INTERNATIONAL CONSORTIUM FOR SUGARCANE MODELLING

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1. INTRODUCTION

The International Consortium for Sugarcane Modelling (ICSM) was established in 2006 and is an international partnership of research and other organizations that have an interest in sugarcane simulation modelling. Current members are Centre de Cooperation Internationale en Recherche Agronomique pour le Dévelopement (CIRAD), Chiang Mai University (Thailand), Commonwealth Scientific and Industrial Research Organisation (CSIRO), South African Sugarcane Research Institute (SASRI), Sugar Cane Growers Cooperative from Florida (SCGC), Sugar Research Australia Limited (SRA), Sugar Research Institute of Fiji (SRIF), and Zimbabwe Sugar Association Experiment Station (ZSAES). The current memorandum of understanding (MoU) is in place until November 2022.

The goal of the ICSM is to promote the development and application of sugarcane simulation models. Key objectives are to coordinate efforts and generate resources for sugarcane modelling projects, and to promote and enable the sharing of knowledge, information and data in the field of sugarcane modelling.

2. ICSM PROJECT ON “MODELLING WORLD-WIDE GXE INTERACTION”

A group of ICSM members (CIRAD, Florida SCGC, SASRI, ZSAES) is conducting research to gain a better understanding of the physiological mechanisms underlying the genetic variation in sugarcane crop response to environmental factors. Crop canopy development, radiation interception, biomass accumulation and partitioning of genetically diverse cultivars grown in diverse environments are monitored using a standardized trial and measurement protocol. The ultimate goal is to develop improved concepts for simulating genetic control of crop response to environmental factors, and to implement these in sugarcane models, with a view to use them to support crop improvement programs, worldwide. The hypothesis is that realistic models with accurate trait parameter values can be used to identify important traits and their ideal values for given environments (including future climates).

Growth analysis experiments were conducted from 2013 to 2016 (plant and ratoon crops) in Pongola, South Africa; Chiredzi, Zimbabwe; La Mare, Reunion Island; and Belle Glade, Florida, USA using different cultivars (N41, R570 and CP88-1762 at all sites, and HoCP96-540, Q183, ZN7 and NCo376 at some sites). Data collected include soil chemical and physical data, weather data, crop management data, shoot emergence, tiller population and height, leaf dimensions and appearance, fractional radiation interception, dry aboveground biomass component weights and stalk composition at harvest.

The first step was to evaluate existing concepts of genotype (G) and environmental (E) control of plant processes for explaining crop development, growth and yield, using the data collected in the experiments. Main findings included:

- Final yields showed significant E and GxE variation; dry above-ground biomass and stalk yields were highest in La Mare and lowest in Pongola. Cultivar rankings in stalk

dry mass for the common cultivars (N41, R570, CP88-1762) varied significantly between Es.
- Significant E variation in phenotypic parameters describing germination, tillering and timing of the onset of stalk growth revealed shortcomings in the underlying simulation concepts.
- Significant G variation was found for germination rate, leaf appearance rate and canopy development rate, and maximum radiation use efficiency, indicating strong G control of the associated underlying processes.
- Solar radiation was found to influence tillering rate and duration of the tillering period, challenging the current theory of thermal time as the sole driver of these processes.

This work was reported in a scientific paper that appeared in Field Crops Research (Jones et al., 2019).

In the second phase of the project the aim was to calibrate, assess, and identify weaknesses and recommend improvements to, three sugarcane models, DSSAT-Canegro, Mosicas and APSIM-Sugar. It was found that cultivar CP88-1762 developed canopy cover faster, intercepted more radiation and out-yielded, R570 and N41 in Es with cool early-season conditions (Belle Glade and Pongola), while R570 outperformed the other Gs in the warm early season E (La Mare). This dynamic was not adequately captured by any of the models. Models captured G and E effects on seasonal radiation interception and radiation use efficiency reasonably well, although the range of variation was underestimated. Models failed to capture GxE interaction effects on seasonal radiation interception, seasonal radiation use efficiency and biomass yield. Results suggest that sugarcane models must accommodate G-specific base temperature model inputs for germination and canopy development processes, and that biomass accumulation and canopy development processes must be linked to allow source-sink control of crop development. These model interventions are anticipated to result in improved simulation of GxE interaction effects on growth and yield, and hence improve capability to identify desirable traits for target environments.

This work was reported in a scientific paper that appeared in Field Crop Research (Jones et al., 2021)

The third phase of the project entails the development and evaluation of an improved model for simulating G and E effects on crop growth by combining strong features from existing models with new concepts to address the weaknesses identified in the study. The main features of the new model include:
- Genotype-specific temperature control of shoot emergence and canopy development.
- Canopy level (as opposed to leaf and shoot level) simulation of leaf area expansion co-regulated by source and sink strength. The latter is determined by temperature, water status and light conditions within the canopy. Leaf density (specific leaf area) varies depending on the balance between assimilate availability and sink demand for leaf expansion. Leaf expansion and senescence therefore now dynamically respond to source availability, sink demand and light conditions, as opposed to being prescribed by empirical inputs. It is also connected to the carbon balance, addressing the problem of a disconnected canopy development used in some existing models.
- A gradual transition (as opposed to an abrupt step change) from the tillering phase to the stalk growth phase is now simulated, which is driven by the light environment within the stool (as opposed to user specified thermal time or above-ground dry biomass threshold). The timing of the onset of stalk growth is now influenced by genetic (temperature sensitivity), environmental (temperature, water status, light), allowing crop development to respond more dynamically to these factors.

