Assessment of risk associated with climate prediction in management of wheat in north-eastern Australia

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Summary. Using simulation analysis, seasonal climate forecasting methods based on the Southern Oscillation Index (S01) have been assessed in terms of their ability to improve risk management in wheat cropping. At low levels of risk the SOI based strategy for nitrogen application demonstrates considerable improvement in average gross margins over a best-bet strategy. Additional increase in yield and gross margin might be possible using frost prediction.

Introduction

In north-eastern Australia, dryland cropping of winter wheat is practised extensively on soils generally high in water holding capacity. This region is characterised by large variations in grain yields and grain quality due to the extremely variable climate (7) and in more recent years, to declining soil fertility (1). The choice of planting time, crop variety and fertiliser strategy to employ to best exploit this environment, and to allow for product price variation in given year, is a complex decision (7).

Rainfall variability (3), and both national wheat and sorghum yield in north-eastern Australia (4) have been related to the El Nino/Southern Oscillation (ENSO) phenomenon. A useful measure of ENSO variability is the Southern Oscillation Index (SOI), generally taken as the difference in normalised pressure anomalies between Tahiti and Darwin. Recently, Stone and Auliciems (5) and Stone and Hammer (6) have demonstrated the value of SOI phases (or SOI 'types') in assessing future rainfall probability distributions in eastern Australia. The SOI phase analysis provides skill in assessing future rainfall probability distributions during the autumn/winter period and this in turn provides a prediction of future wheat yields at the start of the winter wheat growing season. However, no studies have examined the value of this improved level of skill in terms of the trade-off between risk and the benefits obtained.

The timing of the last frost has a major impact on the variety choice decision when planting wheat. Development of a suitable frost prediction technique based on SOI phases may also aid selection of a cultivar with a suitable period to flowering so that the damaging effects of frosting can be avoided. At present, there is no suitable predictor to assess the probable date of last frost.

The objectives of this study were (i) to examine the usefulness of improved methods of predicting seasonal rainfall in risk management of winter wheat in north-east Australia, and (ii) to investigate the usefulness of the SOI phase method in predicting the date of last frost.

Methods

Rainfall and frost prediction

Rainfall prediction methods were those outlined in (6) and used at a number of stations in north-east Australia. The method employs clusters of SOI behaviour over a two month period and relates the five clusters (or SOI phases) to future rainfall probability values. The SOI phase method was also used to obtain a probable date of last frost for a number of locations in the winter wheat growing regions of north-eastern Australia. Reliable long-term (>96 years) temperature data were obtained from the Bureau of Meteorology. Significant differences among seasonal rainfall and frost-date cumulative probability distributions were tested using non-parametric procedures (e.g. Kolmogorov-Smirnov, Wald-Wolfowitz, Median Test).

Crop nitrogen management

Using a method described in (6) the long-term yield likelihoods for a standard production regime assuming non-limiting N were simulated using a crop simulation model (3) and 96 years of weather data (1894-1989) for Goondiwindi, Qld. We calculated the responses of yield and grain protein to varying N fertilizer rates for each year of the long-term simulation and the gross margins associated with each N rate in each year. The long-term average gross margin and the risk of the gross margin being less than $125/ha were calculated for each N rate.

The 96 years of daily rainfall records were also partitioned according to the (five) SOI phases that occur in May. The tactical strategies for N application were developed by considering the sets of years in each of the five categories defined by the SOI phases. Various rates of N application were assigned to each of the set of years until the tactical strategy that maximised the average gross margin at a given risk level was identified. Risk level was measured as the percentage of years that the gross margin fell below $125/ha.

Risks of achieving recovery of fertilizer costs were calculated from the cumulative probability distribution for each strategy (i.e. an all years 'best-bet' strategy and the strategy employed using the SOI phases). The various strategies were compared. The trade-offs between risk and gross margins were made by comparing both the risk of obtaining gross margins less than $125/ha and the average maximum gross margins obtained when taking that risk.

Cumulative effects of temperature on phenology of the crop during the growing season were compared for each of the sets of years that had been partitioned according to the SOI phases. Heat sums were calculated for varying sets of winter wheat planting dates and flowering periods.

Results

Rainfall and frost prediction

Analyses of SOI phases and winter/spring rainfall at the stations analysed suggested a rapidly falling 501 phase during ApriUMay was associated with a high probability of below long-term median rainfall the following winter/spring. A consistently negative SOI phase during April/May was associated with a high probability of a late date of last frost. Conversely, a rapidly rising SOI phase during April/May was associated with a high probability of above average rainfall during the following winter/spring and also a high probability of an early date of last frost. The difference in median date of last frost (minus 1?C in the screen) according to SOI phases differences by 20 days are Roma (Fig. I) and 26 days for the same value at Goondiwindi (S01 rise compared with SOI consistently negative).

