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Monitoring of Acaricide Resistance in Field-Collected Populations of *Tetranychus urticae* (Acari: Tetranychidae) in Korea

점박이응애 야외개체군의 살비제 저항성 모니터링

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ABSTRACT Eight field-collected populations of the two-spotted spider mites. *Tetranychus urticae* (Koch) from apple orchards of different geographical areas were tested for resistance to seven acaricides by leaf disk method in comparison with a susceptible strain Marked regional variations of susceptibility were observed. Only low to moderate resistance to azocyclotin. fenpropathrin, propargite. and abamectin was obtained However, high resistance to dicofol, fenpyroxymate, and pyridaben by eight field-collected populations was produced. Resistance to dicofol and fenpyroxymate was widespread. All of the strains tested were susceptible to one or more of the acaricides used. These results indicate that careful selection of the chemical used against any population of the two-spotted spider mite might result in satisfactory control.

KEY WORDS Acari, *Tetranychus urticae,* monitoring, acaricide, resistance

초 록 전국 8개 지역별 각 사과원에서 채집된 점박이응애(*Tetranychus urticae* Koch)에 대한 저항성 정도를 일본 감수성 계통과 비교한 결과 지역별 현저한 감수성 차이를 보였다 Azocyclotin, fenpropathrin, propargite 및 abamectin에 대해서는 낮거나 중간 정도의 저항성을, dicofol, fenpyroximate 및 pyridaben에 대해서는 높은 저항성을 나타내었다 이들 계통은 한종 또는 두종 이상의 약제에 대해 감수성을 보여 특정 지역에 대해서는 적당한 살비제의 선택적 이용으로 점박이응애를 효과적으로 방제할 수 있을 것으로 사료된다.

검색어 응애목, 점박이응애, 모니터링, 살비제, 저항성

Apple is a major fruit crop in Korea where its cultivation area is approximately 56,000 ha in 1993 and is of increasing every year due to its economic importance (Anonymous 1993b). Among 312 species of the insect and mite pests of apple, the most important of which are two spider mite species (*Tetranychus urticae* Koch and *Panonychus ulmi* Koch), spiraea aphid (*Aphis citricola* van der Goot), and apple leaf miner (*Phyllonorycter ringoniella* Matsumura) (Anonymous 1986, Anonymous 1989a, Lee 1990).

Continued or repeated use of insecticides or acaricides on apple orchards for the past decades has disrupted control of spider mite populations by natural enemies and has led to outbreaks and resurgences, and the development of widespread resistance to acaricides or the acaricide groups (Lee & Yoo 1971, Lee *et al.* 1986, Lee 1990). Although an average of nearly 0.2 million (AI) kg of the 36 acaricides registered for use on apple for controlling spider mites was used in Korea (Anonymous 1993a), many of them have failed to provide adequate cont-

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rol of spider mites after 2~3 yr of use in the field because of the development of acaricide resistance induced by intensive use of acaricides. Decreased efficacy and increasingly adverse effects of the earlier types of acaricide have brought about the need for low application rates of selective acaricides or management programs such as use of rotation of acaricides or mixtures of acaricides for controlling spider mites resistant to acaricides However, monitoring study on acaricide susceptibility to the two-spotted spider mite has not been conducted systematically, although it is major component of acaricide resistance management especially for control of major pest such as two-spotted spider mite.

In the laboratory study described herein, we assess the effectiveness against the laboratory-reared and field-collected populations of *T urticae* of the commonly used acaricides in apple orchards in Korea.

MATERIALS AND METHODS

Chemicals

Acaricides used in this study were as follows azocyclotin 25% wettable powders (WP), pyridaben 20% WP; propargite 30% WP; fenpyroximate 5% suspension concentrates (SC); fenpropathrin 5% emulsifiable concentrates(EC); dicofol 42% EC; and abamectin 0.6% EC Fenpyroximate was kindly supplied by Nihon-Noyaku company, Japan. The other chemicals were of commercial products.

Mites

A total of eight field colonies were collected from apple orchards (eight collection sites) in Korea. Each colony collected from the periphery of the canopy at a height of 1 5~2.0 m apple trees was brought into the laboratory and reared for two or three generations to ensure adequate numbers for testing. A susceptible strain, obtained in 1993 from Dr. N Motoyama of Chiba University, Chibaken, Japan, was used as the standard for comparison. The mites were reared on kidney bean (*Phaseolus vulgaris* var *humilis* Alefeld) seedlings (3 wk after germination) in acrylic cages (40 by 40 by 55 cm) as previously reported (Ahn *et al* 1993), and maintained at 25± 1°C, 40~60% RH, and a photoperiod of 16:8 (L:D) hr.

