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Studies on the Integrated Control of Citrus Pests I. Bionomics of Citrus Red Mite and Natural Enemies

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柑橘害虫의 綜合防除에 關한 研究 I. 귤응애의 生態와 天敵에 關하여

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ABSTRACT

Experiments were conducted to study the integrated control of one of the major pests of citrus, the citrus red mite, *Panonychus citri* (McGregor). Studies were conducted in Seogwipo, Cheju Island, 1973-1976.

Results obtained were;

1. The major peak of citrus red mite occurrence was mid-July to mid-August.
2. Standard field populations of citrus red mite were also high in September, October, and November.
3. A total of 10 species of natural enemies of citrus red mite were found. These included; *Oligota yasumatsui* Kistner, *Anystis baccarum* L., *Hemerobiid* sp., *Semidalis albate* E., *Orius* sp., *Agistemus terminalis* Q., 3 species of lady beetles (Coccinellidae), and one unidentified species of predacious mite.
4. Annual occurrence of citrus med mite tended to decrease in unsprayed fields, but increased in fields receiving standard treatments.
5. With fungicides, there was an increase in mite populations associated with use of Bordeaux mixture and copperpowder sprays. Streptomycin, however, did not effect on increase in mite numbers.

INTRODUCTION

Citrus production has increased rapidly in Korea in recent years. In 1965 there were only 551 ha of citrus, but there were 10,931 ha in 1975. Associated with this 20 fold increase in citrus production area are increasing problems with pests. Economic losses from various citrus pests range from 10—20%.

Citrus pests in Korea on Cheju Island include citrus leaf-miner, leaf-roller, fruit piercing-sucking moths, and an estimated 30 additional pest species. The most important pest is the citrus red mite, *Panonychus citri* (McGregor), which sucks chlorophyll and cellular liquids from leaves and fruit. Assimilation and nutrit-

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ion of trees is weakened by mite feeding, and with heavy infestations there is significant leaf drop. There are 8-13 geneations of citrus red mite in a year, with generation time dependent on environmental conditions. Length of generation period is 9.4 days at 25°C, and 8.4 days at 28°C.[10]

Norizumi (1966)[11] reported two peak times of red mite occurrence, June to early August, and from October to late December. The first population density during the highest peak season (late July to early August) is positively correlated with the mean temperature in May, and negatively correlated with the amount of rainfall in late Jene and not related with population densities before early July.

The second peak density occurrence (December) is positively correated with population densities after October, and negatively correlated with the amount of rainfall in October. There seems to be a negative correlation with the population densitiy during the peak season of first occurrence and the maximum temperature in early August.

With regard to control of mites, Jeppson and Seki M. report[14] the problem of chemical resistance is most formidable. In their trials, resistant mites were noted in previous tests after spraying Demeton 3-4 times, Neotran 11 times, and Aramite 9 times. Tanaka M. and Inoue A. reported[16] that mites could be completely destroyed by rainfall and winds(rainfall, 80mm; wind speed 8m/sec). Seki M. also reported[15] that fungicides such as Bordeaux mixture resulted in increased numbers of citrus red mites.

Biological control of citrus red mites is now recognized as one of the most effective control means. Beetles such as *Saula japonica* Gorham and *Stethorus japonicus* H. Kamiya are effective predators, and additional 16 species of insect and mite natural enemies are known to prey on citrus red mites.[12] Citrus red mite populations are in positive reciprocity with numbers of *Stethorus japonicus* and *Oligota fevicornis*, and negatively interrelated with populations of *Ambyseius largoensis*.[6] Up to now, several studies on citrus red mites ave been reported from other countries, but there have been few in Korea. The tests reported in this paper were conducted to determine population fluctuations of citrus red mites, and to ascertain the effects of fungicidal sprays in integrated control programmes from 1973 to 1976.

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MATERIALS AND METHODS

(Test I). Studies on populations fluctuations of citrus red mites and natural enemies in unsprayed and treated groves.

