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SHORT COMMUNICATION

SIMULATED VERSUS ACTUAL YIELDS: HOW MUCH OF THE DIFFERENCE IS DUE TO NEMATODES?

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Abstract

Simulation modelling is a way of answering operational, tactical and strategic questions. It allows checking of hypotheses, building of experiments and anticipating conclusions in order to support decisions and recommendations. However, to have useful and accurate outputs, a model must integrate as many variables as possible. CANEGRO is a detailed model used by the South African Sugarcane Research Institute for research on sugarcane; the DSSAT v4.5 (beta) crop modelling system version was used for this study. The model uses weather data, soil physical characteristics and plant genetic characteristics to simulate the climatic potential growth of sugarcane. Factors not considered in the model are weeds and pests and diseases. Thus, yields from this model are mostly over-estimated. As a first attempt at integrating nematode losses into CANEGRO, data from two varieties from five variety x nematicide trials were compared with model simulations. In these field trials weeds were controlled, and the effect of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) on yields was determined. Nematodes were controlled in half the plots. No other major pests and diseases were evident. *E. saccharina* effect accounted for only 2.5% of CANEGRO yield. Excluding *E. saccharina*, yields were still lower than modelled yields, averaging only half of CANEGRO for control plots. Where a nematicide was applied, yields averaged two-thirds of CANEGRO estimates.

Keywords: CANEGRO, DSSAT, model, modelling, nematodes, sugarcane

Introduction

With the rise of computer engineering, modelling has become a useful tool in many fields of scientific research. CANEGRO, a crop growth model specific to sugarcane, originated in the early 1990s, and simulates plant growth and development of several sugarcane cultivars under various climatic conditions. Recently, CANEGRO has been assembled as a plant module (CANEGRO-CSM) within DSSAT (Decision Support System for Agrotechnology Transfer) (O'Leary, 1999; Jones *et al*., 2003). Much work has recently been done to improve its use and accessibility for a wider audience (Jones *et al*., 2007). The current model does not, however, simulate several other factors such as the effects of weeds, flowering, nutritional deficiencies, ratoon yield decline and pests and diseases (Bezuidenhout *et al*., 2002). Among the pests of sugarcane, nematodes are a major limiting factor for sugarcane growth, particularly on sandy soils (Spaull, 1995).

It is important that CANEGRO integrate the effect of nematodes on sugarcane growth simulations. This study is a first step in achieving this, and aims to quantify the differences between yields simulated by CANEGRO and actual yields from field trials, with and without the application of a nematicide (Temik).

Materials and Methods

Yield data was collected from five variety x nematicide trials (Table 1). All five trials were planted to sugarcane variety N12, and three of the trials were also planted to N31. These trials typically consisted of randomised complete blocks with untreated (control) and Temik-treated plots. At planting, and at the beginning of each crop cycle, Temik was applied to half of the plots to measure the effect of nematode damage on yield loss. *E. saccharina* levels were also recorded at most sites, and such data were used to control for the *E. saccharina* effect by recalculating the yield according to the extent of *E. saccharina* damage, assuming that 1% internodes bored equates to 1% yield loss (Goebel and Way, 2003).

Weather data for the specific periods of study were collected from weather stations located closest to the trial sites. This data included minimum and maximum temperatures, rainfall, solar radiation, maximum relative humidity and wind speed.

Soil data for each trial were obtained by collecting composite samples from depths of 0 cm to 120 cm from each trial site. A soil augur was used to assess soil depth and to monitor differences in soil profiles (see soil layers in Table 1). Sub-samples were sent for soil physical (% sand, % silt, % clay) and chemical (pH, % organic matter) analyses.

Table 1. Details of the five trials.

Trial	LM 1	LM 2	Otto 1	Zink 2	Klipp 3
Site	La Mercy	La Mercy	Compensation	Zinkwazi	Fawnleas
Duration of trial	1994-2008	1996-2000	2004-2007	2002-2007	2001-2007
Crops*	PC - 12R	PC - 4R	PC - 2R	1R - 3R	PC - 2R
Sugarcane variety	N12	N12	N12/N31	N12/N31	N12/N31
Weather station	Tongaat (manual)	Tongaat (manual)	Tongaat (manual)	Kearsney (automatic)	Wartburg (automatic)
Soil form	Westleigh	Fernwood	Kroonstad	Fernwood	Cartref
Soil layers	0-40 41-100 101-120	0-50 51-100	0-40 41-80 81-120	0-30 31-60	0-40 41-80
Soil pH	5.9 5.0 5.0	5.9 5.8	4.8 5.3 6.1	6.1 5.8	6.1 6.1
Soil % sand	92 89 89	94 94	86 87 90	95 94	93 89
Soil % silt	3 4 3	2 3	5 4 3	2 3	3 3

*PC = plant crop; R = ratoon

Simulations of all trials were run using DSSAT (v4.5 beta) for all the crop stages where data were available. Comparisons were made between the modelled results and the control and Temik-treated field data.

Results and Discussion

The results (Figure 1) showed that, on average, actual yields reached 55.3% (±5.3%, n=98) of simulated yields. The *E. saccharina* effect on the differences between actual and simulated yields averaged only 2.5%. The control plots had actual yields reaching only 46% (±15.6%, n=14) of the simulated yields. When the *E. saccharina* effect was removed, the yields increased marginally to 47.8% (±16%, n=14). For Temik-treated plots, actual yields averaged 61.2% (±15.8%, n=14). For these same plots, when the *E. saccharina* effect was removed, actual yields increased to 64.4% (±16.7%, n=14).

