EFFECT OF AN ORGANOSILICONE SURFACTANT ON SPRAY DROP ADHESION AND RETENTION BY PEA (*PISUM SATIVUM*) LEAF SURFACES

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SUMMARY

The adhesion and retention of spray drops produced by a mono-sized drop generator and applied to pea (*Pisum sativum*) leaves was measured. Silwet L-77 surfactant was used to characterise the influence of increasing amounts of surfactant on the behaviour of water and glyphosate solution drops. Addition of surfactant increased adhesion and retention on leaves at 0° and 22.5° angle of inclination from the horizontal. There was no adhesion with leaves inclined at 45° but retention was substantial provided surfactant concentrations were at or above 0.5% w/v.

Keywords: adhesion, retention, adjuvant, Silwet L-77, glyphosate

INTRODUCTION

Initial drop adhesion onto leaf surfaces is the consequence of dynamic interactions within the spray solution during flight and on impact. Retention is the overall capture of drops by a leaf or plant from either primary drop or secondary droplet impact and adhesion. It has long been stated that small water drops, eg. 20-50 µm in diameter, will adhere to all plant surfaces and that large drops, (eg. 3000 µm) will fragment on impact (Hartley and Brunskill 1958). More specifically, water drops at terminal velocity were retained on pea leaves if they were less than 100 µm in diameter. There was complete reflection if they were over 250 µm in diameter as well as greater reflection of smaller drops at higher leaf angles ie. non-planar leaf orientation. Leaf surfaces with micro-roughness showed lesser drop adhesion and the addition of substances which reduced surface tension enhanced adhesion (Tadros 1987). Adhesion depends greatly on formulation, as well as drop velocity and size, as it has been found that 336 µm diameter water drops at 0.7 m/s velocity could not adhere to leaves at 45°, but with with 0.1% added surfactant could be collected equally well on horizontal and angled leaves (Young *et al.* 1987).

A "retention factor" expression has been derived, linking static solution surface tension, drop contact angles and density (Furmidge 1962) and recently improved further (Watanabe and Yamaguchi 1992). It has been identified that dynamic surface tension instead of solution surface tension was better correlated with retention (Anderson and Hall 1989). Dynamic surface tension is strongly affected by surfactant structure and solution concentration (Wirth *et al.* 1991; Policello *et al.* 1993), and these factors will contribute to leaf adhesion and whole plant retention. Organosilicone surfactants, which provide lower solution surface tensions than many other surfactants, can further enhance drop adhesion (Stevens *et al.* 1993), particularly with drops at higher velocity. Large drops, eg. >500 µm, such as are typical of some New Zealand herbicide spray applications, but which have low surface tensions and are fast moving, may also shatter on impact and produce satellite droplets which are smaller, have lower velocities and will be more capable of adhering to another leaf surface.

The present study was a comparison of the interactions of organosilicone surfactant concentrations and leaf orientations on initial leaf adhesion and individual leaf retention, using pea leaves as a model substrate and applying monosized drops from a drop generator. Surfactant concentrations were varied over a wide range, both in water and glyphosate solutions.

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METHODS

Silwet L-77 (OSi Specialities Inc.) was used at various concentrations in distilled water or a commercial glyphosate formulation (36% ai; Roundup) at the equivalent of 7.5 litres/ha of product in 300 litres of water carrier. All solutions were made up fresh each day prior to use.

Peas (cv. Greenfeast) were grown from seed in pots (70 mm diameter) containing Bloom, a proprietary potting mixture. The plants were illuminated with 450-500 $\mu\text{mol}/\text{m}^2/\text{s}$ for 11.5 h daily by mercury vapour lamps with a 1% red light supplement provided by tungsten lamps. The red light extended for 0.5 h either side of the main photoperiod to provide dawn and dusk periods during which the temperature was changed ($10^\circ\text{C}/\text{h}$) between the night (15°C) and day (20°C) temperatures. Relative humidity was maintained at a constant 70% and water was supplied once daily as required. The adaxial surfaces of fully expanded leaves (approximately 3 cm long), taken from plants 4 to 5 weeks after planting, were used immediately after excision. These were mounted on a stage at 0° , 22.5° or 45° inclination from the horizontal in the impaction zone of the vertically falling drops.