The cumulative effects of temperature on the phenology of the crop during the growing season did not appear to diminish the usefulness of probable date of last frost. For example, growing degree days needed for a crop planted on I June with a flowering period of 110 days showed little alteration in heat sum according to the SOI phases.

Crop nitrogen management

Stone and Hammer (6) showed large variability in yield (median 500kg/ha)(nitrogen unlimiting) from the 'all-years' case depending on whether the SOI phase the previous autumn represented falling or rising SOI. Fig. 2 illustrates the changes in average gross margin according to an SOI phase strategy as a function of a given level of risk. In all instances, the SOI phase tactical strategy results in higher gross margins at a given level of risk than the long-term constant N strategy. For example, applying standard N rates of 40 units for a crop grown at Goondiwindi on I June results in a 12% risk of not making a profit and average gross margins of $162/ha. At the same level of risk, but with applying varying levels of N according to the SOI phases, average gross margins are $180/ha. Clearly, at low levels of risk (e.g. <20%) the SOI phase tactical strategy demonstrates considerable improvement in average gross margins over a constant N strategy. Furthermore, for a given gross margin. the level of risk involved in obtaining that value may be substantially reduced by employing the SOI based tactical strategy.

Discussion

Rainfall and yield distributions vary significantly according to SOI phase. Higher potential yield is probable during years characterised by a rapid rise in SOI during the autumn months. This can be realised by modifying the N rate. The SOI phase strategy has demonstrated the possibility of an increase in average gross margins obtainable for a given level of risk. Overall, however, year to year variability is high resulting in some large wins and some large losses. This means that one could lose in the first year of application if the prediction was 'wrong'. However, depending on the attitude towards risk, the strategy may be to make less risky decisions in those years where the SOI phase indicated a high probability of a 'poor' year. Conversely, in those years where the 501 phase indicated a high probability of a 'good' season the most useful strategy may be to maximise potential profits. As the outcome depends on yield likelihood, it is important to note this will vary with time of planting. location, soil condition and price.

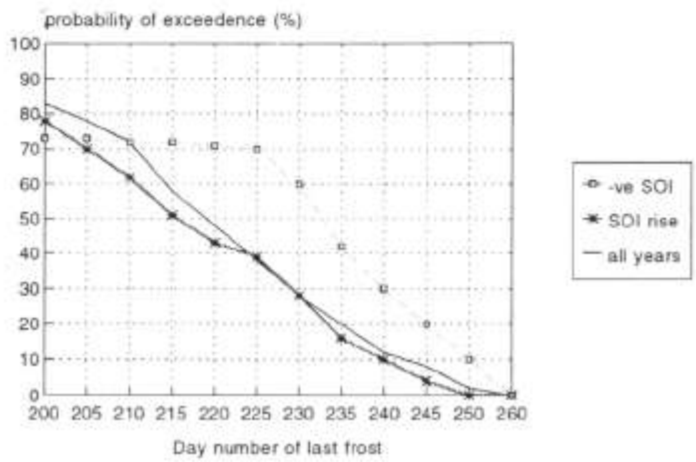

Figure 1. Probability distribution of day number of last frost (minus I ?C in screen) at Roma according to SOI phase, May.

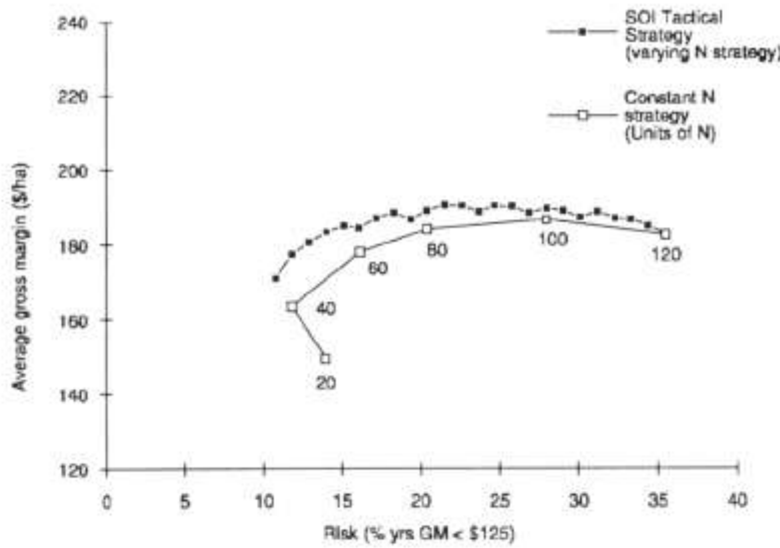

Figure 2. Wheat-N fertiliser strategies (planting 1 June. Goondiwindi, Qld.)

Probable date of last frost according to SO1 phase may have an even greater effect on decisions of cultivar choice and potential yield and gross margins than the effect of a wetter or drier year. As the number of growing degree days varies little depending on SOI phase then the effects of both rainfall and date of last frost likelihood on planting decisions, yield, gross margins, and risk strategy may be significant.

Acknowledgements

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