Adapting rain-fed sorghum agronomy to breeding progress – Cropping system model parameterisation

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Abstract
Over the last decades, there has been considerable investment from the private and public sector in genetic improvement of sorghum hybrids, but the high yield potential of these new genotypes is not always achieved in farmers' fields. Matching these new genotypes to seasonally optimised crop management has the potential to increase productivity. One of the best ways to determine a hybrid's yield potential in a specific location, but also to identify best hybrid by environment by agronomic management combinations and to demonstrate benefits and trade-offs between productivity, investment and risks, is to use a crop model, such as APSIM (www.apsim.info). To enhance APSIM's ability to predict grain yield for various sorghum genotypes, growth and development parameters of new hybrids have to be determined. Here we present flowering time data for one previous and eleven newly-released sorghum hybrids that were parameterised in specially-designed experiments with five different sowing times and the fit between model-predicted and observed values. This information, together with other growth parameters, will be used to parameterise the model to improve APSIM's ability to simulate yield of the new sorghum types.

Key words
Anthesis, thermal time, sowing date.

Introduction

There are many new sorghum hybrids with improved yield potential available to growers in the North-eastern grain belt of South-east Queensland and Northern New South Wales. To ensure these genetic improvements actually lead to greater farm productivity we need to be able to determine whether farm yields are close to the potentially achievable yields as determined by genetic (i.e. hybrid specific) and agro-ecological (i.e. location specific soil and climatic) factors. By definition, yield potential (Yp) describes the maximum yield for a specific location that can be achieved with a hybrid when water and nutrients are non-limiting. For rain-fed crops, water-limited yield potential (Yw) as determined by water availability, may be used (van Ittersum et al., 2013). The gap between potential yields for a specific location and average farm yields in that region is described as the yield gap. Yield gap analysis provides the basis for the study of factors that might limit average farm yields and is therefore essential in identifying opportunities for productivity gains. There are several methods to estimate Yp or Yw, but crop simulation modelling is the most reliable of them, because crop models can account for interactions among crops, weather, soils and management (van Ittersum et al., 2013).

We will use the Agricultural Production Systems Simulator (APSIM www.apsim.info) to develop productivity-investment-risk profiles for promising combinations of genotype and crop management practices for sorghum across the South-east Queensland and Northern New South Wales cropping zones. A clear synthesis of benefits and trade-offs between productivity, investment and risks will be developed to support farmers' decisions on closing the yield gap. It is important, however, that simulations of Yp and Yw are based on recently released cultivars that are used by the farmers in the region (Grassini et al., 2015).

APSIM was initially developed in Australia in the 1990s and consists of individual modules, such as soil modules, a management module and various crop modules (Holzworth et al., 2014). In the crop modules, canopy development and growth are simulated using thermal time targets for various developmental stages (e.g. thermal time to anthesis or grain maturity) (Hammer et al., 1993). To enhance the capacity of APSIM to simulate yield of newly released hybrids, we parameterised eleven recent commercial sorghum hybrids plus (Pacific Seeds) one of the sorghum hybrids that APSIM simulations are currently based on.

Here we present data on thermal time targets for the growth period from emergence to anthesis for these twelve hybrids. There were significant (P<0.0001) hybrid by sowing date interactions for thermal time to anthesis and values ranged from 544 to 731 degree days.

Materials and methods

Five phenology experiments (PHEN 1 to PHEN 5) sown at five different sowing dates (Table 1) were conducted at Hermitage Research Facility in South-East Queensland (28°21' S, 152°10' E; 480 m above sea level) during the 2014-15 sorghum growing season.

In each phenology experiment twelve sorghum hybrids with contrasting maturity types (as previously classified) from three commercial seed companies (Nuseed, Pacific Seeds and Pioneer) were sown in a row-column design with two replications.

Experimental plots were 3 m long and contained four rows at 0.76 m row spacing and plant stands were thinned to 50,000 plants per hectare. All experiments were fully irrigated and enough nitrogen was applied to ensure non-limiting conditions.

Five plants from the two middle rows in each of the plots were tagged for regular observations. Emergence date was defined as the date when 50% of plants in 2 m of row had emerged. Anthesis was rated as the percentage of the panicle on the main stem of each tagged plant that was flowering and the date of anthesis was taken as the date when these ratings averaged 50% across the five tagged plants.

Hourly temperature data was collected from a weather station mounted next to the experiments. Thermal time was calculated using base temperature, optimum and maximum temperatures of 11, 30 and 42 °C, respectively (Hammer et al., 1993).

