# An Investigation of the Control of Two-Spotted Spider Mites (Tetranychus urticae Koch) Resistant to Organo-Phosphates[1]

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## INTRODUCTION

The damage caused by the two-spotted spider mite, Tetranychus urticae Koch, compared with that inflicted by other plant parasites, has been minor importance, whenever proven insecticids such as organophosphorus (O/P) compounds have been used.

Recently, however, this spider mite has become most difficult to control and has developed to be a major pest in horticlture and agriculture (13, 17, 20). Price et al(19) reported the species as the most serious pest with which florsts have to control- and many orchardists and ornamentalists suffer loseses to their crops due to defoliation, reduced tree vigor, poor fruit colour, or small fruit. This situation is primarily due to the development of resistance to acaricides in mite populations.

Each year the problem becomes more severe with an increase in the number of chemicals, to which the species develop resistance. Thus combating the spider mites on economic field crops in the world has proved to be a difficult task in recent years.

The main aim of the present research was to investigate methods for the control of organo-phosphate resistant populantions of two-spotted spider mites.

## MATERIAIS AND METHODS

1. Strains and maintenance of Two-spotted Spider Mites: The following strains of Tetranychus urticae were used in these tests.

Lincoln Normal (LN) : One strain with no history of spray application was collected from beans, growing at Lincoln college.

German Normal (GN) and German Resistant (GR) : Two strains were imported from Germany in 1965 (3).

Timaru Resistant (TR) : From black currants and strawberries in commercial garden at Timaru, South Island. This population had regulary been sprayed with Phosdrin, Methyl demeton and Rogor during the past six years.

Havelock North Resistant (HNR) : From Havelock North off strawberries. This strain had regularly.

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been sprayed with TEPP, Rogor and Methyl demeton during the previous five years.

These five strains were maintained in a glasshouse and reared on trays of bush beans, phaseolus vulgaris. The glasshouse was maintained at temperatures ranging from 25°C to 32°C and relative humidity between 60-80%. Each strain was isolated in the glass house by water barriers. Fresh mite-free plants were added at intervals of 2 weeks or earlier if required to strains so that strong colonies were always available.

2. Acaricidal materials : The acaricides which were used in this work are listed in Table 1.

Table 1. Acaricides used in the Investigations of Resistance in Two-spotted Spider Mites.

| Material | Chemical Name | Type | % Content of a. i. | Croup | Alternative Name |
|---|---|---|---|---|---|
| Parathion E. C. | 0, 0-biethyl-0-4-nitrophenyl phosphorothioate | Technical emulsifiable concentrate | 98.5 | Organo-Phosphate | Folidol, E 605 |
| Methyl demeton E. C. | 0, 0-dimethyl-s-2-(ethylthio) ethylphosphorothioate | Formulated emulsifiable concentrate | 30.0 | -do- | |
| Phosdrin E. C. | 0, 0-dimethyl-0-2-methoxy carbonyl-1-methylvinyl phosphate | -do- | 61.8 | -do- | Mevinphos |
| UC 20047A W. P. | 3-chloro-6-cyano-2-norbornanone 0-(methylcarbamoyl)oxime | Formulated wettable powder | 50.0 | Carbamate | Tranid |
| RS 143 W. P. | 3-methyl-4-dimethyl-aminopheyl-N-methyl carbamate 30% N- (2-methyl-4-chlorophenyl) -N1, N1-dimethyl formamidime 60% | -do- | 90.0 | Carbamate and organo-chlorine | |
| Spidex W. P. | 4-chlorophenyl21, 41, 51-trichloro-phenyl azosulphide 25% 1.1-bis (4-chlorophenyl) ethananol 25% | -do- | 50.0 | Organo-chlorine | |
| Kelthane E. C. | 1, 1-bis (4-chloro-phenyl) -2, 2, 2-trichloroethanol | Formulated emulsifiable concentrate | 40.7 | Organo-chlorine | Dicofol |
| C 8514 E. C. | N-(2-methyl-4-chlorophenyl) N1, N1-dimethylformadine | -do- | 50.0 | -do- | Galecron |
| UC 19786 W. P. | 2-sec-butyl-4. 6-dinitrophenyl isopropylcarbonate | Formulad wettable powder | 50.0 | Nitrophenyl | Dessin, Dinobuton |
| Morocide W. P. | 2-sec-butyl-4. 6-dinitrophenyl 3, 3-dimethylacrylate | -do- | 50.0 | -do- | Hoechst 2784, Binapacryl, Acricid |
| Eradex W. P. | Quinoxaline-2, 3-trithiocarbonate | -do- | 50.0 | Cyclic carbonate | Thioquinox. Bayer 4935 |
| Morestan W. P. | 6-methyl-quinoxaline-2, 3-dithiolcarbonate | -do- | 25.0 | -do- | Bayer 4964 |
| C 8677 W. P. | Not available for chemical name | -do- | 50.0 | | |
| C 9140 W.P | -do- | -do- | 50.0 | | |
| M 2527 W.P | -do- | -do- | 50.0 | | Dowco 213 |

3. Toxicological testing techniques :

The toxicological test techniques used in the present experiments were the topical application (10). and the slide dip technique (5, 21) in order to establish the degree of resistance ; the spray gun for spraying to screen alternative acaricides for contace action plus stomach effect ; and the settling towet (18) for producing residues of the same materialsr The percent mortality results obtained from thes. tests were adjusted for natural mortality by Abbott's method (1). Finneys, probit analysis (8) was used to calculate regression lines the LD50s, LC50s and their 95% confidence limits.

