DEVELOPMENT AND INCORPORATION OF THE DSSAT-CANEGRO SUGARCANE MODEL INTO THE DSSAT V4 SOFTWARE

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SUMMARY

The Canegro sugarcane model, as well as lodging and canopy routines from the Canesim sugarcane model, have been incorporated into DSSATv4.5. The model has been verified to work correctly, and has been validated using two experimental data sets from South Africa. The model performed satisfactorily.

A very successful validation workshop was held from 6 to 9 August 2007 at SASRI, Mount Edgecombe and was attended by 17 delegates from SASRI (South Africa), BSES (Australia), CSIRO (Australia), Chiang Mai University (Thailand), SCGC (Florida), ZSAES (Zimbabwe), SRC (Fiji), CIRAD (France), University of Florida, KESREF (Kenya) and Agriculture Canada. Prof Jim Jones and Dr. Cheryl Porter assisted SASRI staff in leading the workshop and tutoring delegates. The first two days consisted of hands-on training on installing and running the new DSSAT4.5 Canegro model. Delegates received comprehensive model documentation and a licensed copy of the software and were able to set up, execute and interpret simulation runs. The last two days were spent on calibrating the model (adjusting cultivar parameters) using actual observations from field experiments from Australia, Thailand, Zimbabwe, Florida and South Africa. The model performed remarkably well for these widely different locations, even before any adjustment to cultivar parameters. The model underestimated rate of growth in winter for two independent scenarios and this suggests the existence of a model shortcoming that needs investigation. Of the original list of 54 cultivar parameters, seventeen key parameters were identified that described major cultivar differences in the processes of phenological development, canopy development, biomass accumulation and partitioning. The workshop succeeded in testing and expanding the database of cultivar parameters from Nco376 to include two ZN, two Q and four other N cultivars. Valuable comments were obtained from delegates to improve the DSSATv4.5 shell and the Canegro model. The project is on track to release the updated version of Canegro within the DSSATv4.5 shell by March 2008.

1. INTRODUCTION

The overall project goal is to incorporate an up-to-date Canegro model into the DSSAT v4 software. Specific objectives are:

- Addition of Canesim canopy and lodging routines into the Canegro model
- Rewriting the existing Canegro code and new code for recently developed concepts into modules and linking it to other modules within the DSSAT4 structure.
- Validation of the new DSSAT4 Canegro model with experimental data from different countries.
- Documentation of code, modelling concepts and model validation.

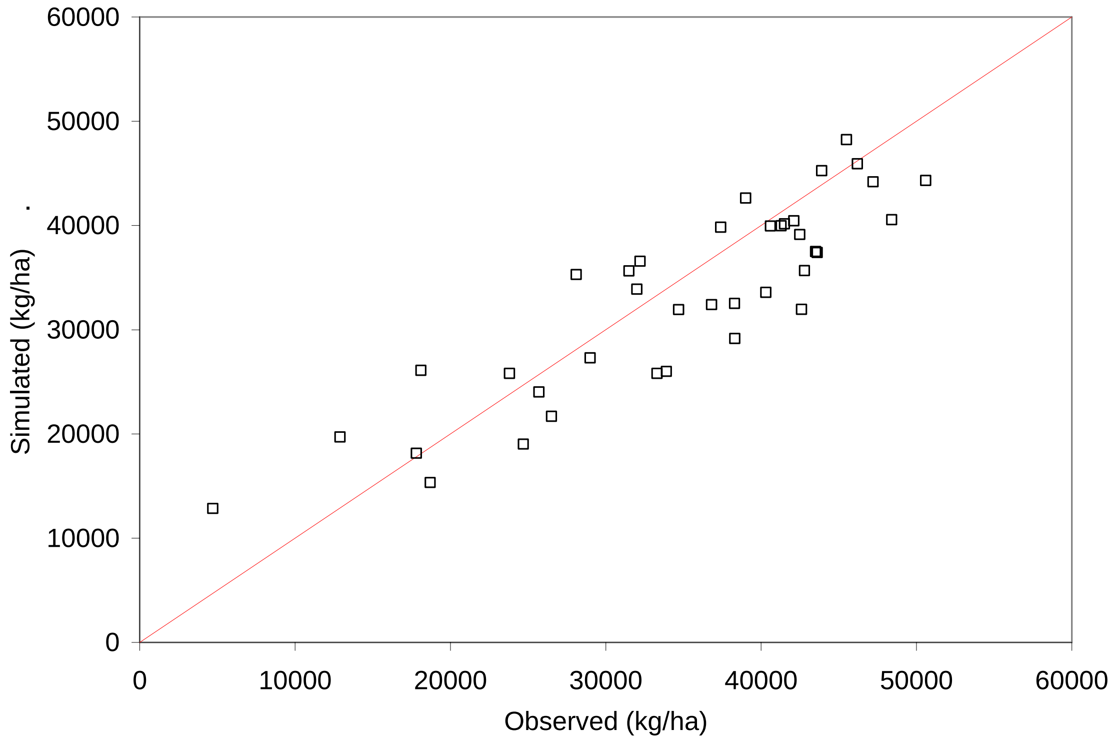
This report describes the progress to date with special emphasis on the validation workshop that was held from 6 to 9 August 2007.

2. INCORPORATION OF CANEGRO INTO DSSAT

The following progress has been made:

- The Canesim canopy and lodging routines have been added to the Canegro model
- The Canegro model has been fully incorporated into the DSSAT 4.5 software and is fully functional
- The model has been verified by comparing the SASRI stand-alone version to the DSSAT 4.5 version for a sequence of 1 plant and 9 ratoon crops. Three water regime scenarios were investigated namely (1) water balance module disabled, (2) water balance module enabled with adequate irrigation applied, and (3) water module enabled with no irrigation applied and frequent water stress. The first scenario produced identical results for the two model versions. The other two scenarios produced discrepancies between the two model versions, but these were deemed acceptable. The origin of these discrepancies could all be traced back to code outside the plant module (such as different ETo calculation).
- Two validation data sets were compiled and entered into the DSSAT4.5 package. The new model was validated by comparing simulated values with observation of LAI, aerial dry mass, stalk dry mass (see Fig. 2.1) and sucrose mass for two South African experiments (irrigated and rainfed). The performance of the model was highly satisfactory and was better than that of the DSSAT3.5 version.

- A first draft of the scientific documentation of the model has been completed but needs further refinement. A user manual is under construction.



