MODELLING LUCERNE GROWTH USING APSIM

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Abstract

The use of simulation to evaluate strategies involving legume leys for improving cropping systems requires models for the growth of the legumes. The APSIM legume module has been specified for lucerne to create a capability for modelling the growth of lucerne, and its fixation of nitrogen, in response to climatic conditions (temperature and radiation) and soil water. The paper describes the lucerne module and illustrates its performance in simulating experiments, under both irrigated and dryland conditions, where yields of lucerne have been measured.

Key words: Farming systems, nitrogen, rotations, soil fertility, Medicago sativa.

Evaluation of the role for legume leys in contributing to the sustainability of farming systems through maintaining soil organic matter and contributing nitrogen (N) would be facilitated by models that were able to simulate such systems (14). While models for the cereals in the system are available, comparable models for the legume leys, such as lucerne (*Medicago sativa* L.), are not.

Previous efforts on modelling lucerne have produced models that respond to climate, water, and management (6, 8). However, they do not deal with other important features of the cropping system such as N dynamics, crop sequences, crop residue management, and feedback between the crop and soil fertility. The software system, APSIM (**A**gricultural **P**roduction **S**ystems s**IM**ulator) (11), represents a new mode of simulating cropping systems. It allows models of crop and pasture product-ion, residue decomposition, soil water and nutrient dynamics, and erosion to be readily configured to simulate various production systems, including crop sequences and intercropping. Soil and crop management can be dynamically simulated using conditional rules. A key concept of APSIM is that the soil provides a central focus; crops, seasons and managers come and go, finding the soil in one state and leaving it in another. Thus APSIM is well suited to examine crop production issues where feedback between the crop and soil is of primary concern, such as those involving legume leys in rotation with cereal crops.

This paper describes the development of the APSIM LUCERNE module and illustrates its performance.

Materials and methods

APSIM LUCERNE and derivation of model parameters

The lucerne module has been developed using the APSIM legume template, which simulates crop development, growth, yield and nitrogen accumulation in response to temperature, photoperiod, soil water and nitrogen supply. The template has adopted many existing approaches to simulating crop growth, with the addition of new subroutines to deal with leaf area development in branching crops, nitrogen fixation, and light interception as influenced by row spacing. It is the basis of other APSIM modules including the food legumes soybean, mungbean, cowpea and chickpea (3) and the pasture legume caribbean stylo (4).

The characteristic demography of the perennial lucerne sward is one of progressive decline in plant density and concomitant increase in basal stems per plant. APSIM LUCERNE uses this conservative feature, treating the stem as the primary production unit and the population of stems as time invariant, unaffected by climatic conditions or management.

Numerous parameters are required to specify the template for a particular crop. These define the functions in the crop growth module. Values used for lucerne originate from a variety of sources including values/functions from published literature and models, functions derived directly from experimental data, and model calibration to experimental data sets. The parameters that characterise lucerne's phenology, leaf area development, bio-mass accumulation and partitioning, water uptake and transpiration, nitrogen uptake and fixation are listed in Table 1. It is to be noted that different values are used for some parameters depending on whether the crop is establishing from seed or regrowing after being cut (Table 1).

Data sources

A field study was conducted under irrigated conditions at Lawes, Qld (27°34'S, 152°20'E) for the purpose of deriving model parameters unavailable from the literature. Replicated plots of lucerne cvs Hunter River and Trifecta were sown on 13 May 1994 at 10 kg/ha on an alluvial clay soil. The stands were managed according to commercial best practice (irrigation and weed control). Forage was cut and removed (harvest height 50 mm) at 10 percent flowering. Sequential samplings, between forage harvests, were made on 24 occasions over 19 months. Leaf weight, stem weight, leaf area and stem number were determined, and plant components were analysed for nitrogen. Biomass of the stubble (below 50 mm) was also sampled. Tube solarimeters (Delta-T) were placed within the stands to log light interception in order to calculate radiation use efficiency and the light extinction coefficient.