4. Experimental procedure of field trials:

For field evaluation of promising acaricides derivep from laboratory screening tests, an area of abou two acres of black currants was available.

The history of miticide applicaton in this fielt showed that mite populations had built up in spite of all of the repeated, regular applications during the previous 6 years of Phosdrin, Rogor or Methye demeton, all of which are O/P compounds. Laborlatory tests proved that the population was resistant to O/Ps.

Field trials were conducted with the four concentrations of the two materials which were found to be most effective among the eleven materials against O/P resistant T. urticae, according to the screening trials.

In this study the fieled trial was plannad in detail after a pilot sampling. In two separate pilot experiments, four replicates, each of 20 and 30 leaves, respectively, were examined. To estimate the optimum number of samples required, the population variance and the percent standard error of the mean (14) were utilized in this study. A randomized block design was used in the trial. Three replicates of each treatment and three control plots were randomized throughout the area.

Thirty leaves of samples per plot (5.7% S E $\bar{X}$) were first made before spraying, then at six day intervals, until complete waning of acaricidal activity. The number of live mites per leaf picked at each fifth leaf from each leader top, was examined in the laboratory with a stereo-microscpe, and total number of each plot was estimated. In calculating population density of field trial mites, the formula used was.

$$\% \text{ mortality} = 100 - \frac{\text{No. of live mites in treated plot}}{\text{No. of live mites in control plot}} \times 100$$

## RESULTS

The experimental results are presented in three major sections;

1. Determination of the Resistance Levels to Organophosphates of several Strains

The results were obtained by the topical application and slide dip techniques. The topical application technique was used to investigate levels of resistance to Parathion. In this technique, very large

Table 2. Summary of the Dosage-Mortality Response of the LN, GN, GR, TR, and HNR strains of T. urticae to Parathion as indicated by the Topical Application Test

| Strain | LD50 in mg/g of mite | 95% confidencelimits | Slope (b) | | Comparison with GN | Comparison with LN |
|---|---|---|---|---|---|---|
| GN | 0.021 | +0.008<br>−0.006 | 2.16 | 1.30 | — | — |
| LN | 0.022 | +0.007<br>−0.006 | 2.59 | 3.05 | 1.1 | — |
| HNR | 9.485 | +3.315<br>−2.450 | 2.03 | 0.57 | 451.7 | 431.1 |
| TR | 10.167 | +4.873<br>−3.297 | 2.23 | 0.90 | 484.1 | 462.1 |
| GR | 21.740 | +5.200<br>−4.200 | 2.90 | 1.96 | 1035.2 | 988.2 |

and very small adult female mites were not included in the tests, in order to eliminate major variations in dose applied per unit mass of mite. The mites were weighed and averaged approximately 23 ug. The 0.0005mm³ of solution was applied per mite. The results are given in Table 2 and Figure 1.

In the slide dip technique, 30 adult females of uniform size were used for each treatment. The LC 50 values were calculated on the basis of percent active ingredient. Results are given in Table 3 and Figure 2.

Table 3. Summary of the Concentration-Mortality Response of the GN, GR, TR and HNR strains of T. urticae to Phosdrin as indicated by the Slide Dip Test.

| Strain | LC50 in % active ingredient | 95% confidence limits | Slope (b) | $X^2$ | comparison with GN |
|---|---|---|---|---|---|
| GN | 0.00008 | +0.000040<br>−0.000031 | 1.92 | 2.63 | — |
| HNR | 0.02130 | +0.00758<br>−0.00558 | 1.74 | 0.69 | 266.3 |
| TR | 0.02188 | +0.00938<br>−0.00618 | 1.69 | 0.95 | 273.8 |
| GR | 0.05082 | +0.00752<br>−0.00656 | 1.92 | 0.58 | 635.0 |

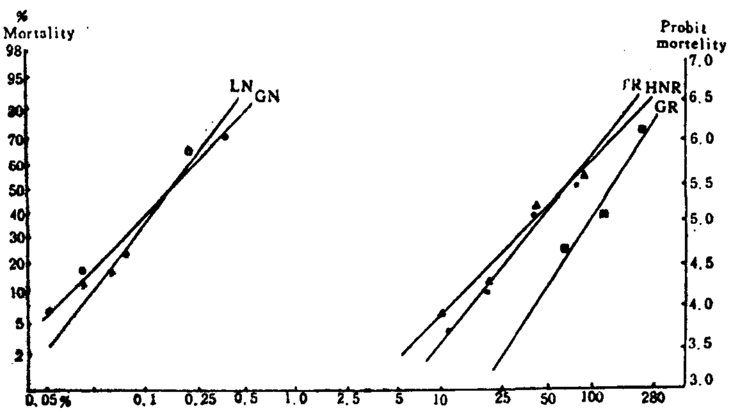



Fig. 1. Toxicity of Parathion to Several Strains of T. urticae as Indicated by Topical Application Test

