POSTHARVEST CONTROL OF DIAPAUSING TWO-SPOTTED SPIDER MITE *TETRANYCHUS URTICAE* KOCH ON FRUIT. I COMPARISON OF INSECTICIDAL SOAPS AND SPRAY ADJUVANTS

P.R. DENTENER and S.M. PEETZ

DSIR Plant Protection, Private Bag, Auckland

SUMMARY

The presence of two-spotted spider mite *Tetranychus urticae* (TSM) on fruit imported by Japan or Australia may result in fumigation with methyl bromide which often reduces fruit marketability. Insecticidal soaps and spray adjuvants show potential as postharvest disinfestation treatments for killing TSM on fruit before packing. Their toxicity to diapausing TSM was compared using a slide dip method. Pulse (an organosilicone wetting agent) was the most toxic of the products tested and killed 99% of diapausing TSM at 0.5% (v/v) when 100 ppm chlorine was present in the solution. Chlorine enhanced the efficacy of the Pulse treatment.

Keywords: Two-spotted spider mites, insecticidal soaps, organosilicones, postharvest dip, vegetable oil

INTRODUCTION

Interception of two-spotted spider mite (TSM) on fresh produce exported from New Zealand may result in fumigation with methyl bromide in countries that consider TSM a quarantine pest. Fumigation treatments may reduce the marketability of crops such as persimmons (Batchelor *et al* 1985), and add to the cost of exporting crops such as kiwifruit. Increased public concern over the use of conventional pesticides in New Zealand and overseas necessitates research into alternative methods of pre- and postharvest insect control.

Although the insecticidal properties of soaps have been known for a long time (Siegler and Popenoe 1925), it is only in the last two decades that soaps and surfactants have proven commercially effective in reducing insect and mite populations. However, field applications of insecticidal soaps are not always effective in controlling the pest without disruption to predators (Osborne and Pettitt 1985). Insecticidal soaps containing potassium fatty acid salts are exempt from residue testing by the United States Environmental Protection Agency because the basic compounds are naturally-occurring fatty acids. This indicates that these compounds are likely to be accepted by other overseas agencies as postharvest treatments.

Spray adjuvants are used frequently to maximise performance of pesticides such as herbicides. Naturoil is registered as a surfactant for mixing with pesticides. Pulse is non-ionic and has been shown to be very effective as an adjuvant for sprays of fungicides, insecticides, growth regulators and foliar nutrients (Stevens *et al* 1988; Balneaves 1988; Balneaves and Fredric 1988; Gaskin and Zabkiewicz 1988). In addition, it is an effective miticide (Searle *et al* 1990). Polydimethylsiloxanes such as Pulse are categorised by the United States Food and Drug Administration as "generally recognised as safe" as a surfactant (Anonymous 1989; 1990).

In this paper we describe research that compared insecticidal soaps and spray adjuvants for their effectiveness in killing diapausing two-spotted spider mites.

MATERIALS AND METHODS

A single strain of TSM was reared on bean plants (*Vicia faba*) at 25°C, 18:6 L:D for 2 weeks and then transferred to 15°C, 12:12 L:D to induce diapause. Diapausing

Proc. 45th N.Z. Plant Protection Conf. 1992: 116-120

TSM were collected on black cardboard traps and stored for about 5 weeks at 4°C in darkness before use in these experiments. Diapausing TSM were used because they are more resistant to postharvest disinfestation methods such as controlled atmospheres (D.C. Whiting, pers. comm. 1992), and heat (Waddell *et al* 1991), than the summer form.

The effect of the chemicals on TSM mortality was assessed using the standardised FAO slide-dip method No. 10a (Busvine 1980). Thirty mites were placed, ventral side up, on a piece of double-sided Sellotape fixed to a microscope slide. Each slide was dipped in a chemical solution or water-only control, and gently agitated for 5 seconds. Solutions containing Naturoil needed to be agitated frequently to avoid the deposit of oily droplets around the mites.