Two experimental groves (an unsprayed and a standard treatment field) at Seogwipo, Cheju Island, were used in this experiment. The unsprayed grove consisted of 265 trees, espacement 1.8x1.8m; and the standard treatment grove contained 265 trees with an espacement of 2.5x2.5m. All trees were mature or near mature, Satsuma mandarins on trifoliate rootstock. Age of trees was 12 years, with height varying from 1.5~2.0m. Counts were made by naked eye with aid of a handlens at weekly intervals. Sample size was 100 leaves selected at random.

(Test II). Populations fluctiations of citrus red mites in relation to fungicidal treatments.

These studies at Seogwipo, Cheju Island, in a field with mature trees on an espacement of 2.5x2.5m. Trees were twelve years old/Satsuma mandarins on trifoliate rootstock. Fungicides were sprayed at 9-10 day intervals from July to September. Counts were also made by naked eye with aid of a handlens, with three replicates for each of the fungicide treatments. The following standard fungicides were evaluated; copper powder (w.p.) at a 1:400x dilution, Bordeau mixture (50:50 lime; coppersulfate) 1000x, difolatan (w.p.) 900x, topsin(w.p.) 1500x, streptomycin(w.p.) 1000x with a control plot.

RESULTS

The actual numbers of citrus red mites per leaf for the years 1973, 1974, 1975, and 1976 for unsprayed and standard fields are plotted in Figures 1 and 2. Considering all years, the highest incidence of citrus red mites occurred in the one month period from mid-July to mid-August.

In the standard field receiving routine pesticide applications (Figure 1) the highest peak populations of mites occurred in 1976. The continued increase in actual mite populations is assumed due to resistance to pesticides employed, with the destruction of natural enemies. Although annual mite populations were highest in the July/August period; there were also significantly high mite populations in the months of September, October, and November with secondary peak populat-ions occurring in late season. Fruit (mad arins) are normally harvested in the Sogwipo area in October-November.

Mite populations in the unsprayed field were highest in the first year of this study, 1973 (Figure 2). In the second year of the study (1974), citrus red mite populations were nearly half the previous year. In direct contrast to the standard treatment grove, there were obvious and dramatic reductions in mite populations in subsequent years.

