The effect of planting and harvest time on sugarcane productivity

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Abstract

The timing of planting, ratooning and harvesting influences the productivity of a sugarcane crop cycle. It is necessary to quantify these effects, both within and outside the current harvest season, to optimise crop cycle productivity and to optimise harvest season length. The effect of different planting times was examined in an experiment in the Burdekin region. The results were compared with results from the production systems model, APSIM. Time of planting significantly affected cane and sugar yield as did crop age. APSIM was able to broadly model these effects and provide insight into why the differences occurred. We found that the yields of the early planted crops before the start of the harvest season were as good as or better than the yield of early and late planted crops during the harvest season. This research shows there is potential in some regions to shift harvest season start times.

Key words

Sugarcane, modelling, planting time, crop age.

Introduction

The Australian sugar industry is facing pressure to increase the amount and efficiency of sugar production in an increasingly competitive world market. Two current areas of research aimed at increasing sugar industry competitiveness are maximising crop cycle productivity and optimising harvest season start and finish times.

Annual sugarcane productivity and crop cycle productivity is affected by the timing of planting and ratooning (2, 5 and 10). Australian studies have found different ratooning times within the harvest season had significant effects on cane and sugar yield (2,5). However, the climatic conditions and how they related to crop growth were not quantitatively measured in these early studies and they indicate little other than general trends in crop response to start time.

Timing of planting and ratooning affects the climatic regime into which a crop grows and this affects canopy development (1) and biomass accumulation (11). The sugarcane model, APSIM Sugarcane (4), incorporates the effects of soil, climate and management on sugarcane growth, however this model has yet to be validated for a range of crop start times. We need to validate the model for the effects of crop start timing and crop age in Australia to be able to identify optimal crop cycle management for different regions.

Optimising the length, start and finish times of the harvest season is one possible avenue for increasing sugar industry competitiveness. Most sugar mills currently operate at capacity or near capacity during the sugarcane harvest season, which typically runs from mid-June to November. In regions where there is pressure to increase production, extending the harvesting season could increase mill capacity to accommodate increased production as well as increasing the utilisation of existing capital. The main concern with harvesting before the start of the current harvest season is that sucrose content will be low due to seasonal conditions and that the productivity of crops harvested during this time will be reduced. However, there is evidence that sucrose content will not be as affected by these seasonal factors and will be acceptable for harvesting prior to the start of the existing season if crop age and stalk biomass production are maximised. This is because sugar yield is related to stalk biomass accumulation (8). There are variations in the relationship that can be attributed to the effects of time of year (climate) and other

factors such as water stress (10); however, sugar yield and hence sucrose content, generally increases with increasing stalk biomass. However, there is little information on the effect of stalk biomass yield on sucrose concentration in the early part of the year in the different growing regions of Australia.

This paper investigates the effect of varying planting time and crop age on cane and sugar yield. Trial results are compared with simulated results generated by the agricultural systems model, APSIM (6). These simulated results are used to help interpret the observed responses and to assess the potential application of the model for extrapolating the findings to other sites and growing conditions.

Material and Methods

Experimental design

The experiment was located at CSR Kalamia Estate (19.32^{o}S, 147.25^{o}E) near Ayr, Queensland. The soil has a clay loam A horizon to 40 cm and a B horizon of medium clay to medium heavy clay to below 160cm. The drained upper limit (DUL) to 50 cm was measured using tension plates and intact cores. DUL for 50 to 180 cm and the lower limit (LL) for 0 to 180cm were estimated using soil texture class. Soil pH, EC, N and C and were also determined. These data were used to parameterise the soil files within the APSIM model.

The site was divided into 4 main blocks, each 24 rows wide (1.5m row centres) by 120m long. Two of the blocks were planted on 10 January 1998 (early planting time) and the remaining two blocks were planted on 13 August 1998 (late planting time). Planting blocks were randomised. At each planting time, each block was divided into 16, 6 row by 25 m plots and 8 plots each were randomly planted to the varieties Q165 and Q96. The early plant crop was sampled at 395, 449 and 496 days after planting and the late plant crop was sampled at 242, 424, 454 days after planting. The experiment was managed under commercial conditions; weeds and other pests were adequately controlled with chemicals, fertiliser was applied at a rate to avoid nutrient stress, and the trial was furrow irrigated. The dates of irrigation were recorded and this data was used in the configuration of the model.