Table 1 Phenology experiments (PHEN 1 to PHEN 5) with sowing dates, average temperatures and average thermal time for the period from emergence to anthesis.

Experiment	Sowing date	Average temperature between emergence and anthesis of the 12 hybrids (°C)	Average thermal time from emergence to anthesis of the 12 hybrids (°C d)
PHEN 1	30/09/2014	21.8	646
PHEN 2	30/10/2014	22.7	658
PHEN 3	25/11/2014	22.6	638
PHEN 4	23/12/2014	22.1	675
PHEN 5	20/01/2015	21.8	657

Results and discussion

Average temperatures and accumulated thermal times from emergence to average anthesis date of all twelve hybrids were quite similar for each of the sowing dates (Table 1). Despite this, significant (P<0.000.1) sowing date by individual hybrid interactions were observed for thermal time to anthesis and some hybrids had more variable flowering times depending on sowing times than others (Fig. 1). The causes for this variation are yet to be investigated.

There were no significant differences in average thermal time to anthesis between the groups of different maturity types. Hybrids that were classified previously as early to medium maturity types on average reached anthesis after 630 growing degree days across sowing dates, while hybrids of medium and medium to late maturity types on average required 657 and 676 degree days respectively to reach anthesis.

The hybrid Buster, one of the hybrids that were previously parameterised for the APSIM model, flowered between 613 to 639 degree days across the five sowing times (Fig. 1). There were hybrids that flowered much sooner and others that flowered much later than Buster and thermal time targets for these hybrids were used to update the APSIM model.

Predicted versus observed times to flowering from simulations using these thermal time targets are shown for

all twelve hybrids (Fig. 2).

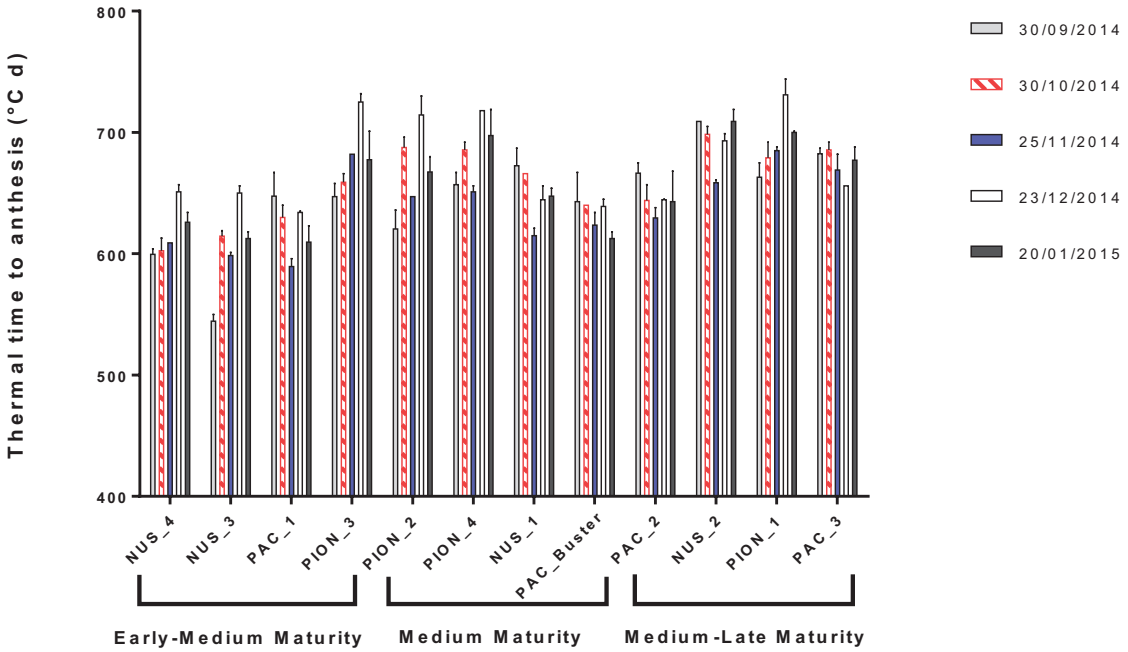

Fig. 1 Thermal time (°C d) to anthesis by sowing date for hybrids that were previously classified as early to medium maturity (NUS_4, NUS_3, PAC_1 and PION_3), medium maturity (PION_2, PION_4, NUS_1 and Buster) and medium to late maturity (PAC_2, PAC_3, NUS_2, PION_1). NUS=Nuseed, PAC=Pacific Seeds, PION=Pioneer. Vertical bars and error bars represent means and standard errors for the two replicates of each hybrid, respectively.

