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Toxicity of Some Pesticides to Twospotted Spider Mite (Acari: Tetranychidae) and its Predator *Amblyseius womersleyi*[1] (Acari: Phytoseiidae)

점박이응애(*Tetranychus urticae* Koch)와 긴털이리응애(*Amblyseius womersleyi* Schicha)[1]에 대한 몇가지 農藥의 選擇毒性

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ABSTRACT Toxicity of 5 acaricides, 4 insecticides, and 6 fungicides to the twospotted spider mite, *Tetranychus urticae* Koch, and its predator *Amblyseius womersleyi* Schicha was assessed in a laboratory using a leaf disk bioassay. Dicofol was equally very toxic to adult females of *T. urticae* and *A. womersleyi*, and caused 46% and 40% mortality of eggs of those two species, respectively. Adult females of *A. womersleyi* dipped in Abamectin solution showed low mortality (16.6%), while all *T. urticae* females died within 24 hours after dipping. Three ovicidal acaricides (Tetradifon, Clofentezine, and Hexythiazox) showed no mortality of predator eggs, but more than 90% mortality of *T. urticae* eggs. Four insecticides (Teflubenzuron, Triflumuron, Diflubenzuron, and Imidacloprid) and three fungicides (Propineb, Fenarimol, and Polyoxin-B·captan) were non toxic to the *A. womersleyi* adult females. The other fungicides (Chlorothalonil, Nuarimol · Mancozeb, and Folpet) were a little toxic to adult females of the predator, showing $\leq$ 23.3% mortality. It may be suggested from these results that 4 insecticides, 4 acaricides, and 6 fungicides described could be incorporated into the integrated pest management system with *A. womersleyi* in apple orchard.

KEY WORDS Twospotted spider mite, *Tetranychus urticae, Amblyseius womersleyi*, Pesticides, Comparative toxicity

적 요 사과원에서 사용되는 살비제 5종, 살충제 4종, 살균제 6종을 추천농도로 희석하여 점박이응애와 긴털이리응애에 대한 상대독성을 엽침지법으로 실험실에서 조사하였다. Dicofol은 점박이응애와 긴털이리응애에 대해 독성이 매우 강하였으며, 이들의 난에 대해서도 각각 46%와 40%의 致死效果가 있었다. Abamectin 溶液에 침지된 긴털이리응애 암컷성충의 사망율은 무처리와 차이가 없었으나 점박이응애의 암컷성충은 24시간 이내에 모두 사망하였다. Tetradifon, Clofentezine, Hexythiazox등 3종의 殺卵性 살비제는 점박이응애의 난에 대해서는 90%이상의 살란효과를 나타내었으나 긴털이리응애 난의 부화에는 아무런 영향이 없었다. Teflubenzuron, Triflumuron, Diflubenzuron, Imidacloprid 등 4종의 살충제와 Propineb, Fenarimol, Polyoxin-B·captan 등 3종의 살균제는 긴털이리응애 암컷성충에 대해 살비효과가 없었으며, Chlorothalonil, Nuarimol · Mancozeb, Folpet 등 3종의 살균제도 23% 이하의 낮은 살비효과를 나타내었다. 이상과 같이 긴털이리응애 난이나 암컷성충에 저독성을 나타내는 4종의 살충제와 4종의 살비제 및 6종의 살균제는 사과원 병해충 종합관리체계에서 긴털이리응애와 함께 이용될 수 있을 것으로 생각된다.

검색어 점박이응애, 긴털이리응애, 농약, 選擇毒性

The dominant mite pest in Korea was the European red mite, *Panonychus ulmi* (Koch) in the past, while the twospotted spider mite (TSM), *Tetranychus urticae* (Koch), was a secondary pest causing only a local problem during late season. However, TSM has become the most important pest of many crops since pes-

[1]This species was recently reassigned from *A. longispinosus* Evans by Ryu (1996) in Korea.

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ticides were widely used in 1970s, and TSM problem is now most serious in apple orchards where pesticides are sprayed in a calendar-based schedule. Lee *et al.* (1994) pointed out that replacement of mite pest was mainly due to the extensive use of acaricides, based on the results of field experiment. According to Lee (1990), apple growers sprayed insecticides 4 to 12 times, fungicides 11 to 17 times, and acaricides 3 to 10 times a year in early 1980s. However, Ryu *et al.* (1995) reported that the spray pattern in apple orchards has little been changed recently.

