**INTERNATIONAL CONSORTIUM FOR SUGARCANE MODELLING**

**RESEARCH PROJECT PROJECT OUTLINE**

**“MODELLING WORLD-WIDE GXE INTERACTION”**

# Background

Sugarcane crop models are valuable tools to support research and management of sugarcane production. A particular application that receives increasing attention is to use process crop models to assist in understanding genotype by environment (GXE) interaction and its underlying physiological mechanisms (Hammer & Jordan, 2007). This requires models that are realistic and biologically robust and that distinguishes between genetic and environmental impacts. It also requires reliable values of genetic trait parameters for different genotypes.

Crop models are often developed and tested with trial data for few cultivars and environments, which limits their usefulness to assist in gaining a better understanding of GXE interactions. Testing and calibration of models for local cultivars and diverse environments in many countries are needed to unlock their full potential.

The International Consortium for Sugarcane Modelling (ICSM) provides an excellent platform to coordinate this research. It can organize the standardization of field trial and data collection protocols and provide essential expertise and resources to participants who may need it.

# Objectives

The goal is to gain a better understanding of the physiological mechanisms underlying the genetic variation in crop response to environmental factors by monitoring key plant processes contributing to yield and quality in a common set of diverse cultivars grown in diverse environments from around the world.

Specific objectives are to

(1) measure canopy development, radiation interception, water use, water stress sensitivity and, biomass accumulation and partitioning for a number of diverse cultivars (from different countries) in diverse environments (in different countries),

(2) determine model trait parameters (genetic coefficients) for each cultivar, derived from development, growth and water use measurements,

 (3) indentify and formulate underlying mechanisms of genotype response to environmental factors, and

 (4) evaluate models ability to simulate genotypic differences in crop performance.

 The hypothesis is that genetic differences in cane yield and quality responses to the environment can be satisfactorily mimicked by simulating the response of physiological processes to environmental factors through appropriate trait parameters and environmental input data. It is believed that through the process of proving (or disproving) this hypothesis, new knowledge would be gained regarding the physiological basis of GXE interaction in sugarcane and that this would benefit the cultivar improvement program.

#  Methodology

* Year 1 to 4 (i) Propagate seedcane for variety collection; (ii) Implement data collection and processing procedures (staff training, instrument calibration, data quality checks), to be verified by ICSM project manager. By end of year 4: (i) Researchers and technicians trained in crop monitoring for model testing; (ii) Uniformity of the methodology verified , and (iii) enough sugarcane available in each country to be used as seed-cane to establish the trials.
* Years 1 to 4: Establish the trials; harvest plant crop and one ratoon according to the agreed protocol Discussion of results at annual ICSM meetings; after harvest of ratoon crop.
* Year 5 to 7: Analysis of results to start after harvest of plant crop. For example: comparison of established models; comparison of modules for different processes; improve definition of genetic coefficients and determine their stability across environments; suggest improvements to specific algorithms.

# Benefits

The project will (1) provide new insights, from a wide perspective, into the physiology of GXE interaction (by indicating physiological mechanisms and associated traits that are responsible for genotype performance), (2) enable the determination of trait parameter values for diverse cultivars, with possible pointers to ideal traits for given environments, (3) enhance model robustness for global conditions and relevance to local conditions, (4) provide valuable growth analysis dataset for future research, (5) utilize scientific input and data from leading sugarcane research organizations to improve models' capability of supporting crop improvement programs, (6) build capacity, particularly in ICSM member countries that don’t have a modelling tradition.

# References

Hammer, G.L. & Jordan, D.R. (2007) An integrated systems approach to crop improvement. In: Scale and Complexity in Plant Systems Research: Gene-plant-crop Relations. (eds. J.H.J. Spiertz, P.C. Struik & H.H. van Laar), pp. 45-61. Wageningen UR Frontier Series Vol. 21, Springer, Dordrecht.

# Appendix

# FIELD TRIAL PROTOCOL

# Soil classification

Soil properties to be described as follows:

* Site, latitude, longitude, altitude, soil taxonomy (USDA), soil albedo, slope, colour, permeability, drainage, stones, residue type and amount, cropping history
* Depth of impermeable layer, comment on drainage and N mineralization properties .
* Soil particle distribution, water retention properties (SAT, DUL, LL) and bulk density per soil layer (30 cm)
* Chemical analysis: pH (water), P, K, Mg, Ca, Si content, organic matter content, CEC for top and sub soil.

# Trial layout

The trial layout is shown in Fig. 1. Four reps (blocks) each for the plant and ratoon crop, each containing six randomized plots for each of the six cultivars (NCo376, R570, Q183, ZN7, CP88-1762, HoCP96-540). Each cultivar plot consists of 9 rows spaced at 1.5 m, 11 m long. Destructive sampling net area consist of 3 rows of 4m long. Guard rows between sample areas and 1 m guard at the end of sample areas. This will allow four destructive samplings to be made. Non-destructive samplings to be done in area reserved for last sampling.