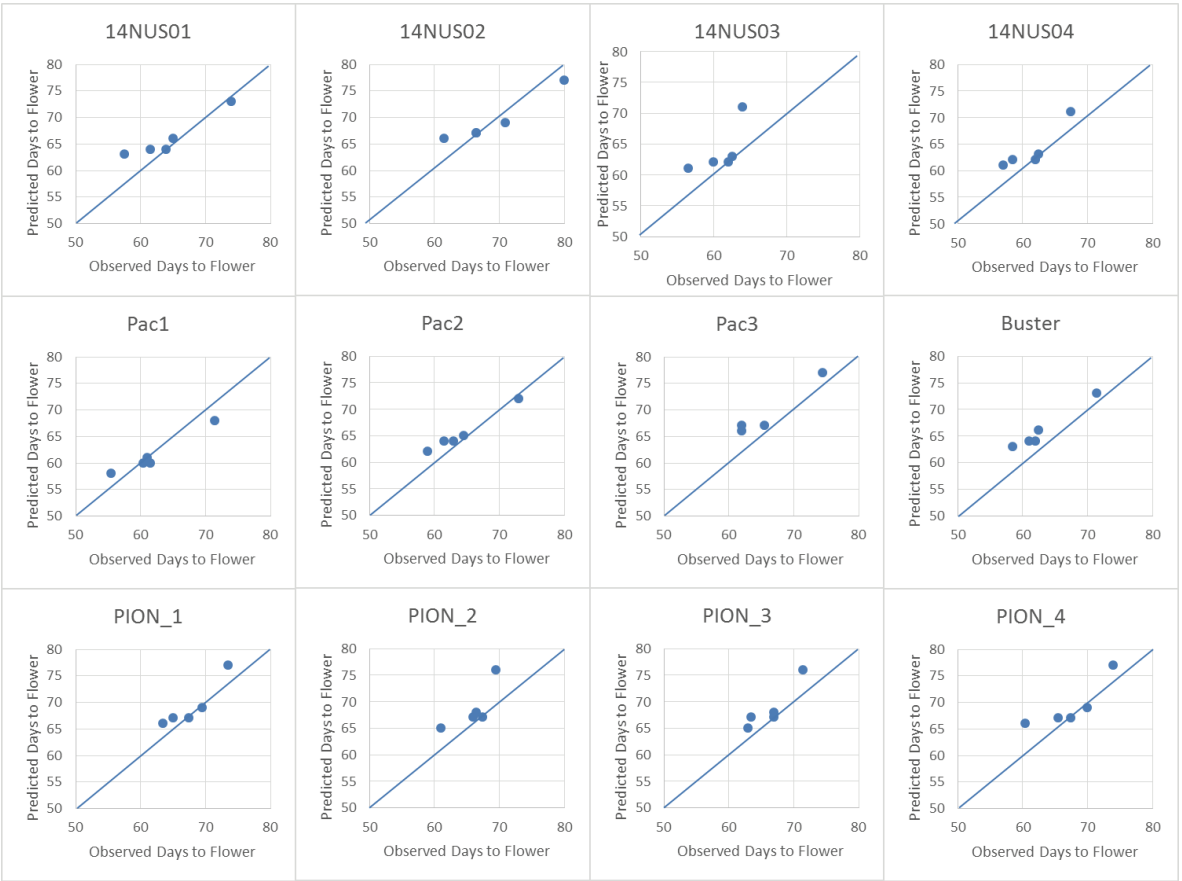

Fig. 2 Observed versus predicted days to flower from simulations with thermal time targets for individual hybrids. Lines equal identity lines.

Conclusions

In this paper we reported on just one of the parameters that are used in APSIM to simulate sorghum crop yield. The parameter (thermal time to 50% anthesis) showed significant hybrid by sowing time interactions and there were both hybrids that were significantly quicker in advancing towards anthesis and hybrids that were slower than the hybrid Buster, which was previously parameterised for the APSIM model.

This information will aid in estimating location-specific potential yields of current sorghum hybrids. This will allow us to match these new genotypes to seasonally optimised crop management taking into account risks and benefits of increasing investments with the aim of increasing productivity and economic returns for sorghum growers across the Queensland cropping zones.

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