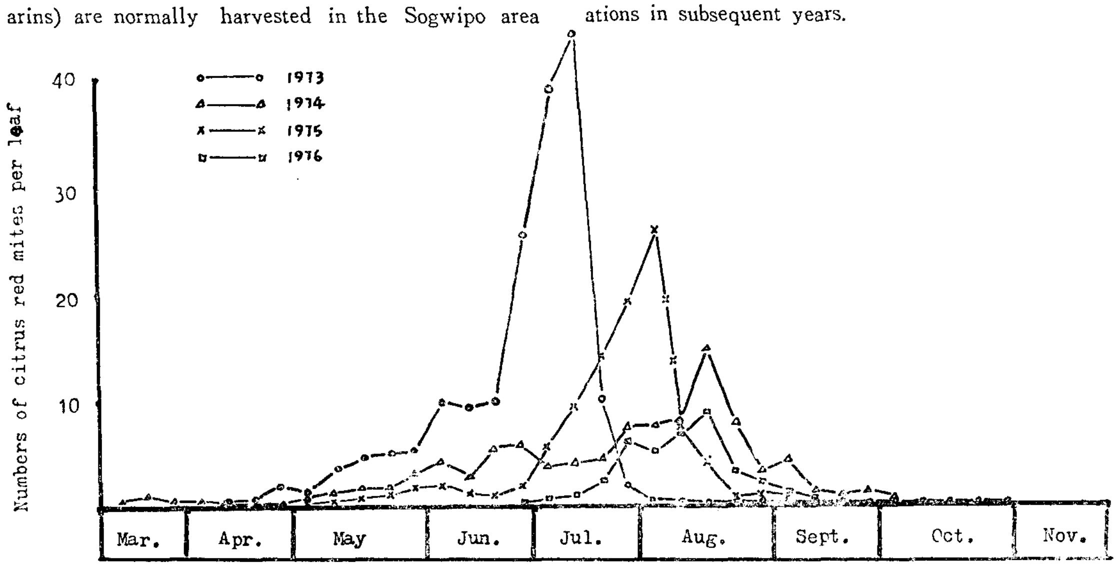

Fig. 1. Population fluctuation of *P. citri* at unsprayed field

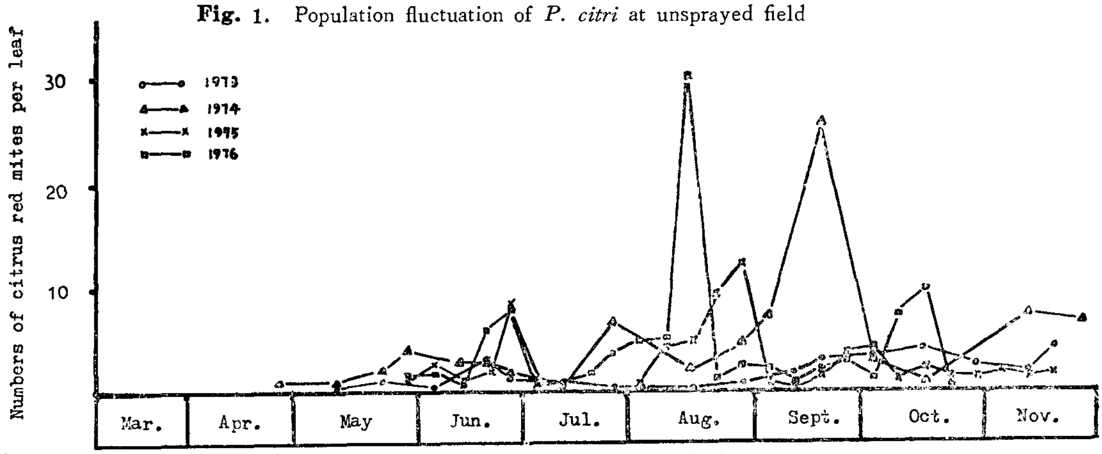

Fig. 2. Population fluctuation of *P. citri* at standard spray programme.

Citrus red mite and natural enemy populations in both the unsprayed and standard field are compared in Table 1. Counts were taken at weekly intervals for the months of June-September. The species of natural enemies included in these observations are listed in the summary. Populations of natural enemies in the standard sprayed field were virtually nil, a total of only 5 natural enemies for detailed reporting period. In direct contrast, a total of 119 natural enemies were observed in the unsprayed grove. The total number of citrus red mites for this period in 1976 was 7660, while the number of mites in the unsprayed field was 4,035.

A comparison of citrus red mite and natural enemy counts over the 4 year period from 1973-1976 is given in Table 2. Actual percent increases in citrus red mite populations over those in 1973 in the sprayed grove were; 1974, 333%; 1975, 254%; and 1976, 399 %. In the unsprayed grove, the following percent reductions in mite populations were; 1974, 42%; 1975, 44%; and 1976, 78%. Significant changes were also observed in the natural enemy populations, which are noted in Table 2. between the sprayed and unsprayed groves.

Table 1. Population fluctuation of *P. citri* and natural enemy in citrus field in Cheju Island (1976)

Citrus red mite and natural enemy \ Date		Jun.				Jul.				Aug.					Sept.				Total
		5	13	20	27	4	11	18	25	1	8	14	22	29	5	12	19	26	
U*	Citrus red mite	13	13	24	31	61	95	210	621	516	678	888	316	264	146	95	40	24	4, 035
	Natural enemy	0	0	0	0	2	3	2	5	7	28	32	4	9	9	7	9	2	119
S**	Citrus red mite	208	103	671	777	5	102	150	368	470	494	3137	94	248	207	176	194	256	7, 660
	Natural enemy	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	2	0	5

