APSIM-Barley model – Adaptation of a wheat model to simulate barley growth and development

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Abstract

This paper describes the adaptation of the APSIM-Wheat module to simulate growth and development of barley by altering the key variables describing the distinguishing physiological traits between the two species. An extensive data set from barley crops grown in southern QLD was used to derive the model parameters describing crop phenology, leaf canopy development, grain filling, and water extraction. Overall, APSIM-Barley was able to predict the observed responses of crop growth attributes to a wide range of management and environmental conditions. Simulation of biomass at maturity and grain yield explained 91 and 82% of the variance (RMSD = 108.2 and 69.7 g m^{-2}), respectively. Model performance was subsequently tested against an independent set of data collected from 9 farmers' fields in Victoria. The model was capable of explaining 81% of variation in grain yield of commercial crops (RMSD = 0.56 t ha^{-1}). Further studies are required to evaluate the capability of APSIM-Barley to predict quality aspects such as grain protein concentration and grain size distribution.

Key Words

Modelling, phenology, leaf area index, biomass, water deficit, sowing date

Introduction

The Agricultural Production Systems Simulator (APSIM) has proven to be a valuable tool to explore the likely impacts of management decisions and environmental conditions on crop productivity and has been used extensively to develop improved risk management practices (Keating et al. 2003). Although APSIM provides simulation capabilities for more than twenty crop species, including wheat, no such a capability exists for barley (*Hordeum vulgare* L.). Experimental results from comparative studies on wheat and barley (L?pez-Casta?eda and Richards 1994; Manschadi *et al.* 2006) suggest that the higher yielding ability of barley in drier environments is largely due to (i) earlier commencement of flowering and maturity, and (ii) faster rate of leaf canopy development and root growth early in the season when vapour pressure deficit is low. These result in reduced evaporative loss of water from the soil surface, and greater water-use efficiency for above-ground biomass production, i.e. the ratio of biomass to total evapotranspiration. Here we present the adaptation of the APSIM-Wheat module to simulate growth and development of barley by altering the key variables describing the distinguishing physiological traits between the two species. The performance of the APSIM-Barley model was tested on an independent set of data from commercial barley crops.

Methods

The parameters that were necessary to adapt the APSIM-Wheat module to simulate barley were derived mostly from extensive field data reported by Goyne et al. (1996). The data were collected from barley cv. Grimmet crops grown at a wide range of sowing dates and water supply regimes at three sites in southern Qld: Hermitage Research Station, Roma, and Wellcamp. The cultivar-specific parameters determining the sensitivities to photoperiod and vernalisation were calibrated for the cv. Grimmet. To account for earlier commencement of anthesis in barley, the duration of the phases from floral initiation to flowering was modified to 2 phyllochrons plus 80 degree-days (^{o}C d) compared to 5 phyllochrons plus 80 ^{o}C d used in the wheat model. The phyllochron interval was set to 75 ^{o}C d based on our observation for cv. Grimmet. The durations of the subsequent phases between anthesis and physiological maturity were left unchanged. Greater early vigour in barley was simulated by altering the variables describing the leaf appearance rate on the main stem, tillering capacity, and specific leaf area. Furthermore, consistent with the changes in the leaf canopy development, the rate of water extraction (govern by the parameter *kl*) from the top 60 cm soil layers was assumed to be higher for barley. The potential rate of grain filling (g grain^{-1} day^{-1}) was set to 0.0030 g grain^{-1} day^{-1}, as calculated from data on barley crops grown under non-limiting water and nitrogen conditions in 1991 at Hermitage Research Station (Goyne et al. 1996). Following the model parameterisation, the performance of the APSIM-Barley module was tested against independent phenology and yield data obtained from farmers' fields in the Mallee and Wimmera areas of Victoria, Australia.

Results

APSIM-Barley model was capable of predicting the phenological development of cv. Grimmet planted within a wide sowing window extending from March 12 to August 7 (Fig. 1). The RMSD values for emergence, anthesis, and maturity were 1, 4, and 8 days, respectively. The model was able to explain 91 and 82% of the observed variation in total biomass at maturity and grain yield, respectively (Fig. 1).

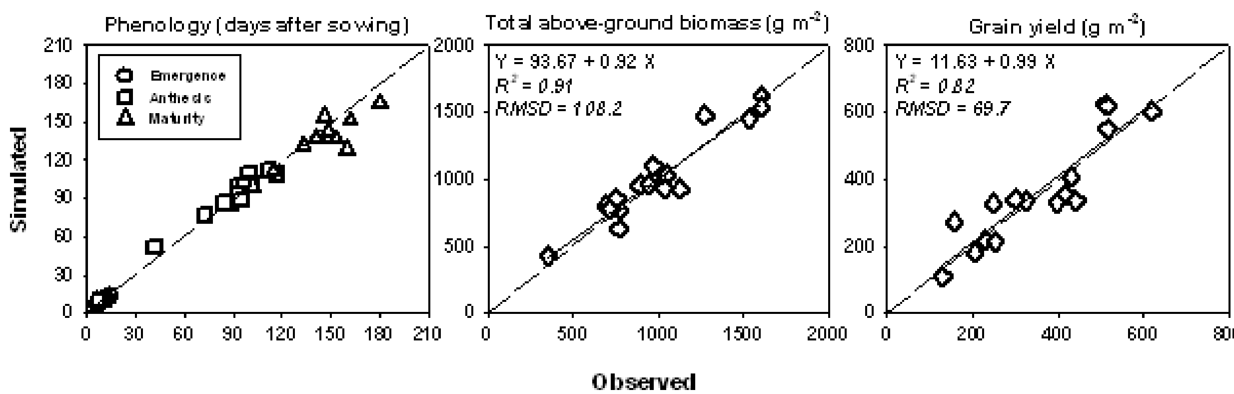
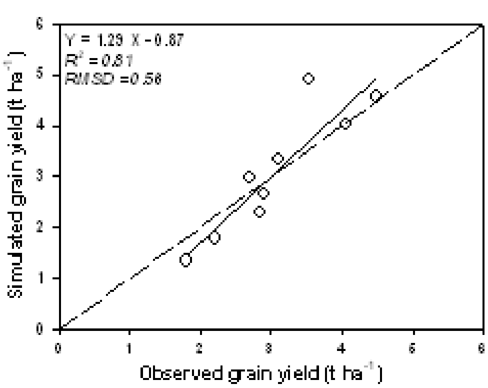


Fig. 1. Observed and simulated phenology, total biomass, and grain yield of the barley cv. Grimmet.



When tested against independent data from farmers' fields in Victoria, APSIM-Barley explained 81% of variation (RMSD = 0.56 t ha^{-1}) in grain yield (Fig. 2). The lower correlation coefficient for the simulation of commercial barley crops may largely be attributed to inaccuracies in estimating the initial soil nitrogen and water conditions. The performance of the model is appropriate for analysing the effects of management decisions and environmental conditions on growth and yield of barley. As grain protein concentration is a key quality trait of malting barley, further studies are required to examine the capability of APSIM-Barley to simulate the dynamics of nitrogen uptake, accumulation and redistribution.

Fig. 2. Observed and simulated grain yield of commercial barley crops in Victoria.

Conclusion

This study demonstrated that modification of only a few key parameters was sufficient to adapt a wheat module to simulate barley. APSIM-Barley proved to be robust in simulating the response of barley crops to management and environmental conditions both at experimental sites and in farmers' fields. The model's capacity to reliable simulate grain protein now needs to be tested.

References

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