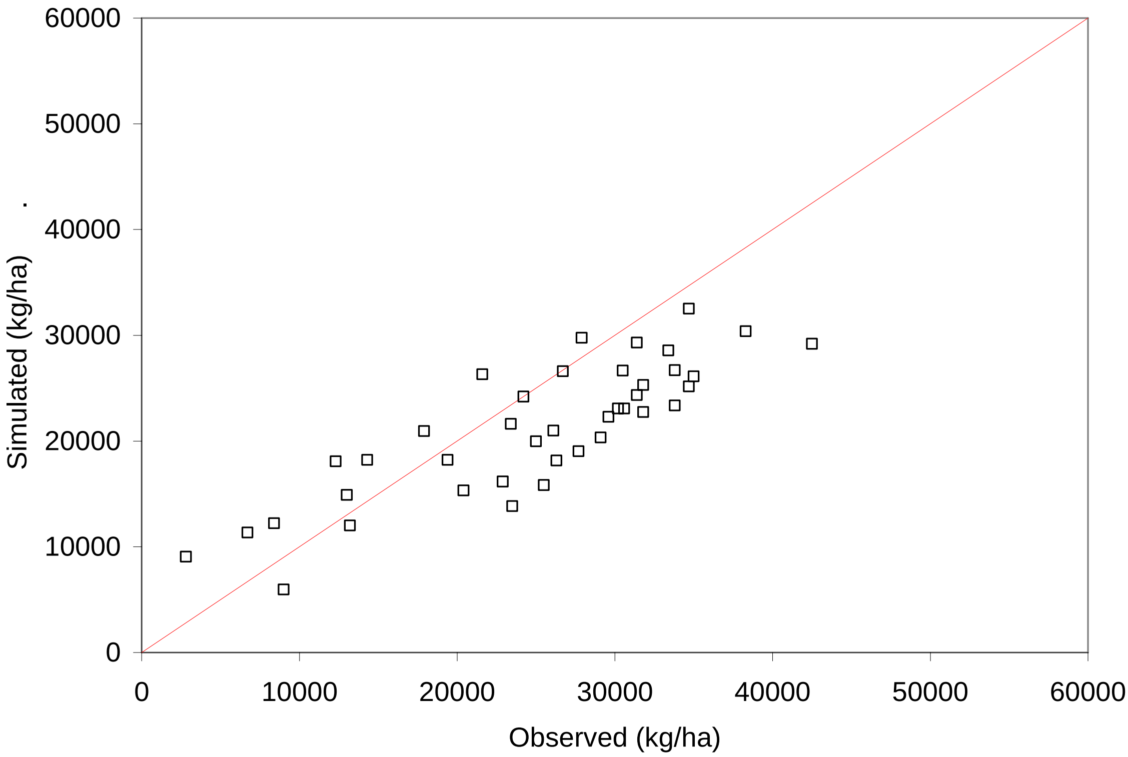


Fig. 2.1 Simulated and observed values of stalk dry mass (kg/ha) for a irrigated crop of NCo376 grown at Pongola, South Africa (1969-71) (top graph) and a rainfed crop grown at La Mercy, South Africa (1989-91) (bottom graph)

3. VALIDATION WORKSHOP

A very successful Canegro validation workshop was held from 6 to 9 August 2007 at SASRI, Mount Edgecombe and was attended by 17 delegates (see Appendix for list of delegates) from SASRI (South Africa), BSES (Australia), CSIRO (Australia), Chiang Mai University (Thailand), SCGC (Florida), ZSAES (Zimbabwe), SRC (Fiji), CIRAD (France), University of Florida, KESREF (Kenya) and Agriculture Canada. Prof Jim Jones and Dr Cheryl Porter assisted SASRI staff in leading the workshop and tutoring delegates.

The first two days consisted of hands-on training on installing and running the new DSSAT4.5 Canegro model. Delegates received comprehensive model documentation and a licensed copy of the software and were able to set up, execute and interpret simulation runs. The last two days were spent on calibrating the model (adjusting cultivar parameters) using actual observations from field experiments from Australia, Thailand, Zimbabwe, Florida and South Africa.

Brief reports of the validation/calibration conducted by each participant in the closed session will now follow.

4. SASRI

Experimental data from a growth analysis trial conducted at a relatively cool site in the Kwazulu-Natal Midlands in South Africa (>1000m a.s.l.) were used. Three contrasting cultivars were started in autumn and spring. The data were used to firstly validate model performance using the set of parameters proposed in the model documentation and provided in the DSSAT cultivar file, and secondly to calibrate cultivar parameters for improved simulation.

4.1. Experimental details

Experimental details are as follows:

- Site: Bruynshill, South Africa (29°25'S, 30°30'E, 1014m)
- Soil: Humic Ferralsols (World Reference Base for Soil Resources, ISBN 92-5-304 141-9.)

- Treatments: Three cultivars (NCo376, N37 & N31), two starting times (October 2003 and April 2004). Cultivar N37 is known for high sucrose content while N31 is a vigorously growing, high yielding type with low sucrose content.
- Main measured variables: Leaf and tiller phenology, leaf area and canopy cover, biomass components.

4.2. Results

4.2.1. Cultivar parameter calibration

Running the CANEGRO model through the DSSAT shell was relatively easy once a basic understanding of the different modules such as XBuild and ATCreate was acquired. Calibration for improved simulation however was difficult without detailed knowledge of how parameters impact on specific processes. It was also a cumbersome process to iteratively change parameter values and compare the resultant simulation output with measurements or with a previous run. Some parameters interact with each other and it is recommended that optimization software be developed to facilitate the calibration process.

Calibration focussed on parameters related to the timing of phenological phases, leaf and tiller development and stalk extension rate.

Original (as proposed by model documentation and provided in the DSSAT cultivar file) and calibrated values of some cultivar parameters are given in Table 4.1. There are several notable differences between original and calibrated values. For example, observed data suggest that less thermal time is required for emergence (TTRATNEM) and for start of stalk growth (CHUPIBASE), than proposed in documentation. Data also suggest a higher base temperature for plant extension (TBASEPER) to reflect the very slow stalk extension rate that was observed in winter.

Table 4.1. Cultivar parameter values before and after calibration.

Cultivar:	NCo376		N31		N37	
Parameter	Before	After	Before	After	Before	After
APFMX	0.88	0.88	0.9	0.92	0.88	0.88
STKPFMAX	0.65	0.65	0.68	0.69	0.65	0.65
SUCA	0.58	0.58	0.57	0.55	0.6	0.65
dPERdT	0.176	0.45	0.23	0.59	0.188	0.5
LFMAX	12	10.4	12	8.7	12	10.3
MAXLFLENGTH	100	146	100	156	100	187
MAXLFWIDTH	3.5	3.8	3.5	3.8	3.5	3.8
MXLFAREA	360	390	360	425	360	520
MXLFARNO	15	24	14	18	14	20
PSWITCH	18	14	14	14	14	14
PI1	69	66	90	56	90	70
PI2	169	160	170	150	170	150
CHUPIBASE	1050	625	1050	470	1050	650
TTBASEEM	10	16	10	16.1	10	16
TTBASELFEX	10	15	10	12	10	14
TTBASEPOP	16	16	16	16	16	16
TBASEPER	10.057	16	10.057	16	10.057	16
TTPLNTEM	428	428	428	428	428	428
TTRATNEM	203	45	203	30	203	35
TT_POPGROWTH	600	460	600	460	600	460
MAX_POP	300	400	300	320	300	360
POPTT16	133000	135000	127000	180000	117000	120000

4.2.2. Validation results

Results of the statistical comparison between simulated and observed values of selected output variables before and after cultivar calibration are summarized in Table 4.2. Detailed results are given in the Appendix.

Table 4. 2. Model performance before and after cultivar calibration (mean values for the three cultivars)

Variable Name	Calibration	Observed mean	Simulated mean	R^2	RMSE	d-Stat.	n
Leaf #	Before	19	18	0.993	2.73	0.965	16
Leaf #	After	19	19	0.995	2.32	0.974	16
LAI	Before	4	4	0.562	1.05	0.507	7
LAI	After	4	4	0.517	0.97	0.573	7
Tiller #/m2	Before	23	20	0.523	8.27	0.789	18
Tiller #/m2	After	23	19	0.759	6.32	0.860	18
FI	Before	0.76	0.80	0.899	0.11	0.954	5.5
FI	After	0.76	0.71	0.978	0.09	0.981	5.5
SH (m)	Before	1.56	1.77	0.928	0.31	0.926	7
SH (m)	After	1.56	1.76	0.925	0.28	0.933	7
TDM (kg/ha)	Before	30314	39155	0.889	10143	0.877	7
TDM (kg/ha)	After	30314	39194	0.888	10177	0.878	7
SDM (kg/ha)	Before	17577	21615	0.937	5430	0.814	6.2
SDM (kg/ha)	After	17577	15793	0.938	3389	0.867	6
Suc (kg/ha)	Before	8602	10173	0.888	2545	0.781	5.5
Suc (kg/ha)	After	8602	6742	0.880	2805	0.782	5.5

LAI - Leaf area index, SDM- Stalk dry mass, TDM – aboveground biomass, Suc- Stalk sucrose mass, SH –Stalk height, FI – fractional interception of radiation.