After dipping, each slide was left on its edge on filter paper to drain, and the remaining free liquid carefully removed from around the mites under a binocular microscope with a narrow strip of filter paper. Mites on slides were left for about 10 minutes at ambient temperature (ca. 20°C) and subsequently placed in humidity chambers containing a 15% solution of sodium carbonate giving 92% RH at 20°C and L:D 18:6.

After 24 hours, mite mortality was assessed by placing the glass slides under a binocular microscope and prodding the mites with a fine (000) camel hair paint brush. Mites were recorded as "dead" when no body or leg movement occurred. Each experiment was carried out twice with 60 mites per concentration.

Each product or combination of products was evaluated at five concentrations (Table 1). Safer's Insecticidal Concentrate (Safer) and Defender were used alone, or in combination with Naturoil (Safer, Defender) and Pulse (Safer) in a 1:1 ratio. However, Defender and Pulse were mixed in a variable ratio. When mixed with Defender, the concentration range of Pulse was adjusted (Table 1) to avoid complete kill of TSM at the higher doses. Experiments were carried out with and without hypochlorite (100 ppm), the addition of which can be used as a postharvest sanitary measure for fresh produce.

TABLE 1: Chemicals and concentrations tested for their effect on diapausing TSM mortality.

Trade name	Chemical name	Rates tested (ml product/litre)	g ai/litre of concentrate
Chlorine	sodium hypochlorite	2	5 (%)
Defender (soap)	fatty acids potassium salts	5, 7.5, 10, 15, 20 ¹ ; 2.5, 3.75, 5, 7.5, 10 ²	250
Naturoil	vegetable oil (adjuvant)	5, 7.5, 10, 15, 20 ¹ ; 2.5, 3.75, 5, 7.5, 10 ²	
Pulse (adjuvant)	oxyalkylene methyl siloxane	1, 2.5, 5, 7.5, 10 ¹ ; 2.5, 3.75, 5, 7.5, 10 ² ; 0.5, 1.25, 2.5, 3.75, 5 ³	
Safer's insecticide concentrate (soap)	fatty acids - potassium salts	5, 7.5, 10, 15, 20 ¹ ; 2.5, 3.75, 5, 7.5, 10 ²	477

¹Concentrations of compound used alone

²Concentrations when combined with other compounds

³Concentrations when combined with Defender

Dose-mortality data were analyzed using probit analysis, to derive LC₅₀ and LC₉₉ values (i.e. the estimated concentrations to achieve 50 and 99% mortality respectively) (Finney 1971). The log values of LC₅₀ and LC₉₉ estimates for the different treatments were compared in a two-way ANOVA using Genstat 5 (Payne *et al* 1987).

A 5 second dip will not be practical under commercial conditions. Therefore, additional experiments were carried out to determine the effect on mite mortality of prolonged immersion in water, and in a 0.75% concentration of Defender.

RESULTS

All data generated using Naturoil (6 to 12% mortality at 2% v/v) and Defender plus Naturoil (30 to 41% mortality at 2% v/v mixture), were excluded from the analysis because of low mite mortality and large variability. The addition of 100 ppm chlorine to Pulse reduced ($P < 0.001$) the LC_{50} (from 0.17 to 0.09%) and LC_{99} (from 1.18 to 0.48%), but did not alter significantly the efficacy of the other chemicals tested. The results presented are only for those solutions to which chlorine was added (Table 2).

TABLE 2: Estimated concentration (% v/v) for 50% (LC_{50}) and 99% (LC_{99}) mortality of diapausing TSM on glass slides, dipped in different soap and surfactant solutions, containing 100 ppm chlorine. 95% fiducial limits in brackets. Mortality of mites dipped in water with 100 ppm chlorine (control) was 0%.