An impulse-jet drop generator (Young 1986) was used to produce mono-sized drops in the range 613-684 μm . The variation was largely due to formulation differences as the generator orifice and electrical pulse height was constant, and electrical pulse width and head pressure adjusted minimally.

The size of drops was determined by a colourimetric method. Erio Acid Red (0.5% w/v; Ciba-Geigy) a UV fluor, was incorporated into the solutions to allow quantitation and visualisation of drops. This dye had no effect on drop size and solution characteristics (Sundaram 1990). Known numbers of drops were collected in a vial, a standard volume of water added and the absorption of the dye determined. Drop size was calculated from the known solution dye concentration and the number of drops collected.

Drops or droplets reflected off leaves were captured also on 20 x 20 cm sheets of plastic covered in silica gel (Eastman Chromatogram Sheet Cat No 13179; 100 μm silica layer). These sheets gave stain sizes which accurately represented droplet volume (Forster and Zabkiewicz unpublished). The stains from reflected droplets were measured by image analysis to give estimates of satellite droplet dimensions. In addition, the entire sheet plus leaf were photographed for illustrative purposes. Drops were permitted to fall a distance of 800 mm. Velocity was determined by multiple-exposure photography using high speed instant film (ISO 3000 Polaroid 667) and stroboscope illumination. Determined impact velocities were in the range 2.35 to 2.59 m/s.

To determine adhesion ten drops were impacted onto each of five replicate leaves, taken from different plants. The fate of each drop was observed (using UV illumination) and the number of drops adhering on initial impact was recorded. Adhesion was expressed as a percentage of drops applied.

Retention was determined from the difference between theoretical 100% retention and measured reflection of parent or satellite droplets off the target leaf. Ten drops containing dye were impacted onto each of 5-12 leaves placed individually in a petri dish. The droplets reflected from the target leaf and caught in the petri dish were recovered using a methanol wash. The methanol solution was evaporated to dryness under a stream of dry nitrogen and a fixed volume of water added, then the dye was quantified in a spectrophotometer (at 565 nm).

Mean values and standard errors were obtained from analysis of variance; where significant effects were indicated by an F-test, means were compared using the LSD.

RESULTS AND DISCUSSION

Results are presented in Table 1 for initial adhesion and retention of drops of water and glyphosate solutions plus Silwet L-77 on single pea leaves in relation to various leaf orientations.

TABLE 1: Percentage adhesion and retention of drops of water and glyphosate solutions +/- Silwet L-77 on pea leaves at varying angles.

	Leaf angle 0°		Leaf angle 22.5°		Leaf angle 45°	
Water + Silwet L-77	Adhesion	Retention	Adhesion	Retention	Adhesion	Retention
0	0 i	0 j	0 i	0 j	0 i	0 j
0.2	34 f	67 de	0 i	8 j	0 i	0 j
0.3	24 g	95 a	0 i	54 f	0 i	0 j
0.5	92 b	100 a	10 h	75 cd	0 i	5 j
1.0	100 a	100 a	88 bc	100 a	0 i	39 gh
2.0	100 a	100 a	100 a	100 a	0 i	57 f
Glyphosate + Silwet L-77						
0	78 d	100 a	0 i	35 h	0 i	0 j
0.2	60 e	95 a	0 i	61 ef	0 i	0 j
0.3	82 cd	100 a	22 g	76 c	0 i	20 i
0.5	84 cd	100 a	40 f	86 b	0 i	24 i
1.0	100 a	100 a	100 a	100 a	0 i	24 i
2.0	100 a	100 a	100 a	100 a	0 i	44g

Adhesion means or retention means sharing common postscripts were not significantly different at $P = 0.05$ (LSD)

Pure water drops did not adhere to horizontal leaves (leaf angle 0°); partial adhesion was observed at 0.2% - 0.5% surfactant; total adhesion at 1% surfactant and above. A similar trend was observed with leaves oriented at 22.5°, but with no adhesion till surfactant concentration was above 0.3% and complete adhesion only at 2% surfactant. There was no adhesion at any concentration of surfactant with leaves oriented at 45°.

Retention was in most cases larger, indicating that there was either reflection of the parent drop or satellite droplets for a short distance, with subsequent capture on the same leaf, or that there was substantial retention of solution from the parent drop in the first instance. The latter effect was most marked with leaves at 45° and higher surfactant concentrations.