Toxicity Test

The toxicity of the acaricides on adult mites was determined by leaf-disk method as previously reported (Ahn *et al.* 1993), and each treatment was replicated three times. Leaves of kidney bean (3 wk after germination) were collected and disks (3 cm diameter) were punctured from each leaf. Thirty *T. urticae* female adults were transferred onto the untreated leaf disk on cotton pad in Petri dishes (5.5 by 2 cm) and test chemicals were sprayed at the rate of 0.1 m*l* per leaf disk by hand sprayer Mortalities were determined 48 hr after treatment, and LC_{50} values were calculated by Probit analysis (Finney 1971). Mites were considered dead if appendages did not move when prodded with a camel's hair brush. Treated samples were maintained at 25± 1°C, 40~60% RH, and a photoperiod of 16:8 (L:D) hr.

A resistance ratio (RR) was calculated according to the formula RR=LC_{50} value of field-collected population LC_{50} value of susceptible strain. RR values of <10, 10~40, 40~160 and >160 indicate low, moderate, high and very high resistance, respectively (Fukami *et al* 1983).

RESULTS

Baseline information on the susceptible strain against several classes of acaricides, upon which the RRs are based, is presented in Table 1. Fenpyroximate and abamectin were very effective on the female adults.

The results from azocyclotin is presented in Table 2. The Andong colony showed moderate resistance (RR=11.1). The other field-collected colonies had RRs<8, indicating low resistance to this standard organotin compound used for mite control

Toxicities of dicofol to the eight field colonies of *T urticae* are shown in Table 3 High and moderate resistance were observed in mites from Yeasan (RR=82.3) and Naju (RR=48.6), and Suwon (RR=19 4), Kimje (RR=20.6), Chungju (RR=38.5) and Andong (RR=38.3). However, the Yeongi colony was more susceptible to dicofol than the susceptible

Table 1. Toxicities of acaricides to the susceptible strain of *Tetranychus urticae*

Acaricide	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)
Azocyclotin	181	1.55 (0.33)	14.33 (4.73-24.09)
Dicofol	139	5.61 (0.83)	21 25 (18.66-23.23)
Fenpropathrin	108	3.03 (0.37)	16.65 (14.23-18.90)
Fenpyroximate	268	0.80 (0.23)	0.53 (0 02-1 48)
Propargite	118	2.40 (0.51)	50.21 (22.16-71.84)
Pyridaben	181	1.74 (0.21)	42.03 (33.30-50.53)
Abamectin	244	1.17 (0 83)	0.03 (0.02- 0.04)

Table 2. Toxicities of azocyclotin to the field-collected populations of *Tetranychus urticae*

Collection site	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)	RR[a]
Suwon	203	3.84 (0 42)	54.50 (48.24-60.51)	3.8
Yeasan	141	1.79 (0.31)	76.67 (62.23-93.23)	5 4
Naju	131	2.25 (0.28)	47.32 (36.31-58 14)	3 3
Yeongi	115	2.89 (0.46)	36.02 (27.39-43.48)	2.5
Kimje	121	1.73 (0.18)	110.84 (87 69-137 58)	7.7
Chungju	107	1.94 (0.24)	47.50 (34.92-59 99)	3.3
Andong	149	2.24 (0 35)	159 18 (115 53-194.48)	11.1
Kunwi	88	0.90 (0.16)	38.46 (25.58-57 10)	2.7

[a]Resistance ratio, LC_{50} value of field-collected strain/LC_{50} value of susceptible strain.

Table 3. Toxicities of dicofol to the field-collected populations of *Tetranychus urticae*

Collection site	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)	RR[a]
Suwon	299	1 68 (0.23)	411 66 (281 18-528.60)	19.4
Yeasan	144	2.74 (0.38)	1749.21 (1383.93-2055.21)	82 3
Naju	182	1.68 (0.18)	1033.55 (816.59-1288.22)	48.6
Yeongi	107	1.34 (0.17)	14.57 (10.51-19.10)	0.7
Kimje	122	1.58 (0.21)	437.18 (289.16-584.89)	20.6
Chungju	116	2.62 (0.33)	818.71 (715.19-951.22)	38 5
Andong	127	1.56 (0.18)	814 28 (620 39-1031 99)	38.3
Kunwi	122	1 05 (0.18)	64.20 (28.39-102.60)	3.0

[a]For explanation, see Table 2.

strain

Recently, resistance to pyrethroids released has been studied. With fenpropathrin, RRs for seven field-collected colonies except the Suwon colony ranged from 3.4- to 14.0-fold (Table 4), indicating low and moderate resistance. The Kunwi colony showed no signs of resistance to fenpropathrin

The results from fenpyroximate are presented in Table 5. Very high resistance was observed in the Yeasan colony (182.1). The two with RRs 80-160 (high resistance) were from Kimje and Andong. The remainder had RRs <30 Clearly, resistance to fenpyroximate is prevalent in the two-spotted spider mite.