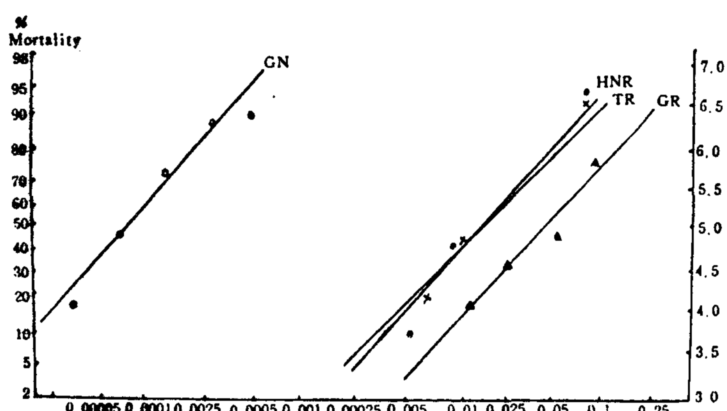



Fig. 2. Toxicity of Phosdrin to Several Strains of T. urticae as Indicated by Slide Dip Test

2. Laboratory testing of the formulated acaricides against a resistant strain.

Eleven chemical formulations in the laboratory for their contact plus stomach toxicity and their residual effect against the GR strain. These materials were 3 organo-chlorines, 2nitrophenyls, 2 cyclic carbonates. 1 carbamate, 1 mixture of a carbamate and an organo-chlorine, 3 compounds undefined as yet chemically. At least 3 and usually 4 concenırtaions of each of the acaricides used were tested for each concentration-mortality curve. The Table 4 gives the LC50 and LC95 levels and the 95% confidence limits together with the slope of the regression lines.

Table 4. Summary of the results of analyses of the data giving toxicities of eleven acaricides at the LC50 and LC95 to the GR strain of T. urticae.

| Acaricide | LC50 in % active ingredient | 95% confidence limits | LC95 in % active ingredient | 95% confidence limits | Slope (b) |
|---|---|---|---|---|---|
| UC 20047A | 0.0406 | +0.0011<br>−0.0011 | 0.2143 | +0.0289<br>−0.0251 | 2.28 |
| UC 19786 | 0.0327 | +0.0017<br>−0.0016 | 0.0942 | +0.0132<br>−0.0116 | 3.52 |
| C 8514 | 0.0208 | +0.0047<br>−0.0039 | 0.0724 | +0.0045<br>−0.0043 | 3.04 |
| Eradex | 0.0287 | +0.0028<br>−0.0026 | 0.1303 | +0.0027<br>−0.0027 | 2.50 |
| Morocide | 0.0094 | +0.0032<br>−0.0006 | 0.0209 | +0.0020<br>−0.0013 | 4.72 |
| Morestan | 0.0193 | +0.0007<br>−0.0007 | 0.0718 | +0.0089<br>−0.0080 | 2.28 |
| Spidex | 0.0101 | +0.0001<br>−0.0001 | 0.0290 | +0.0029<br>−0.0031 | 3.30 |
| Kelthane | 0.0083 | +0.0049<br>−0.0044 | 0.0188 | +0.0012<br>−0.0012 | 4.62 |
| C 8677 | 0.0222 | +0.0006<br>−0.0006 | 0.0736 | +0.0143<br>−0.0093 | 3.10 |
| M 2527 | 0.0100 | +0.0011<br>−0.0011 | 0.0367 | +0.0054<br>−0.0046 | 2.90 |
| RS 143 | 0.0233 | +0.0020<br>−0.0018 | 0.0724 | +0.0090<br>−0.0080 | 3.34 |

Figures 3 and 4 show the probit mortalitylog concentration regression lines of all the acaricides.

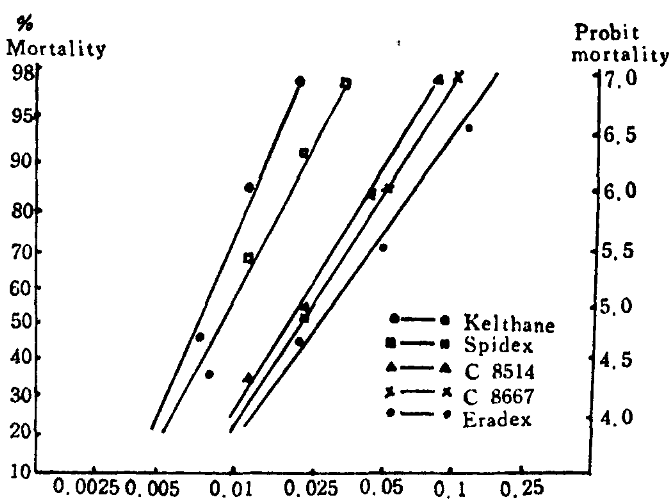



Fig. 3. Toxicity of Formulated Acaricides to an Organo-Phosphate Resistant Strain of T. urticae

