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PROFESSIONAL UPDATING

Economics of film antitranspirant application: a new approach to protecting wheat crops from drought-induced yield loss

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ABSTRACT

Drought is a major cause of economic loss to the world's wheat growers; estimated at up to US$20 billion (£12.5 bn) in 2000. Film antitranspirants are polymers applied to foliage to reduce water loss and have recently been shown to increase droughted wheat yield. This increase is linearly related to the drought severity (soil moisture deficit [SMD]) at the time of application. This paper demonstrates how this linear relationship can be used to calculate an economic threshold SMD, above which an economic yield response should be obtained, from spray cost and expected grain price. This will enable agronomists and growers to make a clear decision on the cost-effectiveness of spraying to protect from drought damage. Sensitivity analysis shows that using the correct spray decision threshold SMD is especially important when the wheat grain price is expected to be low.

KEYWORDS: Spray decision-making; spray threshold; water stress; polymers; grain price

1. Introduction

World production of food needs to increase to supply the forecast nine billion population by 2050 (Godfray *et al.*, 2010), but drought is a serious impediment to increasing food production. There is little information on the economic impact of drought on food production, but comparing yield of rainfed and irrigated crops should give an approximate quantitative estimate of drought effects. Recent data on the yield of separate rainfed and irrigated crops are not readily available, but Molden (2007) gives irrigated and rainfed data for the major cereal crops for the year 2000. For wheat, one of the world's main food crops, rainfed crops gave 2.4 t/ha yield and irrigated crops gave 3.4 t/ha. The total wheat area in 2000 was 215 Mha (FAOSTAT, 2011), and if it is assumed that all wheat had given the same yield as the irrigated wheat, then wheat production would have been 731 Mt instead of the recorded 586 Mt (FAOSTAT, 2011). World wheat grain price from the Home Grown Cereals Authority data archive (HGCA, 2011) for the calendar year 2000 was US$138/t (£87/t)[2], thus it can be estimated that drought may have caused up to (731-586) × 138 = US $20 billion (£12.5 bn) loss to wheat growers in 2000.

The above value will be an overestimate of drought effects for several reasons. In addition to water, irrigated crops will tend to be given more yield-enhancing inputs, such as fertilizer, than rainfed crops so that not all the difference between yield of rainfed and irrigated crops is due to drought. Also the price of wheat would be likely to fall as production increases. Nevertheless, this estimate gives a crude quantitative indication of the upper limit of the economic impact of drought on wheat in this particular year.

Availability of water for irrigation is declining as a result of climate change-related reductions in rainfall and increasing competition from industrial and domestic use (Morison *et al.*, 2008). Therefore alternative technologies, applicable to rainfed crops, are needed to reduce drought-induced yield loss. One approach is to breed drought resistant varieties, but this is proving a difficult task due to the complexity of drought resistance (Cattavelli *et al.*, 2008).

A new agronomic approach for ameliorating drought effects on wheat is to use sprays of film antitranspirant polymers, which reduce water loss from leaves (Kettlewell *et al.*, 2010). This approach has given up to a 42% yield increase (Kettlewell & Holloway, 2010) if applied at the most drought-sensitive stage of develop-

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[2] Currency conversions approximate, as at 11 July 2011.

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ment, just before the heads emerge (Saini & Westgate, 2000). Yield loss from drought is related to the severity of the drought, and thus for wheat growers to make cost-effective use of this new approach a method of assessing drought severity and the likely yield increase from a film antitranspirant spray is needed. The aim of this paper is to show how an economic threshold drought severity can be calculated to assist decision-making on spraying a film antitranspirant on wheat, and to illustrate the sensitivity of this threshold to grain and to film antitranspirant prices.

