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Applying sunflower oil to rapeseed plants reduces water loss

Rudy Gomes Pereira de Godoi and Peter Stephen Kettlewell*

Abstract

BACKGROUND: Hydrophobic polymers are used as antitranspirants to block stomata and reduce water loss from plants and thus drought stress, although the use of current commercial products is limited because they are expensive. Plant oils may be much cheaper hydrophobic polymers if they have similar efficacy to commercial antitranspirant products. Two experiments with pot-grown rapeseed plants were conducted to compare sunflower oil with the commercially-available antitranspirant di-1-*p*-menthene (DPM) for efficacy in reducing water loss, and to test for a linear response to increasing oil concentration.

RESULTS: Sunflower oil at the same concentration as DPM (0.5%) was similar in efficacy in reducing the rate of water loss, measured as both rate of weight loss of the plant and rate of stomatal conductance decline. There was a linear response to increasing concentrations of oil, as found in previous research with DPM on rapeseed, with a slower rate of water loss the greater the concentration.

CONCLUSION: If other plant oils are equally or more effective in reducing water loss as sunflower oil, there may be potential for plant oils to be used as low-cost antitranspirants to reduce drought damage on large-scale commodity crops, and also by smallholder farmers in low-income countries using locally-produced plant oils.

Keywords: antitranspirant; stomatal blocker; transpiration; drought; water stress

INTRODUCTION

A need for water-saving technologies in crop production is being driven by a combination of increasing demand for food from the rising global population, together with climate change leading to less water available for irrigation and greater crop losses from drought.[1] One under-utilised technology is the reduction of plant water loss by using sprays of hydrophobic polymers, such as terpenes, to block stomata, often referred to as film antitranspirants in this role.[2] These products are expensive, and thus currently justified mainly on high value crops or ornamental plants, but, nevertheless, they have potential to increase yield under drought of major global food crops such as wheat and rapeseed.[3] If cheaper polymers could be shown to have similar efficacy to the terpene antitranspirants, then there may be greater likelihood of their adoption for reducing drought damage to food crops, especially by smallholder farmers in low-income countries.

Early research into film antitranspirants showed that a wide range of hydrophobic polymers such as fatty acids, long chain alcohols and petroleum-derived wax can reduce plant transpiration,[4] Plant oils are also hydrophobic polymers and thus may also have potential as film antitranspirants, although there is little indication in the literature that this role for plant oils has been evaluated. Therefore, the present study aimed to investigate the efficacy of applications of a plant oil in reducing plant water loss. Two experiments were conducted with sunflower oil applied to glasshouse-grown rapeseed plants. The null hypothesis being tested was that applying sunflower oil has no effect on water loss from rapeseed plants.

MATERIALS AND METHODS

Plant material

Seeds of spring rapeseed (*Brassica napus* L.) cultivar Mirakel were sown on 22 July 2019 (Exp 1) and 6 September 2019 (Exp 2) into John Innes Number 2 compost (John Innes Manufacturers Association, Chilton, UK) in 1-L pots. The pots were placed on a bench in a glasshouse with temperatures in the range 15–28 °C during the experiments, thinned to one plant per pot at the first leaf stage, and watered daily until all plants had three fully developed leaves, when spraying with the treatments took place.

Treatments

Ten replicate plants for each treatment were sprayed on 7 August 2019 (Exp 1) and 24 September 2019 (Exp 2) using a custom-built

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automatic pot sprayer with a pair of nozzles (Hypro Flat Fan 110-03; Retrofitparts, Newark, UK) at a height of 50 cm from the plants, and operating at 0.2 MPa pressure and nominal 1 m s^{-1} forward speed delivering the equivalent of 200 L ha^{-1}. The five treatments were: water; di-1-*p*-menthene (DPM) as Vapor Gard (96% DPM; Miller Chemical, Hanover PA, USA) at 0.5% (equivalent to a field rate of 1 L ha^{-1}); food-grade sunflower oil at 0.5% mixed with a non-ionic wetting agent at 0.5% (Activator 90; De Sangosse, Newmarket, UK); sunflower oil at 1.0% with wetting agent at 1.0%; sunflower oil at 1.5% with wetting agent at 1.5%.

