TRIAL-YEARS without tears: enhancing recommendations of flowering and yield in wheat

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ABSTRACT

This paper describes the performance of the APSIM model in predicting the flowering time of short and long season cultivars of wheat grown at eight locations across the southern agricultural areas of Western Australia. The potential for outputs from the model to be used to extend the number of "trial-years" and enable recommendations to be made based on probable outcomes is highlighted.

Key words

Wheat (*Triticum aestivum* L.), anthesis, sowing date, yield, modelling, APSIM.

Introduction

Flowering time (anthesis) is an important determinant of the yield of wheat grown under the dry-land production systems of southern Australia. The yield of a crop may be reduced by frost damage during flowering and/or water stress after flowering (2, 6, 9). The "flowering window", or optimal time of flowering, is chosen to minimise the risk of frost damage and the potential for water stress (11).

Recommendations to farmers regarding the best cultivars to select for their environment are based on the performance of the cultivars in testing programmes. However, the seasons in which the cultivars were grown may influence their rankings greatly, and hence the recommendations that are made. A simulation model that has been tested using local data can be used to "grow" cultivars over a wider range of seasons and hence add value to testing programmes. This is particularly useful where field testing of a cultivar is limited to a 3-5 year period with seasons that represent only a fraction of the long-term variability, resulting in an incorrect assessment of that cultivar's suitability to a region.

The Agricultural Productions Systems Simulator (APSIM) is a software tool that contains various submodels that can be combined to allow simulation of agricultural systems (8). Predictions of wheat production, drainage and nitrate leaching from APSIM have been validated against several datasets from wheat growing in the mediterranean-type environment of south-western Australia (3, 4).

This paper reports the findings of a preliminary study in which predicted flowering dates of short and long season cultivars using the APSIM model were compared with field observations from eight locations in the agricultural areas of Western Australia. Simulated yields for a range of sowing dates and 100 seasons are used to illustrate the potential for model outputs to provide useful information to farmers regarding the choice of cultivar and sowing date.

Materials and Methods

Observed flowering dates

Dates of anthesis for two cultivars of wheat, Spear (a long season type) and Kulin (a short season type) were obtained from results of field trials conducted by Agriculture Western Australia (1). Additional data were obtained from Gregory and Eastham (7) and unpublished work by R.J. French. Data from Balla (1989 – 1990, 6 sowing dates), Wongan Hills (1990 - 1992, 15 sowing dates), Merredin (1990 - 1993, 26 sowing dates), East Beverley (1989 - 1992, 24 sowing dates), Katanning (1989 – 1990, 8 sowing dates), Newdegate (1989 - 1992, 14 sowing dates), Esperance (1991 – 1992, 9 sowing dates) and Salmon Gums

(1991 – 1992, 9 sowing dates) were used. These represent locations in the north-eastern, central, eastern and south-eastern wheatbelt of Western Australia (Figure 1). In these trials, crops were sown at various dates between 9th April and 19th July.

Long-term simulations of flowering dates and yields

Growth of two cultivars of wheat, Amery and Spear, was simulated in a loamy sand using the APSIM model (nwheat, version 1.55). The soil and phenological parameters used were those described previously (4). Model runs were conducted using 100 years of historical weather data (1900-1999) with 150 kg N/ha applied as 90 kg at sowing and 60 kg 4 weeks after sowing. Soil water and nitrogen were re-set at the
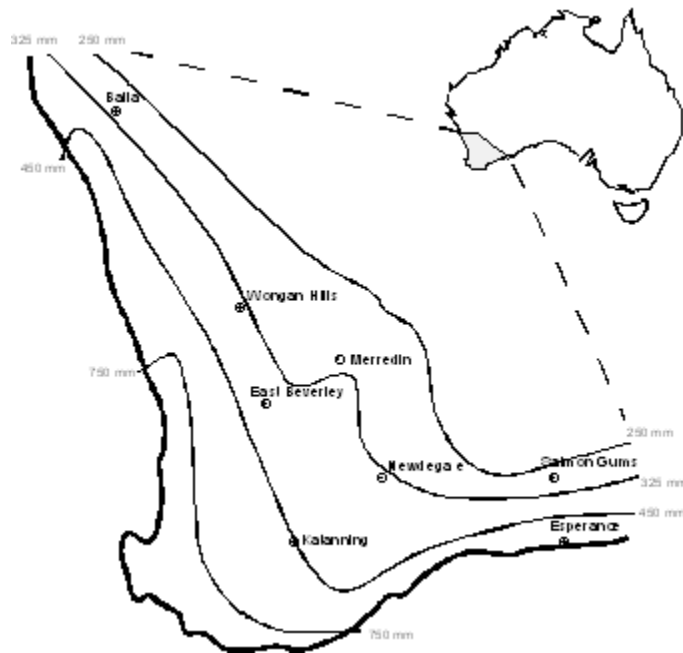
Figure 1. Map of southwestern Australia showing rainfall isohyets and the locations used in this study.