2. Threshold calculation

Kettlewell *et al.* (2010) have shown in the UK that the yield response of droughted wheat to a spray of film antitranspirant is linearly related to both the development stage and to the drought severity (expressed as the SMD) at the time of spray application. The multiple regression equation of yield response against both numerical development stage and SMD given in Kettlewell, Heath and Haigh (2010) can be used to calculate the fitted line for estimating the likely yield response for a given SMD. This relationship is illustrated in Fig 1 assuming that spraying occurs at the development stage which Kettlewell *et al.* (2010) found to give the greatest yield response (Zadoks Growth Stage 37 [ZGS 37], flag leaf appearance [Zadoks *et al.*, 1974]). If strong wind or other reasons delay timely spraying, then the multiple regression equation given in Kettlewell *et al.* (2010) can be used to calculate the yield response – SMD relationship for a later development stage.

A calculation of the minimum yield response needed to cover the cost of spraying film antitranspirants can be made using expected grain price, film antitranspirant price and spray application cost. Using the price of the film antitranspirant as £20 ($32) per litre (B. Lewis, personal communication) gives a cost per hectare for the product, at 2.5 l/ha applied (Kettlewell *et al.*, 2010) of £50 ($80) per hectare. An average spraying cost of £10 ($16) per ha (Nix, 2010), gives a total application cost of £60 ($96) per ha. For a wheat grain price of £200 ($319) per tonne, a minimum yield response to film antitranspirant of 60/200 = 0.3 t/ha is therefore necessary to cover the cost.

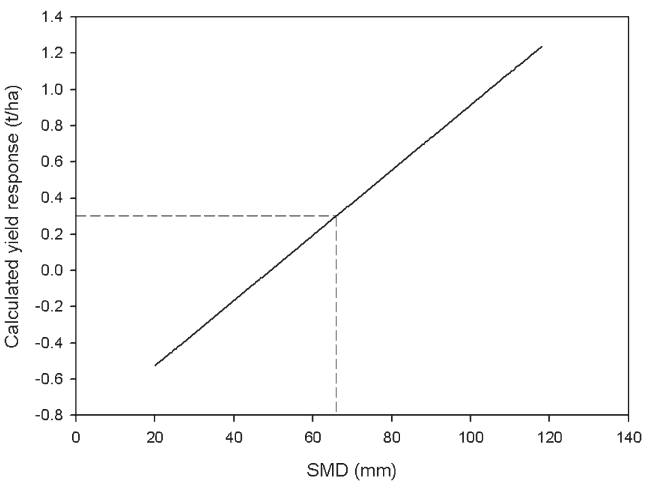

Figure 1. Yield response of wheat grown on a loamy sand soil to film antitranspirant application at ZGS 37 in relation to SMD at the time of application.
Note: Equation of the solid line is: yield response=(0.018 SMD) −0.874. Broken line shows the economic threshold SMD assuming a wheat grain price of £200 ($319) per tonne and an antitranspirant price of £20 ($32) per litre.

Using this yield response in Fig.1 shows that the economic threshold SMD is 64 mm for the soil type from which the multiple regression data was acquired. Spraying at an SMD above this threshold would thus be necessary to make a profit. The threshold SMD will vary with the available water capacity (AWC) of the soil, and for more general use the threshold SMD can be expressed as the proportion of available soil water. Since the AWC of the soil used to generate the relationship shown in Fig. 1 was approximately 180 mm, the economic threshold can be stated as one third of the available water on this soil type for a wheat grain price of £200 ($319) per tonne and a film antitranspirant price of £20 ($32) per litre.

It is possible that the cost of spraying the antitranspirant could be reduced by tank-mixing the antitranspirant with a fungicide, since wheat crops are routinely sprayed with a fungicide at around ZGS 39 in the intensive production systems used in Western Europe. Furthermore, there is evidence that the materials used as film antitranspirants can reduce fungal diseases (Walters, 2009), so that it might be possible to reduce fungicide cost by using a lower fungicide application rate whilst maintaining disease control.

