

Pesticide adjuvants for greenhouse growers

Final report to
**The New Zealand Vegetable and Potato Growers
Federation**

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and co-workers
Crop & Food Research
Forest Research

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1 EXECUTIVE SUMMARY

This report contains the final recommendations for greenhouse growers' use of pesticide adjuvants and includes a report on the effects of additives on crop wetting. It is completed by two popular reports: one on our findings, and one on the uses of different pesticide adjuvants.

The key recommendations (Section 2) are a list of prohibitions rather than a list of positive suggestions. The key is to avoid using adjuvants in any way that inhibits or reduces the efficacy of pesticides.

Adjuvants have most use where crops are hard-to-wet because of waxy leaves or crop architecture.

Adjuvants vary in how they affect physical performance of pesticides in terms of spray atomisation, deposition, retention, coverage and uptake, yet there is very little information (if any) about how these physical factors interact with biological efficacy of insecticides and fungicides in greenhouse crops.

2 RECOMMENDATIONS FOR THE USE OF PESTICIDE ADDITIVES BY GREENHOUSE GROWERS

Our research found that:

- the activity of **contact pesticides** was either reduced, or not affected by use of an adjuvant on two easy-to-wet greenhouse crops.
- the activity of **systemic pesticides** was either not affected, or enhanced by the use of adjuvants.

We recommend:

1. If a pesticide manufacturer does not recommend use of an adjuvant, growers should use caution in applying one, especially on easy-to-wet crops.
2. If a pesticide manufacturer expressly *prohibits* use of adjuvants, DO NOT USE THEM.
3. NEVER exceed the manufacturer's rate recommendation when adding an adjuvant to a pesticide mix.
4. The interactions of adjuvants with pesticide, crop, application rate, application method and water rate are complex. It is possible to make a pesticide mixture spread so well that it runs off the plant, or to bind it up tightly on the leaf surface so that it cannot penetrate into the plant. Pesticide companies have a variable track record in determining how much and what additives will benefit the efficacy of their product: but READ THE LABEL.
5. ONLY use adjuvants supported by sound and relevant research results. Ask questions of the adjuvant supplier!

3 ADJUVANT EFFECTS ON RETENTION OF PESTICIDE SPRAYS ON VEGETABLE CROPS

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3.1 Introduction

The aim of this study was to illustrate the importance of optimising adjuvant selection for pesticide spray applications to different crops. Surfactants are known to affect spray retention to a greater extent on water-repellent species than on those more readily wetted, where frequently they do not enhance retention compared to mixtures with water alone. Organosilicone surfactants, for example, are known to increase the adhesion and coverage of pesticide sprays on hard-to-wet foliage due to their high surface activity, but they may also reduce the retention of sprays when their concentration and spray volumes are too high, or plant architecture/foiar characteristics are inappropriate. In this work, the effect of adjuvants on the retention of insecticide sprays on two contrasting plant species were determined.

3.2 Materials and methods

3.2.1 Crops

Spreading studies: cucumber (Polaris BX38; Webling & Stewart Seeds Ltd, Petone) and pea (Greenfeast; Watkins Seeds) plants were grown from seed in individual pots containing Bloom potting mix (Yates NZ Ltd). Plants were reared to three weeks of age under controlled environment conditions (20°C day/15°C night, 70% RH and 12 h photoperiod, ~500µmol/m²/sec).

Retention studies: individually potted cucumber plants were grown under controlled environment conditions, as above, and transferred to the glasshouse just before spraying at three weeks (three fully expanded leaves). Pea plants were raised in the glasshouse until their use at three weeks of age (four fully expanded leaves).

3.2.2 Chemicals

A broad spectrum systemic insecticide, Orthene 75 (750 g/kg acephate; WSP; Nufarm), was prepared at the rate of 1 g/l for both spreading and retention studies. Adjuvants (Table 3.1) were added separately to insecticide solutions at 0.1-7.5 ml/l.

Table 3.1: Adjuvant; use rate, type and supplier.

