NOVEL ORGANOSILICONE ADJUVANTS TO REDUCE AGROCHEMICAL SPRAY VOLUMES ON ROW CROPS

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ABSTRACT

Onion and potato crops require frequent applications of high-volume agrochemical sprays. The use of two novel organosilicone adjuvant blends, Du-Wett and Bond Xtra, is being developed with the aim to halve conventional spray volumes on these crops. Adjuvant use rates have been optimised through extensive studies of the physical characteristics of sprays. These include leaf coverage, retention, foliar penetration and phytotoxicity. Comparisons with conventional horticultural and other organosilicone adjuvants are made to illustrate the unique properties of Du-Wett and Bond Xtra, which can improve the retention and coverage of sprays on onions and potatoes without increasing the risk of crop phytotoxicity.

Keywords: organosilicone surfactants, agrochemicals, spray volumes, potatoes, onions.

INTRODUCTION

Onions (*Allium cepa* L.) and potatoes (*Solanum tuberosum* L.) are row crops requiring intensive, high-volume agrochemical spray inputs to ensure their yield and quality are maintained. The economic and environmental benefits of lowering spray application volumes on such crops are well recognised but not easy to achieve. Both crops present inherent problems and different challenges; potatoes due to their dense, layered canopy and onions because of their vertical, waxy leaves. The major reason for using high volume applications is to increase retention and coverage of sprays on foliage. Spray adjuvants are known to affect these processes (Holloway 1998) and the organosilicone superwetters were identified as a class of adjuvant with the potential to reduce spray volumes without adversely affecting agrochemical performance. However, these surfactants were developed primarily as adjuvants for herbicides (Stevens 1993) and some of their physical properties are less desirable in a horticultural adjuvant. In particular, their ability to provide stomatal infiltration of spray solutions at high volumes and concentrations could lead to unacceptable crop phytotoxicity when used with protectant or contact pesticides, which are not intended to penetrate into foliage. Additionally, their superwetting properties may result in a loss of efficacy due to runoff or reduce the rainfastness of protectant chemicals.

This paper reports on the studies undertaken with two organosilicone adjuvant blends which aimed to at least halve agrochemical spray volumes on onion and potato crops without adversely affecting spray efficacy. The effects of the adjuvants on the physical characteristics of a wide range of the multi-component sprays applied to both crops, including insecticides, fungicides, foliar nutrients and plant growth regulators (PGR), were determined. This included spray retention and distribution on plants of all ages, droplet spreading on leaves, spray penetration via stomatal infiltration and crop phytotoxicity.

MATERIALS AND METHODS

The two adjuvants investigated in this study were Du-Wett (blend of organosilicone and organic surfactants; Elliott Chemicals Ltd) and Bond Xtra (mix of synthetic latex and organosilicone surfactant; Loveland Industries, USA). Du-Wett is a novel

superwetter intended for use where improved retention and coverage of horticultural sprays is desired. Bond Xtra is a sticker-spreader type adjuvant designed to improve spray deposition, coverage and rainfastness of agrochemical sprays. The adjuvants included for comparison were Citowett (alkylaryl polyglycol ether; BASF), Silwet 408 and Silwet L-77 (silicone polyalkyleneoxide copolymers; Witco Corporation, USA) and LI 700 (phosphatidylcholine/surfactant blend; Loveland Industries, USA).

The study covered a range of more than 50 combinations of active ingredients (ai), including fungicides, insecticides, nutrients and PGR, routinely used in onion and potato foliar spray programmes. The necessarily restricted number of treatments described in this paper to include formulations or mixes of mancozeb, azoxystrobin, carbendazim, copper hydroxide, dimethomorph, lambda-cyhalothrin, endosulfan and maleic hydrazide.

Spreading measurements were made on freshly detached leaves from outdoor-reared potato (cv. Iam Hardy) and onion (cv. Regular Long Keeper) plants. Treatment solutions containing fluorescent dye (1% Blankophore P) were applied as droplets (0.5 µl) with a microsyringe. Spread areas were visualised under UV light and measured using V for Windows image analysis software. A minimum of ten replicates on three leaves, sourced from separate plants, were used for each treatment.

Infiltration of spray into the stomata of potato leaves was determined using a radiolabelled probe, ^{14}C -deoxyglucose (Amersham, UK). Droplets (0.24 µl) of solution were applied to an adaxial leaf surface on five separate plants, to approximate spray application rates of 200 and 1000 litres/ha, and infiltration determined at 10 min after treatment as described previously (Gaskin *et al.* 1996).