beginning of each year. To cover the range of sowing dates used in the field trials, simulated crops of each cultivar were "sown" on at least 51 fixed sowing dates between 9th April and 19th July in each year.

Note: Amery is a short season cultivar that replaced Kulin. The two cultivars have almost identical phenology, differing by only two days in flowering date (5). They have the same phenological parameters in the model. For clarity, the name 'Amery' will be used in the remainder of this paper when referring to the short season cultivar.

Analyses of observed and simulated data

Observed and simulated times of flowering were compared over the eight locations. The observed and simulated yields for different sowing dates were examined for Wongan Hills for 1990 to 1992. To illustrate an application of the model, a broader analysis of the yields for Wongan Hills was conducted using simulated data for 100 years of historical weather information. Each year between 1900 and 1999 was classified into a season type based on the amount of rainfall over the year (annual), over the months of January to March, inclusive ("summer"), and in April and May (early season) (Table 1). The cut-off points used in these classifications were based on the average rainfall in each of the three categories.

Table 1. Classification of the years 1900 to 1999 into eight season types. Season types were defined by three categories of rainfall: "summer" rainfall (Jan. to Mar.), annual rainfall and early season rainfall (Apr to May). Data are for at Wongan Hills.

Rainfall (mm)

Season type	summer	annual	early season	No. years
1	<=45	<=390	<=140	32
2	>45	<=390	<=140	7
3	<=45	<=390	>140	7
4	>45	<=390	>140	2
5	<=45	>390	<=140	5
6	<=45	>390	>140	18
7	>45	>390	<=140	14
8	>45	>390	>140	15

Results

There was good agreement between the observed and simulated dates of anthesis over the eight locations (Figure 2). The root mean squared deviation between observed and simulated dates was greater for Spear than Amery (Table 2). In general, the observed and simulated anthesis dates were closer for later sowings.