Crop sampling

Whole stalks were cut at ground level from 10 m of row length (15 m^2) in each plot for measurement of total fresh weight and total stalk number. From this harvested sample, 15 whole stalks were randomly selected for partitioning into leaf, cabbage (leaf sheaves and the top part of the stem above the break), stem and dead leaf. The fresh and dry weights of each component were then determined. Stems from the subsample were milled using a JEFFCO grinder. CCS, sucrose content and stalk dry matter content were measured using the methods described by Muchow et al. (8).

Simulations were performed using the APSIM systems model (Agricultural Production Systems Simulator (7)). In this study, the sugar crop module APSIM-Sugarcane (5) was linked with the soil water module SOILWAT (10), the soil nitrogen module SOILN (10), and the surface residue module RESIDUE (10). The model was configured to represent the soil, climate and management conditions of the field experiment. A Campbell Scientific automatic weather station recorded daily weather data. The APSIM Sugar model has not been configured for Q165, so observed and simulated results are shown for Q96 only.

Results and discussion

Biomass (Figure 1a) and sugar yield (Figure 1b) of the early plant crop harvested prior to the current harvest season, in April, aged 395 days exceeded that for the late plant crop harvested within the current season, in October, aged 424 days. Further, the sucrose yield of the early plant crop at 449 days in May was not different to sucrose yield for the late plant crop at 454 days in November. These results show that it is possible to achieve comparable or higher levels of productivity from crops harvested prior to the current harvest season.

Biomass estimates from APSIM were in close agreement with observed results, with the exception of the late planted crop at 454 days of age for which the model under-estimated biomass. The late planted crop may have experienced some water stress as irrigation was not applied during this period for management reasons. However, APSIM may have over-estimated the actual water stress the crop suffered, as there was evidence of a water table, which may have supplied the crop with additional water that was not captured in the simulation. APSIM reliably predicted the planting time and age effects on sugar production across all treatments.

The daily output of the APSIM simulation was used to explain the differences in observed yields between planting times. Early and late planted crops showed very different patterns of daily radiation interception and biomass accumulation (Figure 2). Daily radiation interception by the early planted crop steadily increased until around 340 days of age. The decrease in daily radiation interception after 340 days reflects a reduction in incident radiation between February and August 1999 (data not shown).

In comparison, daily radiation interception by the late planted crop increased rapidly and peaked at an earlier age. The pattern followed a bimodal form, the first and largest peak occurring at 165 dap (late January 2000) and the second at 426 dap (mid October 2000). The decreased daily radiation between the two peaks coincided with lower incident radiation between February and August 1999. Water stress after 330 days of age may have reduced daily radiation interception further.

Radiation interception is a primary driver of biomass accumulation, and the rapid increase in daily radiation interception by the late planted crop predicted by the model was matched by a rapid accumulation of biomass up to around 245 days of age (Figure 2). Thereafter, the rate of accumulation fell. After 324 days of growth, biomass accumulation by the late plant crop remained lower than that of the early plant crop for the same crop age. In addition, the model simulated almost constant water stress after about 340 days for the late planted crop, which would have reduced predicted biomass accumulation further. In contrast, the gradual increase in daily radiation interception and the relative absence of water stress resulted in an almost linear accumulation of biomass for the early planted crop.

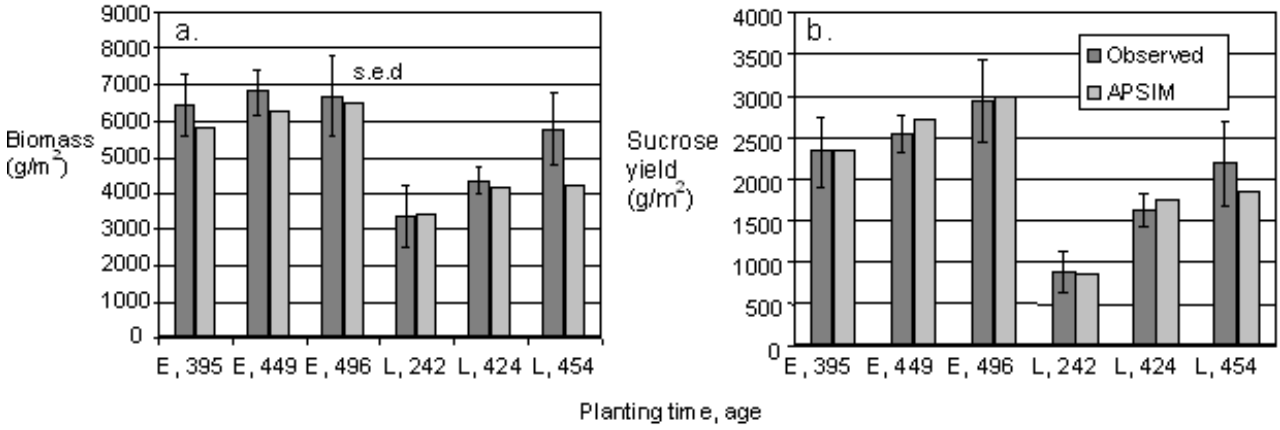

Figure 1. Observed and simulated biomass (a) and sucrose yield (b) for early (E) and late (L) planted Q96 at different crop ages.