The calibration brought about marginal or no improvements in model performance in most cases. The adjustment of the thermal time requirements for phenological development (TTRATNEM, CHUPIBASE and TT_POPGROWTH) brought about marked improvements in the simulation of tiller population (Fig. 4.1) and fractional interception.

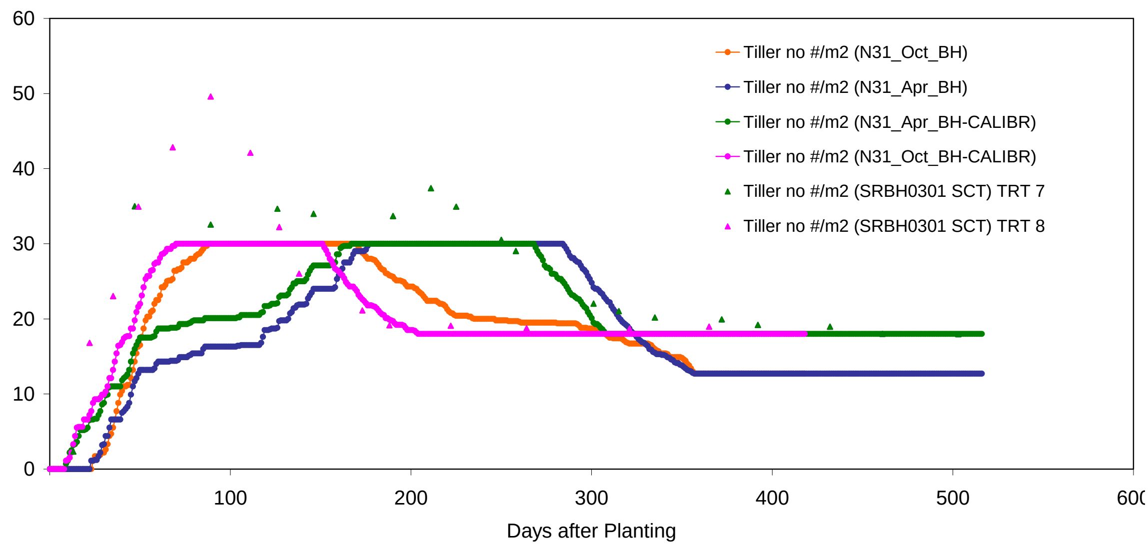


Fig 4.1: Simulated (lines) and observed (symbols) tiller population for cultivar N31 for an October and April crop start.

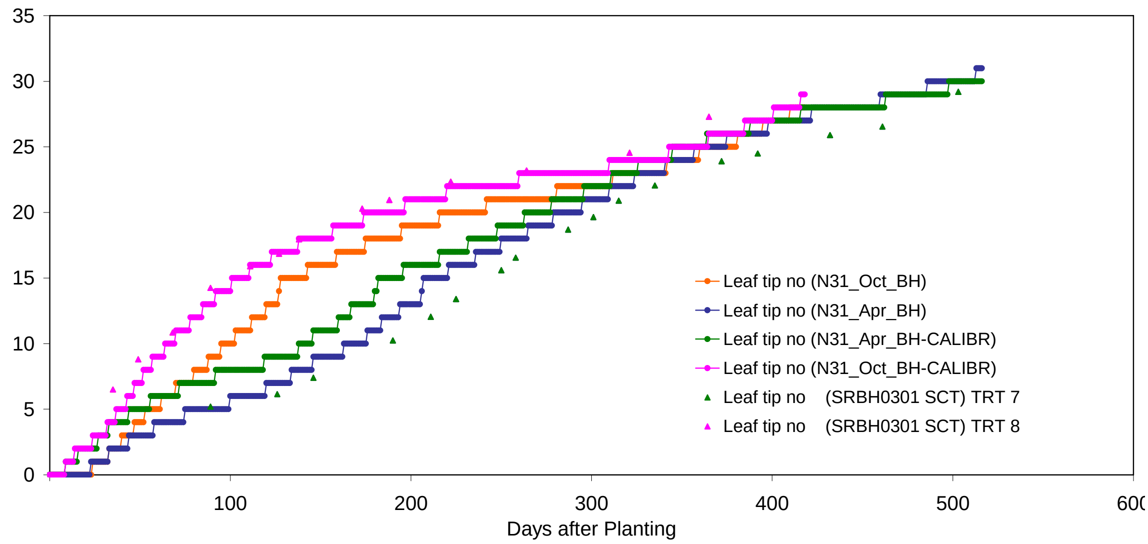


Fig 4.2. Simulated (lines) and observed (symbols) values of leaf tip emergence stalk height for cultivar N31 for an October and April crop start

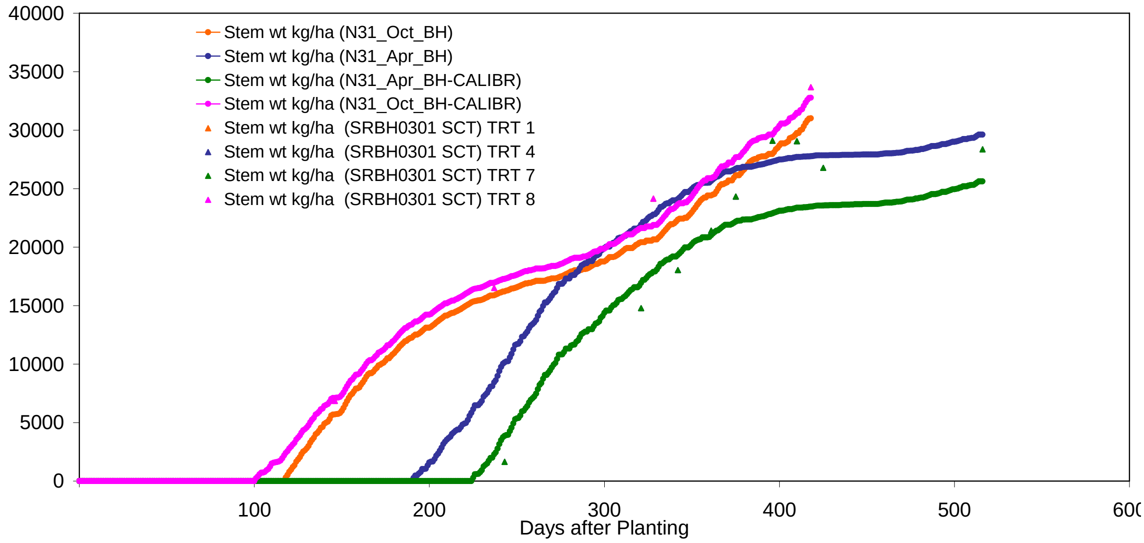


Fig 4.3: Simulated (lines) and observed (symbols) stalk dry mass for cultivar N31 for an October and April crop start.

Simulation of leaf emergence is shown in Fig. 4.2. The rate of emergence was too slow for the October start and slightly too quick for the April start. Adjusting phyllochron values resulted in a good fit for the October start but a poorer fit for the April start. This response to calibration was also observed for other variables such as biomass and stalk mass (see Fig. 4.3). This suggests the existence of a model shortcoming that needs to be investigated more closely.