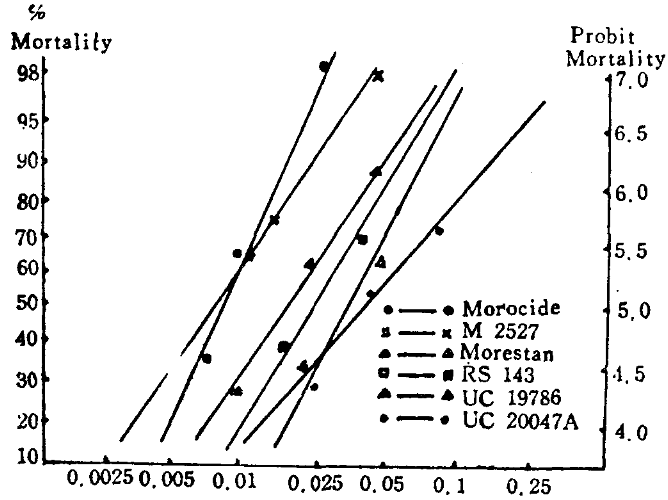
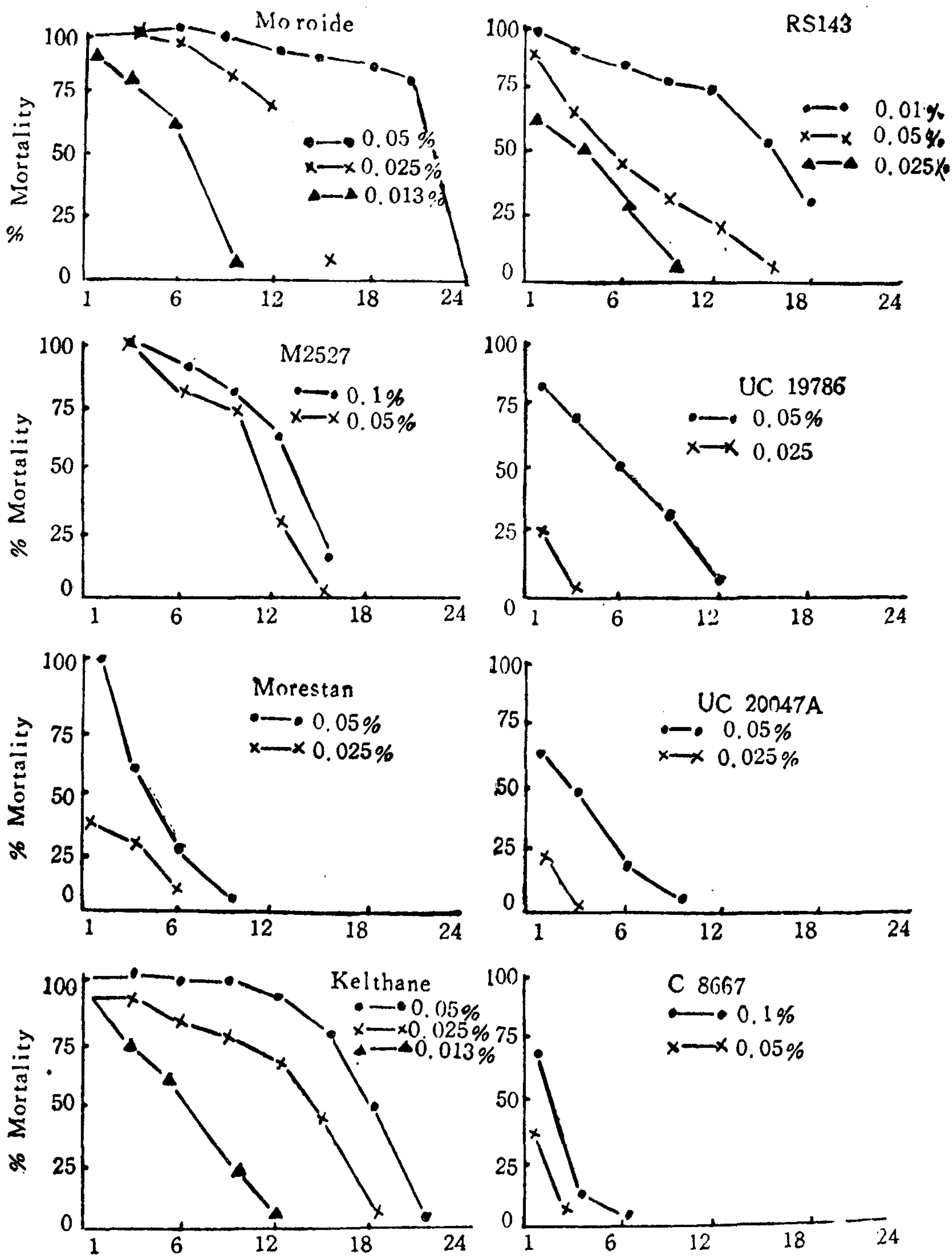



Fig. 4 Toxicity of Formulated Acaricides to an Organo-Phosphate Kesistant Strain of T. urticae

The residual life of acaricdes on bean leaves was obtained by recording the mortality at intervals until waning. The results are given in Table 5 and Figure 5. Figure 5 shows the residual life of acaricides on bean leaves as indicated by mortality of the GR strain.