Data from a study at Warra, Qld (26°47'S, 150°53'E) (E.J. Weston and K.J. Lehane, unpublished) has been used to test the model under water-limiting conditions. Four treatments were established by under-sowing lucerne cv Trifecta into wheat in 1988. After different periods (1-4 years), the lucerne was killed by use of a blade plough. Following a 7-8 month fallow, the plots were sown to wheat. During the leys, the lucerne was cut at three monthly intervals. Total biomass (above 50 mm) and plant population were determined. Soil water and nitrate-N were measured at establishment and at the conclusion of each ley.

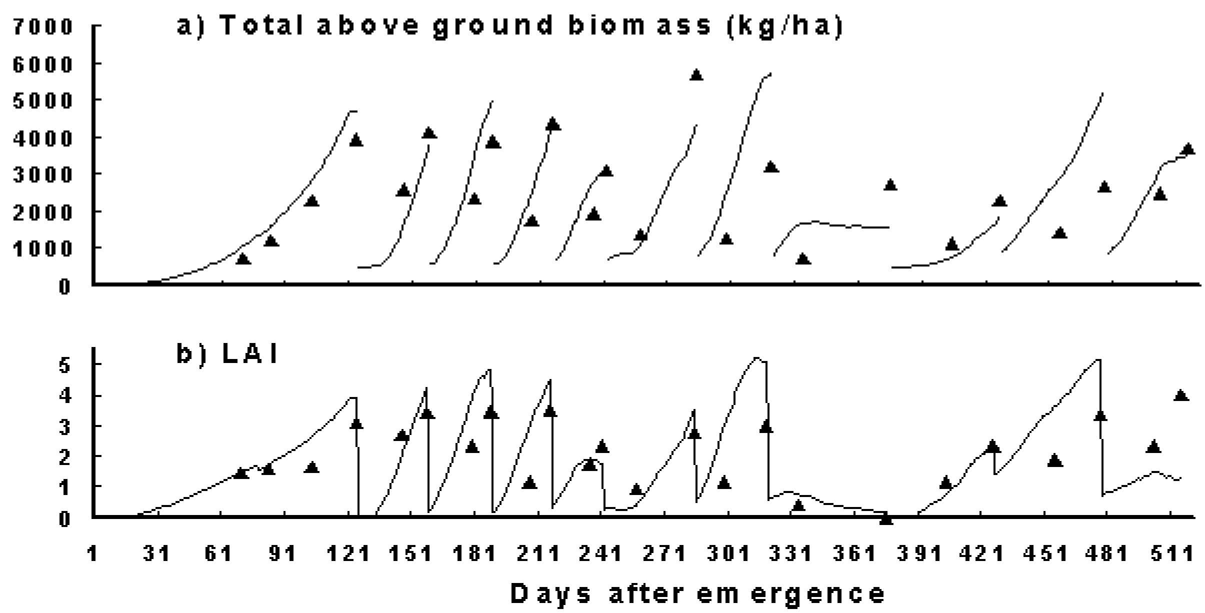

Figure 1

Results

Model performance under water-non-limiting conditions has been tested by simulating the 19 month growth period at Lawes. The model gave satisfactory prediction of the time course for biomass, leaf area index (Fig. 1) and above-ground N accumulation (not shown). The low leaf area in the growth period around day 360 was associated with leaf loss under severe water stress (when irrigation water was not available); this was captured by the model.

An independent test of model performance is provided by the data from Warra (Fig. 2). Under dryland conditions this is a much lower-yielding environment and crop growth was limited by water. Agreement between predicted and observed yields is not as good as for the irrigated site. The simulated lucerne crop lowered soil water content to values similar to the measured data, though it may not have used water sufficiently rapidly during 1990. In this experiment, harvests were made at 3-monthly intervals and not at flowering. This undoubtedly contributes to the disparity between modelled and observed yields. On the one hand there would have been considerable leaf fall, so observed yields are not a measure of production. On the other hand, there is lack of knowledge on how to simulate biomass partitioning and senescence during the post-flowering period. We are currently collecting data on this aspect of lucerne growth.