5. BSES

5.1. Experimental details

- Site: BS
- Soil: Ferrosol (Telegraph)
- Cultivar: Q138 & Q141
- Irrigation: Fixed amount (actual irrigation gave large under prediction of yield)
- Start and harvest dates: Plant 14Aug1991 – 17Nov1992; 1R 10Aug1992-23Nov1993
- Treatments: 2 cultivars, 2 starting and harvest dates
- Main measured variables: Biomass components (stalk, green leaf, top, trash, stalk sucrose), LAI

5.2. Results

5.2.1. Cultivar parameter calibration

Table 5.1 shows how the two cultivars were classed in terms of broad categories of different traits. However, for the actual cultivar calibration, the set provided for NCo376 were used as a basis, and values of four parameters were changed for Q141 and one for Q138 (see Table 5.2).

Table 5.1. Broad categorization of two Q cultivars compared with NCo376.

Trait	**NCo376**	Q138	Q141
Tiller population	H	M	M
Leaf emergence	H	H	H
Leaf size	L	L	L
Canopy development	H	H	H
Stalk growth	M	M	M
Sucrose content	L	M	H

Table 5.2. Parameter values for cultivars Q138 and Q141, that are different from that of NCo376.

Parameter	***Process***	**Q138**	**Q141**
SUCA	Sucrose accumulation	0.59	0.65
TBFT			27
STKPFMAX	Stalk growth		0.68
CHUPIBASE	Phenology		1150

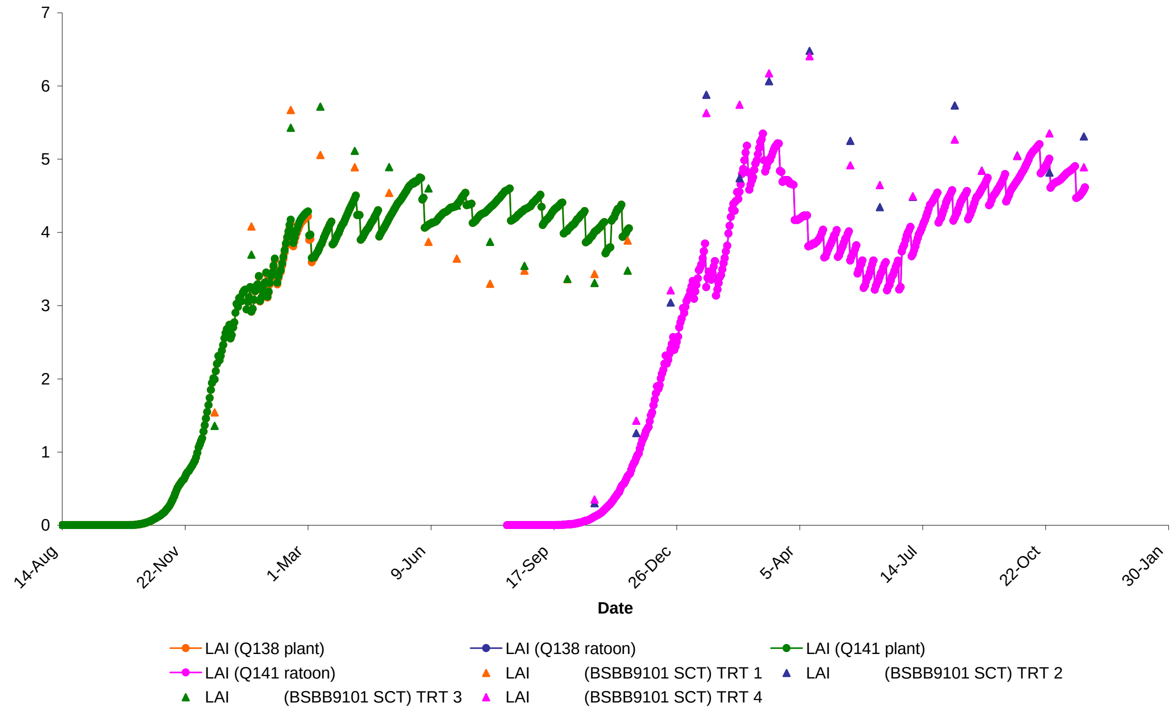
5.2.2. Validation results

Statistical results are given in Table 5.3. Model performance are illustrated in Fig. 5.1.

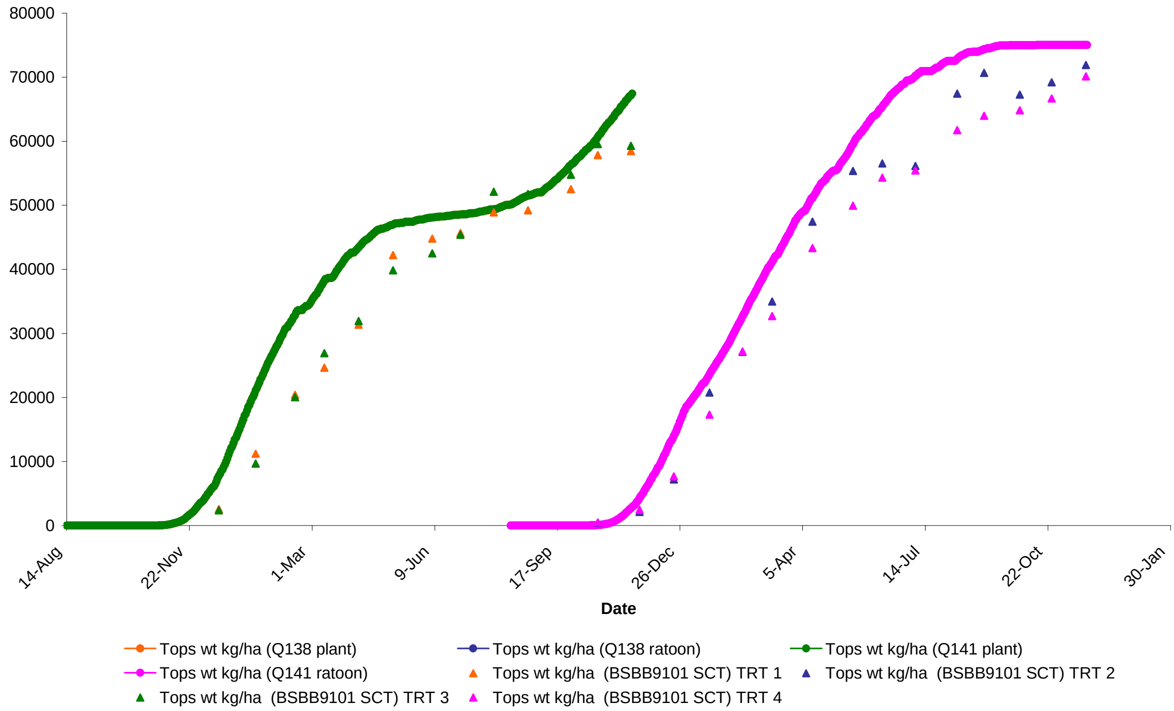
Table 5.3. Validation results (Note: Leaf dry mass = meristem DM + green leaf DM +Trash)

Variable	**Mean observed**	**Mean simulated**	**R^2**	**RMSE**	**n**
Q138 Plant					
LAI	3.905	3.899	0.304	0.829	13
Aerial dry mass	37669	43974	0.947	7599	13
Stalk dry mass	25968	24399	0.928	5666	13
Sucrose mass	13333	12189	0.861	4303	7
Trash dry mass	7629	7286	0.711	1915	13
Leaf dry mass	13698	14684	0.909	1714	13
Q138 ratoon					
LAI	4.508	3.59	0.753	1.239	15
Aerial dry mass	43639	48978	0.987	6210	15
Stalk dry mass	32938	30283	0.979	4377	15
Sucrose mass	17474	13657	0.976	5114	9
Trash dry mass	8168	8803	0.942	1143	15
Leaf dry mass	15092	15053	0.969	1256	15
Q141 plant					
LAI	4.057	3.903	0.432	0.85	13
Aerial dry mass	38160	43979	0.941	7569	13
Stalk dry mass	26083	22236	0.906	6994	13
Sucrose mass	16295	11991	0.838	7115	7
Trash dry mass	6695	7971	0.907	1890	13
Leaf dry mass	14082	16052	0.886	2298	13
Q141 ratoon					
LAI	4.56	3.59	0.81	1.198	15
Aerial dry mass	41209	48928	0.99	8572	15
Stalk dry mass	29576	28375	0.988	2706	15
Sucrose mass	17731	14271	0.987	4369	9
Trash dry mass	6874	9422	0.91	2769	15
Leaf dry mass	15576	16170	0.968	1370	15