Fig. 1. Trial design (Two randomized block for plant and ratoon crop, four reps indicated with roman numericals, and six cultivars. Each plot provides for four areas of destructive sampling.

# Seed cane

Seed cane should be propagated locally following a standard procedure (disease free sets to produce approximately 1500 stalks for each cultivar).

Amount of seed required:

9 rows X 11m = 99 m@1.5 stick = 149 m cane per cultivar per rep

149 m X 4 reps = 596 m of stick per cultivar per trial

596 m X 2 trials (plant and ratoon1) = 1192 m

1192 m @ 1.5 m/stalk= 794 stalk per cultivar

Assume yield of 8 stalks per m of seed planted: 99 m of seed to be planted at single stick. Approx. 50 to 80 stalk needed.

If disease-free seed of a given cultivar is not available in a given country, the source country should provide tissue-cultured plantlets or disease free one-eyed buds. This would be grown under quarantine for 9 months and then bulked up to allow the planting of a seedcane plots that will produce 1500 stalks of seed cane.

# Planting procedure:

Seed should not be older than 12 months, should be dipped in fungicide and planted at 150mm planting depth as one and half stick (set length of +-40cm). Cover the sets with a uniform 50mm of soil. About 2.5L/m water in the furrow before closing will improve germination. The approximate number of buds per plot should be recorded.

# Crop husbandry

Irrigation (schedule by profit and loss to maintain water content above 50% of capacity in the top 1 m of the root zone

Fertilizer application as per recommendation for soil type & based on soil analysis

Pest and disease management: regular fungicide and insecticide application.

# Non-destructive measurements

* Date of planting
* Date of emergence – (See definitions)
* Date of peak population – (See definitions)
* Number of shoots for 8m row length at bi-weekly intervals from crop start till one month after peak population and then monthly until final harvest.
* Light interception bi-weekly with ceptometer (10 reading per plot) or canopy width
* Stalk (TVD height) and canopy height (every two weeks)
* *TVD leaf number (also write the number on leaf with a marker pen), TVD date and leaf size (length (from the stalk to the tip of the leaf) and width (maximum width) every week for 8 tagged shoots in each plot. (optional)*
* *Total number of leaves up to the spindle and height from ground to TVD leaf every week on the same 8 tagged shoots. (optional)*
* *TVD leaf chlorophyll at TPeak and at time of destructive sampling. Use a Minolta SPAD or instrument calibrated against the SPAD. (optional)*

# Destructive sampling

Total aboveground fresh biomass of 18m2 cut and weighed four times (3, 6, 9 and 12 months of age). Sub sample of 2 m of cane taken beforehand in this area to determine:

* Number of tillers
* Number of millable stalks (longer than 0.5m)
* Total fresh mass
* Total millable stalk fresh mass
* Total green leaf fresh mass (green leaves excluding sheaths),
* Average stalk length from ground level to the apex (tip of soft point)
* *Average diameter 4th internode from top, middle and 4th node from bottom (optional)*
* Total millable stalk dry mass (Dry samples at 80oC for 3 days and then 105oC for 3 hours)
* Total green leaf dry mass (excluding sheaths)
* Leaf sheath dry mass
* Tops dry mass (immature green leaves and meristem
* Trash dry mass (dead leaves and non-millable shoots)
* Stalk brix, fibre, pol, non-pol and moisture content (DAC analysis method)
* Leaf fresh mass and leaf area of a smaller sub -sub-sample (say 5 to 10 stalk - to derive LAI)
* Complete TVD leaf analysis (N, P, K, Ca, Mn, Fe, *Cu, Si*) of actively growing crop after 4 months of age.

#  Definitions and procedures

## *8.1 Shoot number*

Shoot number will include tiller and stalk number. Tillers are counted when its first TVD is visable (shoot usually >5cm in length). Tillers are shoots of which the stalk apex has not emerged above ground and stalks are shoots with millable stalk showing above ground. Stalks generally start to emerge at time of peak population or about 10 leaves.

Tiller number will progressively account for primary, secondary and higher order tillers. In ratoon cane the first count will represent re-growth from tillers of which the stalk apex has not emerged above ground at the time of cutting. Square leaf tips on the first leaves from these rapidly re-emerging tillers will clearly show that it has been cut.

Primary tillers come from buds on the planted stalks. The first secondary tillers will emerge approximately 300Cd (TT16) later (Singels et al.,… ) and represent shoots that comes from below ground nodes on primary tillers. Shoots can also emerge from buds on secondary shoots and the proportion of higher order tillers will depend on the light conditions and space available to the stool.

Shoot number will reach a peak when competition for light forces the senescence of those that cannot support continued growth. Peak population (TPeak) is not associated with a fixed thermal time period or plant growth stage and both number and time to peak TPeak will be affected by factors such as cultivar, bud density, ground cover, radiation, temperature, soil fertility, soil water, etc. When approaching TPeak, the counting of shoots should be done weekly to ensure a reasonable accuracy of the date. After peak population was reached, shoot number will decline and stabilise at a predictable population typical of the given cultivar.