Table 5. Duration of toxicity of 11 chemical formulations to the resistant strain (GR) of T. urticae.

| Acaricide | % Conc. a. i. | No. of mites tested | Mortality of acaricidal life in days (adjusted for natural mortality) 1 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UC 20047A | 0.05 | 40 | 61 | 45 | 16 | 12 | 0 | | | | | |
| | 0.025 | 40 | 25 | 4 | 0 | | | | | | | |
| UC 19786 | 0.05 | 40 | 78 | 71 | 56 | 37 | 15 | 0 | | | | |
| | 0.25 | 40 | 27 | 7 | 0 | | | | | | | |
| C 8514 | 0.05 | 40 | 91 | 53 | 16 | 2 | 0 | | | | | |
| | 0.025 | 40 | 29 | 14 | 7 | 0 | | | | | | |
| Eradex | 0.05 | 40 | 78 | 63 | 48 | 23 | 4 | 0 | | | | |
| | 0.025 | 40 | 18 | 6 | 0 | | | | | | | |
| Morocide | 0.05 | 40 | 100 | 100 | 100 | 100 | 100 | 98 | 92 | 84 | 14 | 0 |
| | 0.025 | 40 | 100 | 100 | 94 | 84 | 71 | 4 | 0 | | | |
| | 0.013 | 40 | 94 | 88 | 59 | 8 | 4 | 0 | | | | |
| Spidex | 0.05 | 40 | 100 | 100 | 100 | 100 | 87 | 73 | 47 | 14 | 0 | |
| | 0.025 | 40 | 100 | 79 | 49 | 36 | 23 | 2 | 0 | | | |
| | 0.013 | 40 | 96 | 72 | 37 | 10 | 0 | | | | | |
| Kelthane | 0.05 | 40 | 100 | 100 | 100 | 100 | 98 | 75 | 53 | 2 | 0 | |
| | 0.025 | 40 | 100 | 96 | 90 | 80 | 62 | 44 | 2 | 0 | | |
| | 0.013 | 40 | 100 | 82 | 67 | 30 | 2 | 0 | | | | |
| RS143 | 0.1 | 40 | 100 | 96 | 90 | 82 | 79 | 56 | 27 | 8 | 0 | |
| | 0.05 | 40 | 94 | 66 | 45 | 29 | 16 | 2 | 0 | | | |
| | 0.025 | 40 | 63 | 57 | 25 | 0 | | | | | | |
| C 8677 | 0.1 | 40 | 68 | 12 | 6 | 0 | | | | | | |
| | 0.05 | 40 | 46 | 2 | 0 | | | | | | | |
| M 2527 | 0.1 | 40 | 100 | 100 | 91 | 88 | 65 | 14 | 0 | | | |
| | 0.05 | 40 | 100 | 100 | 79 | 71 | 35 | 6 | 0 | | | |
| Morestan | 0.05 | 40 | 94 | 57 | 23 | 6 | 0 | | | | | |
| | 0.025 | 40 | 38 | 25 | 4 | 0 | | | | | | |


Moroide
% Mortality
100
75
50
25
0
1
6
12
18
24
0.05 %
0.025 %
0.013 %
RS143
0.01 %
0.05 %
0.025 %
M2527
0.1 %
0.05 %
UC 19786
0.05 %
0.025
Morestan
0.05 %
0.025 %
UC 20047A
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Kelthane
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C 8667
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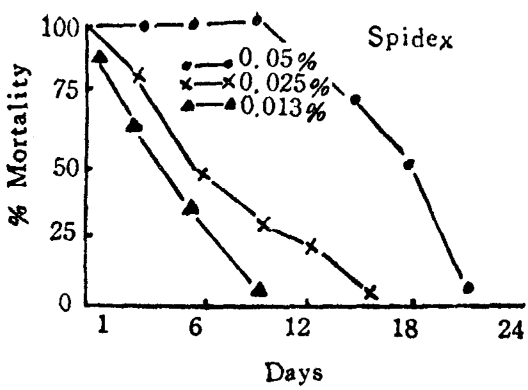
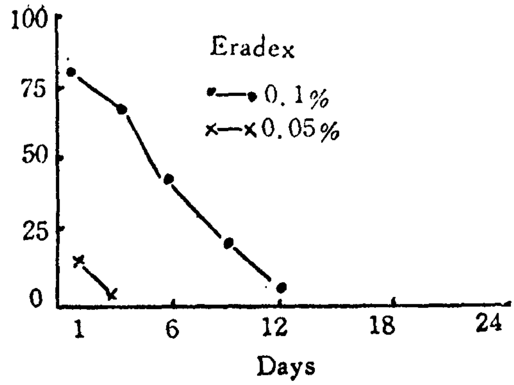
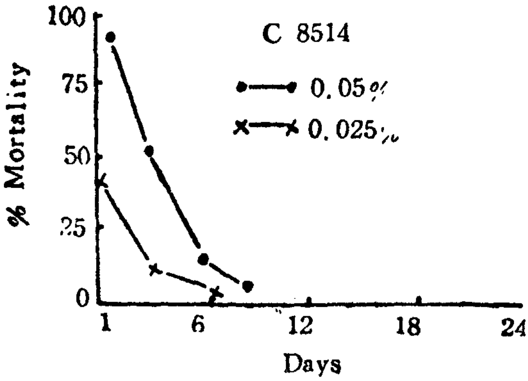
0.05 %




3. Field trials with Kelthane and Morocide

Kelthane and Morocide were chosen for field evafuation because they were found to be the most eflectve against the O/P resistant population (GR strain) of T. urticae according to the laboratory testing summarised in Table 4. They were also selected for sevaral other reasons: (1) They are not related chemically toO/Ps (2) Their potential use against O/P resistant Mites was determined under semi-field conditions (Table 4); (3;) The residual effect of morocide was comparable with andeven longer than Kelthane (Table 5). The two concentratons of each mterial were chosen on the basis of the mortality results of previous trials (Table 4).