The observed and simulated yields at Wongan Hills (1990-92) showed similar patterns of an increase to a maximum followed by a linear decrease with later sowings (Figure 3). While the yields differed in the three years, the patterns were the same. The decrease in yield appeared more pronounced for Spear than for Amery. These patterns and differences between cultivars were more pronounced using simulated yields for 100 years (Figure 4). Grouping the yields according to eight broad classifications of season type reveals additional useful information. Yields in better seasons (types 6, 7 and 8) are higher than those in poorer ones (types 1, 2 and 3), but the variability in maximum yield is greater for the better seasons.
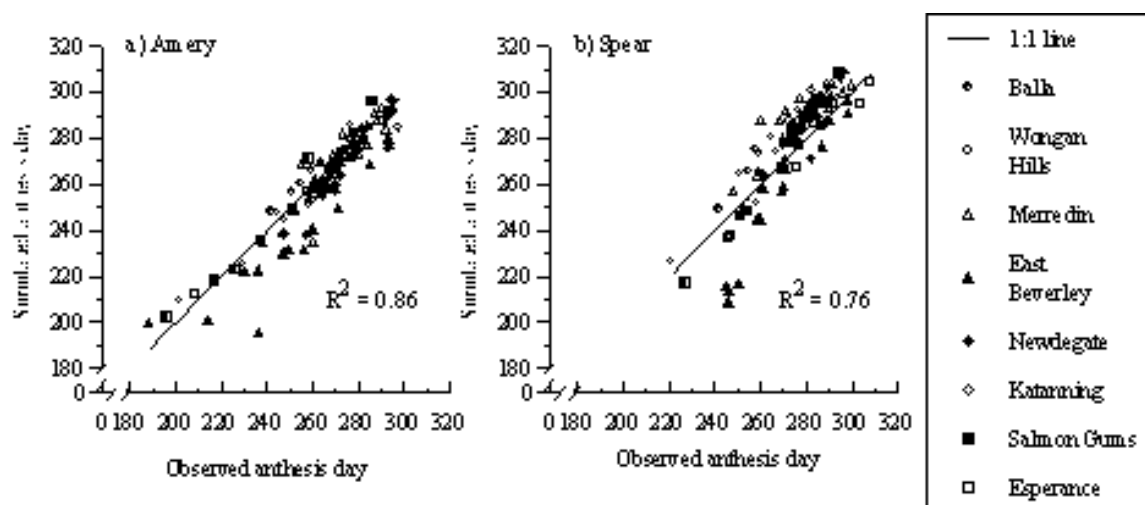
Figure 2. Observed and simulated dates of anthesis (day of year) for the Amery and Spear grown at eight locations in the southern agricultural areas of Western Australia between 1989 and 1993.

Table 2. The root mean square deviation (RMSD), bias and precision between observed and simulated dates of anthesis for short and long season cultivars of wheat grown at eight locations in the wheatbelt of Western Australia between 1989 and 1993. The interval between sowing and anthesis is also shown.

Cultivar	RMSD (days)	bias (%)	precision	Average interval sowing to anthesis (?se)	
				observed	simulated
Amery	9.5	1.4	0.82	112 (?2.1)	108 (?2.0)
Spear	12.1	-1.0	0.47	124 (?2.2)	127 (?2.1)

**Discussion and conclusion**

Anthesis dates for wheat predicted using the APSIM model were in good agreement with field observations at eight locations in south western Australia. The model predictions were not good for the earliest sowing dates, which was illustrated by the greatest relative differences between simulated and observed anthesis dates occurring at the early anthesis dates (190-260d). The small number of observations at most locations exacerbated this effect. Also, the development of wheat sown in trials before the onset of the winter rains may have been affected by water stress and nutrient availability, which is not accounted for by the model. In addition, there are errors associated with the assessment of flowering date by different observers. The large discrepancies between observed and simulated anthesis dates at East Beverley, for which three sources of observed data were used, may be a reflection of this.

Flowering in Spear is sensitive to photoperiod, while Amery is less sensitive. The simulated anthesis dates for Spear did not fit the observations as closely as those of Amery, especially at the more northerly (hotter) locations. This may be because the model does not take account of the interaction between photoperiod and temperature (10) and hence over predicts the anthesis date at these locations.

The observed and simulated yields of wheat grown at Wongan Hills in 1990-1992 illustrate the importance of flowering time to achieve the maximum yield for a crop while avoiding damaging frosts by

flowering too early. Use of a larger dataset of simulated yields for 100 years categorised into season types illustrates the considerable variation that is possible. Summarising the data according to these categories serves to illustrate the power of an adequately validated simulation model to enable recommendations to be made based on a large number of trial-years. Long-term runs of the model can predict the likely production for combinations of sowing date, variety, location, soil type and management. Such simulations can compliment data from cultivar testing programs.