Formulation	LC_{50}		LC_{99}	
Defender	0.87	(0.65 - 1.16)	1.50	(1.12 - 2.01)
Safer	0.55	(0.41 - 0.74)	1.04	(0.77 - 1.39)
Pulse	0.09	(0.07 - 0.12)	0.48	(0.36 - 0.65)
Defender + Pulse	0.51 ¹	(0.38 - 0.69)	1.36 ¹	(1.02 - 1.83)
Safer + Naturoil	1.04 ²	(0.77 - 1.39)	2.29 ²	(1.71 - 3.06)
Safer + Pulse	0.48 ²	(0.36 - 0.65)	1.32 ²	(0.98 - 1.77)

¹Values of mixture (variable ratio; see Table 1)

²Values of mixture (1:1)

Pulse was more toxic to TSM than any of the other chemicals used individually, or combined ($P < 0.01$). When Pulse was mixed with Safer, the range of concentrations of Pulse in the mixture was adjusted (See Table 1) to achieve a level of TSM mortality, sufficient for probit analysis. The LC_{50} values for Safer plus Pulse, Defender plus Pulse, and Safer could not be distinguished, and they were all more toxic than Defender ($P = 0.05$), or Safer plus Naturoil ($P < 0.01$). Also, the LC_{99} values for Safer, Defender plus Pulse, Safer plus Pulse, and Defender could not be distinguished, and they were all more toxic than Safer plus Naturoil ($P = 0.05$). When Pulse was mixed with Defender, Pulse reduced ($P = 0.05$) the concentration needed to kill 50% of the mites.

Submersion of TSM in water for periods as long as 7 hours did not induce mortality (Table 3). When mites were dipped in a 0.75% solution of Defender, there was no statistically detectable increase in mortality with submersion periods from 5 seconds (18.3%) to 5 minutes (25.0%). This compares with about 18% mortality observed when TSM were dipped for only 5 seconds in a 0.75% solution of Defender in the earlier experiment.

TABLE 3: The effect of dipping time on mortality of diapausing TSM in water and Defender (0.75% v/v) solutions containing 100 ppm chlorine.

Solution	Dip time	Total	No. dead	% Mortality
None Water	0	61	0	0
	5 secs	117	1	0.9
	2 mins	121	2	1.7
	5 mins	121	1	0.8
	1 hour	61	3	4.9
	7 hours	60	0	0
Defender	5 secs	60	11	18.3
	30 secs	60	10	16.7
	1 min	60	11	18.3
	2 mins	64	13	20.3
	5 mins	60	15	25.0

DISCUSSION

Comparative tests with different solutions of insecticidal soaps and adjuvants as postharvest disinfestation dips showed that Pulse was the treatment most toxic to diapausing TSM. About 0.5% (v/v) of Pulse was needed to achieve 99% mortality when 100 ppm chlorine was included in the solution. Insecticidal soaps, which are already registered for pre-harvest control of TSM, needed twice (Safer) to three times (Defender) that concentration to achieve the same level of mortality as Pulse. Safer and Defender are used as pre-harvest orchard treatments, when TSM are still in their summer form, and no claims are made by the marketing companies regarding their postharvest efficacy. Pulse has been approved in New Zealand as a penetrant when used in combination with glyphosate (Roundup) herbicide.

TSM survived long periods of submergence, and mortality did not significantly increase with time when mites were immersed in water or a 0.75% solution of Defender.

Fluorescence microscopy of herbicide solutions showed that formulations containing Pulse were able to penetrate plant tissue rapidly via stomatal pores rather than through the cuticle (Buick *et al* 1990). For stomatal infiltration to occur, the surface tension of the formulation must be less than or equal to the critical surface tension value for that surface and solution (Schönherr and Bukovac 1972). While this principle has only been described for plants, it may be possible that a similar process applies to the spiracles in insects. Since TSM regulates its water loss via a relatively impermeable cuticle, and control of diffusion of water from the tracheal system (McEnroe 1961), Pulse may reduce the surface tension around the spiracles which could cause excessive water loss, or, alternatively, asphyxiation due to capillary action of Pulse into the trachea.

Further research is necessary to establish the effect of Pulse in dislodging mites from fresh produce. In addition, taste panel research needs to be carried out on crops which could benefit from this postharvest dip.