Spray retention on outdoor-grown potted plants was determined using a calibrated belt tracksprayer and with tartrazine dye incorporated in all sprays (Murray *et al.* 1998). Treatments were applied (20 plant replicates) at either 200 or 500 litres/ha equivalent through a hollow cone nozzle (TXVS-6, 220 kPa) mounted 0.5 m above mean plant height. Onion and potato plants were harvested at ground level, washed immediately after spraying to recover the retained dye and dry weights (DW) determined subsequently. Onions with more than three true leaves, or potatoes >150 mm tall, were sub-sectioned to determine spray distribution on upper and lower canopies. Surface areas of representative plants were measured to correlate DW with area and the correlations for onion and potato were $R^2=0.89$ and 0.98 , respectively. Thus, retention per unit weight was a very good indicator of retention per area for both crops. Retention of tartrazine dye was calculated and transformed into the equivalent rate of ai for direct comparison between different application volumes. Extra replicates were sprayed in all treatments and monitored for four weeks thereafter for signs of spray phytotoxicity.

All experiments were analysed as factorial designs and analysis of variance and least significant difference (LSD) tests at $P<0.05$ were used to compare treatments. Stabilising transformations were performed where necessary prior to analysis.

RESULTS AND DISCUSSION

Spreading

The spread of more than 300 different spray formulations was determined on onion and potato foliage and examples of varying combinations of adjuvants and ai are presented (Table 1). Potato leaves were more readily wetted than the waxy onion foliage. The superwetter adjuvants, Du-Wett and Silwet 408, markedly improved droplet coverage on onion compared to the conventional adjuvant, Citowett, and generally more so with Silwet 408. Bond Xtra spray solutions spread significantly less than Du-Wett, but often more than the conventional adjuvant, Citowett, used at the recommended rates for these crops.

It was the varying and often unpredictable effects of different agrochemical formulations, and their combinations in tank mixes, on organosilicone adjuvant spreading that made comprehensive screening necessary. Droplet spread was dependent on both adjuvant concentration and agrochemical formulation. In standard mancozeb sprays on both species, increasing the rates of organosilicone-based adjuvants gave a

significant ($P < 0.05$) and substantial increase in spreading (Table 1). Agrochemical formulations can have varying effects on organosilicone performance due to the presence of other surfactants in those formulations (Policello *et al.* 1996). Potato treatments (Table 1) illustrate the adverse effect on coverage of an additional product, lambda-cyhalothrin, included in a mancozeb spray. A typical beneficial effect on Du-Wett spreading is shown on onions, where the coverage of a mancozeb spray was improved with the addition of two extra fungicides, dimethomorph and copper hydroxide, in the spray tank (Table 1). The extensive spreading data gathered for Du-wett and Bond Xtra allowed predictions of optimal adjuvant rates to maximise coverage for a wide range of tank-mix agrochemical combinations on foliage of both crops.

TABLE 1: Spreading (mm^2) of spray formulations (0.5 μl droplet) on onion and potato foliage with adjuvants.

Adjuvant	Rate (ml/100 litres)	Potato		Onion	
		m ¹	m+l ¹	m ¹	m+d+c ¹
Citowett	25	3.9 d	3.3 c	-	-
	70	-	-	5.9 f	5.9 e
Du-Wett	10	5.1 d	3.3 c	-	-
	50	14.5 c	6.0 c	12.6 e	14.1 c
	100	25.8 b	8.4 bc	23.0 d	34.8 b
	150	-	-	33.0 b	48.2 a
Silwet 408	10	6.0 d	4.7 c	-	-
	50	24.5 b	12.5 b	13.9 e	17.4 c
	100	50.7 a	45.8 a	26.5 c	31.9 b
	150	-	-	41.4 a	51.7 a
Bond Xtra	165	11.7 c	5.3 c	5.8 f	3.9 e
	330	-	-	12.5 e	10.0 d

¹m=mancozeb, l=lambda-cyhalothrin, d=dimethomorph, c=copper hydroxide

Means within columns sharing common postscripts are not significantly different ($P=0.05$)

Stomatal infiltration

There were significant differences in the amount of stomatal infiltration promoted by Du-Wett and Silwet L-77 on potato (Table 2). Infiltration by Du-Wett solutions was similar at all concentrations (i.e. there was no rate response) and was never more than with L-77. In contrast, infiltration increased with increasing L-77 concentration. Infiltration by Bond Xtra solutions was similar to, or less than, Du-Wett. The practical implication of these results is that organosilicone blends, such as Du-Wett and Bond Xtra, are less likely than a pure organosilicone to cause crop damage when used with pesticides which are not intended to penetrate into plants. Infiltration of solutions was consistently greater at the higher application volume for both surfactants (Table 2), an organosilicone effect which is well established (Gaskin *et al.* 1996). This also indicates a potential for greater phytotoxicity with high spray application volumes.