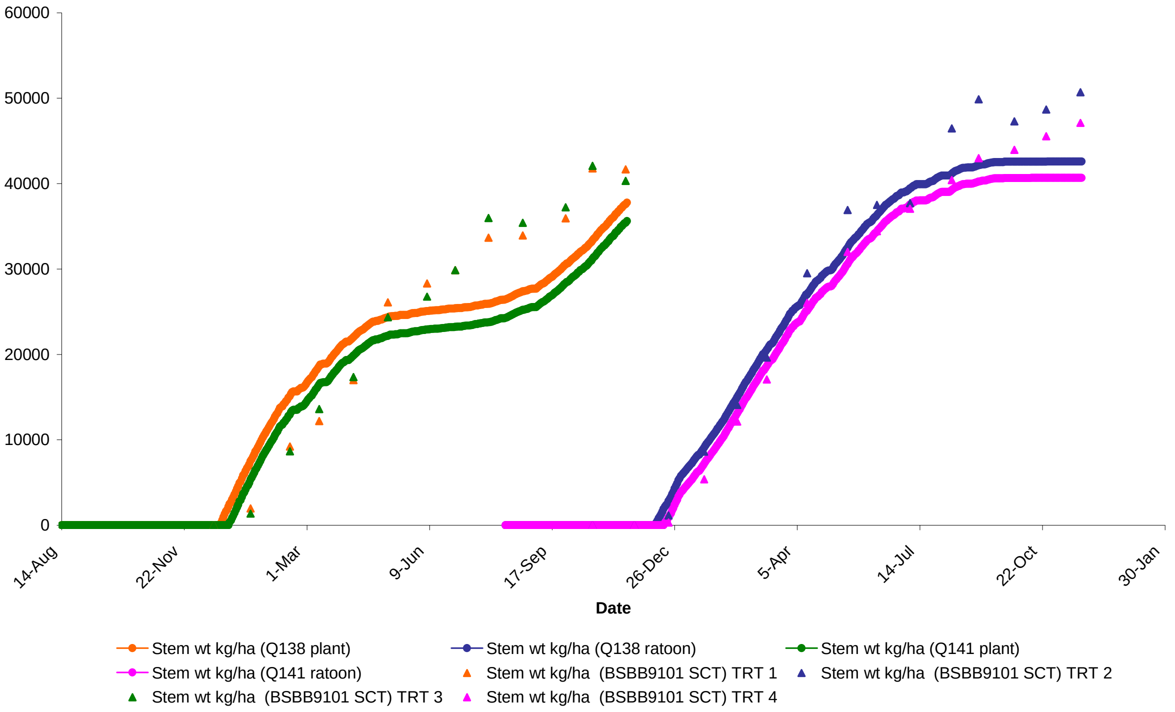
LAI



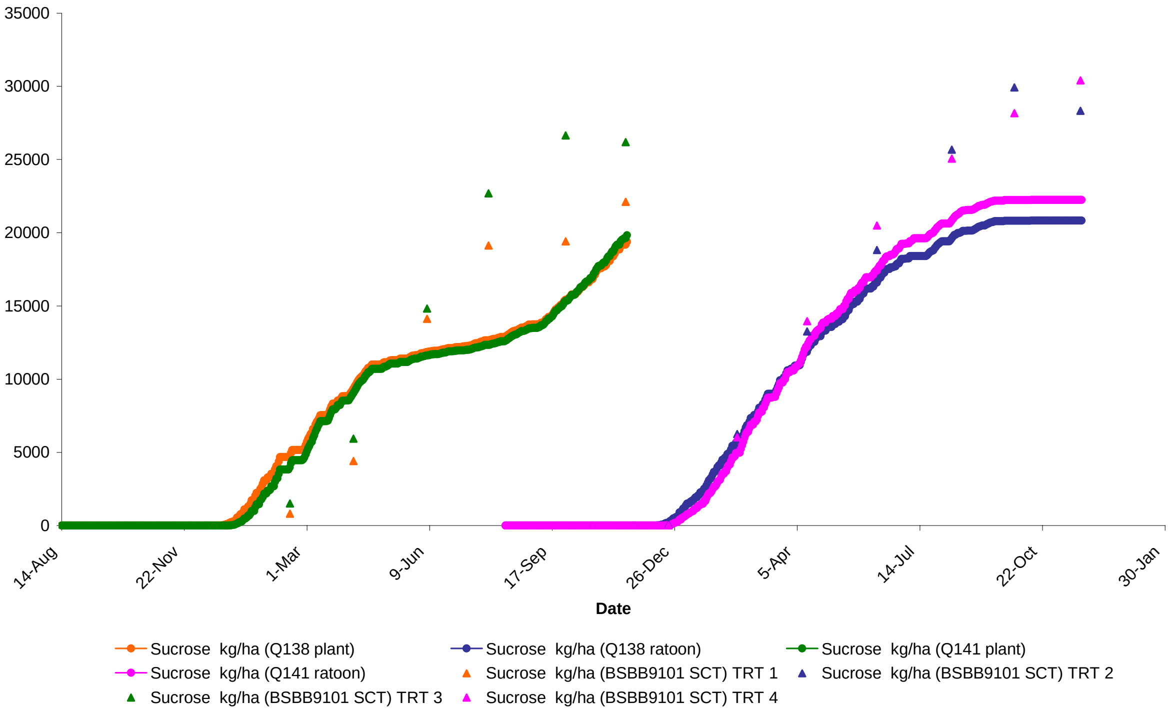
Aerial biomass



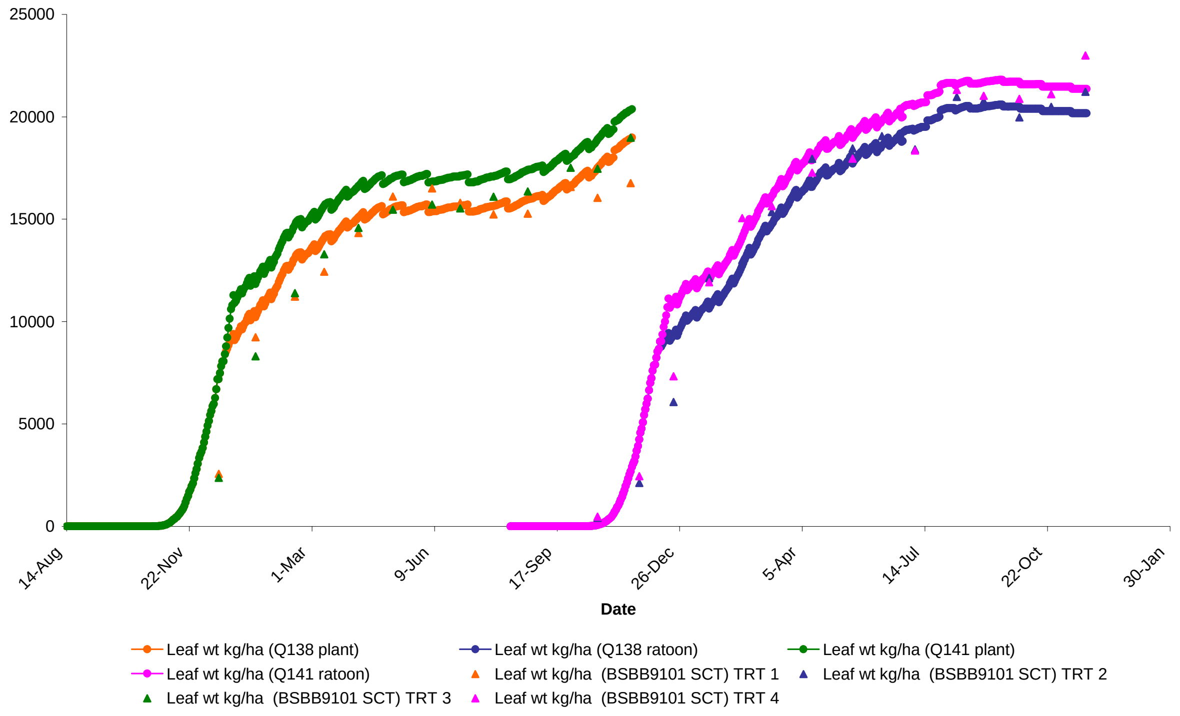
Stalk dry mass



Sucrose mass



Meristem + green leaf + trash dry mass (LWAD)