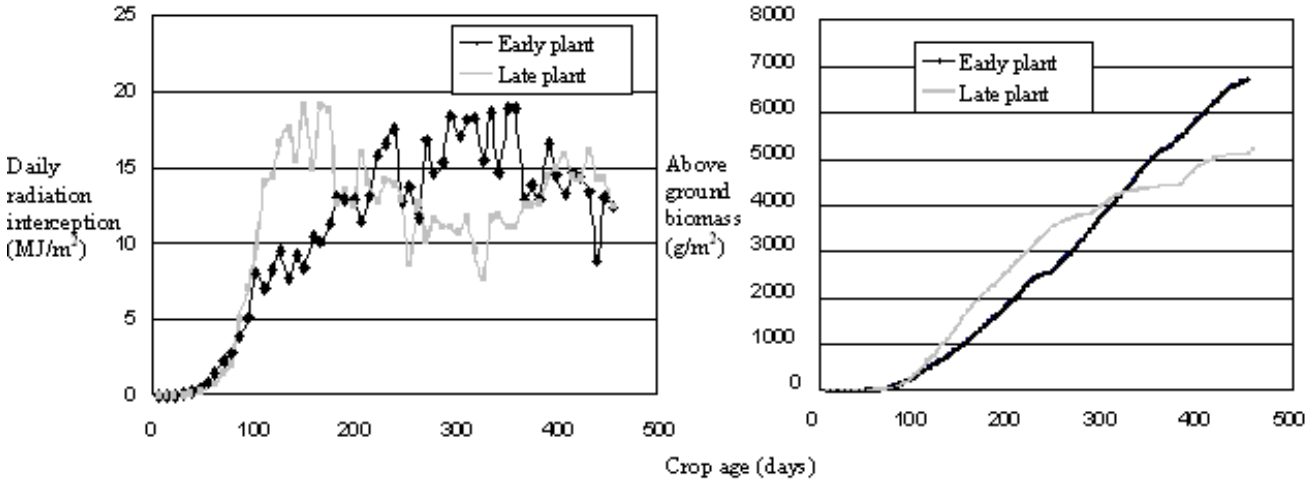

Figure 2. Simulated daily intercepted radiation (7 day average) and biomass production for early and late planted Q96.

The modelled patterns of biomass accumulation for the different planting times were consistent with observations of Rostron (11) and Inman-Bamber (1) who found higher growth rates in crops that start growing into regimes of higher radiation and temperature while crops that commenced growing into regimes of lower temperature and radiation had much slower initial growth. Rostron (11) also observed that the crops that grew into low temperature and radiation conditions and had slow initial growth rates generally yielded higher than the crops that grew into a regime of high temperature and radiation and had high initial growth rates. Thus, both studies found that high initial growth rates did not translate into higher yields and that the climatic regime into which a crop grows over a period of 12 months or more affects the potential yield. Thus, timing of planting is important in determining yield as it sets the climatic regime into which a crop grows.

While APSIM was able to adequately capture responses in these trials, it should be noted that the model does not take into account losses associated with pests, weed competition, lodging and waterlogging. These caveats should be borne in mind when running simulations in circumstances where these conditions prevail.

Conclusion

The time of planting and crop age significantly affected cane and sugar yield. We were able to show that early planted crops harvested prior to the start of the normal harvest season could achieve productivity equal to or better than that of crops of similar age harvested during the harvest season. Thus, we have demonstrated that there are opportunities to harvest crops prior to the start of the current harvest season. We were also able to demonstrate that the APSIM model was able to simulate the responses to planting times and crop age. The close agreement between observed and simulated results show that under controlled experimentation and in the absence of factors such as disease, pests and waterlogging, the effects of crop age and start time follow recognised principles of crop physiology which are embodied in the APSIM Sugarcane model. Hence, the existing sugar model could be used to investigate the effect of different crop start times and crop ages, thus allowing mill regions to examine optimal crop cycle planning and optimal harvest season start and finish dates. The development and incorporation of a simulation capability for waterlogging may further broaden the model's applicability within the industry.

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