Assessments

After spraying, the pots were arranged on the glasshouse bench in a randomised block design, watered to field capacity and the surface covered with plastic beads to minimise water loss from the soil surface. Water loss was assessed by weighing the pots immediately before spraying and then at regular intervals. Additional assessment of stomatal blockage for Exp 2 was by measuring stomatal conductance on one fully-expanded leaf per plant of four replicates. The same leaf was measured at regular intervals from 8 days after spraying (DAS) using a dynamic diffusion porometer (model AP4; Delta T Devices, Cambridge UK) between 12.00 h and 14.00 h and with air temperatures in the range 20–25 °C.

Statistical analysis

The pot weight data for each plant were standardised by calculating the value at each measurement time as a percentage of the initial value recorded on the day of spraying. Graphs of percentage of initial weight over time were examined to determine the duration of the linear period of decline, and only data for the linear period were included in further analysis. The measurement times for the linear period were 1, 2, 5, 6, 7, 8 and 9 DAS and 1, 5, 7 and 10 DAS for Exps 1 and 2 respectively. Regression coefficients (rates of decline) of percentage of initial weight against time were calculated separately for each pot and because the results were similar for both experiments, the coefficients from both experiments were combined and analysed in an analysis of variance (ANOVA) using Genstat, 20th Edition (VSN International, Hemel Hempstead, UK). The ANOVA was weighted with the reciprocal of the variance of each experiment because Exp 1 was more variable than Exp 2. Stomatal conductance decline appeared to be linear over all dates (8, 10, 15, 17 and 22 DAS) and regression coefficients of rate of decline in stomatal conductance were calculated separately for each pot and the coefficients analysed in an ANOVA. Four orthogonal contrasts were calculated in the ANOVAs: water *versus* mean of antitranspirants, DPM *versus* mean of sunflower oil, linear response to sunflower oil concentration, and deviations from linear response to sunflower oil concentration.

RESULTS

Across both experiments, the rapeseed plants treated with antitranspirants lost weight at a lower rate on average (1.5% day^{-1}) than water-treated plants (1.86% day^{-1}; $P = 0.005$) and sunflower oil on average (1.43% day^{-1}) was more effective in reducing the rate of loss than DPM (1.72% day^{-1}; $P = 0.026$) (Fig. 1). There was a strong linear effect of increasing sunflower oil concentration in reducing the rate of weight loss ($P = 0.004$) with 1.5% oil being the most effective. Although there was an indication in Fig. 1 that 1.5% oil was more effective than expected from linearity, the deviations from linearity were not significant ($P = 0.230$).

The rate of decline in stomatal conductance in Exp 2 showed broadly similar results to the rate of weight loss (Fig. 2), although DPM (50.5 mmol m^{-2} s^{-1} day^{-1}) was not significantly different to oil on average (44.7 mmol m^{-2} s^{-1} day^{-1}; $P = 0.487$). The linear effect of sunflower oil was, however, significant ($P = 0.002$) with 1.5% giving the slowest rate of stomatal conductance decline (19.7 mmol m^{-2} s^{-1} day^{-1}). Similar to rate of weight loss, there was also an indication from Fig. 2 of a greater response in stomatal conductance decline from 1.5% sunflower oil than expected from a linear effect (deviations from linearity, $P = 0.088$).

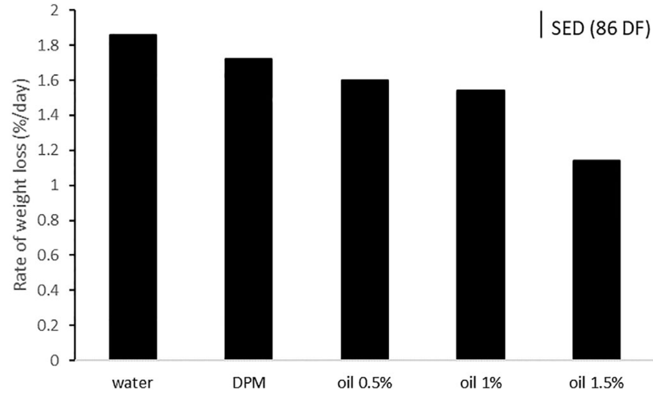

Figure 1. The effect of DPM or sunflower oil on rate of weight loss of unwatered rapeseed plants. Data combined from Exp 1 (1–9 days after spraying) and Exp 2 (1–10 days after spraying).