Adjuvant	Use rate (ml/ℓ)	Type	Supplier
Citowett	0.25	spreader	BASF
Silwet 408	0.1-0.5	spreader	Witco
Pinene II	7.5	sticker	Elliott Chemicals
Bond Xtra	2.5	spreader-sticker	Elliott Chemicals

3.2.3 Spreading

Spreading of formulations was determined on the upper top surfaces of fully expanded cucumber and pea leaves. Blankophor-P fluor (10 g/ℓ; Bayer) was incorporated into all treatments to "visualise" droplet spread. Ten replicate droplets (1 µl) of each treatment were applied to separate leaves in an air-conditioned environment and spread areas of dried droplets were measured under UV illumination by image analysis (V for Windows).

3.2.4 Retention

Cucumber

Treatments were applied (20 replicate plants) using a calibrated, moving belt tracksprayer at two application rates equivalent to approximately 530 and 950 ℓ/ha. Twin nozzles (TwinJet 60s; 8002E) were operated at about 275 kPa, mounted 50 cm above the plants to simulate ground-based application on arable crops. Tartrazine dye (10 g/ℓ; Bayer) was incorporated into all treatments. Plastic disks of 10 cm diameter were sprayed as application standards.

Cucumber plants were cut off at ground level and foliage was washed thoroughly in 500 ml water within 15 min. of application. Application standards were washed in 100 ml water. Absorbance of each sample was measured using a Pye Unicam UV/VIS spectrophotometer (tartrazine $\lambda=427$ nm) and concentrations calculated. Foliage was placed into paper bags for oven drying at 70°C. Dry weights (ODW) were determined after four days.

Surface areas of the 20 replicate plants were measured using image analysis (V for Windows) and areas of treated plants were correlated with ODW. Retention was expressed per plant (µl/plant), per unit weight (µl/g ODW) and as a percentage of maximum possible spray deposition, where:

$$\text{retention (\%)} = \frac{(\mu\text{g dye/cm}^2 \text{ foliage}) * 100}{(\mu\text{g dye/cm}^2 \text{ reference target})}$$

Pea

Treatments were applied (20 replicate plants) as for cucumbers but at one application rate of approximately 510 l/ha. An even spray flat fan nozzle (TeeJet 8002EVS) was operated at 200 kPa, mounted 50 cm above the plants. Tartrazine dye (10 g/l; Bayer) was incorporated into all treatments so that the level of retention could be determined. Plastic disks of 10 cm diameter were sprayed as application standards.

Pea plants were cut off at ground level and foliage was washed thoroughly in 200 ml water. Application standards were washed in 100 ml water. Dye concentrations, dry weights, plant surface areas and retention data were determined and calculated as for cucumber.

3.2.5 Statistical analyses

Analysis of variance and least significant difference (LSD) tests were used to compare treatments. Stabilising transformations were performed where necessary before analysis.

3.3 Results and discussion

3.3.1 Spreading

Cucumber has a thin covering of amorphous wax on the leaf surface and is regarded as easy-to-wet. Its broad, flat leaves and pronounced deep veining predispose it to runoff. Pea is a difficult-to-wet species whose leaves are covered in a dense layer of microcrystalline epicuticular wax. Droplets spread on cucumber leaves predominantly via the veins, while on pea, spread is even over each leaf.

All adjuvants increased the spread of insecticide on both species (Table 3). At the lowest concentration of Silwet 408 (0.1 ml/l), there was no difference in spreading relative to the conventional surfactant, Citowett. However, at the highest concentration (0.5 ml/l), the organosilicone increased spread approximately x30 on cucumber and x20 on pea in comparison to the insecticide control, and increased as the concentration of Silwet increased. Poor-spreading formulations were similar on both species. Silwet 408 solutions spread better on cucumber than on pea, but predominantly via veins. In contrast, the formulation of Bond Xtra, which contains an organosilicone, was less inclined to run via leaf veins and spread much better on pea. This may be due to a higher solution surface tension and/or increased viscosity of the solution imparted by the latex "sticker" component. The spreader-sticker combination of Silwet 408 + Pinene II reduced Orthene spread markedly in comparison to the organosilicone alone at the same concentration (0.05%).

Table 3.2: Spreading of Orthene (1 g/l) formulations on upper top leaf surfaces (mm²).

