Performance of APSIM-Lucerne in Gansu, north-west China

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Abstract

The APSIM-Lucerne module was parameterised and tested using an experimental data set from Gansu, China. A lucerne field experiment was conducted on the well-fertilized Heilu soil during 1985-1987 at the Qingyang Research Station, Gansu, China. The experiment consisted of three different cutting regimes (cutting at bud, early flowering, and late flowering). Flowering data was well simulated with the module except for the first harvest in 1987 spring. Compared with observed data, dry matter yield was well simulated for early and late flowering harvest treatments, but, for bud treatment, dry matter yield was poorly simulated as the effect of cutting on biomass partitioning to the roots is currently not included in the model.

Overall, the APSIM-Lucerne module simulated growth and production of strongly winter-dormant lucerne growing in Gansu, China well. Further improvements to model performance in the area of lucerne phenology, growth and its impact on soil water and nitrogen dynamics are necessary in order to capture the observed growth and development of lucerne in Gansu and its subsequent impact on crop production, and evaluate climate and market risk associated with changing from current to forage legume-based cropping systems.

Key words

Lucerne, Medicago sativa, soil water erosion, cropping system, simulation

Introduction

The Loess Plateau of China is one of the world's worst examples of soil erosion with 0.28 million km^2 of severely eroded land. In this region, annual rainfall is highly variable with 60% of the annual rainfall occurring in the 3 months between July and September, often in the form of intense thunderstorms. Predominant winter wheat cropping together with the summer fallow after the wheat harvest between July and September, leads to the severe soil water erosion, which is the major threat to sustainable crop production.

Developing cropping systems with increased soil cover and higher water use is the key to reduce soil water erosion and sustain crop yields in this region. Compared with continuous winter wheat cropping systems, including perennial forages such as lucerne (*Medicago sativa*) in crop rotations could reduce soil water erosion by 80%, particularly during July-September (1). The studies also indicate that reducing winter wheat, increasing summer crops such as maize and replacing the summer fallow with sowing early maturity crops (soybean and millet) and annual forage legumes (common vetch), could synchronize seasonal water demand by crops with rainfall, significantly improve rainfall utilization for crop production and reduce soil runoff (2). Although benefits of including lucerne in cropping systems to reduce soil water erosion have been well demonstrated but farmers are still unsure about crop yield benefit following lucerne, and climate and market risk associated with changing from current to forage legume-based cropping systems. These issues need to be addressed with the aid of modelling approach.

A new ACIAR project (ACIAR LWR2/1999/094) was initiated in 2001 to improve the productivity and sustainability for the western Loess Plateau of Gansu province by developing conservation tillage systems, legume-cereal crop rotations and analysing 'current ' and proposed 'novel' cropping systems with the aid of system simulation models. The Agricultural Production Systems Simulator (APSIM) has been used in the project to evaluate current and 'novel' cropping systems being proposed to combat soil water erosion in the region. The application of APSIM is dependent on their ability to accurately predict development and growth of different crops in the regions outside those in which they were developed. The APSIM-Lucerne module has been tested in Australia and New Zealand (3,4), but it requires testing in cool temperate climate of the Loess Plateau of Gansu, China before it can be used as a tool to evaluate 'novel' cropping systems and quantify risk associated with changing from traditional to 'new' farming systems to combat soil water erosion problem. Thus the central purpose of this paper was to investigate the accuracy of the APSIM-Lucerne module in simulating growth of strongly winter-dormant lucerne.

Methods

APSIM-Lucerne module

The lucerne module has been developed using the APSIM legume template, which simulates crop development, growth and nitrogen accumulation in response to temperature, photoperiod, soil water and nitrogen supply (5). In the APSIM-Lucerne module, thermal time is used to drive phenological development and canopy expansion. Thermal time is calculated using 3 cardinal temperatures: base, optimum and maximum. Potential daily biomass production is predicted from LAI, a radiation extinction coefficient and the crop radiation use efficiency (RUE). Daily biomass production is determined by the intercepted radiation, which is affected by temperature, nitrogen stress and soil water supply (4).