ACKNOWLEDGEMENTS

Chemicals were supplied by Yates Ltd, Watkins Ltd and Monsanto Ltd. We thank Mr G.K. Clare for supply of diapausing two-spotted spider mites; Mr J.H. Maindonald for statistical analysis of the data; Dr T.A. Batchelor for comments on the manuscript.

REFERENCES

- Anonymous, 1989. Code of Federal Regulations. Protection of the Environment. Vol. 40. Office of the Federal Register of the National Archives and Records Administration. 721 pp.
- Anonymous, 1990. Code of Federal Regulations. Food and Drugs. Vol. 21. Office of the Federal Register of the National Archives and Records Administration. 589 pp.
- Balneaves, J.M., 1988. Effects of metsulfuron methyl and Silwet L-77 on the control of young gorse. *Proc. 41st N.Z. Weed and Pest Control Conf.*: 171-172.
- Balneaves, J.M. and Fredric, B.J., 1988. Silwet M improves performance of glyphosate on gorse. *Proc. 41st N.Z. Weed and Pest Control Conf.*: 146-148.
- Batchelor, T.A., Beever, D.J., O'Donnell, R.L. and Yearsley, C.W., 1985. Persimmon fumigation: insecticidal and phytotoxic effects of a range of fumigants. *Proc. Ruakura Hort. Conf., Hamilton, New Zealand*: 22-26.
- Buick, R.D., Field, R.J. and Robson, A.B., 1990. The effects of Silwet L-77 on triclopyr absorption. *Proc. 43rd N.Z. Weed and Pest Control Conf.*: 174-177.
- Busvine, J.R., 1980. Revised method for spider mites and their eggs. FAO method no. 10a, p. 49-54. *In: Recommended methods for measurement of pest resistance to pesticides. FAO Plant Production and Protection Paper, 21.*
- Finney, D.G., 1971. Probit Analysis. 3rd edition. Cambridge University Press, London.
- Gaskin, R.E. and Zabkiewicz, J.A., 1988. Effect of Silwet L-77 on uptake and translocation of metsulfuron in gorse. *Proc. 41st N.Z. Weed and Pest Control Conf.*: 149-152.
- McEnroe, W.D., 1961. The control of water loss by the two-spotted spider mite (*Tetranychus telarius*). *Ann. Ent. Soc. Amer.* 54: 883-887.

- Osborne, L.S. and Pettitt, F.L., 1985. Insecticidal soap and the predatory mite, *Phytoseiulus persimilis* (Acari: Phytoseiidae), used in management of the two-spotted spider mite (Acari: Tetranychidae) on greenhouse grown foliage plants. *J. Econ. Entom.* 78: 687-691.
- Payne, R.W., Lane, P.W., Ainsley, A.E., Bicknell, K.E., Digby, P.G.N., Harding, S.A., Leech, P.K., Simpson, H.R., Todd, A.D., Verrier, P.J., White, R.P., Gower, J.C., Tunnicliffe Wilson, G., Paterson, L.J., 1987. Genstat 5. Reference Manual. Rothamsted Experimental Station, Harpenden, United Kingdom. 749 pp.
- Schönherr, J. and Bukovac, M.J., 1972. Penetration of stomata by liquids. *Plant Physiology* 49: 813-819.
- Searle, G.G., Penman, D.R. and Chapman, R.B., 1990. The toxicity of herbicides to the gorse spider mite *Tetranychus lintearius*. *Proc. 43rd N.Z. Weed and Pest Control Conf.*: 178-181.
- Siegler, E.H. and Popenoe, C.H., 1925. The fatty acids as contact insecticides. *J. Econ. Entom.* 18: 292-299.
- Stevens, P.J.G., Gaskin, R.E. and Zabkiewicz, J.A., 1988. Silwet L-77: a new development in spray adjuvants. *Proc. 41st N.Z. Weed and Pest Control Conf.*: 141-145.
- Waddell, B.C., Birtles, D.B. and Maindonald, J.H., 1991. High temperature disinfestation of nectarines of two-spotted mites (Acari: Tetranychidae). Full report of 1991 trials. *DSIR Plant Protection Technical Report*. 105 pp.