Adjuvant	Rate (ml/l)	Cucumber	Pea
nil	-	2.2 e	1.4 f
Citowett	0.25	5.3 d	4.8 e
Silwet 408	0.1	4.5 d	4.5 e
Silwet 408	0.25	14 b	6.2 d
Silwet 408	0.5	63 a	29 b
Silwet 408 + Pinene II	0.5 + 7.5	8.2 c	9.2 c
Bond Xtra	2.5	11 b	39 a

Treatments within columns sharing common letter are not significantly different (LSD; P=0.05)

3.3.2 Retention

Cucumber

Data were log transformed before analysis. No surfactant increased the retention of Orthene sprays on cucumber at either spray volume (Table 3.3). More liquid was retained on plants at the higher application rate, but retention was decreased more, proportionally, by the addition of surfactants. This run-off, and/or reduced droplet adhesion on pre-wetted surfaces, is of concern on this species.

Increasing amounts of organosilicone generally decreased retention (Table 3.3) and the addition of Pinene II sticker to Silwet 408 had no statistically significant effects. In contrast, the organosilicone-containing Bond Xtra frequently provided better retention than Silwet 408, but never better than the conventional surfactant, Citowett, nor the nil surfactant control. It appears that any surfactant addition to Orthene sprays applied to cucumber at application volumes ≥ 500 l/ha may reduce insecticidal activity due to decreased spray retention.

Table 3.3: Mean retention values for Orthene sprays plus adjuvants on cucumber.

Treatment	Surfactant rate (ml/L)	Retention (μ l/plant)		Retention (μ l/g ODW)	
		530 l/ha	950 l/ha	530 l/ha	950 l/ha
		Orthene (1 g/l)	-	824	1290
+ Citowett	0.25	831	962*	740	957*
+ Silwet 408	0.1	652*	954*	731	864*
+ Silwet 408	0.25	648*	770*	595*	712*
+ Silwet 408	0.5	541*	834*	531*	710*
+ Silwet 408 + Pinene II	0.5+7.5	623*	816*	588*	755*
+ Bond Xtra	2.5	684*	902*	715	845*

* Treatments are significantly different to Orthene control (LSD; P=0.05; log (retention) \pm 0.0782 and \pm 0.0577 for μ l/plant and μ l/g ODW respectively).

Pea

Adjuvants substantially improved the retention of Orthene sprays on pea foliage (Table 3.4), in the best instance by >5x. Bond Xtra gave the greatest retention, but the other spreader-sticker combination (Silwet + Pinene) also provided better retention than the spreader surfactants. However, in contrast to the cucumber data, retention increased with increasing organosilicone concentration (Fig. 1). There was no visible evidence of run-off from foliage in this study, suggesting that retention may be improved still further with higher concentrations of Silwet 408. These results suggest that scope to improve retention on pea; at best only 10% of potential spray volume intercepted by pea foliage was retained on the plants (Table 3.5). There is potential to improve retention through both adjuvant addition and manipulating spray volumes. In contrast, spray retention on cucumber is most likely to be improved by reducing spray volume and maintaining good coverage of foliage.

Table 3.4: Mean retention values for Orthene sprays (510 l/ha plus adjuvants) on pea.

Treatment	Surfactant rate (ml/l)	Retention (μ l/plant)	Retention (μ l/g ODW)
Orthene (1g/l)	-	6.6 e	72 d
+ Citowett	0.25	23 c	176 c
+ Silwet 408	0.1	7.0 e	50 d
+ Silwet 408	0.25	12 d	88 d
+ Silwet 408	0.5	26 c	212 c
+ Silwet 408 + Pinene II	0.5+7.5	33 b	290 b
+ Bond Xtra	2.5	49 a	376 a

Treatments within columns sharing common postscripts are not significantly different (LSD; P=0.05).

Figure 1: Retention of Orthene on pea and cucumber foliage with increasing rates of organosilicone surfactant (ca 500 l/ha).

Table 3.5: Retention (as % of maximum possible deposition) of Orthene sprays on cucumber and pea foliage at ca 500 l/ha spray volume.