Trash dry mass

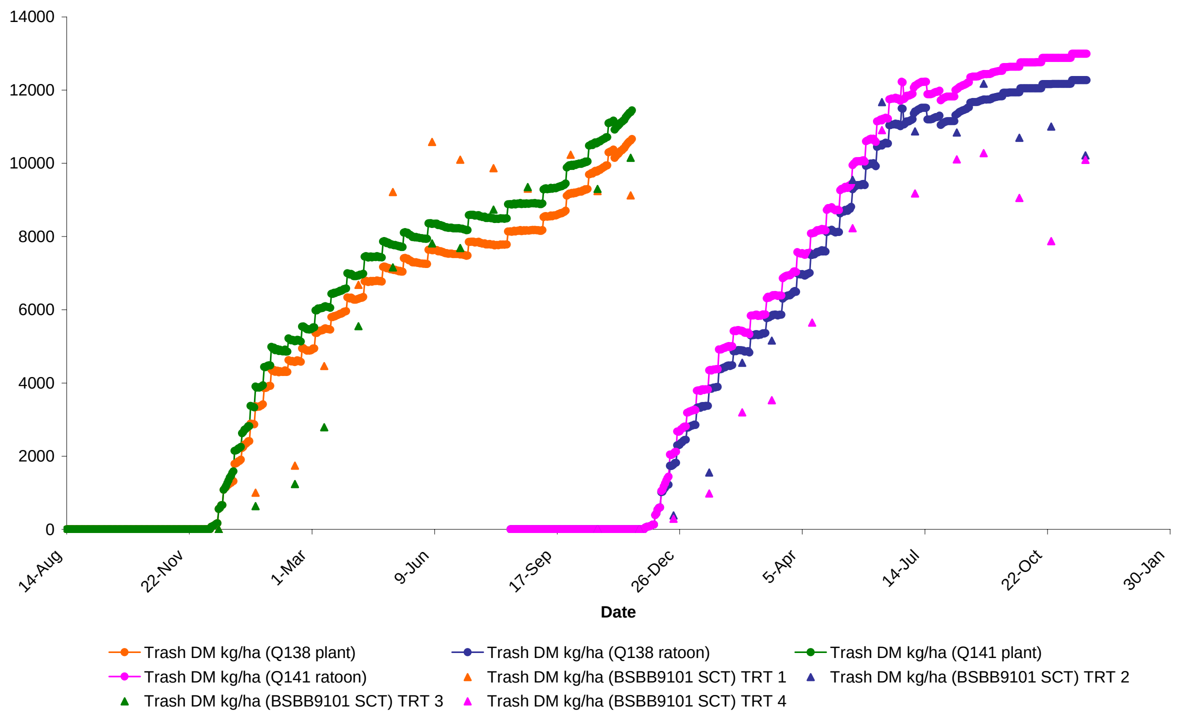


Fig 5.1 Observed and simulated values of LAI, Aerial biomass, Stalk dry mass, Sucrose mass, canopy dry mass, and trash mass for the BSES experiments.

5.3. Concluding comments

It appears that some irrigation data was missing and the automatic irrigation option was used. Excellent fits were obtained with observed biomass and leaf and stalk mass. There is a simulated slump in growth rate during winter that was not as pronounced in observations from the experiment. An investigation of base temperatures for stalk and leaf growth is therefore indicated.

6. ZSAES

6.1. Experiment details

The data was from a trial done to model cultivar differences in canopy growth and development of sugarcane using Canegro. The trial was furrow irrigated at 50 % moisture depletion. Other details are as follows:

- Site: N1 Block, ZSAES, Zimbabwe (21º 01' S, 28 º 38' E, Alt 430 m)
- Soil: The soil was sandy loam from deep red soil referred to as siallitic soils derived from gneisses. The top-soil being reddish brown with a red sub-soil. The soil is 1m deep. More details are given in Table 6.1.
- Planting date and harvest date: 19 October 2001 and 19 October 2002.
- Treatments: Cultivars: NCo376, N14, ZN7 and ZN6
- Row spacing: 1.5 m

Table 6.1. Soil profile information used for modelling.

Depth Bottom (cm)	Clay (%)	Silt %	Lower Limit cm^3/cm^3	Drained Upper Limit cm^3/cm^3	Saturation cm^3/cm^3	Bulk Density g/cm^3	Saturated Hydraulic conductivity	Rooting Weight
30	16.4	5.6	0.15	0.27	0.467	1.34	2.59	1
40	18	4	0.143	0.283	0.409	1.50	2.59	0.497
55	14	6	0.13	0.25	0.373	1.60	2.59	0.387
70	12	6	0.12	0.23	0.373	1.60	6.11	0.287
85	12	6	0.11	0.21	0.373	1.60	6.11	0.212

100	10	6	0.101	0.20	0.373	1.60	6.11	0.157

6.2. Results

6.2.1. Cultivar parameter calibration

Broad trait categories were assigned to the three cultivars based on the suggestions in the model documentation and on expert opinion (Table 6.2). The parameter values used are shown in Table 6.3.

Table 6.2. Broad cultivar categorization compared to that of NCo376.

Trait	**Cultivars**			
	NCo376	**N14**	**ZN7**	**ZN6**
Tiller population	H	M	VL	M
Leaf emergence	H	H	M	H
Leaf size	L	H	M	H
Canopy development	H	H	L	H
Stalk growth	M	M	H	M
Sucrose content	L	L	M	H

Table 6.3. Proposed cultivar parameter set for three cultivars.

Parameter	***Process***	**N14**	**ZN7**	**ZN6**
SUCA	Sucrose accumulation	0.57	0.6	0.62
TBFT		25	26	27
AFPMX	Stalk growth	0.88	0.88	0.88
STKPFMAX	Stalk growth	0.65	0.675	0.65
MXLFAREA	Leaf size	600	500	500
MXLFARNO		16	16	16
PI1	Leaf emergence	90	110	110
PI2		170	200	200
PSWITCH		14	14	14
POPCF(1)	Tiller population	1	0.6	1
POPCF(2)		0	0	0
POPCF(3)		850	830	850
POPCF(4)		-0.99	-0.99	-0.99
POPTT16		110000	70000	110000
CHUPIBASE	Phenology	1050	1050	1050
TTPLNTEM		428	428	428
TTRATNEM		203	203	203

6.2.2. Validation results

Simulated and observed values of leaf area index (LAI), tiller population and leaf numbers per stem and stalk heights are compared. Statistical comparisons are given in Table 6.4.