* U: Unsprayed field
** S: Standard sprayed field

Table 2. Occurring tendency of citrus red mite and natural enemy

Citrus red mite and natural enemy \ Year \ Treatment	Unsprayed field				Standard sprayed field			
	1973	1974	1975	1976	1973	1974	1975	1976
Citrus red mite (Number of Total counts)	18, 288	10, 538	10, 247	4, 103	1, 570	5, 233	3, 982	6, 267
Natural enemy (Number of Total counts)	89	252	205	124	9	0	16	9

The major species of natural enemies found in the unsprayed versus sprayed fields in the 1973-1976 period are given in Table 3. A total of 67 natural enemies were found in the unsprayed grove, versus only a total of 34 for the sprayed field, a 20 fold difference. Predaceous mite species were the most common, 42.6 %; followed by *Oligota yasumatsui*, 26%; and specie of coccinellid beetles, 19.4%. The more favorable populations of natural enemies, and the decreased mite populations, in the unsprayed versus sprayed groves were highly significant.

Table 3. Natural enemy occurrence in unsprayed and sprayed citrus groves Seogwipo, Chejudo

Natural Enemy Species \ Treatment \ Year	1973		1974		1975		1976		Total	
	U*	S**	U	S	U	S	U	S	U	S
Predaceous mites	0	0	161	0	103	4	29	4	293	8
Oligota yasumatsui	89	9	24	0	44	6	8	4	165	19
Coccinellidae	0	0	56	0	58	6	16	1	130	7
Green lacewing	0	0	2	0	0	0	73	0	75	0
Orius sp.	0	0	9	0	0	0	0	0	9	0
	89	9	252	0	205	16	126	9	672	34
									Grand total	706

* Unsprayed grove
** Sprayed grove

In addition to the affects of insecticides on citrus red mite and natural enemy populations in standard treatment and unsprayed groves, the principal fungicides used on citrus were evaluated. A series of five fungicides were compared with a control (untreated fungicide check). Highly significant results were obtained indicating fungicide applications can influence the levels of citrus red mite populations. Mite populations on trees treated with Bordeaux, copper, or difolatan fungicides were signif-icantly higher than treatments with topsin, streptomycin, or the untreated control. Numbers of mties in the streptomycin and control treatments were lowest (Table 4).

Of further significance was the trend for decreasing

Table 4. Selective Fungicide Trials and Mite Populations on Citrus, Seogwipo, 1975

Rep. / Treatment	Date of Sampling, No.of Mites 7/10	7/16	7/23	7/30	8/8	8/14	8/21	Total	Mean*	
Bordeaux	252	924	752	656	540	851	164	4, 139	591.28	a
Copper	226	649	812	1024	440	473	110	3, 734	533, 42	ab
Difolatan	150	565	589	674	355	1967	3	3, 403	486.14	abc
Topsin	131	552	438	301	400	179	0	2, 001	285.85	cd
Streptomycin	221	546	289	277	40	34	1	1, 408	201.14	d
Control	218	547	366	135	105	8	0	1, 379	197.00	d
Total	1, 198	3, 783	3, 246	3, 607	1, 880	1, 880	278	16, 064		

*Any two means not followed by the same letter significantly different at the 5% level as analyzed by Duncan's Multiple Range Test (Duncan, 1955).

of mite populations in late August, but with Bordeaux and copper fungicide treatments, populations were still extremely high (Table 5). Populations of mites in the three other fungicide treatments were either nil or not significant at this time, indicating Bordeaux and copper treatments were continuing to foster and support relatively high mite populations.

To control unusually high mite populations on citrus on Chju, the usage of dormant oils was initiated in 1974, and was employed extensively in the 1975 season (December-February). These trials are the subject of a forthcoming paper in which experiments with superior oils during the main growing season are included.

DISCUSSION

The results of our integrated control programme develonment in Korea are similar to those obtained in Japan. It requirs approximately four years to develop populations of natural enemies in untreated groves or orchards where selective pesticides and treatments are employed to combat major citrus pests(Nohara, 1976).

