**SURFACTANT FOR POSTHARVEST CONTROL OF
DIAPAUSING TWOSPOTTED SPIDER MITE
TETRANYCHUS URTICAE KOCH ON APPLES**

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SUMMARY

Experiments were carried out to determine the effect of immersion time in dilute Pulse solutions, and subsequent waiting time before rinsing off Pulse with water, on mortality of diapausing twospotted spider mite (*Tetranychus urticae* Koch; TSM) held on double-sided tape placed on apples. Increasing immersion time from 5 to 21 minutes, and/or increasing the waiting time from 1 to 9 minutes, reduced the concentration of Pulse needed to achieve 99% TSM mortality from 2.0% to 1.4%. In experiments with long waiting times, the 99% mortality level for 1 and 5 minute immersion times was achieved at concentrations below 1.5% Pulse but required waiting times of between 4 and 8 hours.

Keywords: twospotted spider mite, postharvest dip, Pulse, immersion time, waiting time

INTRODUCTION

In 1991 we used a slide dip method to compare the effects of insecticidal soaps and spray adjuvants on diapausing twospotted spider mite (TSM) mortality using a 5 second immersion time (Dentener and Peetz 1992). We found that Pulse (Silwet L-77, an organosilicone adjuvant) was the most toxic of the products tested, providing 99% mortality of diapausing TSM at a concentration of 0.48% (v/v) in water containing 100 ppm sodium hypochlorite. These experiments, however, excluded subsequent removal of the chemicals using a water rinse which may be required to reduce residue levels on the produce.

In this paper we describe experiments carried out using commercially more realistic conditions to determine the effect of Pulse concentration, dip time in Pulse, and subsequent waiting time (i.e. "stand-down" time between dipping and rinsing-off Pulse with water) on diapausing TSM placed on double-sided tape on apples.

MATERIALS AND METHODS

A single strain of TSM was reared on bean plants (*Vicia faba*) at 25°C, 16:8 L:D for 2 weeks and then transferred to 15°C, 12:12 L:D for at least 4 weeks to induce diapause (Singh and Clare 1993). Diapausing TSM were collected on black cardboard traps and stored for 5 weeks at 4°C in darkness before use in these experiments.

Between 20 and 40 mites were placed, ventral side up, on a piece of double-sided Sellotape (18 by 40 mm) fixed to the cheek of an apple (n=5 apples) which had been degreased with 70% ethanol. A flexible PVC ring measuring ca. 20 x 30 mm, and 15 mm high was connected to each individual apple surface with a thin strip of Bostik Blutack to avoid mites being squashed during immersion. Mites on apples were conditioned at ambient temperature (about 20°C) for 3-5 hours (waiting times of 1 to 9 minutes) or for 18 hours overnight (waiting times between 1 and 8 hours) before treatment.

Each apple with mites was immersed in a Pulse solution or water-only control. In addition, some apples with mites received no treatment at all. Sodium hypochlorite (100 ppm) was added to both the Pulse and water-only solutions to enhance the

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efficacy of the Pulse treatment (Dentener and Peetz 1992). Five apples containing mites were placed inside a mesh (12 x 12 mm) cage measuring 210 (W) x 200 (L) x 105 (H) mm, elevated on feet to provide a 15 mm clearance and submerged in a test solution in a 10 litre bucket. The solutions were mixed continuously using a magnetic bar and a Nuova II stir plate. After immersion, the mites on apples were held at 20°C for a waiting period and then rinsed for 1 minute (0.5 to 9 minute waiting times) or 3 minutes (1 to 8 hour waiting times) in fresh water. The water-only controls were treated in a similar manner but were rinsed off after only a 1 minute waiting time. Subsequently, all apples were placed overnight at 20°C, 80% RH and a photoperiod of L:D 16:8.

After 24 hours, mite mortality was assessed under a binocular microscope (30 x) by prodding the mites with a fine (000) camel hair paint brush. Mites were recorded as "dead" when no body or leg movement occurred.

A number of different combinations of Pulse concentration, immersion time and waiting time were tested (Table 1).

TABLE 1: Chemicals, immersion and waiting times tested for their effect on diapausing TSM mortality

Trade name	Chemical name	Rates tested (ml product/litre)	Time (minutes)	
			Immersion ¹ (minutes)	Waiting ¹
Pulse	sodium hypochlorite (5%)	2	1	1
	oxyalkylene	(i) 5, 7.5, 10, 12.5, 15, 17.5, 20	0.5, 1, 2, 5, 9, 13, 17, 21	0.5, 1, 2, 5, 9 minutes
	methyl siloxane	(ii) 5, 10, 15	1, 5	1, 2, 3, 5, 8 hours

¹Long immersion and waiting times were combined with low Pulse concentrations, shorter immersion and waiting times with higher concentrations. For explanation, see text.

Initial experiments concentrated on immersion times between 0.5 and 21 minutes followed by ("short") waiting times of 0.5 to 9 minutes. Based on statistical analysis of these data, the regions of high mite mortality were identified. Subsequent experiments then concentrated on immersion times of 1 and 5 minutes only, ("long") waiting times of between 1 and 8 hours and Pulse concentrations between 0.5% and 1.5%. Low Pulse concentrations were combined with long immersion and waiting times, and higher Pulse concentrations with shorter immersion and waiting times. Therefore, not all possible combinations of immersion and waiting times (Table 1) were evaluated.