The pilot sampling trial referred to above for estimating the optimal sample number was undertaken and data analyzed by LeRoux and Reimer's formula (14). Table 6 shows the size of the sample units, the means, the range in populaton the size coefficient ofvariations, % standard errors for the counts and the projected number of sa mples for 5%, 10% and 20% standard error of the mean respectively. From these results it was decided to use sample of 30 leaves per replicate (as already indicated in methods). This gave a 5.7% standard error.

The results of field evaluation with Kelthane and Morocide are prasented in Table 7. Figure 6 shows the persistence and efficiency of Kelthane and Morocide to O/P resistant population of T. urticae in the field.

Table 6. Results of preliminary Sampling plans for Acaricide Field Evaluation to estimate the Optimal Sample Number

| Experiment | Reps. | No. of sample units (leaves) | X (mites) | Range | CVn | SEX | SEX | projected No. of sample for SEX | SEX | SEX |
|---|---|---|---|---|---|---|---|---|---|---|
| I | 1 | 20 | 23 | 11-32 | 33.4 | 1.7 | 7.5 | 45 | 10 | 3 |
| | 2 | 20 | 26 | 12-47 | 32.3 | 1.9 | 7.2 | 42 | 10 | 3 |
| | 3 | 20 | 18 | 8-36 | 34.6 | 1.5 | 8.2 | 69 | 12 | 3 |
| | 4 | 20 | 21 | 12-31 | 29.2 | 1.3 | 6.5 | 34 | 9 | 2 |
| | Av. | 20 | 22 | 11-37 | 32.4 | 1.6 | 7.4 | 48 | 10 | 3 |
| II | 1 | 30 | 24 | 16-49 | 30.2 | 1.9 | 5.5 | 36 | 9 | 2 |
| | 2 | 30 | 22 | 9-35 | 32.2 | 1.3 | 6.0 | 42 | 10 | 3 |
| | 3 | 30 | 19 | 8-31 | 33.6 | 1.2 | 6.1 | 45 | 11 | 3 |
| | 4 | 30 | 20 | 10-33 | 27.6 | 0.6 | 3.2 | 30 | 8 | 2 |
| | AV. | 30 | 24 | 11-37 | 31.0 | 1.3 | 5.2 | 38 | 9 | 2 |

Table 7. Control of Organo-phosphate Resistant Strain of T. urticae on the Black Currants with Kelthane and Morocide.

| Acaricide | Conc. a. i. | Reps. | No. of Mites of 30 Leaves | Density | Post-treatment pooulation changes 6 days No. of Mites | 6 days % Density | 12 days No. of Mites | 12 days % Density | 18 days No. of Mites | 18 days % Density | 24 days No. of Mites | 24 days % Density |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kelthane | 0.04 | 1 | 1017 | 100 | 4 | 0.4 | 54 | 5.3 | 498 | 49.0 | 1057 | 103.9 |
| | | 2 | 1141 | 100 | 11 | 1.0 | 103 | 9.0 | 616 | 54.0 | 1278 | 112.0 |
| | | 3 | 795 | 100 | 32 | 4.0 | 95 | 12.0 | 469 | 59.0 | 856 | 107.7 |
| | | X̄ | 984 | 100 | 16 | 1.8 | 84 | 8.3 | 527 | 54.0 | 1063 | 107.9 |
| | 0.02 | 1 | 824 | 100 | 82 | 10.0 | 255 | 31.0 | 651 | 79.0 | 1302 | 158.0 |
| | | 2 | 1026 | 100 | 50 | 5.0 | 277 | 27.0 | 851 | 82.9 | 1503 | 147.0 |
| | | 3 | 625 | 100 | 75 | 12.0 | 212 | 33.9 | 544 | 87.0 | 868 | 138.9 |
| | | X̄ | 824 | 100 | 69 | 9.0 | 248 | 30.6 | 682 | 83.0 | 1226 | 148.0 |
| Morocide | 0.05 | 1 | 675 | 100 | 8 | 1.2 | 27 | 4.0 | 284 | 42.1 | 658 | 97.5 |
| | | 2 | 876 | 100 | 20 | 2.3 | 59 | 6.7 | 393 | 45.1 | 832 | 95.0 |
| | | 3 | 756 | 100 | 33 | 4.3 | 54 | 7.1 | 366 | 47.8 | 842 | 110.0 |
| | | X̄ | 772 | 100 | 20 | 2.0 | 46 | 5.9 | 347 | 45.0 | 777 | 100.8 |
| | 0.025 | 1 | 714 | 100 | 71 | 9.9 | 264 | 37.0 | 565 | 79.1 | 828 | 116.0 |
| | | 2 | 1041 | 100 | 125 | 12.0 | 427 | 41.0 | 854 | 82.0 | 1400 | 134.5 |
| | | 3 | 664 | 100 | 93 | 14.0 | 279 | 42.0 | 558 | 84.0 | 823 | 124.6 |
| | | X̄ | 804 | 100 | 96 | 12.0 | 323 | 40.0 | 659 | 81.7 | 1017 | 125.0 |
| Check | — | 1 | 683 | 100 | 895 | 131.0 | 943 | 138.1 | 1557 | 228.0 | 1639 | 140.0 |
| | | 2 | 964 | 100 | 1320 | 136.0 | 1446 | 150.0 | 2024 | 210.0 | 2468 | 256.0 |
| | | 3 | 748 | 100 | 1092 | 146.0 | 1181 | 157.9 | 1646 | 220.1 | 2057 | 275.0 |
| | | X̄ | 798 | 100 | 1102 | 138.0 | 1190 | 148.7 | 1742 | 219.4 | 2054 | 257.0 |

## DISCUSSION

1. The Determination of Resistant Levels of Toxicity of O/Ps of Several Strains

The levels of resistance of several populations of the two-spotted spider mite to O/P insecticides are clearly indicated from results of the topical application and the slide dip tests. For all strains the slope values were higher for the topical application than the slide dip technique. The latter technique might be more difficult to standardize as it is not so precise as the former and there is possibly variation in the distribution of solution on the slides.

