Simulation of field pea growth and yield in diverse environments

Wen Chen[1 6], Michael Robertson[2], Li Lingling[3], William Bellotti[4], Robert French[5] and Richard Bell[1]

[1] School of Environmental Science, Murdoch University, WA 6150 Australia
[2] CSIRO Sustainable Ecosystems, Centre for Environment and Life Sciences, Private Bag 5 PO Wembley WA 6014 Australia
[3] Agronomy Faculty of Gansu Agricultural University, Lanzhou 730070, China.
[4] School of Agriculture, Food and Wine, University of Adelaide. Roseworthy SA 5371 Australia
[5] Department of Agriculture and Food, Western Australia, Dryland Research Institute, Merredin 6415 Australia
[6] Department of Agriculture and Food, South Perth, WA 6151 Australia,

Abstract
Field pea (*Pisum sativum L.*) is frequently grown as a rotation crop with cereals in Australia. Modelling capacity to simulate field pea growth and production would be a useful tool for assessing crop management options in response to the fungal disease, blackspot. Field studies in South Australia (SA), Western Australia (WA) and Gansu, China were used to develop and test a field pea module for inclusion in APSIM. A new crop species was created using the “legume” template. Data on phenology, leaf area, biomass and components and grain yield were collected in field experiments in 2002 and 2003 in SA, and used to derive phenology parameters to test the model for biomass accumulation and yield. Data from WA and a wheat-field pea rotation experiment in Gansu, China were used to independently test the APSIM field pea module performance.

Flowering dates, ranging from 80 to 105 days after sowing, were accurately predicted. The developed field pea module was also able to accurately simulate biomass accumulation, leaf area index and grain yield across the different seasons and experimental sites. Biomass accumulation was simulated with a RMSD of 555, 719 and 208 kg/ha, respectively in experiments in SA, WA and China. Observed grain yield ranged from 1000 to 3000 kg/ha and were also well simulated with a RMSD of 253 kg/ha. The above results suggest that the developed APSIM-field pea module can be used for assessing agronomic management options and quantifying potential yields for different environmental and soil conditions.

Key words
APSIM-Field pea, model performance, crop development, flowering date, biomass

Introduction

In Australia, field peas (*Pisum sativum L.*) are most frequently grown as a rotation crop with cereals, providing soil nitrogen build-up and a break against soil-borne cereal diseases, particularly cereal cyst nematode and take-all. Compared with chickpeas and faba beans, field peas have the advantage of being able to be sown late (while it still can achieve economic yields) but harvested earlier than the major cereal crops. The most important constraint to the production of field peas in Australia is the fungal disease, blackspot. Delaying sowing is a common agronomic practice that most producers use to avoid infection from air-borne ascospores (Davidson and Ramsey 2000); however, delaying sowing to escape the peak in aerial inoculum could also impose a yield penalty. Thus, a modelling approach is needed to develop a ‘balanced’ (in-crop disease management vs. delaying sowing) management practice to maximum field pea performance under different climatic and soil conditions. The purpose of this paper is to report the development and testing of a field pea simulation model for inclusion as a module in APSIM.

Methods

The development of crop modules in APSIM has largely followed a template approach where a framework uses different parameter sets to simulate different crop species. A new crop species is created using the template by simply altering the parameters in a crop input file. In this study, the legume template was used. A typical crop input file for the legume template has in excess of 200 parameters. Not all of these parameters have to be derived anew with equal rigour when defining the parameters for a new species (Robertson et al. 2002). The essential parameters related to phenology, leaf growth, radiation interception, and biomass accumulation and partitioning, were derived based on experiments and literature information in this study.

Flowering times measured for 4 field pea varieties (Parafield, Kaspa, Parvic and Mukta) from 3 sowing dates (experiment 1) were used to derive phenology parameters for a conventional leaf-type pea variety (Parafield). The model was then tested against data in two field experiments (2 and 3) (Table 1). The cardinal temperatures used to calculate thermal time for phenology progression and other parameters related to leaf growth, radiation interception, biomass accumulation and partitioning were all derived from the literature (Lecoeur and Sinclair 2001; Olivier and Annandale. 1998; Thomson et al. 1997, Thomson and Siddique 1997).