*8.2 Leaf profile (optional)*

Sugarcane leaves emerge sequentially and is usually attached alternatively to opposite sides of the stem in approximately the same plane (van Dillewijn, 1952). Leaves can be counted from the top down or the bottom up depending on the objective of the study. In this co-operative trial, it will be counted from the bottom and leaf number one will be the first fully developed leaf with a leaf blade longer than 5cm, thus ignoring the scales at the very bottom. Each leaf on 8 primary stalks randomly selected in each plot, should be numbered physically with a marker pen at the time it becomes the TVD leaf. This practice will assist in keeping track of the count after the bottom leaves start to senesce and go missing.

The TVD leaf can be recognised and dated when the first signs of a leaf collar and dewlap become visible. This leaf is fully elongated and is used to record non-destructive width and length measurements and for physiological measurements such as leaf chlorophyll, chlorophyll a fluorescence, photosynthesis and leaf temperature. The TVD leaf is also commonly used for leaf chemical analysis.

Leaf number (LN) represents all leaf positions on the stalk from the base to spindle leaf at the top. Green leaf number (GN) indicates the number of leaves with more than 50% green leaf area up to and including the TVD leaf.

Node number (NN): Stalk nodes can be numbered the same as the associated leaf number. The first +\_10 leaves will have nodes below ground level. For purpose of biochemical analysis is it common practice count from the top and the node and internode associated with the TVD leaf will be no 1. The moment a leaf reaches the TVD stage, its growth stops and elongation of the internode below node 1 is initiated.

Procedure could be simplified by only recording every 3rd leaf (date, height and size)

*8.3 Stalk emergence and elongation*

Stalk emergence can be checked non-destructively as the time when the base of the sheath connected to the TVD leaf becomes visible above ground. This usually happens after about 10 leaves have emerged and also at the approximate time of peak population for standard planting practice.

Stalk elongation can be monitored indirectly by means of the TVD leaf. The leaf blade and sheath are fully mature and at maximum length when the collar and dewlap become visible. Any increase in plant height as measured on the dewlap is therefore due to stalk growth. Most of this growth takes place in the internode just below the base of the TVD sheath and all the elongation can be accounted for in the top six to seven internodes. Stalk height for specific stalks do therefore not necessarily have to be measured from a ground level every time but can more accurately be measured from a reference node at a known height from the ground.

*8.4 Measuring light interception*

Radiation intercepted by the crop canopy can be estimated by measuring fractional interception (FI) and the daily influx of sun energy. The latter can be calculated from pyranometer measurements from the nearest automatic weather station and FI can be calculated as the difference between radiation measurements taken below and above the green leaf canopy. Two sensors are commonly used namely the ceptometer or sunscan that measures photosynthetic active radiation (PAR) and solarimeters that measure total shortwave radiation.

FI should be measured close to midday and the sensor rod should be held below the lowest green leaf and at an angle to the row so as to cover half of the inter-row width. At least 4 readings on either side of the row should be averaged to get a representative reading for each plot. FI is then calculated as the fraction of the difference between the above and below canopy readings.

When PAR is measured, it should be converted to global radiation before calculating the estimated radiation intercepted.

FI will be influenced by the condition of the crop. During times of stress when green leaves are rolled, the FI values will be lower than when leaves are fully open.

*8.5 Date of emergence**(DE)*

For seed crops the date of emergence is commonly taken as the date when 50% of the seedlings have emerged. The equivalent date for cane will be the date when 50% of planted buds germinated and emerged above ground. For ratoon cane, the date of emergence can be taken as the date when 50% of the final population of the previous crop is achieved.

* 1. *Flowering*

Rapid increase in distance between leaves and thinning of the sheaths is a sign of eminent flower emergence and should be noted.

*8.7 Lodging*: Lodging (stool tipping or stalk bending) should be avoided or it may cause difficulty to compare datasets. Date of lodging should be recorded and the trial be discontinued after that.

*8.8 Disease, insect, frost, or hail damage:* Stress that impact on biological yield should be avoided or quantified in order to account it for when reporting.

# Weather data

Daily data for shortwave radiation, rainfall, wind run, min max humidity, min and max air temp.

# Equipment requirements

10.1. Mass Balance

10.2. Ceptometer (PAR line quantum sensor)

10.3. Tape measure in metric units

10.4. *Leaf area meter (optional)*

*10.5. Leaf Chlorophyll meter (Minolta SPAD, optional)*

10.6. Automatic Weather Station in close proximity to the trial

10.7. Micro Soft compatible spreadsheet (Excel)

**11. References**

* Smit MA, Martiné JF, Van Den Berg M. 2009. Towards Data Collection Standards For Sugarcane Growth Monitoring. Icsm Document
* Van Dillewijn, C., 1952. Botany of Sugarcane. Book Department, The Chronica Botanica Co, Waltham, MA, USA