LEAF SURFACES OF WHEAT AND RYEGRASS AND DROPLET SPREAD

K.J. Levick[1], N.D. Hallam[1] and J.H. Combellack[2]
[1] Department of Ecology and Evolutionary Biology, Monash University, Melbourne, Australia
[2] Keith Turnbull Research Institute, Melbourne, Australia

Summary. The leaf surfaces of wheat and ryegrass were investigated using scanning electron microscopy. Wheat had stomata and trichomes on both the upper and lower surface. Ryegrass had stomata and trichomes only on the upper leaf surface. There were crystalline waxes on both surfaces of wheat and on the upper surface of ryegrass but the lower surface of ryegrass had amorphous waxes. Water droplets spread most on the lower surface of ryegrass but droplets of four oil-in-water emulsions spread most on the upper surface of ryegrass. Static surface tension of the emulsions had no effect on droplet spread.

INTRODUCTION

Annual ryegrass (*Lolium rigidum* Gaud.) is an important weed of wheat crops in southern Australia. The efficacy of foliar herbicides depends on their ability to be retained, spread over, and then penetrate the leaf surface. The wettability of a leaf is dependent on the roughness of the leaf surface, which may be due to macroscopic (eg. venation), microscopic (eg. trichomes and epidermal cell shape) or ultramicroscopic (eg. wax morphology) factors. The properties of the spray liquid, such as surface tension and viscosity, also have an effect on the spread of a droplet on the leaf (3).

This paper examines the leaf surfaces of wheat and annual ryegrass and compares the spread of droplets of water and a number of oil-in-water emulsions on these leaf surfaces.

METHODS

Spray deposits. Droplets of distilled water were sprayed onto the upper and lower surfaces of wheat and ryegrass using a hand operated spayer fitted with a hollow cone nozzle. Samples of the leaf carrying the droplets were then frozen by plunging them into liquid nitrogen. When frozen the leaf segments were sputter-coated with a layer of gold using an EMSCOPE SP 2000 unit before being examined (still frozen) with a Hitachi 540 scanning electron microscope (SEM).

Leaf surface characteristics. *(a) Microscopic factors.* Wheat cv. Meteor and annual ryegrass were grown in a glasshouse during summer under prevailing light and temperature conditions. When the plants were at stage 15 (Zadoks scale) samples were taken fron the middle section of the youngest mature leaf, fixed in 5% glutaraldehyde, dehydrated using an ethanol series and critical-point-dried. The leaf samples were attached to stubs, sputter-coated with a layer of platinum and examined in the SEM.

(b) Wax structures. To avoid solubilization of wax by ethanol, the wax structures on the leaf surfaces were examined using both air- and freeze-dried samples. The samples were attached to stubs and sputter-coated with platinum before being examined in the SEM.

Droplet spread. 0.5 uL droplets (containing 5.0 g/L flourescein (Harcross Colours) as a marker) of each of 5 solutions were placed on leaf segments. After the droplets had dried the deposit length was measured using a binocular disecting microscope with a graticule. The solutions used were distilled water and 1% (v/v) emulsions of KTRI 8, KTRI 9 (emulsifiable canola oils) and D-C-Trate and Shell EDM (emulsifiable petroleum oils).

Surface Tension. Equilibrium surface tension of each solution was measured using a CAHN DCA analyser.

RESULTS

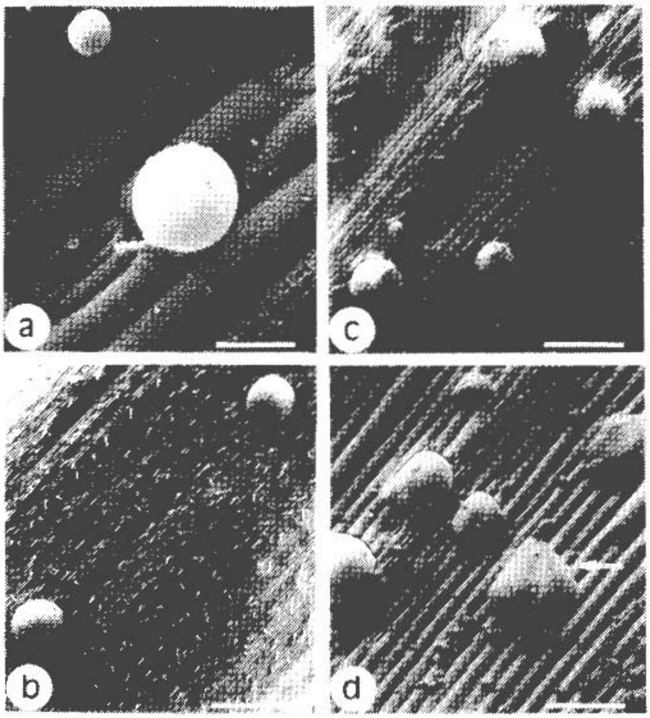

Figure 1. Droplets of water on wheat and ryegrass. (a) upper surface of wheat (bar=43μm), (b) lower surface of wheat (bar=0.6mm), (c) upper surface of ryegrass (bar=250μm), (d) lower surface of ryegrass (bar=176μm).

Spray deposits. Scanning electron micrographs of water droplets on the upper and lower surfaces of wheat and ryegrass are shown in Fig. 1. For both the upper and lower surface of wheat and the lower surface of ryegrass the droplets are spherical and show no spreading. On the lower surface of ryegrass the droplets are flattened and making obvious contact with the leaf (arrow). On the upper surface of ryegrass most of the droplets have been caught by trichomes and are held above the leaf surface.