Data source

A lucerne field experiment was established at the Qingyang Research Station (35? 40'N, 107?5'E; elev. 1298 m above sea level) and used to parameterise and test the APSIM-Lucerne module. Average, maximum and minimum daily temperature for the station are 9?C, 39.6?C and –21.3?C, respectively, and annual rainfall is 480-660mm. The experiment consisted of three different cutting regimes (cutting at bud, early flowering, and late flowering), and was conducted on the well-fertilized Heilu soil (a sandy loam of loess deposits or the Los-Orthic Entisols based on the FAO soil classification) during 1985-1987 without irrigation (6). Plot size was 5m x 2.25m. Lucerne was cut to residual height of 3cm. The total fresh weight of lucerne in the harvest area was recorded. A subsample of 200g fresh material was taken from each plot, oven-dried and re-weighed to determine dry matter yield. The drained upper limit (DUL) and lower limit (LL) down to 3m of plant available water for lucerne were measured at the same site in 2001 (Shen *et al*. unpublished).

Results

The relationship between the thermal time accumulation and day-length in determining lucerne flowering date was derived from the above experimental data set. This relationship was used to set phenology parameters for local lucerne cultivar. Flowering date was well simulated with the APSIM-Lucerne module except for the first harvest in 1987 spring (cycle number 5, Figure 1). Overall, the model simulated flowering date about 5 days earlier than the observed dates for 1986 and 1987.

The APSIM-Lucerne module does not explicitly deal with winter dormancy as seen in north-west China, hence, the model was configured to reflect seasonal changes of local lucerne growth and development in this typical cold temperate environment. For a period in the autumn, RUE was reduced from 1.3, 1.3 and 0.7 to 0.6, 0.6 and 0.5 g/MJ, for end_of_juvenile, floral_initiation and flowering, respectively to simulate increased partitioning of biomass to roots at this time of year, followed by the frost killing 'harvest' and then a dormant period where phenological development, and hence leaf area development ceased. Compared with observed data, dry matter yield was well simulated with the model for early and late flowering harvest treatments. However, for bud harvest treatment, dry matter yield was poorly simulated (Figure 2). Total seasonal dry mater yield at early flowering harvest treatment was 10.2, 10.9 t/ha in 1986 and 10.7, 10.1 t/ha in 1987 for observed and simulated data, respectively. These values were close to the lucerne variety evaluation experiment of Chen (7) who found that local lucerne produced 11 t/ha dry matter yield in the first and second years after the establishment. The poor simulation of yield in the bud treatment was expected as the effect of cutting on biomass partitioning to the roots is currently not included in the model.

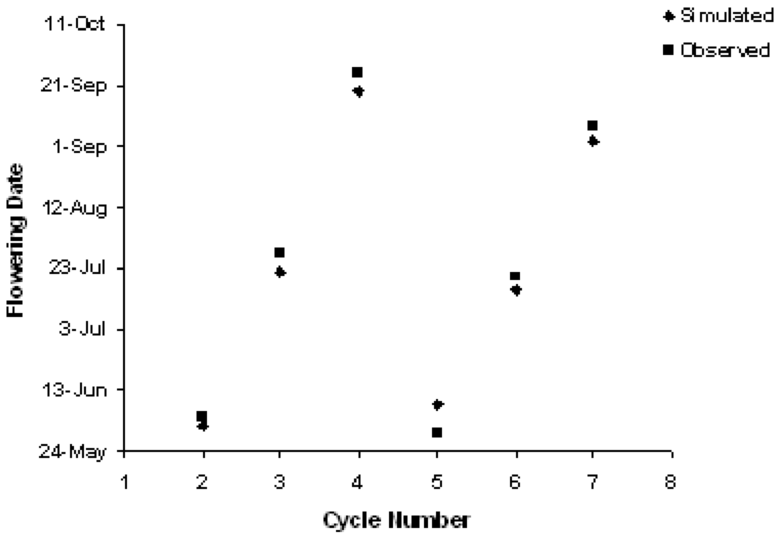

Figure 1. Observed and simulated flowering date for local lucerne over 2 years of 6 cutting cycles in 1986 and 1987 (cycle number 2-4 and 5-7 refer to three cuts in 1986 and 1987, respectively when lucerne was at early flowering) in Gansu, China.