The results suggest that the APSIM model can be used to predict the time of anthesis of wheat in south-western Australia. Further work comparing model predictions with a wider range of observations is required to ensure adequate validation of the model.
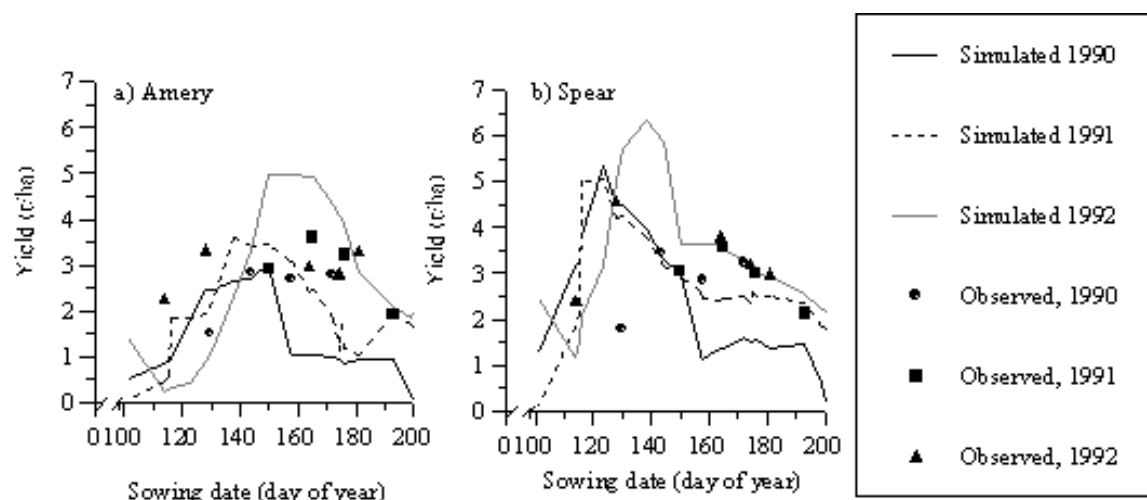
Figure 3 Observed and simulated yield of Amery and Spear sowing on various dates between 9th April and 19th July. Data are for crops grown on a loamy sand soil at Wongan Hills between 1990 and 1992.
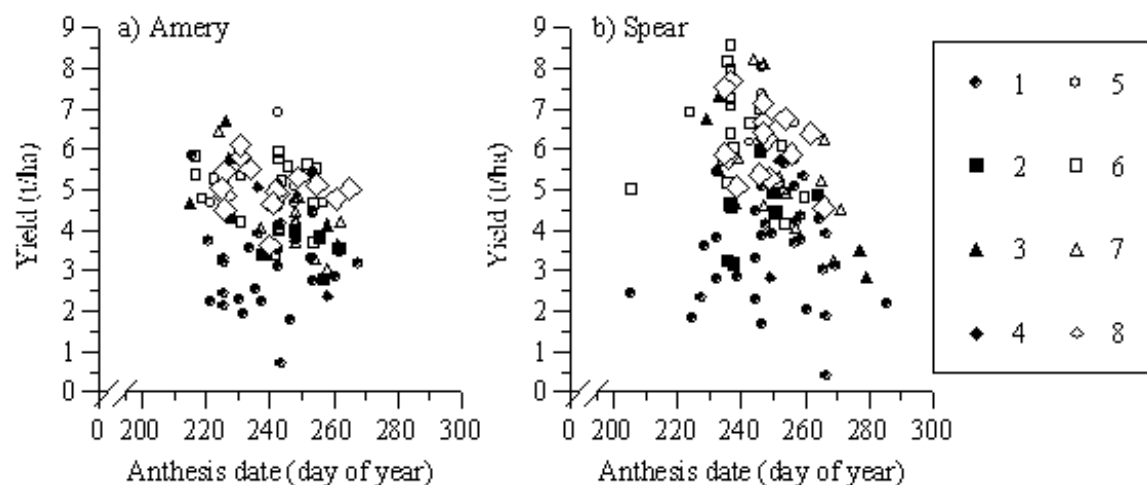
Figure 4 Maximum simulated yield of Amery and Spear for a loamy sand soil at Wongan Hills. Data are for 100 years between 1900 and 1999. Yields are grouped according to season type 1 to 8.

Acknowledgments

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