Natural enemies, in general, play an important role in integrated pest management. However, natural enemies often failed to surpress pest population due to heavy use of broad sprectrum agro-chemicals. In fact, natural enemies of spider mites, in particular, can rarely survive from those heavy chemical application. A question arisen is then how to conserve biological control agents when chemical application is necessary to manage the pest population under the economic injury level. An approach is to use selective pesticides less toxic to natural enemies than to the pest species (Helyer 1985, Hoy and Ouyang 1985).

A native predacious mite, *Amblyseius womersleyi* Schicha, is a predominant predator of spider mites in apple orchards (Lee 1990) and in tea tree plantation (Lee *et al.* 1995) in Korea. Lee *et al.* (1994) reported that *A. womersleyi* was less susceptible to pesticide applications than other phytoseiid predators.

Lee (1990) concluded that the application numbers of insecticides and acaricides could be reduced greatly without substantial fruit damages and decrease of tree vigor by adopting an alternative way to conventional pesticide application. He suggested that selective pesticides should be applied to control key pests and to conserve the effective natural enemies. However little information is available on the selectivity of chemicals to the native predacious mite.

Here we report results of laboratory experiments conducted to evaluate the comparative toxicity of some acaricides, insecticides and fungicides currently used in apple orchards on the survival of both TSM and *A. womersleyi*.

MATERIALS AND METHODS

Colonies Tested: The experiment cohort of *A. wom-*

Table 1. List of chemicals used in this test

Common name	Trade name	Purity (%)	Field rate (ppm)[1]
Acaricides			
Tetradifon EC	Tediran	8	100
Dicofol EC	Kelthane	42	420
Clofentezine WP	Saran, Bisfen	50	250
Hexythiazox WP	Nissoran	10	25
Abamectin EC	Olstar	1.8	6
Insecticides			
Triflumuron WP	Alsystin	25	100
Diflubenzuron WP	Dimilin	25	100
Teflubenzuron SC	Nomolt	5	25
Imidacloprid WP	Cornidor	10	50
Fungicides			
Folpet WP	Folpet	50	1,000
Chlorothalonil WP	Daconil, Thalonil, Kumbira	75	938
Nuarimol · Mancozeb WP	Tridal-M	61	1,007-1,220
Propineb WP	Propi, Antracol	70	1,155-1,400
Fenarimol EC	Fenari	12.5	42
Polyoxin-B · Captan WP	Polycaptan	65	650-1,300

[1]Every chemical was diluted in distilled water to the field rate and tested.

ersleyi came from a laboratory colony originally collected from natural population on mulberry trees in 1985, and maintained since then with all stages of TSM as food source on pesticide free kidney bean (*Phaseolus vulgaris* var. *humilis* Alefeld) leaves in the laboratory. The twospotted spider mite has been reared on kidney bean seedlings free from pesticide application since 1986. All experiments were conducted under 22-27°C, 40-70% RH and 16L: 8D.

Chemicals: Fifteen commercial pesticides (5 acaricides, 4 insecticides, and 6 fungicides) were used in this study. Chemicals were diluted in distilled water to the field rates (Table 1). Leaf disks infested with TSM or *A. womersleyi* were dipped in an aqueous solution of each chemical for about 5 seconds, while the solutions were being agitated. The leaf disks were inspected to determine whether the test mites were dead or alive. Mites that did not respond to physical stimulation by using a fine camel-hair brush were considered dead. Mites that could walk to more than their body length when stimulated were considered alive. The number of mites drowned in the water-saturated cellucotton was also counted.

Effect of Chemicals on the Survival of TSM and *A. womersleyi*: Adult females of TSM or its predator were transferred from the source colony to square bean leaf disks (3 by 3cm) with aid of a fine camel-hair brush. Each disk was infested with 20 TSM female adults or 10 to 20 female adults of *A. womersleyi* with 4 to 5 replicates. The bean leaf disks with mites were dipped in distilled water or aqueous solution of each chemical for 5 seconds, allowed to dry for 90-120 minutes, and placed bottom-side up on moist cellucotton in Petri-dishes (2.2 by 8.8cm). The number of adults on leaf disks were then counted, because some mites disappeared during the process. The drowned adults in saturated cellucotton throughout the experiment were not included in the number of tested adults. In the test of *A. womersleyi*, a number of fresh adult females of TSM (more than 50) were supplied when needed to ensure an abundance of food. The survival was evaluated at 24 h, 48 h, and 72 h after treatment.