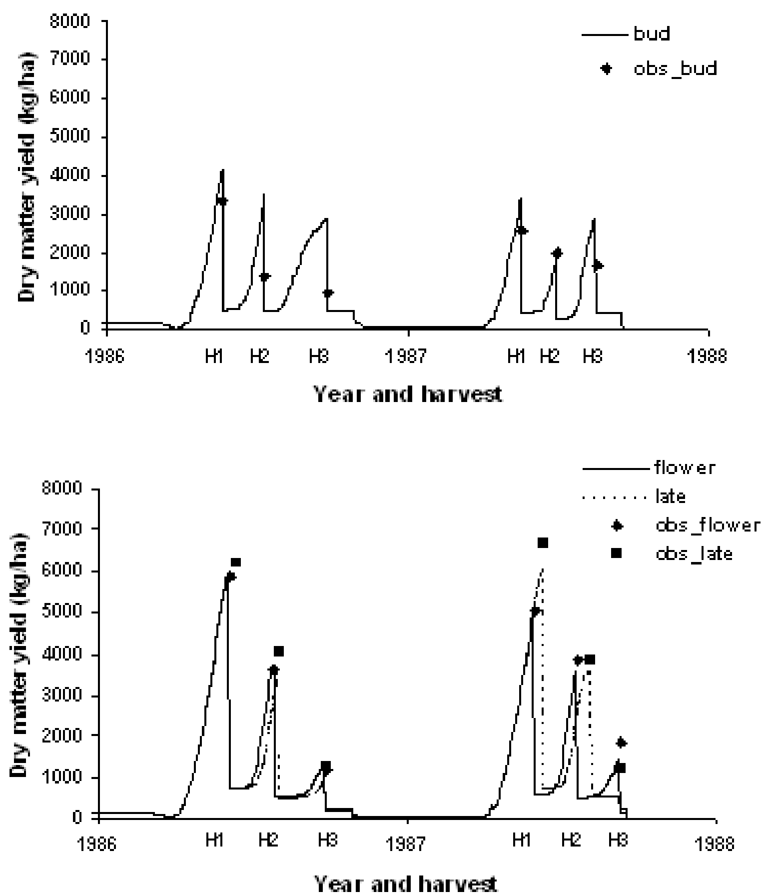

Figure 2. Observed (points) and simulated (lines) dry matter yield for local lucerne harvested at bud, early flowering and late flowering in Gansu, China.

Biomass water use efficiency (WUE) in lucerne was also estimated based on simulated soil water content, dry matter yield during the growing season in 1986 and 1987, and recorded in-crop rain. WUE was 26 and 25 kg/ha.mm for 1986 and 1987, respectively; and 75-84% water was derived from rainfall to support lucerne dry matter production over the two growing seasons. The simulated WUE was vary similar to the value of 25 kg/ha.mm which was estimated in the field, Gansu, China (2), but higher than the ones (16 kg/ha.mm in autumn-spring growth, 10 kg/ha.mm in spring-autumn growth) estimated for lucerne growing in southern Australia (8). The different seasonal rainfall and temperature during lucerne growth between the two environments could be responsible for such large differences in WUE.

Conclusion

APSIM shows promise in simulating growth and development of lucerne in Gansu, China. Further improvements to model performance in the area of lucerne phenology, growth and its impact on soil water and nitrogen dynamics are necessary. Collecting detailed data on lucerne development, growth, water use and nitrogen balance at two ACIAR research sites in Gansu are currently in progress. This new data will be used to further refine model performance in order to capture the observed growth and development of lucerne in Gansu and its subsequent impact on crop production, and evaluate climate and market risk associated with changing from current to forage legume-based cropping systems.

Acknowledgments

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