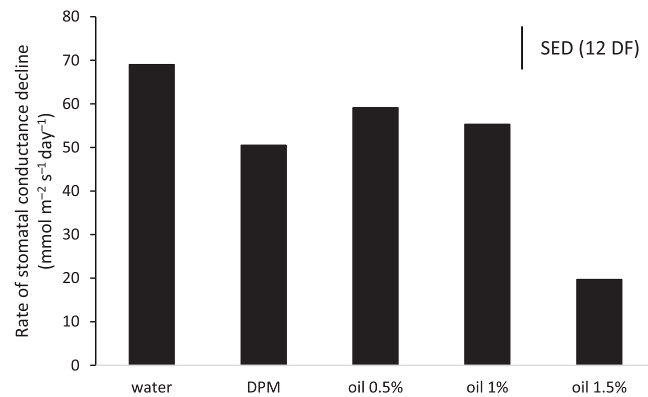

Figure 2. The effect of DPM or sunflower oil on rate of decline in stomatal conductance of unwatered rapeseed plants between 8 and 22 DAS in Exp 2.

DISCUSSION

Determining the loss in weight of the pots as an estimate of water loss from the plants is a common method in both manual[5] and automated[6] physiological studies. The plastic beads covering the compost surface will improve the accuracy of estimation by reducing direct evaporation from the compost surface. Some inaccuracy will result because photosynthetic product accumulation will reduce the weight loss, such that the weight loss is an underestimate of water loss. Over the short period of the experiments, this underestimate will be very small and probably unlikely to differ much between treatments. Furthermore, the broadly similar conclusions from rate of weight loss in the two experiments combined and rate of decline in stomatal conductance in Exp 2 gives confidence in the rate of weight loss as a measure of rate of water loss.

The slower decline in stomatal conductance in antitranspirant-treated plants was expected from reduced loss of water improving water status of the plants. Treatment differences in rate of stomatal conductance decline (Exp 2 only) were not exactly the same as the rate of weight loss, even in the same experiment (separate experiment data not presented), although this could be attributable to the time difference in the measurements: rate of weight loss in Exp 2 was over 1–10 DAS, whereas stomatal conductance decline was measured over 8–22 DAS. The linear effect of oil on the rate of stomatal conductance decline is similar to the linear effect of DPM on stomatal conductance in older rapeseed plants found in other work,[7] and is also consistent with the reductions in transpiration found in early research with other hydrophobic polymers.[4]

There are indications from research on fruit that other plant oils may also reduce water loss. Soybean oil can reduce weight loss of stored apple fruit[8] and a much cheaper unspecified vegetable oil can act in a similar way to an expensive antitranspirant in reducing cherry fruit splitting.[9] Further work aiming to evaluate other oils on plant water loss in addition to sunflower oil would be useful.

In addition to lower cost, plant oils have at least four other advantages for reducing plant water loss compared with commercial petroleum-derived polymers:

(1) Local availability throughout the world, and so easily accessible for smallholder farmers;
(2) Lower environmental impact because of faster biodegradability[10];
(3) Non-fossil fuel, and so no net contribution to carbon dioxide emissions when the plant oil degrades;
(4) No harvest interval, if a food grade oil is used.

CONCLUSIONS

These experiments have shown the potential of sunflower oil as a film antitranspirant to reduce drought damage, although further research is needed to evaluate other plant oils. If other plant oils are equally or more effective in reducing water loss as sunflower oil, there may be potential for plant oils to be used as a lower-cost alternative to commercial antitranspirant products on large-scale commodity crops. The ready availability of plant oils locally throughout the world may also make it feasible for smallholder farmers in low-income countries to use plant oils to limit drought damage to their crops.

AUTHOR CONTRIBUTIONS

RGPdG was responsible for investigations and methodology. PSK was responsible for conceptualisation, formal analysis, supervision, visualisation, writing the original draft, and reviewing and editing.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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