Retention

While treatments covered a wide range of ai and combinations of them applied throughout the crop rotation, only a selection of mancozeb sprays on potato are presented here (Table 3). Reduced volume sprays (200 litres/ha) containing an organosilicone were retained equally to, or better than, conventional applications at 500 litres/ha. As potato size (and canopy density) increased, the benefits of superwetter adjuvants increased. Du-Wett (100-200 ml/ha) provided equivalent or better retention of reduced-volume sprays than the recommended (and commonly used) Citowett treatment (125 ml/ha) at full volume. Bond Xtra treatments (330 ml/ha) were retained

TABLE 2: Stomatal uptake (as % of applied ai) of Du-Wett, Silwet L-77 and Bond Xtra solutions, from low and high volume applications to potato foliage.

Adjuvant	Rate (ml/100 litres)	Application volume	
		200 litres/ha	1000 litres/ha
Du-Wett	50	18 c	50 bc
	200	21 bc	53 b
	500	22 bc	55 b
Silwet L-77	50	28 bc	53 b
	200	35 b	79 a
	500	80 a	90 a
Bond Xtra	500	18 c	39 c

Means within columns sharing common postscripts are not significantly different (P=0.05)

TABLE 3: Retention of sprays on foliage (mg mancozeb/g DW) of potatoes of varying size with adjuvants.

Adjuvant	Rate (ml/100 litres)	Spray vol. (litres/ha)	Potato size ^{1,2}				
			1	2	3	4	5
Citowett	25	500	2.20 a	1.35 ab	0.54 b	0.46 c	0.41 c
Du-Wett	50	200	1.96 a	1.10 b	0.62 b	0.56 b	-
	100	200	-	1.27 b	0.66 b	0.51 bc	0.50 b
Bond Xtra	165	200	2.31 a	1.74 a	0.86 a	0.71 a	0.62 a

¹ 1 = 5-10 cm tall, 2 = 10-15 cm, 3 = >40 cm, 4 = >65 cm, 5 = >30 cm (mature, diseased)

² sizes 1-3 & 5 sprayed with mancozeb, size 4 with mancozeb(+azoxystrobin)

Means within columns sharing common postscripts are not significantly different (P=0.05)

TABLE 4: Retention of sprays on foliage (µg ai/g DW) of onions of varying size with different adjuvants.

Adjuvant	Rate (ml/100 litres)	Spray vol (litres/ha)	Onion size ^{1,2}					
			1	2	3	4	6	>8
Citowett	70	500	-	-	-	310 c	89 b	-
LI700	250	500	95 ab	77 a	50 b	-	-	212 ab
Du-Wett	150	200	82 bc	97 a	66 ab	570 b	-	190 b
	200	200	72 c	-	63 ab	650 ab	153 a	266 a
Bond Xtra	330	200	104 a	93 a	73 a	690 a	104 b	210 ab

¹ number of true leaves emerged

² sizes 1-3 sprayed with carbendazim, 4 with mancozeb, 6 with mancozeb (+endosulfan), >8 with mancozeb(+maleic hydrazide)

Means within columns sharing common postscripts are not significantly different (P=0.05)

consistently better than Citowett sprays on plants with mature, dense canopies (≥ 40 cm).

Similar results were obtained on onions (Table 4), where adjuvants were used at higher rates due to the difficulty of getting good spray retention and coverage on this crop. As onion size increased, the benefit of the organosilicones, and increasing Du-Wett rate, became apparent with a wide range of tank-mixes. Newly emerged onions (single-leaf) were susceptible to runoff of Du-Wett sprays. However, once the crop reached the 2-leaf stage, low-volume Du-Wett sprays (300-400 ml/200 litres/ha) were retained equally as well as conventional 500 litre/ha sprays containing either Citowett (350 ml/ha) or LI 700 alone (1.25 litres/ha). Retention of low-volume sprays containing Bond Xtra (660 ml/200 litres/ha) was generally similar to Du-Wett treatments and at least as good as conventional high-volume applications.

Spray distribution and phytotoxicity

The distribution of sprays on plants (data not presented) showed that reduced-volume sprays containing organosilicone adjuvants consistently directed more chemical to the lower portions of the crop relative to conventional, full volume sprays ($P=0.05$). In onions, this is expected to aid thrip control in the difficult-to-access "throat" region; in potatoes it would assist in blight control, which frequently develops within the humid environment provided by the dense canopy.

There were no phytotoxic effects observed from any treatment applied to onions or potatoes throughout this study. The use of Du-Wett and Bond Xtra, at the rates tested here, is not expected to cause any crop damage with the agrochemicals routinely applied in foliar spray programmes.

This study confirms the potential of two novel organosilicone adjuvants to reduce spray volumes in row crops while improving spray deposition and retention. Trials to monitor the field performances of Du-Wett and Bond Xtra are currently in progress.

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