Effect of Teflubenzuron on the Reproduction of *A. womersleyi*: The effect of teflubenzuron on the reproduction of adult female of *A. womersleyi* was assessed in contrast to abamectin. The bean leaf disks infested with predators (4 replicates with 10 adult females per replication) were dipped in each chemical solution for 5 seconds, and then allowed to dry until the solution on disks disappeared completely. Those leaf disks were placed bottom-side up on a water saturated cellucotton in Petri-dishes. A number of fresh TSM adult females were supplied daily to the predators as the above experiment. Survival and reproduction were evaluated at 1, 2, and 3 days after treatment.

Effect of Acaricides on Egg Hatchability of TSM and *A. womersleyi*: To assess the hatchability of TSM and *A. womersleyi* eggs, 10 adult females of each species were placed on a respective leaf disk (3 by 3 cm) for 24 hours to allow oviposition. On the leaf disks which female adults of *A. womersleyi* were infested, 50 TSM adults were placed as their food source. After 24 hours, all adults were removed from the disks, and then the number of eggs on the disk were counted. Leaf disks containing eggs of each species were dipped in chemical solutions for 5 seconds at one day after oviposition. Larvae and egg shells were counted daily, until every larvae emerged in the water treatment.

RESULTS AND DISCUSSION

Effects of Chemicals on the Survival of TSM and *A. womersleyi*: Results of the bioassay for the survival of TSM and *A. womersleyi* were shown in Table 2. Within 72 hours after treatment, TSM adults dipped in abamectin solution showed 97% mortality, while *A. womersleyi* showed only 16.6% mortality which was not significantly different from the result of water treatment. Some of *A. womersleyi* (46.3% of treated mite) were disappeared from leaf disk dipped in abamectin solution at 72 hours after treatment. It is uncertain, at present, whether those escaped predators would survive or not in field condition. But there is some possibility that the predators escaped from leaves sprayed with chemicals can survive in the field, if they can move to fresh leaf, as in the case of *Metaseiulus oc-*

Table 2. Susceptibility of adult females of *T. urticae* and *A. womersleyi* on bean leaf disks dipped in some aqueous acaricides

Acaricides	Conc. (ppm)	No. females tested	% Cumulative mortality (% abscent from leaf disk)		
			24 h[a]	48 h	72 h
T. urticae					
Abamectin	6	100	97.0(3.0)a	97.0(3.0)a	97.0(3.0)a
Dicofol	420	76	92.3(0.0)a	92.3(1.3)a	94.9(1.3)a
Tetradifon	100	100	15.0(5.0)b	38.0(5.0)b	59.0(9.0)b
Dist. water	0	100	0.0(9.0)c	9.0(11.0)c	19.0(11.0)c
A. womersleyi					
Abamectin	6	41	2.3(24.4)b	14.3(36.6)b	16.6(46.3)b
Dicofol	420	70	97.2(0.0)a	98.6(0.0)a	100.0(0.0)a
Dist. water	0	40	0.0(0.0)b	2.5(0.0)b	7.5(2.5)b

[a]In each column, means followed by the same letter are not significantly different (P<0.05; Least Significant Difference Test)

Table 3. Mortality of adult females of *A. womersleyi* on bean leaf disks dipped in solutions of insecticdes and fungicaides 3 days after the treatment

Chemical	No. females tested	% Mortality	% Abscent
Insecticides			
Triflumuron	30	0.0	10.0
Diflubenzuron	30	0.0	3.3
Teflubenzuron	40	0.0	12.5
Imidacloprid	30	0.0	13.3
Fungicides			
Folpet	30	16.7	30.0
Chlorothalonil	30	23.3	23.3
Nuarimol · Mancozeb	30	23.3	13.3
Propineb	30	3.3	23.3
Fenarimol	30	3.3	10.0
Polyoxin-B · Captan	30	3.3	13.3
Distilled water	30	0.0	3.3

cidentalis which has ability to deposit eggs when removed from abamectin residues (Grafton-Cardwell & Hoy 1983). Consequently, our result indicates that abamectin is less toxic to acarine predator than to their prey, which generally coincide with other studies (El-banhawy & El-bagoury 1985, Zhang & Sanderson 1990, Park *et al.* 1995).

Dicofol was highly toxic to both TSM and *A. womersleyi*. TSM of 5.1% and no predator survived when treated with dicofol solution. This result suggested that dicofol should not be used in IPM system in Korea where *A. womersleyi* is a dominant predator in apple orchard, although dicofol has been used to control *P. ulmi* and *T. urticae* throughout the world for more than 30 years (F-Kolmes 1991).

Tetradifon had some mortality effect on TSM female adults, although this chemical is originally known to have ovicidal effect. Although we did not test the effect of tetradifon on the adult female of *A. womersleyi*, Lee (1990) reported that there was little effect of the ovicide on adult female of the predator.