In tests with propargite (Table 6), the Andong colony had RRs 39.4. Moderate resistance was observed in the Kimje colony. However, the Yeongi colony was more susceptible to propargite than the susceptible strain. No signs of resistance to propargite was obtained for the Kunwi colony The remainder showed low resistance.

Results from tests with pyridaben showed increasing levels of resistance (Table 7). High resistance

Table 4. Toxicities of fenpropathrin to the field-collected populations of *Tetranychus urticae*

Collection site	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)	RR
Suwon	173	1.79 (0.23)	22.64 (18.10-27.63)	1.4
Yeasan	91	1.21 (0.16)	151.15 (109.66-201.82)	9 1
Naju	99	1.80 (0.18)	56.73 (45.96-70.37)	3.4
Yeongi	95	0.83 (0.15)	233.55 (153.25-371.35)	14.0
Kimje	126	1.15 (0.16)	83.02 (61.27-120.11)	5.0
Chungju	107	2.06 (0.20)	147.71 (121.09-178.67)	8.9
Andong	105	1.43 (0.17)	125.79 (94.19-161.98)	7.6
Kunwi	108	1.82 (0.19)	34.99 (28.00-43.09)	2.1

Table 5. Toxicities of fenpyroximate to the field-collected populations of *Tetranychus urticae*

Collection site	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)	RR
Suwon	251	1 32 (0.20)	18 91 (13.32-24 12)	35.7
Yeasan	134	2.00 (0.35)	96 50 (62.08-140.10)	182.1
Naju	139	1.28 (0 18)	15.83 (9.97-21.89)	29.9
Yeongi	104	1.97 (0 23)	9.35 (7.21-11.58)	17.6
Kimje	107	0.98 (0.17)	47.10 (21.99-73.78)	88.9
Chungju	127	1 98 (0.20)	16 01 (12.96-19 49)	30.2
Andong	98	1.83 (0.22)	57.07 (46.72-69.63)	107.7
Kunwi	136	0.90 (0.20)	2.61 (0.31-6.27)	4.9

Table 6. Toxicities of propargite to the field-collected populations of *Tetranychus urticae*

Collection site	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)	RR
Suwon	383	0 76 (0.09)	14.11 (6.85-23.56)	0.3
Yeasan	81	0.90 (0.16)	327.27 (212.61-480.18)	6.5
Naju	125	1.08 (0.17)	142.49 (83.95-204.16)	2.8
Yeongi	100	1 90 (0 22)	156.18 (119.76-194 24)	3.1
Kimje	116	1.33 (0.20)	621.56 (440.22-791.16)	12.4
Chungju	98	2.85 (0.36)	537 65 (454.06-614 61)	10.7
Andong	131	1.29 (0 31)	1978 06 (1160.76-2606.06)	39.4
Kunwi	115	0.77 (0.10)	55.60 (30 84-85 38)	1.1

Table 7. Toxicities of pyridaben to the field-collected populations of *Tetranychus urticae*

Collection site	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)	RR
Suwon	241	1.43 (0.22)	290.14 (160.18-420.14)	6.9
Yeasan	113	2.74 (0.33)	3255.70 (2851.34-3722.78)	77 5
Naju	174	1 18 (0.18)	413.63 (282.43-751.54)	9.8
Yeongi	101	2.14 (0.26)	326.98 (264.79-427.79)	7.8
Kimje	141	2.36 (0 34)	2133.69 (1731.55-2495.65)	50 8
Chungju	98	1.13 (0.17)	456.30 (329.19-710.98)	10.9
Andong	99	1.04 (0.16)	402.19 (285.18-567.69)	9.6
Kunwi	92	1.60 (0.20)	251.65 (175.92-328.70)	6 0

Table 8. Toxicities of abamectin to the field-collected populations of *Tetranychus urticae*

Collection site	n	Slope (± SEM)	LC_{50}, ppm [AI] (95% FL)	RR
Yeasan	115	3.79 (0.41)	0.29 (0.25-0.33)	9.7
Naju	179	1.56 (0.33)	0.17 (0.09-0.22)	5.9
Yeongi	151	1.09 (0.18)	0.04 (0.02-0.06)	1.3
Kimje	138	2.63 (0.29)	0.30 (0.25-0.35)	10.3
Chungju	134	2.96 (0.27)	0.35 (0.31-0.39)	12.1
Andong	164	1.33 (0.20)	0.06 (0.03-0.09)	2.1
Kunwi	177	0.77 (0.14)	0.01 (0.002-0.025)	0.3

(RRs=40~160) was observed in the Yeasan and Kimje colonies. The remainder had RRs <10.

Toxicities of abamectin to the eight field colonies are presented in Table 8. Cross resistance was also detected. The Kunwi colony was more susceptible to abamectin than the susceptible strain The highest RR was 12.1 in the Chungju colony. The remainder had RRs <10, meaning low resistance.

