanzawai* adult females and *A. longispinosus* at all stages in different tea fields in Makinohara, Shizuoka, in 1983

····○···· : *T. kanzawai* adult females } Surveyed by sampling damaged leaves.
—●— : *A. longispinosus* at all stages

···△···: *T. kanzawai* adult females surveyed by the random sampling method.

Large arrows indicate application of insecticides showing LC_{50} below 100 ppm to *A. longispinosus*: A; isoxathion, B; methidathion, C; fenvalerate, and D; pyrethrins.

Small arrows indicate acaricidal application: E; progargite, F; cyhexatin, G; polynactin complex and BPMC mixture, H; dicofol, I; petroleum oils, J; binapacryl.

2) *Seasonal occurrences of A. longispinosus and T. kanzawai*

Seasonal occurrence of both predator and prey was surveyed in five tea fields of Makinohara, Shizuoka, by two methods i.e. random sampling of 100 leaves (mainly from the upper surface of tea hedge) and sampling of 100 leaves damaged by the spider mite (mainly from the side part of tea hedge) from 1982 to 1984. Fig. 5 shows the result in 1983.

The random sampling surveys showed that the population density of prey and predator was low throughout all seasons in most of the fields. The surveys by sampling damaged leaves showed that the population density of the spider mites increased in June and the predator also increased somewhat late. At the peak of predators, the ratios of predator to prey were much higher than the critical ratio[2] at which predators can suppress the prey population. The density of the prey and that of the predator decreased rapidly after the peak of predators. In autumn also, the density of predators showed an increase following the increase of the prey although it did not occur commonly, unlike the case in June.

Most of the chemicals applied did not influence the occurrence of the predators. But in the field where a synthetic pyrethroid, fenvalerate, was used, no predator occurred after the application, and a severe outbreak of the spider mite occurred as shown by Kanaya A of Fig. 5. Another example of the outbreak of the spider mite with no predators was found as a result of the combined application of isoxathion and (polinactin complex and BPMC mixture) in 1984. In many of the other fields or years, the increase of predator subsequent to the increase of prey was commonly recognized, so that the population density of spider mites on the upper surface of tea hedge was maintained at a low level.

However, when the synthetic pyrethroid, such as permethrin, fluvalinate, or fenpropathrin was used, the outbreak of the spider mites occurred without predators.

The recent decrease of the spider mite outbreak recognized in Shizuoka Prefecture was attributed to the predacious activity of *A. longispinosus* highly resistant to chemicals.

References

1) Croft, B. A., Brown, A. W. A. & Hoying, S. A.: Organophosphorus resistance and its inheritance in the predacious mite *Amblyseius fallacis*. *J. Econ. Entomol.* **69**, 64–68 (1976).

2) Hamamura, T.: Prey consumption and biological control ability of *Amblyseius longispinosus* (Evans) (Acarina: Phytoseiidae) as a predator of *Tetranychus urticae* Koch. *Study of Tea*, **64**, 15–23 (1983) [In Japanese with English summary].

3) Hamamura, T.: Regional difference in cyhexatin resistance of the Kanzawa spider mite, *Tetranychus kanzawai* Kishida (Acarina: Tetranychidae) collected from tea fields. *Tea Res. J.*, **62**, 46–51 (1985) [In Japanese with English summary].

4) Hamamura, T.: The role of insecticide resistant *Amblyseius longispinosus* in tea field. *Plant Protection*, **39**, 252–257 (1985) [In Japanese].

5) Hamamura, T.: Studies on the biological control of Kanzawa spider mite, *Tetranychus kanzawai* Kishida by the chemical resistant predacious mite *Amblyseius longispinosus* (Evans) in tea fields (Acarina: Tetranychidae, Phytoseiidae). *Bull. Nat. Res. Inst. Tea*, **21**, 121–201 (1986) [In Japanese with English summary].

6) Hoy, M. A.: Recent advances in genetics and genetic improvement of the phytoseiidae. *Ann. Rev. Entomol.*, **30**, 345–370 (1985).

7) Mori, H. & Saito, Y.: Biological control of *Tetranychus urticae* Koch (Acarina: Tetranychidae) populations by three species of phytoseiid mites (Acarina: Phytoseiidae). *J. Fac. Agr. Hokkaido Univ.*, **59**, 303–311 (1979).

8) Osakabe, M.: Biological studies on the tea red spider mite, *Tetranychus kanzawai* Kishida, in tea plantation. *Bull. Tea Res. Sta.*, **4**, 35–156 (1967) [In Japanese with English summary].

9) Roush, R. T. & Hoy, M. A.: Laboratory, glasshouse, and field studies of artificially selected carbaryl resistance in *Metaseiulus occidentalis*. *J. Econ. Entomol.* **74**, 142–147 (1981).

10) Schulten, G. G. M. & G. van de Klashorst: Genetics of resistance to parathion and demeton-S-methyl in *Phytoseiulus persimilis* (Acari: Phytoseiidae). Proc. 4th Int. Cong. Acarol. Saalfelden, Austria, 519–524 (1979).

11) Shinkaji, N. & Adachi, T.: The effct of certain pesticides on the predacious mite *Amblyseius longispinosus* (Evans) (Acarina: Phytoseiidae). *Bull. Fruit Tree Res. Sta.*, E **2**, 99–108 (1978) [In Japanese with English

summary].

12) Stone, B. F.: A formula for determining degree of dominance in case of monofactorial inheritance of resistance to chemicals. *Bull. W. H. O.*, **38**, 325–326 (1968).

13) Whalon, M. E., Croft, B. A. & Mowry, T. M.: Introduction and survival of susceptible and pyrethroid-resistant strains of *Amblyseius fallacis* (Acari: Phytoseiidae) in a Michigan apple orchard. *Environ. Entomol.*, **11**, 1096–1099 (1982).

(Received for publication, October 6, 1986)