- Structural stalk growth is also co-regulated by source and sink strength. When assimilate availability cannot fulfil sink demand, stalk growth rate is reduced accordingly. When assimilate supply exceeds the demand, the excess is stored as sugars in the stalk, provided adequate capacity for it is available.

The model has been calibrated for R570 on the dataset collected in this project and shows promising results (see Fig 1).

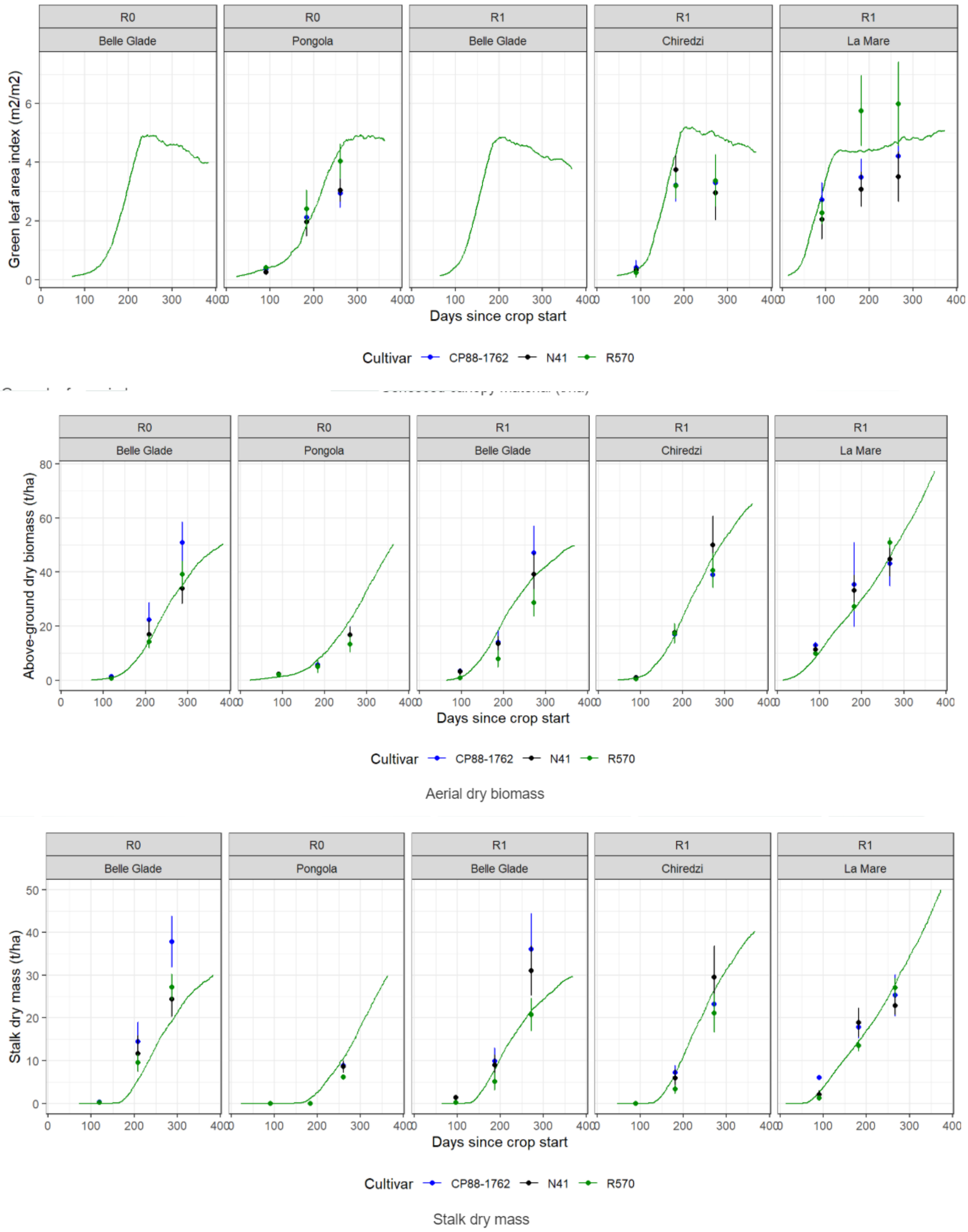

Figure 1. Simulated (line) R570 and observed (markers) green leaf area index, aboveground biomass and stalk mass for three cultivars in five experiments.

For the remainder of the project (2021/22) the focus will be on the further development of the new model and evaluating its potential for supporting sugarcane breeding. The project is due for completion in March 2022.

3. ICSM ADMINISTRATION

Zero income was received in 2020/21, while expenditure (research assistant salary) amounted to ZAR 166 500. The balance of funds at 30 March 2021 was ZAR 132 974, compared to ZAR 299 375 at March 2020. The exchange rate at time of writing was ZAR 14 ZAR/US$.

Johan van der Molen was appointed as research associate on a one-year contract in July 2020 to assist principal investigator Matthew Jones, who is now a full time employee of SASRI. Johan's job is to assist with modelling and data processing and analysis. In the reporting period Johan's tasks focussed on (1) investigating the use of soil temperature, rather than air temperature, to simulate bud germination and shoot emergence, (2) preparation of non-ICSM experimental data sets for model development and evaluation, and (3) coding the new ICSM model in the DSSAT platform. The outcomes from these efforts are reported in more detail by Jones (2021)

4. REFERENCES

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