Leaf surface characteristics. The upper and lower surfaces of wheat and the upper surface of ryegrass had only crystalline wax in platelet form (Table 1). The lower surface of ryegrass was covered by amorphous wax. Wheat stomata were more dense on the upper than on the lower surface. However, ryegrass stomata were found only on the upper surface. On wheat fewer trichomes were found on the upper than on the lower surface. Trichomes were found only on the upper surface of ryegrass. Venation on the upper surface of ryegrass was much more pronounced than that of wheat. On both species venation was evident as parallel ribs on wheat and ryegrass. Neither species showed substantial venation on the lower surface.

Table 1. Surface characteristics of wheat cv. Meteor and annual ryegrass

Surface	Wheat		Ryegrass	
	upper	lower	upper	lower
stomata (mm^{-2})	73.32 ± 2.26	23.87 ± 3.07	119.89 ± 7.65	0.00
trichomes (mm^{-2})	33.39 ± 6.49	96.34 ± 5.58	25.51 ± 5.10	0.00
venation (mm^{-1})	6.82 ± 0.43	0.00	12.12 ± 1.83	0.00
wax type	crystalline	crystalline	crystalline	amorphous

Droplet spread. Table 2 shows that distilled water spread further on the lower surface of ryegrass than on the other three surfaces. For each emulsion the greatest spread was on the upper surface of ryegrass. The spread of each of the solutions was significantly ($p=0.05$) different on the upper and lower surface of wheat.

Table 2. Droplet spread and equilibrium surface tensions

Solution	Surface tension (dyne/cm)	Wheat		Ryegrass	
		upper	lower	upper	lower
H_2O	72.59 ± 0.21	0.92 ± 0.30	0.92 ± 0.30	0.89 ± 0.15	2.42 ± 0.09
KTRI8	30.87 ± 0.18	4.79 ± 0.51	3.63 ± 0.30	10.70 ± 1.95	6.83 ± 0.33
KTRI9	30.97 ± 0.12	8.40 ± 0.62	6.77 ± 0.77	16.39 ± 1.56	6.63 ± 1.09
Shell EDM	32.07 ± 0.22	10.67 ± 0.49	11.34 ± 0.67	15.50 ± 1.33	9.50 ± 1.00
DC Trate	38.33 ± 0.60	9.05 ± 0.45	8.90 ± 0.53	14.88 ± 1.09	8.71 ± 1.58

On the upper surface of ryegrass there was no significant ($p=0.05$) difference between the spread of KTRI9, Shell EDM and DC Trate. On the lower surface of ryegrass there was no significant ($p=0.05$) difference between the spread of KTRI 8, KTRI 9 or D-C-Trate. There was also no difference between the spread of Shell EDM and D-C-Trate on the lower surface of ryegrass. All of the solutions spread almost entirely along the length of the leaf with very little lateral movement. This was most pronounced on the upper surface of ryegrass, where the entire volume of the droplet would often spread along one or two interveinal grooves.

DISCUSSION

When spray droplets land on a leaf surface and are retained, they can either spread across the leaf surface or dry at the point of impact (4). In this study, the water droplets dried at the point of impact on the upper surfaces of wheat and ryegrass and spread on the lower surface of ryegrass. However the droplets of the emulsions spread, to differing degrees, on all the leaf surfaces.

In the present studies the addition of emulsified seed and petroleum oils to water resulted in reduced surface tension and increased spread on the leaf surfaces examined. However, within the group of emulsions there was no obvious relationship between surface tension and droplet spread.This supports the finding of Abbot etal (1) who found that surface tension, critical micelle concentration and contact angle were poor predictors of spread.

However, the nature of the leaf surface had a large effect on spread. For example, water droplets spread most on the lower surface of ryegrass, which was the smoothest of the surfaces examined (amorphous waxes and no stomata or trichomes). The emulsions however, spread most on the upper surface of ryegrass which was, on the basis of stomate number and venation, the 'roughest' leaf surface studied. The greater spread on the upper surface of ryegrass may be due to the 'wicking' effect mentioned by Johnson and Dettre (2). It is more likely that the bulk of the droplets on the upper surface of ryegrass spread along only one or two veins, resulting in a very long, narrow deposit which did not necessarily cover a surface area greater than the shorter, wider deposits formed on the other leaf surfaces. Measurement of the total area covered by a deposit would be a more reliable method of comparing the behaviour of droplets of different formulations on various surfaces. Unpublished data (Levick) indicates that there is an interaction between droplet spread and droplet size, adjuvant concentration and surface structure. The complexities of the interaction of spray formulation and droplet size with waxes and other leaf surface structures need further study in order to clarify the patterns of spread and their effect on spray efficacy.

ACKNOWLEDGEMENTS

This work is part of a project funded by the Grains Research and Development Corporation, Australia. The petroleum oils were provided by Shell Chemical (Australia) Pty Ltd.

REFERENCES

1. Abbot, H.A. and van Dyke, L.P. 1990. Pest. Sci. 14, 645-658.
2. Johnson, B.E. and Dettre, R.H. 1964. In: Contact Angle, Wettability and Adhesion. (Ed. F.M. Fowkes) (American Chemical Society). pp 112-144.
3. Martin, J.T. and Juniper, B.E. 1970. The Cuticles of Plants. (Edward Arnold (publishers) Ltd: Great Britain).
4. de Ruiter, H., Uffing, A.J.M., Meinen, E. and Prins, A. 1990. Weed Sci. 38, 567-572.