In the use of topical application techniquea double application technique, i. e. applying two drops to each individual mite, was necessary in the resistant strain tests with Parathion(100% active ingredient). It was considered that if a higher mortality than that obtained by 2 drops was desired the results of using more than 2 drops would introduce errors of such magnitude as the make the effort unwarranted Busvine (4) has pointed out that for resistant populations which require high concentrations of topically applied doses, the regression line is frequently much flatter than similar lines for susceptible

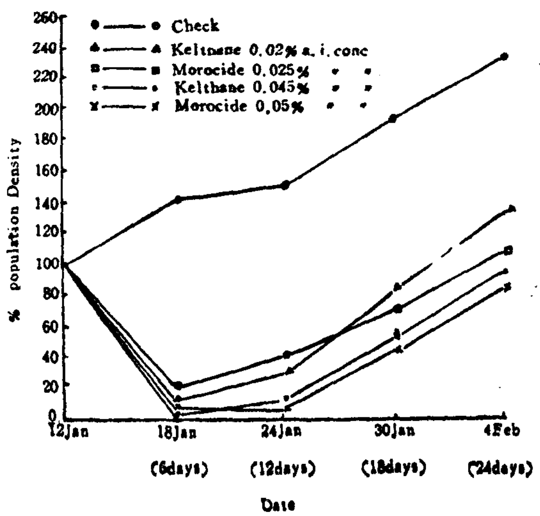



Fig. 6. population Changes in Field Trials with Kelthane and Morocide for Control Organo-phosphate Resistant Timaru Strain of T. urticae.

populations due to a proportional decrease in the amount of dose absorbed over that applied. However, in the present tests where double drops of the high concentration were used the dosage mortality line for the GR strain is not unduly flat.

When comparing the topical application and slide dip methods as techniques for the determination of resistance levels it is possible to pick out advantages and disadvantages in each.

The topical application method is precise, gives reproducable results but is relatively slow and entails the use of mite holding cages pinned on bean leaves. The slide dip method is relatively fast in adaptable so that samples of several populations can be treated simultaneously and does not require any mite holding cages (22) but is not precise as far as individual mite dose is concerned. Both methods require the minimum of equipmet (16) and can be learned readily by operators. For routine comparisons of populations it would appear that the slide dip method is preferable but for cases where accuracy if dose is important the topical application method should be used.

2. Screening Tests of Acaricides on O/P Resistant Mites

The first thing that is obvious from the results of tests of the series of acaricide (Figures 3 and 4) is that they can be divided into three groups with respect to their contact plus stomach toxicity and residual effect on the O/P resistant strain (GR) of T. urticae. UC 19786, Eradex and UC 20047A showed a relatively low level of toxicity and fall into one group. C 8514, C 8677 and RS 143 gave an immediate level toxcity and form a second group. Morocide, Kelthane, M 2527 and Spidex show relatively high toxicities, and makes third group. These last four compounds showed very little difference in the LC50 values Table 4, but the difference is greater at the LC95 level. Kelthane and M2577 and Spidex at this level. Morocide is the most toxic of all the acaricides tested. The residual effect shown by Morocide is also one of its most outstanding properties (8) With a cancentation of 0.05% a.i. a residual effect of 21 days on the bean leaves was registered in the laboratory tests against the GR strain. Kelthane was the net best with a concentration of 0.05 % lasting 15 days, and then Spidex with 0.05% coecntration lasting 12 days (Table 5 and Figure 5).

Both Kelthane and Morocide are known to act on immature stages and eggs, as well as adults, so that their effect in the field could be greater than indicated by the laboratory tests. A wide range of workers(9, 12, 15) report good control of O/P resistant mites with Kelthane. The two materials appear to have different modes of action and could have a valuable place in combating resistance. Kelthane and Morocide, therefore, were the most promising acaricides for the control of O/P resistant mites in the laboratory findings and were chosen for the field trials.

3. Fields Trials with Kelthane and Morocide

The optimal sample required: on the basis of the low standard errors (S E $\bar{X}$) achieved in the pilot experiments it appears that a very high degree of precision of the order of 5% should be possible. Table 6 showed that 30 leaves per replicate had the highest degree of precision.

In ecological work it has been suggested that population estimates with a stands error of 10% of the mean are highly desirable. In acaricidal work as low an error margin as possible is obviously required, but no one appears to have indicated what is the optimal or arbitrary degree of precision. The samples required for a 5%, 10% and 20% standard error of the mean are given for each replicate in this study in Table 6. The higher error margins are projected for peoples who what some indication of the numbr of samples required for less precise work, but who wish to state the precision of their study. There is a need for government and commercial company field research officersto plan their work at a specified error level and to state the degree of precision, achieved in these studies. This is often lacking in studies carried out by such people at present.