Table 6.4. Validation results

Variable Name	Observed	Simulated	Ratio	R^2	RMSE	n
LAI (Run 1)	2.456	4.195	1.7	0.337	2.156	24
LAI (Run 2)	3.084	3.713	1.298	0.576	1.261	24
LAI (Run 3)	2.01	2.663	1.381	0.273	1.344	24
LAI (Run 4)	2.468	3.451	1.48	0.452	1.646	24
Tiller no #/m2 (Run 1)	16.7	18.5	1.154	0.189	5.52	24
Tiller no #/m2 (Run 2)	13.5	14.6	1.102	0.385	4.959	24
Tiller no #/m2 (Run 3)	9	10.8	1.206	0.232	4.663	24
Tiller no #/m2 (Run 4)	11	13.6	1.328		6.419	24
Leaf number (Run 1)	8.52	10.17	1.203	0.283	2.483	24
Leaf number (Run 2)	9.64	9.79	1.006	0.546	1.76	24
Leaf number (Run 3)	10.8	9.82	0.893	0.612	2.061	24
Leaf number (Run 4)	10.19	9.96	0.957	0.696	1.657	24
Stalk height m (Run 1)	1.645	1.781	1.295	0.942	0.22	21
Stalk height m (Run 2)	1.533	1.811	1.566	0.986	0.316	21
Stalk height m (Run 3)	1.72	1.954	1.395	0.95	0.287	21
Stalk height m (Run 4)	1.629	1.828	1.463	0.967	0.26	21

Calibration of tiller development was problematic. There was overestimation of LAI. The model did not adequately account for the measured decline in LAI and the decrease in green leaf numbers in older crops. Nevertheless, simulated sucrose yields were close to that measured. The import of experimental leaf and yield data into DSSAT needs further attention to complete a proper validation.

7. CHIANG MAI UNIVERSITY

Sugarcane is a major field crop in Thailand, and covered an area of one million hectares during the crop year 1997/98. Growers begin sugarcane planting during the end of the rainy season in order to maximize cane and sugar yields in sandy soils under rainfed condition, especially growers in the Northeast region of the country. There are several incentives for the growers and the industry in adopting such a technique. For this reason, it is necessary to test the ability of the model in predicting contrasting planting dates in the areas.

7.1. Experimental details

- Sites:
  - Mae Hia Research and Training Station, Chiang Mai University, Chiang Mai, Thailand (18o 45’N 98o 55’E),
  - Agronomy Farm, Khon Kaen University, Khon Kaen, Thailand (16^{o} 28’N 102o 48’E)
  - Suphan Buri Field Crop Center Farm, U-Thong, Suphan Buri, Thailand (14^{o} 18’N 99^{o} 52’E).
- Soil: Oxic Paleustults based on Soil Taxonomy system
- Irrigation: Fully irrigated
- Treatments: Four planting dates (28 February 1995 (D1), 28 April 1995 (D2), 19 November 1995 (D3), and 16 January 1996 (D4)) and two ultivars (K 84-200 and U-Thong 2)
- Main measured variables: Plant samples were taken from two adjacent hills, at monthly intervals, to determine the number of tillers and/or stalks, leaf area index, dry mass of stems, leaf , and sucrose.

7.2. Results

7.2.1. Cultivar parameter calibration

Cultivar names: Uthong 2 (A early maturing cultivar and flowering around the end of November) and K84-200 (A late maturing cultivar and does not produce flower). For the initial testing, I used the coefficients for NCo376.

7.2.2. Validation results

Figure 7.1: Comparison of simulation (coloured lines) and observed stem dry wt (SWAD) data sets of Chiang Mai site, planted on February 28, 1995.

Validation results suggest that the phenological development of these two cultivars are quicker than that of NCo376 and that stalk mass could be predicted more accurately when cultivar parameters are adjusted accordingly. Comparison of simulated and observed sucrose contents and mass for these contrasting cultivars would be interesting.

8. CONCLUSIONS FROM MODEL CALIBRATION AND VALIDATION

The model performed remarkably well for the Australian, Thai and South African data sets. These data represent widely different genotypes grown in widely different climatic conditions. This is indicative of the robustness of the DSSAT Canegro model and hold promise for even wider application in the rest of the world. The model was also able to simulate well for certain aspects of the Zimbabwean data set. A complete validation for this set still needs to be performed.

The model exhibited a slump in growth rate during winter for the South African and Australian data sets that was more pronounced than what was observed. This needs to be investigated more closely.

The cultivar calibration process gave insight into the sensitivity of development and growth processes to changes in cultivar parameters and the likelihood of significant variation in traits between varieties – and thus the need for user accessibility to adjust these parameters. . Seventeen parameters were thus identified. Parameter sets for four new cultivars (two South African and two Australian) were determined.

9. SUGGESTIONS TO IMPROVE DSSAT CANEGRO

Several issues were identified during the workshop for possible attention by the project team for further improving the usefulness and performance of the DSSAT4.5 Canegro model.

9.1. Programming issues

9.1.1. XBuild

Suggestions for improvement for XBuild:

- Check that the start of simulation date is less than or equal to planting date, for all planting dates. The models require this, so it would be good to check it in XBuild.
- XBuild requires plant population, which is not used by Canegro. It should be reserved for bud population.
- XBuild should use Model read from DSSATPro file as a default. If model is present in simulation controls, this model should be used. The model is used to determine the cultivar file.
- Attend to the potential clash between DSSAT and computer date formats.
- The automatic irrigation management feature needs further refinement to improve clarity and to allow flexible irrigation cycles (e.g specifying a minimum cycle period to allow for portable irrigation systems such as dragline and centre pivots). The limit on the number of recorded irrigations should also be increased to, say 1000, to accommodate drip irrigations on multi-year crops.

9.1.2. Sbuild

Check WR values. These are required by the model and so SBuild should not leave blanks, or "-99"'s for missing values.

9.1.3. GBuild

Treatment names for measured values shown in graphs are generated from the experimental file and are not consistent with treatment names given to simulations.

9.1.4. ATcreate

- The abbreviations "A" and "T" should be explained on the opening screen
- When data is inspected and saved via the DSSAT DATA / EDIT FILE routine, rows tend to fill up from the left and cause a frame shift in empty columns.

9.1.5. DSSAT output

Several suggestions were received to change the output of the Plantgro module. Some output variables were not applicable to sugarcane, some variables unique to sugarcane were not present, and many variables had inappropriate names and/or units. The acronyms, names and descriptions that appear in the plot and view frames of the Plantgro output should be changed to address these problems (adjust text in DATA.CDE). The user documentation of the model should fully define terms that are not common. Changes are also needed to the Plantgro module to output newly defined variables. The main issues follows below.

The primary plant components are roots, stalks and leaves and the mass units should be t/ha. Leaf dry mass should include the mass of dead and green leaves (fully expanded and expanding) and not include meristem mass. Stalk dry mass is the mass of millable stalk. Secondary components are stalk sucrose, trash and tops. Trash dry mass is the mass of all dead leaves attached to living stalks, while tops dry mass equals aerial biomass minus stalk dry mass minus trash dry mass.

The following variables should be added to output files:

- Stalk sucrose content (dry and fresh mass basis) in Plangro.out
- Date of harvest in Summary.out and Overview.out

- Phenological phase (germination, tillering, stalk elongation, flowering) in Overview.out
- Thermal time in Plantgro.out

The following variables can be removed from Plantgro output - Incoming photosynthetic radiation (a confusing term already given in the weather output file); shelling percentage, canopy width and nodule weight (not relevant for sugarcane); potential evaporation and transpiration (already provided in ET output); potential root water uptake (complicated, abstract term), photosynthesis rate (confusing).