Data were analysed by modelling logit mortality as a function of immersion time, waiting time and concentration of Pulse, using the software language S-Plus (Statistical Sciences Inc. 1991). A spline function was used to model changes in mortality with waiting time. Terms were added that allowed for (1) a quadratic change in logit mortality with concentration; (2) a linear change in logit mortality with immersion time; (3) a linear change in logit mortality with concentration x immersion time; and (4) a linear change in logit mortality with concentration x waiting time.

The analysis used a 'robust' method that was designed to smooth out the effect of occasional data values that did not fit the major pattern. It was assumed that the variance of the observed mortality was a constant multiple of that for a binomial distribution. Contour plots were used to summarise the results.

RESULTS

The average control mortalities for diapausing TSM kept dry (n=900), or immersed in a 100 ppm sodium hypochlorite in water solution (n=920) varied for all

Figure 1: Mortality contours of fitted response surface. Plotted points show observed diapausing twospotted mite mortalities. a-c: 1, 5 and 9 minute waiting time respectively; d-e: 1, and 5 minute immersion time respectively.

experiments between 0.4% and 1.6%. Previous research had shown mites were not killed by submersion in water for up to 7 hours (Dentener and Peetz 1992).

Figure 1a-c (short waiting times) and Figure 1d-e (long waiting times) present diapausing TSM mortality contours of the fitted response surface at different Pulse concentrations, and varying immersion and waiting times. The plotted points in the graphs show the observed mortalities. The following are approximate standard errors for model predictions, i.e. for individual points on a contour line: 90% contour: $\pm 1.4\%$; 99% contour: $\pm 0.3\%$; 99.9% contour: $\pm 0.05\%$. Because there may be a model bias, individual observations will deviate from prediction. Accurate estimates of the error that is realistic for a particular treatment combination will require further trials at those settings.

Diapausing TSM mortality increased with increased concentrations of Pulse, increased immersion time and increased waiting time (Fig. 1). A 1 minute waiting time between immersion and rinsing-off achieved a maximum predicted level of mortality of 98% only at the longest immersion time (20 minutes) and a concentration of about 1.8% Pulse, or an immersion time of approximately 16 minutes and the highest Pulse concentration (2.0%) (Fig. 1a).

In contrast, a 99.9% predicted mortality was achieved after a 5 minute waiting time using 1.9% and 2.0% Pulse concentrations and 20 and 19 minute immersion times respectively (Fig. 1b). Interpolation of the results (Fig. 1c) indicated that a 99.9% predicted mortality could be achieved after a 9 minute waiting time using 1.4% and 2.0% Pulse concentrations and 20 and 14 minute immersion times respectively. The absolute increase in mortality was greater when the waiting time was increased from 1 to 5 minutes than when it was increased from 5 to 9 minutes.

Experiments carried out with longer waiting times showed that, in general, diapausing TSM mortality increased with increasing concentrations of Pulse, and increasing waiting time but not to the same extent as described above for short waiting times. A 1 and 5 minute immersion time (Figs. 1d, e) only achieved a 99.5% predicted mortality at the highest Pulse concentration (1.5%) used and the mortality response curve flattened out indicating that waiting times longer than 4-5 hours did not further enhance diapausing TSM mortality. Visual observation of the slopes of the contours indicate that the concentration of Pulse has a greater effect on increasing predicted diapausing TSM mortality than either immersion or waiting time, especially with waiting times of 4 hours or shorter. The predicted 99.5% diapausing TSM mortality is a conservative estimate since we obtained 100% mortalities at a 1.5% Pulse concentration and waiting times of 2, 3, 4 and 5 hours (Fig. 1e). The increase in diapausing TSM mortality with increasing levels of Pulse concentrations between 1.0% and 1.5% may be greater than allowed for in the statistical model.

DISCUSSION

Experiments carried out with diapausing TSM on apples immersed in different concentrations of Pulse containing 100 ppm sodium hypochlorite showed that immersion in 2% Pulse for 19 minutes followed by a minimum waiting time of 5 minutes or longer before rinsing-off was required to achieve a predicted 99.9% mite mortality. The Pulse concentration needed to achieve this mortality could be reduced to 1.4% by increasing the immersion time from 14 minutes to 20 minutes, with a waiting time of 9 minutes. However, since immersion times under commercial conditions may be less than 5 minutes, this level of mortality can be achieved in commercial practice only by increasing the Pulse concentration, and/or increasing the waiting time.

Further research aimed at using shorter and commercially more acceptable immersion times achieved a predicted 99.5% diapausing TSM mortality for immersion in 1.5% Pulse for a minimum time of 5 minutes, with a waiting time between immersion and rinsing-off of about 5 hours. There were no obvious increases in predicted mite mortality with waiting periods longer than 4-5 hours. It may be possible that there are similarities between the uptake characteristics of Pulse in mites and in plant material. Zabkiewicz *et al.* (1993) found that uptake of Pulse into a bean leaf

increased up to 3 hours after its application. However, no further uptake was observed in the subsequent 3 hours. To increase the diapausing TSM mortality levels, the immersion time may have to be increased beyond 5 minutes, and/or the Pulse concentration increased to values between 1.5% and 2.0%.

Future research should concentrate on testing the effect of Pulse concentrations between 1.0% and 2.0%, 5 minute immersion times and waiting times between 0.5 hour and 5 hours on diapausing TSM mortality.

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