Treatment	Surfactant rate (ml/l)	% retention	
		cucumber	pea
Orthene (1g/l)	-	59 a	2.0 e
+ Citowett	0.25	55 a	4.1 d
+ Silwet 408	0.1	55 a	1.4 e
+ Silwet 408	0.25	46 b	2.5 e
+ Silwet 408	0.5	32 d	5.5 c
+ Silwet 408 + Pinene II	0.5+7.5	37 cd	7.9 b
+ Bond Xtra	2.5	39 c	10.1 a

Treatments within columns sharing common postscripts are not significantly different (LSD; P=0.05).

3.4 Conclusions

- Adjuvants provided no advantages in retaining sprays, applied at >500 l/ha, on easy-to-wet cucumber foliage; in most cases they reduced spray retention.
- Adjuvants could substantially increase spray retention, from 500 l/ha applications, on hard-to-wet pea foliage.
- Pesticide sprays are not retained well on pea and there is considerable scope to improve this with adjuvants.
- Increasing organosilicone surfactant concentration (and spread) reduced spray retention on cucumber but increased it on pea, at ≥500 l/ha application rate.
- Citowett performed similarly to or better than an organosilicone, at the same concentration, in improving spray retention on pea.
- Sticker-spreader adjuvants are promising candidates for improving spray retention on hard-to-wet species.
- These descriptions of the various adjuvants and types may help growers with decisions on the benefits of use or avoidance of adjuvants in their spraying programmes.

4 POPULAR SUMMARY: RISKS AND BENEFITS OF USING ADJUVANTS

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There are many adjuvants available these days and more are in the pipeline. They include some old faithfuls like Codacide and Citowett; an increasing diversity of organosilicone products such as Pulse; and innovative plant-derived products such as LI-700.

As a grower, how do you make good quality decisions about which adjuvants to use? Do you realise how important it is to avoid adjuvants for some uses? Do you know that overuse of adjuvants can cost you significant amounts of money?

In this article we will try to answer these questions based on our research over the last three years with funding from the Fresh Vegetable Development Committee of Vegfed. As our work was confined to easy-to-wet greenhouse crops, the results may not be applicable to all situations.

Our findings are relatively simple, but implementation of our conclusions by growers is complex, as much of the information is negative.

Put simply, we have found that the activity of the two contact pesticides we tested did not benefit from the use of any type of adjuvant, and the activity of the two systemic pesticides tested could benefit from the use of adjuvants. Unfortunately we now have to consider all the "buts".

- (1) We tested only two insecticides and two fungicides on two easy-to-wet crops. These will not, of course, represent all the pesticides or crops greenhouse vegetable grower might work with.
- (2) Complicated interactions occur when adjuvants are used. Key issues to consider are: crop type and stage (size, height, density, wettability of foliage), application method, water rate, target organism(s) and pesticide. It is almost impossible to make clear and specific recommendations in such complex circumstances.
- (3) Water rate can affect spray retention depending on the crop. On cucumber four quite different adjuvants reduced spray retention, but they enhanced spray retention on peas. On easy-to-wet crops, use of an adjuvant is generally not necessary.

- (4) Follow the pesticide label recommendations. Some modern formulations are supplied with the complement of adjuvants needed for full efficacy and further additions are not required or recommended. Where a generic adjuvant is recommended on the label (e.g. spreader), seek advice from a reputable adjuvant supplier.
- (5) Adjuvant suppliers should make recommendations based on sound research. Ask to see the relevant trial data. If in doubt get advice from a third party.
- (6) Never add extra adjuvant just to make sure - more is *not* always better!

What is the take home message then? Never use an adjuvant just "in case". You need to decide which adjuvant will help your specific situation. Check for relevant research, ask questions of adjuvant suppliers. For example, a superspreading organosilicone may greatly improve pesticide efficacy on a hard-to-wet pea crop, but it may equally reduce activity on cucumber because of excessive spray runoff. Or, a latex-type sticker may enhance control with a contact insecticide but reduce activity of a systemic fungicide because it prevents penetration into the plant.