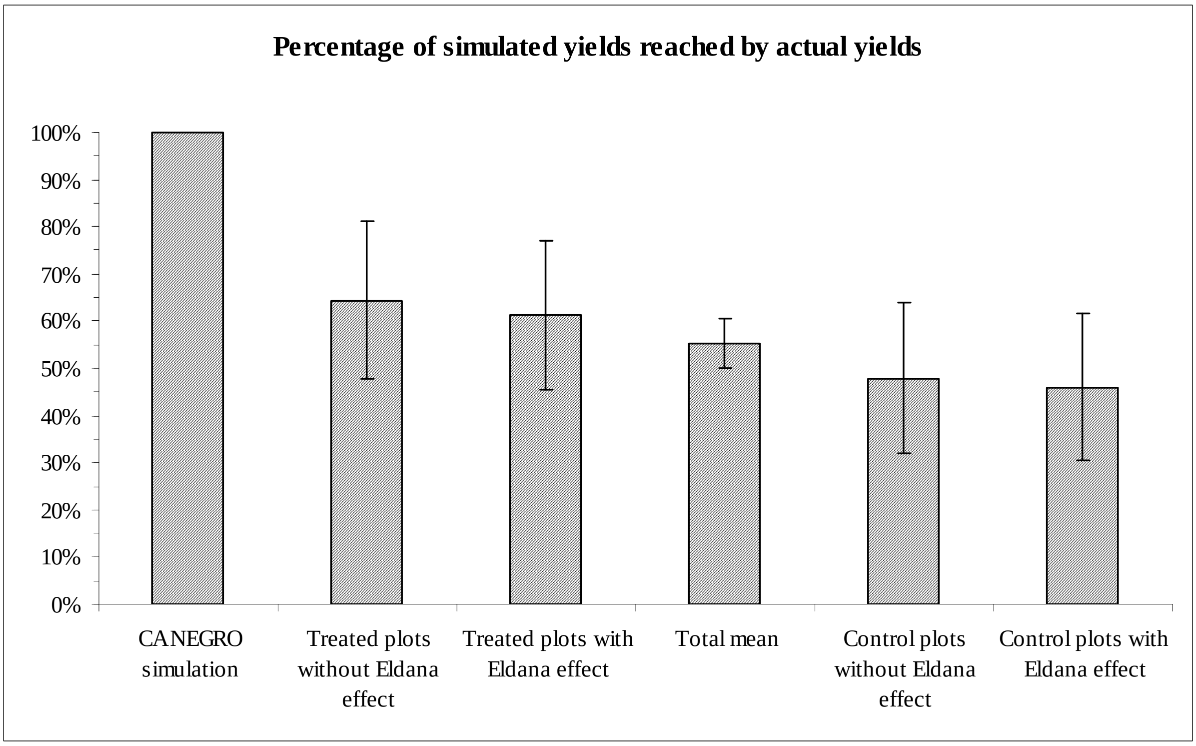

Figure 1. Percentage of actual yields from field data compared with simulations using the CANEGRO model. Confidence intervals were calculated at 5%.

It is possible to extract components of the differences between simulated and actual yields. On average, 35.6% reduction was due to unknown limiting factors, 16% reduction due to the non-application of nematicide and 2.5% due to *E. saccharina*.

Some assumptions could be made to define these unknown limiting factors. The first could be the inaccuracy and time resolution of the weather data used in the model. This could be related to the distance between trial sites and weather stations, and the time intervals between data recordings at the stations.

The second assumption is that, besides *E. saccharina* and nematodes, other pests and diseases could be present despite attempts to control them: for example, it is not rare to find *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) damage in trials deemed to be free of this pest. The same is possible for fungi, viruses and weeds, factors not simulated by CANEGRO. Even where the individual impact of each factor may not be strong, their cumulative impact could be important in terms of yield losses.

The third assumption concerns the accuracy of the soil data; certain soil characteristics estimated by DSSAT (e.g. water holding capacity and drainage rates inferred from clay content) could be different to the soil characteristics at the trial sites.

Finally, comparing Temik-treated plots with control plots does not show the whole ‘nematode effect’, but rather the ‘nematicide effect’. Indeed, nematicide application does not signify the complete absence of nematodes. Thus, part of the nematode effect not suppressed by nematicide application is included in these unknown limiting factors.

This study should be expanded to further investigate and eventually incorporate the nematode effect into the CANEGRO model. It will be important to pay more attention to the nematode communities and to link these with their associated damage to particular sugarcane varieties, under different soil characteristics. It would be appropriate, as a first step, to implement and validate the simulated crop response to nematodes, before attempting to model the nematode populations. This could include more systematic measurements, such as crop growth (above and below ground), changes in nematode communities, and sensitivity to differences in soil properties. This could lead, as Tixier (2004) suggested, to an index that better captures the soil biological effect on cane production.

Nevertheless, this study highlights that management options to reduce the gap between actual and modelled yields should take into consideration the ‘nematode effect’, which may result in the under-utilisation of resources such as fertilisers and water.

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