3. Sensitivity analysis

In producing general guidelines for wheat growers, it is necessary to know the likely variation in the economic threshold SMD. The film antitranspirant used in the studies of Kettlewell *et al.* (2010) has recently increased markedly in price (B. Lewis, personal communication) and the spray threshold SMD was calculated for a range of potential antitranspirant prices at a constant grain price of £200 ($319) per tonne using a rearrangement of the equation given for Fig. 1. Similarly, wheat grain prices in the UK have varied dramatically in the last decade and the above calculation of spray threshold SMD was conducted for a range of expected grain prices at a constant antitranspirant price of £20 ($32) per litre. These calculations show that changes in spray threshold SMD in response to film antitranspirant price are relatively small (Fig. 2), and that for the soil type in the example given, using a threshold SMD of one-third of AWC would not be greatly in error for a wide range of prices. The threshold SMD is however, especially sensitive to expected wheat grain price when the latter is low (Fig. 3). Thus growers and agronomists should pay particular attention to calculating the threshold SMD when expected grain prices are low.

4. Conclusions

The data presented here show that it is possible to aid the decision whether to spray a film antitranspirant on wheat for ameliorating drought by calculating an economic threshold SMD. The threshold SMD will vary with expected grain price and with antitranspirant

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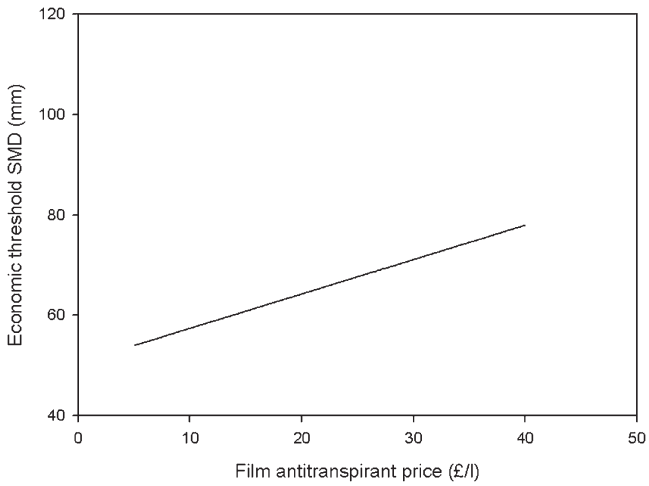

Figure 2. Relationship of the economic threshold SMD for spraying film antitranspirant on wheat with the film antitranspirant price (at a wheat grain price of £200 ($319) per tonne and a spraying cost of £10 ($16) per ha).
Note: Equation of the line: SMD=(((antitranspirant price*2.5+10)/200)+0.874)/0.018

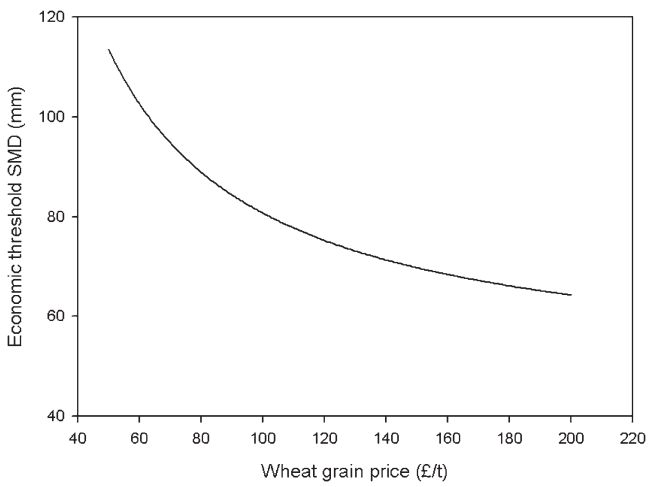

Figure 3. Relationship of the economic threshold SMD for spraying film antitranspirant with the wheat grain price (at a film antitranspirant price of £20 ($32) per litre.and a spraying cost of £10 ($16) per ha).
Note: Equation of the line: : SMD= ((60/grain price)+0.874)/0.018

price, but it is especially important to take account of low expected grain price. Further field experiments on soils differing in AWC and in different cropping systems and environments are needed to establish the general applicability of these conclusions and the possible variation in the equation used to derive the threshold.

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