Field evaluation of Kelthane and Morocide against O/P resistant: As expected the efficient control of the O/P resistant population (TR) of T. urticae in the field was obatned with Kelthane and Morocide (Table 7). The 0.05% a.i. concentration of

Morocide applied to the black currant bushes gave very good control for about 13 days, but the 0.025 % a.i. concentration showed efficient control for about seven days (Fig. 6) at which time the experiment was concluded. Hoyt and Kinney (11) have similarly obtained very good ontrol in field experiments with Moricide against the O/P resistant Tetranychus sp. The 0.04% a. i. concentration treatment of Kelthane was shown to give the control of mite population for 11 days, while the 0.02% a.i. concentration gave only five days protection (Figure 6). Ascher and Cwilich(2) reported similar results of Kelthane throughout their field trial. One application of Kelthane or Morocide, under the conditions of the trial, resulted in a high degree of the control of the O/P resistant population of T. urticea. In the field, however, a second application of these may sometimes be necessary, depending upon the ciroums tances such as temperature, humidity and state of the host plant concerned, due to the fact the spider mites can build up their populations quickly.

## CONCLUSIONS

1. Determination of resistance levels ot chemicals in strains of two-spotted spider mites can be made quantitatively by topical application or slide dip techniques.

2. Organo-phosphate resistant populations of Tetranychus urticae can be susceptible to some alternative acaricides not only under laboratory conditions, but also under field conditions. Good control of O/P resistant population in the field can be obtained with Kelthane or Morocide.

3. In deciding on the optimum sampling plan for the population in the field evaluation of acaricides, note should be taken of the sampling plan used in this work as it can be used as a guide for obtaining a very high degree of precision.

4. In future field trials evaluative acaricides, it would be advisable to include a treatment of an O/P to which the spider mites are resistant, as the level of resistence in the field could be different to that shown in the ladoratory. Such a procedure would give a useful field comparison of insecticides.

5. To obtain the satisfactory control of O/P resistant spider mites with alternative acaricides, the development of further systemics should be considered. This is because spider mites can inhabit the undersides of leaves and there are not readily controlled except by acaricides that are sprayed to cover leaves completely, or by those that are toxic in the vapour phase, or that are capable of translation at least throughout the leaves of the plant.

## SUMMARY

The study involved determination of resistance levels of spider mites to organo-phosphates using topical application and slide dip techniques; laboratory screening tests of alternative acaricides using an O/P resistant strain and a field trial of the screened materials.

1. Strains of Tetranychus urticae were from Timaru (TR), Havelock North (HNR), Lincoln (LN), Germany (GR, GN). Comparisons of the resistant strains and normal strains at the LD50 and LC50 levels were as follows :

(a) Using the topical application technique; with Parathion, resistant levels of the GR, TR and HNR strains of T. urticae were respectivuly, 1035, 484 and 452 times as resistant as the LN strain.

(b) Using the slide dip technique; with Phosdrin, resistant levels of GR, TR and HNR strains of T. urticae were 635, 274 and 266 times greater respectively, than the GN strain.

2. The laboratory screening tests were carried out for their contact plus stomach and residual effect to assess the toxicities of eleven alternative materials which would be used for control of O/P resistant strain of T. urticae. The acaricide groups represented were 3 organo-chlorines (Spidex, Kelthane and C 8514), 2 nitrophenyls (UC 19786 and Morocide), 2 cyclic carbonates(Eradex and Morestan), 1 carbamate (UC2004 7A), 1 mixture of carbamate and organo-chlorine and 2 other chemicals (C 8677 and M2527). From all acaricide tested, Kelthane and Morocide were the most effective, followed by Spidex and M2527. Morestan, C8514, C8677 and RS 143 were intermediate, but Eradex, UC 19786 and UC 20046A were poor.

3. The number of sapmles required for estimation of the population in the field evaluation of acari-

cidal effects was chosen as one giving the highest practical precision. It was decided, after preliminary sampling trials. to use samples of 30 leaves per replicate which gave a 5.7% standard error.

4. In the field trials, Morocide applied at the 0.05% and 0.04% a.i. conc. to black currant trees gave excellent control of O/P resistant population of T. urticae for about 12 days, but Morocide 0.025 and Kelthane 0.02% a.i. conc. gave efficient control for about 6 days. In other words, first applications of Kelthane ane Morocide gave very high degrees ofcontrol of O/P resistant population of the two-spotted spider mite. However, the results indicate that secondary application would sometimes be necessary. There was no foliage damage of black currants and strawberries by either acaricides at the concentrations used.

**Acknowledgment**… The authors are grateful to:

Dr. R.P. pottinger, Senior Lecturer in Agricultural Zoology, Lincoln college, New Zealand, for his helpful assistance in aiding with the organization of thd field work.

Departement of agriculture officers for mite colonies.

Mr. D. A. Slade, Technicol Advisor, Fruitgrowers' Federation (now at Massey Uuiversity) for his assistance and provision of mites for testing.

Mr T. McRae of Timaru for permission to use his crops for field tests.

The following chemical companies and / or their New Zealand agents for so readily supplying samples of acarides;

Ivon Watkins-Dow Limited.

Fruitgrowers Chemical Company Limited.

Henry H. York & company (New Zealand).

Shell Oil (New Zealand) Limited.

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