With principal pests such as citrus red mites, population increases in standard treatment groves are attributed even with increased number of spray treatments-to development of acaricide resistance and reduction of natural enemies(Nakao *et al.*, 1972). Jeppson (1958) and Seki, M. (1961) maintain the problem of chemical resistance is a major factor where repeated and excessive pesticide applications are employed. In citrus groves on Cheju, some of the standard treatment groves received as many as 6-10 applications per season. With these high levels of acaricide application, mite populations continued to increase at an alarming rate. It is for this reason was directed to the bionomics of citrus red mite, and the possibility of using natural enemies in an integrated control programme.

The main population density of citrus red mites occurs in July to August, and is in positive correlation with the mean temperature in May, and negatively correlated with the amount of rainfall in June. Minor secondary peaks in the fall or winter season are again influenced by rainfall and temperature, and also the fact farmers are picking citrus in early fall and do not spray. It is acknowledged populations of sucking pests, including mites, are favored by high temperatures; and discouraged by rainfall and periods of relatively higher humidity. Tanaka, M. and Inoue, A. (1962) reported mite populations could be completely destroyed by rainfall of 80mm and a wind speed of 8m/sec. In Japan when mites reach high levels, and to aviod acaricidal sprays in integrated control blocks, high pressure water sprays are effective. In such applications, the spray nozzles are removed and trees are treated with water at apressure of 14 torricelli (Nakao et al., 1972). Natural enemy popul ations on water-sprayed trees were not as high as those on untreated trees, but higher than on acaricide-treated trees.

High populations of citrus red mites on trees treated with Bordeaux funicide were previously reported by Seki, M. (1968). In our trials, copper and Bordeaux fungicide sprays were also found to foster and maintain higher mite populations than streptomycin or topsin, or the untreated check. These findings indicate the total treatment program of citrus, including fungicide applications, influence pest and natural enemy populations.

Experiments on the integrated control of citrus red mite and other major citrus pests in Japan are summarized by Yasumatsu (1974). Studies have been in progress in Japan since 1953 on the the possibility of using integrated control for all major citrus pests. It is possible to produce citrus at commercial levels without any pesticide application whatsoever, relying completely on natural biological control. Cost benefit analyses indicate higher returns are obtained from these groves than ones in which standard or modified spray schedules are employed. Although yields in untreated groves were not as high in some instances as those of modified treatment groves, they surpassed standard treatment groves where conventional pesticides and schedules were employed (Yasumatsu, 1969). The number of pesticide applications, including fungicides, were restricted to as low as 3-4 applications per year, with emphasis on specific pesticides and machine oil applications (Yasumatsu, 1966). The majority of control programs on Cheju are now using 7-14 pesticide sprays a year.

Studies will be continued on the biological and integrated control of citrus red mite and other major pests of citrus on Cheju. The success of this approach elsewhere, and progress to date, indicate significant gains can also be expected in Korea. Emphasis will be placed on bionomics of principal pest and natural enemy species, selection of specific pesticides—including fungicides not conductive for build up of mite populations, proper timing of applications, high water pressure spraying, and the use of dormant and/or summer oil sprays. Untreated blocks will also be encouraged to allow for buildup of predators and natural enemies.

적 요

감귤해충 종합방제 확립을 위한 기초자료를 얻고저 제주도 서귀포에서 1973~1976년까지 4년간 실시한 결과 다음과 같은 결과를 얻었다.

1. 귤응애는 7월 중순에서 8월 중순 사이에 1회의 큰 peak를 나타냈다.
2. 한편 관행살포구에서는 7,8월뿐 아니라 9~11월에도 높은 밀도를 나타냈다.
3. 귤응애의 천적으로 *Oligota yasumatsui* K., *Anysits baccarum* L., *Hemerobiid* sp. *Semidalis albate* E., *Orius* sp., *Agistemus terminalis* Q., 무당벌레류 3종 포식응애 1종등 10종이 발견되었다.
4. 귤응애의 년도별 발생경향을 보며 무살포구에서는 매년 감소하는 경향이고 관행살포구에서는 계속 증가하는 경향이었다.
5. 살균제로서 석회볼드액과 동수화제 처리구는 귤응애밀도가 높았으나 항생제인 Streptomycin은 낮은 밀도 였다.

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