After impact, water drops were reflected at varying angles and over long distances for all leaf orientations. Addition of 0.3% Silwet L-77 caused most drops to stick onto horizontal leaf surfaces but some satellite droplets were produced; at 22.5° leaf orientation, predominantly satellite droplets were produced which were reflected; at 45° all drops were reflected but for a greater distance than at 22.5° leaf orientation. At 1.0% surfactant and leaf angle at either 0° or 22.5° there was complete retention and drop spreading; at 45° there was partial retention of liquid after impaction, but continued reflection of satellite droplets. At the same leaf orientations, there was a trend for reduced reflection distance with increasing surfactant concentration.

Adhesion of drops of glyphosate solutions on horizontal leaves was substantial without any added organosilicone surfactant, and in fact decreased on the addition of 0.2% organosilicone surfactant and did not reach 100% adhesion till surfactant concentrations were 1%. Leaves oriented at 22.5° showed adhesion trends similar to those for water plus surfactant alone, ie. nil at 0.2%, partial adhesion at 0.5% and complete adhesion at 1% surfactant. Leaves at 45° did not show any adhesion at all.

Retention behaviour of glyphosate solutions in general showed the same trends as with water alone plus surfactant, ie. enhanced retention at all leaf orientations with increasing surfactant. The increase in retention on leaves at 45° was greater at 0.3% and 0.5% surfactant concentrations than with equivalent water plus surfactant solutions, but less at 1% and 2%.

In contrast to water only drop behaviour, the surfactants in the glyphosate formulation caused the drops to be retained 100% at 0° leaf orientation. The majority were reflected at 22.5° and all were reflected at 45°. With 0.3% Silwet L-77 added, drops were weakly reflected at 22.5° but recaptured onto the leaf, while at 45° most were reflected off the leaf with some satellite droplet formation. At 1.0% surfactant and leaf angle of either 0° or 22.5° there was no reflection. At 45° behaviour was as for water plus surfactant drops ie. there was partial retention of liquid after impact and substantial reflection of parent drops.

These results show that very high concentrations of surfactant can give substantial retention of spray solution even at high leaf impact angles.

Earlier studies (Stevens *et al.* 1992, 1993) demonstrated that organosilicone surfactants could provide superior adhesion of drops of water plus surfactant on pea leaves. Generally adhesion decreased as drop size, velocity and angle of incidence increased. It was shown that adhesion decreased rapidly with increasing velocity. For example, adhesion onto a horizontal leaf of 700 µm drops was approximately 80% at a velocity of 1.5 m/sec but fell to approximately 10% at 2.5 m/sec. The above determination were made with surfactant solutions up to 0.5% w/v water and did not take into account additional retention of applied solution through re-capture on the same leaf or partial retention of drops and/or satellite droplets.

In the current study, velocities of drops, (over the size range 613-684 µm) were all above 2 m/sec and it was of interest to determine whether under conditions where there was low or nil initial adhesion, leaf surfaces could still retain some of the water or herbicide spray formulations. The results obtained illustrate clearly that this can happen. However, with whole plants and under field conditions, there needs to be further consideration of the total applied spray volume. One study (Stevens unpublished) has found that pea plants can absorb an application volume of 800 litres/ha without any evidence of run-off losses, when sprayed with water containing 0.2% Silwet L-77. Further field testing of these laboratory evaluations is required to confirm this behaviour.

CONCLUSIONS

Solutions containing Silwet L-77 organosilicone surfactant show the same trends for droplet adhesion on leaf surfaces as found previously with other surfactants. Addition of low amounts of surfactant can assist with adhesion on difficult to wet leaf surfaces. In this study, large drops with relatively high velocities and surfactant concentrations were capable of adhering onto non-horizontal leaf surfaces.

Moderate concentrations of surfactant (above 0.2%) increased actual leaf retention, in relation to initial adhesion values, and high (above 0.5%) concentrations provided good retention even on leaf angles of 45°.

Endogenous surfactants in the glyphosate solution were sufficient to give complete or partial retention at low leaf angles, but not for high leaf angles. Addition of 0.3% or more Silwet L-77 was needed to enhance retention on leaves at 45°.

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