Table 1. Details of the field experiments used to derive phenology and evaluate the field pea module

Experiment	Source	Location	Year	Sowing date	Soil type	Comment
1	Chen (unpublished)	Roseworthy, SA	2002	17th May, 6th June and 25th June	duplex	Variety x sowing time trial
			2003	10th June		
2	French (unpublished)	Merredin, WA	1993	1st June	duplex	Variety trial
3	Li (unpublished)	Dingxi, Gansu, China	2003	7th April	deep silt loam	Wheat-field pea rotation

After the parameterisation, observed biomass, grain yield and leaf area index from experiments 2 and 3 were used to test the model performance. Soil water parameters (drained upper limit, crop lower limit) and soil chemical and physical parameters (pH, bulk density, organic carbon) were measured at the experimental sites. In experiment 1, as the soil water content was not measured at the beginning of the season, the soil water content of the soil profile was initialised based on rainfall received from 1 January. The soil water content was reset to the oberved value for experiments 2 and 3. The model performance against observed data was assessed using regression analysis and the root mean square deviation (RMSD) methods.

Results and Discussion

Sowing dates ranged from April to June across the 3 experimental sites. Flowering dates ranged from 80 to 105 days after sowing, and the dates were predicted by the model with a RMSD of 3.5 days (data not shown).

Overall, the simulated biomass accumulation over time across 3 experimental sites was in close agreement with the observed (Figure 1, 2 and 3). At Roseworthy, total biomass observed in the dry (2002) and wet (2003) years was simulated accurately with a RMSD of 555 kg/ha, equivalent to 17 % of the observed mean (r^2=0.98) (Figure 1). At Merredin, the observed total biomass over time was simulated with a RMSD of 719 kg/ha, 30 % of the observed mean (r^2=0.91), and leaf area index was also well simulated (Figure 2). In Gansu, where field pea was grown in rotation with spring wheat, crop biomass accumulation over time was simulated with a RMSD of 208 kg/ha, 12 % of the observed mean. Soil water dynamics in the wheat-fallow-field pea rotation was also accurately simulated (Figure 3).

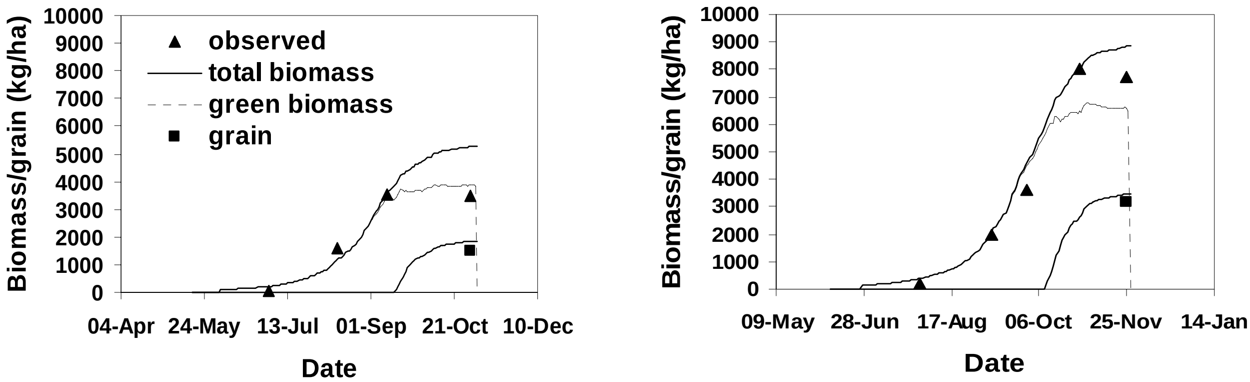

Figure 1. Simulated (line) and observed (point) total biomass and grain yield for field pea sown 17th May 2002 and 10th June 2003 at Roseworthy, South Australia.

Grain yield observed across 3 experiments with different seasons and soils ranged from 1000 to 3000 kg/ha (Figure 1, 2 and 3), and was simulated with a RMSD of 253 kg/ha, 16 % of the observed mean (r^2=0.96).

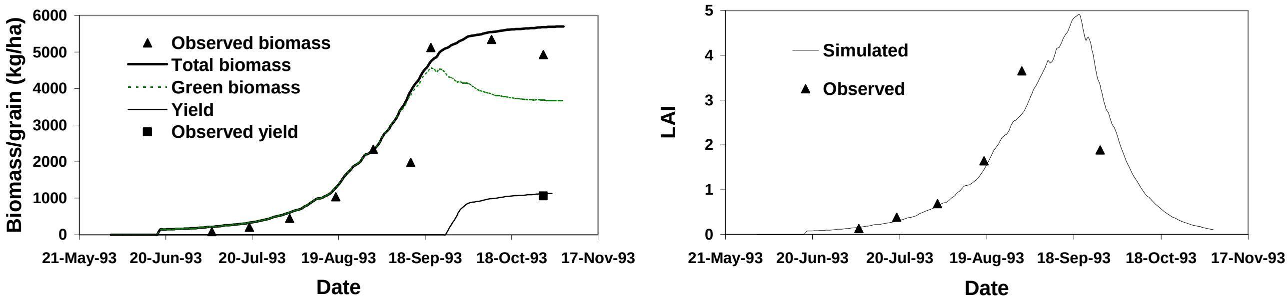

Figure 2 Simulated (line) and observed (point) total biomass and leaf area index over time and grain yield at harvest for field pea sown 1st June 1993 in Merredin Western Australia.