DISCUSSION

A major objective of monitoring studies of the kind reported here is to determine if any information and patterns emerge from the data. In a laboratory study with eight field-collected populations of *T. urticae*, marked regional variations of acaricide susceptibility exist. Regional variations were not particular to any specific sites due to the extensive and repeated use of certain registered acaricides (approximately five times a year). These results indicate that resistance mechanism(s) with different genetic or biochemical nature might be involved in acaricide susceptibility. However, every field-collected mite studied was susceptible to one or more of the acaricides examined. Therefore, careful selection of an appropriate acaricide against any population of the two-spotted spider mite might result in satisfactory control.

Dicofol was introduced in about 1960 in Korea. Control failures by this compound in apples were reported as early as 1968 (Lee 1969). Since then, various acaricides or acaricide groups have been used to control *T. urticae* populations for over 20 yr. However, many of them have failed to provide adequate control of *T urticae* after 2~3 yr of use in the field (Anonymous 1992). In our study, development of resistance to various groups of acaricide is a serious problem. High resistance to dicofol, fenpyroximate, and pyridaben by the eight field populations was produced. Resistance to dicofol and fenpyroximate was widespread although the latter has been registered in Korea in 1992.

Because of their excellent acaricidal activity, no cross-resistance to other groups of acaricide, and relative nontoxicity to predators (Perugia *et al.* 1986, Croft *et al.* 1987), organotin compounds have been the most widely used acaricide in Korea although the use of cyhexatin has been prohibited since 1990 because of the hazard to human health (Anonymous 1989b). In the present study, only low to moderate resistance to azocyclotin was observed. Fortunately, this chemical is currently used widely for mite control in Korea. Similar results were also observed in fenpropathrin, propargite, and abamectin, in spite of their short-term use.

In conclusion, management of field populations of *T. urticae* of economic importance in apple orchards requires a properly timed and appropriate acaricide treatment as well

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REFERENCES

Ahn, Y. J., M. Kwon, J K Yoo & S J. Byun 1993. Toxicity of flufenoxuron alone and in mixture with alphacypermethrin or fenbutatin oxide to *Tetranychus* *urticae* and *Panonychus ulmi* (Acari: Tetranychidae). *J. Econ. Entomol* **86**: 1334-1338

Anonymous 1986. A List of Plant Diseases, Insect Pests, and Weeds in Korea. The Korean Society of Plant Protection, Suwon. Republic of Korea.

Anonymous 1989a. Ecology and control of insect pests of fruit trees. Agricultural Sciences Institute Rural Development Administration, Suwon, Republic of Korea

Anonymous 1989b Korea Official Gazette (April) No. 11,200.

Anonymous 1992. Factors affecting insecticidal activity, pp 236-245. Res. Rep Agricultural Chemicals Research Institute

Anonymous 1993a. Agrochemical year book. Korean Agricultural Chemicals Industrial Association, Seoul, Republic of Korea

Anonymous 1993b. Statistical Yearbook of Agriculture, Forestry & Fisheries, pp. 86-87. Ministry of Agriculture, Forestry & Fisheries, Republic of Korea

Croft, B. A., S. C. Hoyt & P. H Westigard 1987. Spider mite management on pome fruits, revised. organotin and acaricide resistance management *J Econ. Entomol.* **80**: 304-311.

Finney, D. J. 1971. Probit Analysis (3rd ed). Cambridge University Press, London.

Fukami, J., Y. Uesugi & K. Ishizuka. 1983. Pest Resistance to Pesticides. Soft Science, Inc.. Tokyo, Japan.

Lee, S. C 1969 Studies on chemical resistance of mites I. Resistance to parathion and kelthane of mites in Korea. Res. Rep 12: 91-94. Office of Rural Development, Republic of Korea

Lee. S .C. & J K Yoo. 1971. Studies on chemical resistance of mites II orchard mite control and their resistance to metasytox, folidol and C-8514 in Korea. *Korean J. Plant Prot.* **10**: 109-116.

Lee, S. C, W. Y. Kim & S. S Kim. 1986. Method comparison of chemical resistance level determination and field resistance of the two-spotted spider mite, *Tetranychus urticae* Koch to benzomate, cyhexatin and dicofol. *Korean J. Plant. Prot.* **25**: 133-138.

Lee, S. W. 1990. Studies on the pest status and integrated mite management in apple orchards. PhD Thesis. Seoul National University, Republic of Korea.

Perugia, G, C Ingelsfield & J. D Tipton. 1986. The evaluation of a novel acylurea (flufenoxuron) on top fruit and citrus in Italy. *In* Proceedings 1986 British Crop Protection Conference - Pests and Diseases 3C-13

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