A REVIEW OF THREE SUGARCANE SIMULATION MODELS IN THEIR PREDICTION OF SUCROSE YIELD

GJ O'LEARY

South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe, 4300, South Africa

Introduction

There are two main sugarcane simulation models currently in use in the major sugar producing regions of the world, excluding the more numerous regression-type models utilised in site specific studies. These are an Australian model, APSIM-Sugarcane, and a South African model, CANEGRO. The CANEGRO model is employed as the Decision Support System for the Agrotechnology Transfer Sugarcane model that has been widely used throughout the Americas, Africa and Asia. These two models, while developed independently, have similar origins and have precursor models that are still utilised today. There is, however, another less well known model (QCANE) that was recently developed in Australia. This paper summarises the performance of the three models with the aim of highlighting their strengths and weaknesses with respect to the simulation of sucrose yield.

Descriptions of models

APSIM-Sugarcane simulation model

The APSIM suite of crop and soil models comprises a collection of models termed 'modules', assembled in a way specified by the user (McCown *et al.*, 1996). APSIM-Sugarcane, therefore, generally represents a model of sugarcane that is generic in structure to the other crop modules in APSIM, but its crop specific characteristics are defined in a table of input variables (Keating *et al.*, 1999). The model simulates the fixation of carbon from the atmosphere using an uncoupled radiation use and transpiration efficiency theory on a daily time step. Daily growth is partitioned into leaf, cabbage, stalk (structural and sucrose fractions) and roots by various fractions for particular phenological phases. Stress factors due to water, nitrogen and temperature are first applied to leaf and stalk growth, with a resultant relative increase in sucrose partitioning. APSIM-Sugarcane alters the partitioning fractions to sucrose in the stalk for different cultivars, providing an ability to simulate different sucrose content for a range of cultivars.

CANEGRO sugarcane simulation model

The origins of the CANEGRO model date back to the early 1970s, with the development of equations of photosynthesis and respiration. Its first assembly into a simulation model occurred in 1991 at the South African Sugar Association Experiment Station (SASEX) (Inman-Bamber, 1991). Improvements were later added to the photosynthesis and water balance calculations to include single leaf photosynthesis, quantum efficiency and growth respiration (Inman-Bamber, 1995). No direct effects of temperature on photosynthesis were included. To provide an annual sinusoidal pattern of the sucrose concentration an empirical day of year function is employed. This is coupled to a stalk biomass function for both irrigated and rainfed conditions, and an additional age of cane function for rainfed conditions.

QCANE sugarcane simulation model

The QCANE model was developed by the Bureau of Sugar Experiment Stations (BSES) in Queensland, Australia (Liu and Kingston, 1995). The purpose of QCANE was primarily to study sugar accumulation and ways to maximise this. Strong emphasis was, therefore, applied to photosynthesis, respiration and partitioning of photosynthate. Allocation of photosynthate to stalk sucrose is determined by growth stage, growth rate and temperature. At present, QCANE is not being developed any further ([1]personal communication), although progress to date with this model has been encouraging.

Performance of models

APSIM-Sugarcane

The performance of APSIM-Sugarcane in biomass and sucrose production has been evaluated across a range of environments in Australia, South Africa, Swaziland and the USA with considerable success (Keating *et al.*, 1999). In an earlier comparative test (Keating *et al.*, 1995) the root mean squared deviation (RMSD) was 1,97 Mg/ha for the simulation of millable stalk biomass over the range 0 to 80 Mg/ha. Since the 1994 comparative test, important improvements to leaf dynamics and sucrose simulation have been made.

APSIM-Sugarcane and CANEGRO have been used for benchmarking analyses in Australia and South Africa (Muchow *et al.*, 1997; Inman-Bamber *et al.*, 1998). In the Australian study, potential sucrose yields were simulated for two different localities, and the means compared well with the typical maximum observed yields. The most recent testing has shown encouraging performance, with sucrose yield simulation having an absolute error of 4,93 Mg/ha (Table 1).

[1] P Twine, BSES, Brisbane, Qld 4000, Australia

Table 1. Comparison of coefficient of determination (R^2), root mean squared error (RMSE) and source of data for each model in the prediction of sucrose yield.

Model	R^2	RMSE (Mg/ha)	Source
APSIM-Sugarcane	0,83	4,93	Keating *et al* (1999)
CANEGRO	0,07 0,41	4,32 5,06	[1]Unpublished data (1999) [2]Unpublished data (1999)
QCANE	0,92-0,97	2,46-3,64	[3]Unpublished data (1999)

[1]RA Donaldson SASEX Mount Edgecombe KZN 4300 South Africa
[2]CN Bezuidenhout SASEX Mount Edgecombe KZN 4300 South Africa
[3]De Li Liu, NSW Agriculture, Wagga Wagga, NSW 2650, Australia

While these results are encouraging, further testing is needed to show the seasonal response of sucrose yield to changes in weather, planting date, nutrients and cultivars, all of which have been acknowledged as markedly influencing sucrose yield.

CANEGRO

The CANEGRO model has been extensively tested in its performance in simulating total above-ground biomass for one popular South African variety (NCo376). In the comparative test of Keating *et al.* (1995) without water or N stress, the model was shown to be generally robust. The accuracy of the simulation of millable stalk biomass was reasonable (RMSD=0,95 Mg/ha; range 0-80 Mg/ha), with no obvious bias at either low or high biomass. In another test CANEGRO explained between 70 and 83% of the variance in observed cane yield (biomass) at two different locations (Inman-Bamber *et al.*, 1998). Recent unpublished data show a similar accuracy to APSIM-Sugarcane in simulating sucrose yield (mean RMSE = 4,69 Mg/ha) (Table 1).

QCANE

QCANE had the lowest error in simulating biomass and LAI in the comparison with APSIM-Sugarcane and CANEGRO (Keating *et al.*, 1995). Indeed, the error of QCANE was less than half that of APSIM-Sugarcane in millable stalk biomass (0,85 Mg/ha c.f. 1,97 Mg/ha). The seasonal changes in biomass and LAI also followed closely the observed data in other validation studies. The performance of the model in simulating sucrose yield was also fairly good for four crops across such a diverse range of environments (sub-tropical to tropical) (Liu and Kingston, 1995). The RMSE quoted ranged from 2,46 to 3,64 Mg/ha ([2]unpublished data) (Table 1). Thus, while the validations of QCANE are encouraging with respect to the accuracy of sucrose yield, more tests are warranted to confirm the utility of the partitioning functions employed.

Conclusions

Despite limited published performance data, all the models performed reasonably well although responses were not the same. Performance in simulating sucrose yield or concentration could be assessed as realistic from the published data for APSIM-Sugarcane. More amendments to sucrose partitioning under stressed conditions are needed. Limited unpublished sucrose simulation data were found for CANEGRO and QCANE. The challenge ahead is to test and document more fully the performance of these sugarcane simulation models in their accuracy in simulating sucrose yield and concentration. This is particularly important for CANEGRO, given its wide distribution with DSSAT.

[2] De Li Liu, NSW Agriculture, Wagga Wagga, NSW 2650, Australia

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