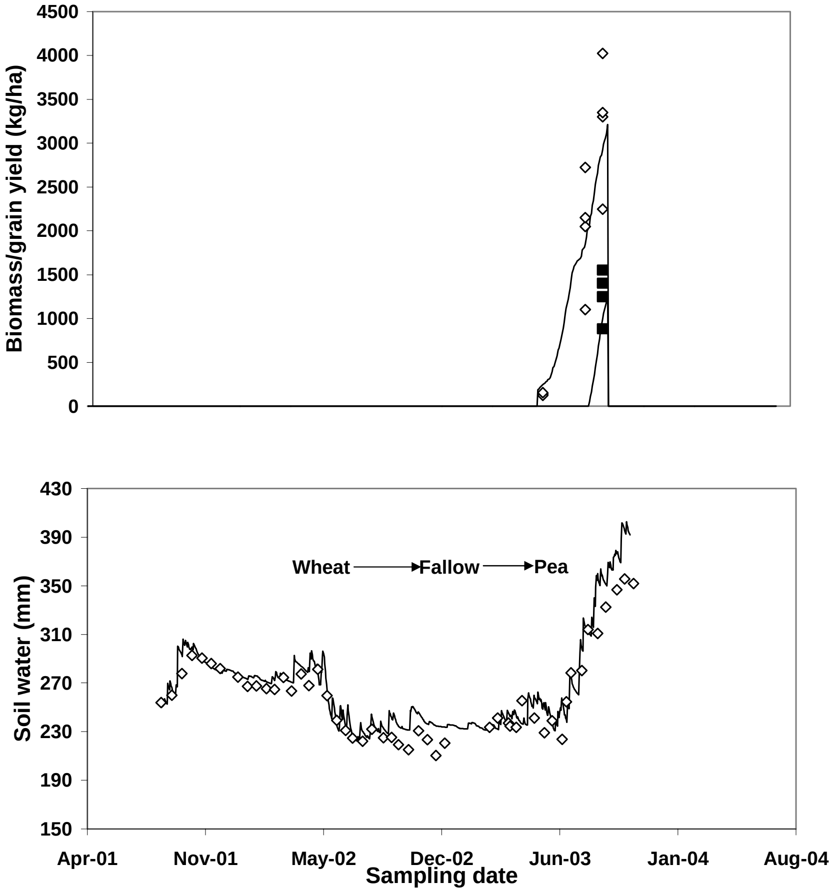

Figure 3 Simulated (line) and observed (point) total biomass over time and grain yield at harvest and soil water content (0-2m) for field pea sown on 7th April 2003 following wheat crop, in Dingxi, Gansu, China.

The above developed APSIM-field pea module can predict disease-free yield potential under different climatic, soil and agronomic management conditions. There are two approaches that could be considered when using the model for blackspot disease management. The direct approach is to build a direct relationship (in the APSIM routines) between blackspot severity and reduction in the radiation use efficiency (RUE) of pea crop canopy as demonstrated by the modelling work of Le May et al. (2005). The indirect approach is to link APSIM with the yield loss functions being developed. For example, Shtienberg (unpublished data) used the data from 11 field trials in SA and developed a useful relationship between pea potential yield loss and disease severity (0-5 scale). Furthermore, 'Blackspot Manager' developed by Dr Moin Salam, DAFWA, (http://www.agric.wa.gov.au/content/pw/ph/dis/crop_disease_forecast.htm) is currently being used to forecast disease risk and assist in determining optimum sowing dates in both WA and SA. Such forecasting could be more informative when developing a pea sowing guide for growers if it is integrated with the APSIM-field pea model to simulate yield loss due to delayed sowing.

Conclusion

The APSIM-field pea module was developed based on the APSIM-legume template and parameterised based on data from the literature and experiments. The model testing against the observed data on flowering dates, leaf area index, biomass accumulation and grain yields indicates that the developed APSIM-field pea module can be used for assessing agronomic management options and quantifying potential yields for different environmental and soil conditions. Future research should focus on how to effectively integrate the APSIM-field pea with other information and tools to help growers choose optimum sowing dates in response to different disease risk and yield potential scenarios.

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