In apple orchards in Korea, insect growth regulators (IGRs) are often used to control aphids and lepidopterous pests. We tested the effects of 3 IGRs and one insecticide on the survival of *A. womersleyi*. All the IGRs and imidacloprid tested caused no mortality of female adult of predator in field rates (Table 3). These results showed that IGRs are very safe for predatory mite. One of the test with IGR, diflubenzuron, was found to be harmless to *Stethorus* adults and predatory mites (Bower & Kaldor 1980, Wearing & Thomas 1978).

When *A. womersleyi* female adults were dipped in aqueous solutions of six fungicides (Table 3), chlorothalonil, nuarimol · mancozeb, and folpet killed 17% to 23% of this predatory mite, while other three fungicides caused low mortality (≤3%). Therefore, it may be said that those fungicides which are commonly used in farmer's apple orchards are safe to *A. womersleyi*, even though these fungicides were not tested with the effect on the reproduction of female adults and on the survival of immature stages of the pre-

Table 4. Reproduction of adult females of *A. womersleyi* on bean leaf disks dipped in a teflubenzuron and abamectin solutions

Treatment	No. eggs/female/day			
	1st	2nd	3rd day	mean
Teflubenzuron	1.2±0.2	2.1±0.2	1.8±0.9	1.7±0.4
Abamectin	0.9±0.6	0.8±0.2	0.7±0.2	0.8±0.2
Dist. water	1.3±0.5	1.3±0.3	2.2±0.6	1.6±0.3

datory mite. Some researchers demonstrated that many kinds of fungicides were safe to *P. persimilis* (Cho *et al.* 1995) and to *A. womersleyi* (Lee 1990), but mancozeb was toxic to female adult and eggs of the predator (Lee 1990).

Effect of Teflubenzuron on the Reproduction of *A. womersleyi*: When *A. womersleyi* female adults were dipped in Abamectin solution, their reproductivity was lower than when the mite were treated with distilled water (Table 4). In contrast, however, teflubenzuron caused no effect on the reproduction of *A. womersleyi*. The number of eggs layed by the female adult of *A. womersleyi* dipped in teflubenzuron solution was almost same as those dipped in distilled water. In addition to this, a preliminary test showed that teflubenzuron solution killed 31.3% of the tested *T. urticae* female adult. In this point of view, we may conclude that IGRs has little effect on the survival and reproduction of *A. womersleyi*.

Effects of Acaricides on the Egg Hatchability of TSM and *A. womersleyi* Eggs: The eggs of TSM dipped in tetradifon, clofentezine, and hexythiazox solutions showed very low hatchability of 0%, 10.1%, and 1.7%, respectively on 8 days after the treatment (Table 5). In contrast, every eggs of *A. womersleyi* dipped in these three ovicide solutions hatched to larvae. Dicofol had almost the same effect on the eggs of TSM and *A. womersleyi*. Fourty five percentage of *A. womersleyi* eggs could not emerge to larvae when they were dipped in dicofol solution at field rate. Other researchers reported similar results that Tetradifon was highly selective to *A. womersleyi* (Lee 1990), and to *P. persimilis* (Cho *et al.* 1995). Clofentezine and hexythiazox caused low mortality of adult females, larvae, and eggs of

Table 5. Hatchability of eggs of *T. urticae* and *A. womersleyi* on bean leaf disks dipped in some aqueous acaricides

Acaricides	No. eggs tested	% Hatchability (%)		
T. urticae		5th[a]	7th	8th day
Tetradifon	210	0.0a	0.0c	0.0c
Clofentezine	267	0.7a	9.3c	10.1c
Hexythiazox	233	0.0a	1.7c	1.7c
Dicofol	135	0.0a	41.1b	45.9b
Dist. water	106	0.9a	93.2a	98.2a
A. womersleyi		3th	4th	6th day
Tetradifon	74	51.8a	94.5a	100.0a
Clofentezine	60	47.2a	95.0a	100.0a
Hexythiazox	147	14.1b	96.5a	100.0a
Dicofol	102	1.4b	39.9b	44.8b
Dist. water	64	50.6a	88.8a	100.0a

[a]In each column, means followed by the same leter are not significantly different ($P<0.05$: Duncan's Multiple Range Test)

M. occidentalis (Hoy & Ouyang 1986) and eggs of *P. persimilis* (Cho *et al.* 1995). Thus, we suggest here that these three ovicides are particularly useful in an integrated mite management system, where *A. womersleyi* should be conserved.

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