Our work suggests that growers should critically evaluate the promises made by some adjuvant salesmen; always ask to see trial reports from recognised independent researchers if a recommendation for use is not included on the label by the pesticide manufacturer. There are obvious costs in using pesticides to aid production of quality produce and growers can't afford preventable failures through inappropriate use of adjuvants.

5 POPULAR SUMMARY: WHICH ADJUVANT?

5.1 What does an adjuvant do?

An adjuvant is a material added to a pesticide to increase the efficacy of that pesticide. It is not pesticidal on its own. We use adjuvants to optimise the biological effects of a pesticide, that is, to improve pest and disease control. Barriers to biological efficacy of a pesticide are many. We can categorise the benefits of adjuvants under five headings. The pesticide application processes that can be modified (benefited) by the use of adjuvants are:

- spray atomisation
- spray retention
- crop coverage
- crop penetration
- chemical stability

Many terms are used to describe adjuvants. The most common ones are wetters, spreaders, stickers and penetrants. Most adjuvants have more than one mode of action, that in turn may depend on the pesticide being used.

Table 1: Types of adjuvants.

Compounds	Mode(s) of action
Organic surfactants	improved retention on crop, increased penetration, enhanced coverage.
Organosilicone	improved leaf coverage, improved rain fastness, stomatal penetration.
Oils (mineral, vegetable, transesterified vegetable)	improved coverage, improved crop penetration, improved availability of ai in some insecticides.
Terpene derivatives	reduce wash off, reduce volatility
Polymers and synthetic latex	reduced droplet drift, increased retention on crop.
Inorganic salts	increased penetration

Using Table 1, look at the adjuvant you are intending to use, fit it to its general type, and think about what you want it to do to help make a rational choice.

Another way to look at adjuvants is to classify them as activators, spray modifiers or utility modifiers. Activator adjuvants help pesticides get into a plant and may be useful when you use systemic pesticides. Spray modifiers help maximise spray delivery to its target and maximise its retention on the target. A utility modifier will enhance pesticide activity under difficult conditions such as when water pH is sub-optimal, or the target crop is dusty.

There is a trend within the adjuvant industry to provide better quality information to growers and this is helped by major pesticide companies putting more research effort into adjuvant technology.

5.2 Effects of adjuvants

Wetting and spreading agents reduce the surface tension of the pesticide droplet, and reducing droplet bounce and allowing it to spread out more than it would without the adjuvant present. When too much adjuvant is used the droplet has such a low surface tension that spray runoff can occur.

Penetration is a complex process important for systemic pesticides and is much better understood for herbicides than it is for insecticides and fungicides. Pesticides penetrate into foliage through waxy cuticles or via stomatal pores, and specific adjuvants, notably surfactants and oils, will assist these processes. Note there is *no universal penetrant*. What works well with one pesticide, may not work with another.

Translocation of pesticide within the plant, once penetration has occurred, can be affected by adjuvants. Too much, or the wrong choice of, adjuvant can damage plant cells and reduce translocation.

5.3 Choosing an adjuvant

You can develop a rule-of-thumb decision process for your own situation. By recording what you do and why, and noting the results, you are likely to be able to build up a personal database that will help make sure that over time you make quality decisions.

Use simple experiments to help your decision making process. Perhaps adding a spray dye for the last few plants during a normal spraying will give you an idea of how good your coverage is. Record conditions, including sprayer operator data; crop height/age/stage and note efficacy a week later. How long until you have to spray again? Have you taken shortcuts? Did you follow the label recommendations? Using a process like this you should be able to develop a system that will guide expenditure across total pesticide operations.

In the case of a difficult problem that defies solution, consider doing some research yourself. There are a number of ways to get full or partial funding for practical research projects, either by yourself or with a group of growers. For more details contact one of Crop & Food Research's Business Managers.

6 THE WAY AHEAD

We are carrying out a further experiment (funded by Crop & Food Research) to test the contact/systemic pesticide variation in the value of using adjuvants. We expect that as a result of the project to date there will be some commercial interest in rigorous scientific testing of adjuvant use. For the longer term we will investigate development of a PGSF application for further in-depth studies on the use of adjuvants to improve pesticide use in horticulture.