Conclusion

Simulation of lucerne in farming systems has not been possible because of a lack of a model with capability to account for nitrogen dynamics, feedbacks between crop and soil, and follow-on effects to successive crops. The APSIM LUCERNE module is intended to fill this void. The perennial nature of lucerne provides new challenges that do not arise with modules for other annual legumes. For example, in parameterising the lucerne module it has been found that different values are required for the seedling and regrowth phases; this situation has some similarity with the sugarcane module where some parameters vary for plant crops and ratoons.

Model performance was realistic for the irrigated site at Lawes, but less so under the water-limiting conditions at Warra. Further developments of the module are clearly needed in order for it to deal more credibly across a wide range of environments. For example, partitioning of biomass and N to below-ground organs (crowns, taproot and fibrous roots) is elementary in the present model and needs to be made more dynamic in response to factors such as water stress (2), cutting frequency (8) and post-flowering processes. Effects of cutting on root function, maximum depth of rooting, and extraction of water is another area of uncertainty. Finally it remains to be shown that such a model for lucerne growth can recycle N through roots and tops to sensibly predict changes in soil N and N supply to subsequent crops.

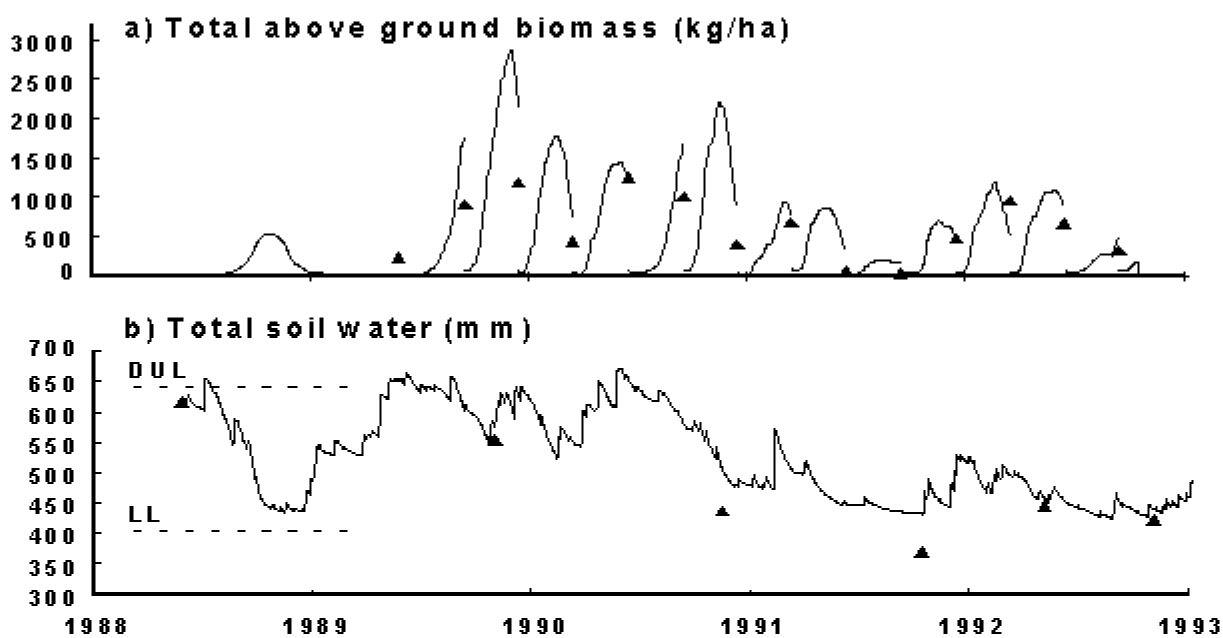

Figure 2

Acknowledgments

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