The following changes are required to variable names or units:

- References to "weight" should be replaced with "mass". The term "tops" is confusing for sugarcane users and should be replaced with "aerial biomass".
- The term "stem" should be replaced with "stalk".
- The units of "The extent of lodging (FLDG)" is "fraction of stalks lodged".
- Change the acronym for "green leaf area" to "GLAI"
- Water stress factors: Rename "Water stress factor for photosynthesis" and "Water stress factor for expansive growth" as these are swapped around at present.
- Rename "water stress factor for tillering" to "Water stress – tillering (0-1) (SW30)" and group it with the other two stress factors.
- Rename "Gross photosynthesis (GRSP, ton/ha/day)" to "Gross photosynthesis rate (GRSP, t/ha/day)" and provide a full definition in user documentation.
- Rename "Biomass increase per day" to "Biomass accumulation rate "

9.1.6. Coding errors

The following possible coding errors were identified and needs to be investigated and corrected if necessary:

- Negative values for PARCE (radiation conversion efficiency) when temperature drops below the base temperature of 7^{o}C.
- The ratoon-carryover function does not work properly in crop sequences and needs to be corrected before the model can implement any kind of carryover of root mass, root length density, or root depth

- The Canesim canopy option calculates canopy cover without simulating leaf area. However, total leaf area is needed to calculate soil evaporation, and the links between Plantgro and other modules require green and total leaf area to be passed between modules. Therefore, green leaf area (GLAI) is back calculated from green canopy cover using Beer's law. Total leaf area (TLAI) is set equal to GLAI, a temporary measure that needs refinement. It is recommended that leaf and tiller number be used to calculate total leaf area from green leaf area. (fit a function to leaf number and total leaf area for Canegro simulated run).

9.2. Content issues

9.2.1. Phenological development

Phenological phases should be defined more clearly and should be reflected in the output of the model. This should enable the specification of different base temperatures and management inputs (e.g. ripener applications) for different phases if required.

9.2.2. Tillering

The tillering model is highly empirical and difficult to understand and therefore it is extremely difficult to adjust population parameters to achieve the required tiller population curve. It seems that the parameter sets suggested in the user documentation for different cultivar types is not always producing the intended population curve.

A more mechanistic algorithm for tillering is being developed and will be included in future versions. It will account for the effect of genotype, bud density, crop class (plant or ratoon) row spacing, temperature and radiation penetration into the canopy. The effect of planting depth and planting method (seedcane or transplants) should also ideally be taken into account.

9.2.3. Leaf development

The broken stick approach to simulating leaf appearance can be improved by using a power function to simulate a more gradual increase in leaf phyllochron. Fewer parameters will be needed for this, simplifying it further. Some of leaf parameters in the extended cultivar parameter dataset (AREAMX's and LMAX's) are also very difficult to understand and therefore to adjust. Their importance for accurate simulations is unknown.

9.2.4. Specie, Ecotype and Cultivar parameters

The process of cultivar calibration was difficult, partly because there were so many variables. A user-friendly genetic coefficient calculator (wizard) to enable optimization of a set of cultivar parameters on experimental data will address this problem. This, however, falls outside the scope of this project.

Calibration of parameters for leaf and tiller development proved particularly difficult and it was suggested that ecotype parameters should be provided for canopy categories describing various leaf and tiller characterises such as leaf width, leaf length, leaf erectness, leaf appearance rate and tiller production rate. The existing parameters for leaf and tiller development and for light interception could then be moved from cultivar files to ecotype files, so that these would still be available for adjustment if required.

It was also proposed that cultivar parameters for each cultivar that were calibrated by delegates be included in the final DSSAT 4.5 package.

Maximum PAR conversion efficiency is currently hard-coded in the model, and has a value of 9.9 g/MJ. This value should be expressed as a cultivar parameter. Base temperature for PAR conversion is hard-coded as 7 ^{o}C. This should be a specie parameter.

9.2.5. Lodging

The lodging algorithm was calibrated assuming substantial interception of overhead irrigation and rainfall by the canopy. As the model does not calculate water mass intercepted by the canopy and lodging is likely to be underestimated. Users should be advised to re-calibrate cultivar parameters for lodging to accommodate this. It is recommended that the interception of rainfall and overhead irrigation be included in future water balance routines of DSSAT. This will improve the simulation accuracy of the water balance and lodging.

9.2.6. Wish list

There is a need to simulate flowering and its effects, soil and plant nitrogen dynamics and to take into account the effect of crop class, sett size, and water stress on root growth. Flowering is more prevalent in other parts of the world than in South Africa and has a greater impact on leaf size profiles, leaf appearance rates, stalk growth and biomass partitioning. Modellers should consider including the simulation of genotypic and environmental control of flowering and its impacts on development, growth and biomass partitioning.

It is also recommended that an option for calculating reference evapotranspiration from A-pan evaporation data be included in the ET module of DSSAT. This will enable better use of the model for sites where only rainfall, temperature and A-pan evaporation data is available (quite common in sugar industries).

10. NEXT STEPS

The project team will now attend to the issues highlighted by the workshop and will adjust the code accordingly. The adjusted code will be tested by comparing simulated and actual values for the verification and validations data sets. Model documentation will be further elaborated and finalized. The target date for completion of these tasks is 29 February 2008.

The code and documentation will then be handed over to the DSSAT team for final testing and approval for release by 30 March 2008. It is recommended that the release of DSSAT Canegro be well publicized and a DSSAT training course be held to launch the new model.

The project team believe that at least two scientific articles could be published from this work, namely one on model description and one on model calibration/validation. Abraham Singels will draw up a proposed framework for these articles that will indicate the contributions required by each project team member.

11. APPENDIX

11.1. List of delegates to Canegro workshop

	NAME	Type of participants	INSTITUTION
1	Benaichata Lazreg	Non-ICSM	Université Ibn Khaldoun de Tiaret, Algeria
2	Chinorumba Simbarashe	DSSAT sponsor	ZSAES, Zimbabwe
3	Chipansi Ashwin	Non-ICSM	Agriculture Canada-PFRA
4	Inman-Bamber Geoff	Non-ICSM	CSIRO, Australia
5	Jintrawet Attachai	DSSAT sponsor	TRF/Chiang Mai, University
6	Jones James	Tutor	University of Gainesville, Florida
7	Jones Matthew	Tutor	SASRI
8	Kingston Graham	DSSAT sponsor	BSES, Australia
9	Kirungu Caroline	Non-ICSM	KESREF, Kenya
11	Lecler Neil	Non-ICSM	SASRI
12	Martine Jean Francois	ICSM	CIRAD, France
13	Nayamuth Rasack	Non-ICSM	MSIRI, Mauritius
14	Porter Cheryl	Tutor	University of Florida
15	Rounds Pedro	ICSM	SRIF, Fiji
16	Royce Fred	Non-ICSM	University of Florida
18	Shine Jim	DSSAT sponsor	SCGC, Florida
19	Singels Abraham	Tutor	SASRI
20	Smit Michiel	DSSAT sponsor	SASRI
21	Van Den Berg Maurits	Tutor	SASRI

11.2. Detailed results for the SASRI model calibration

Variable Name	Treatment	Mean Obs	Mean Sim	Mean Ratio	R^2	Mean Diff.	Mean Abs. Diff.	RMSE	D Stat.	n
Leaf tip no (Run 1)	N31_Oct_BH	18	14	0.743	0.992	-3	3	3.646	0.928	13
Leaf tip no (Run 8)	N31_Oct_BH_Calib	18	15	0.822	0.994	-2	2	2.525	0.964	13
Leaf tip no (Run 2)	N37_Oct_BH	19	16	0.765	0.996	-3	3	3.493	0.948	16
Leaf tip no (Run 9)	N37_Oct_BH_Calib	19	17	0.838	0.997	-2	2	2.367	0.975	16
Leaf tip no (Run 3)	NCo376_Oct_BH	21	19	0.843	0.997	-2	2	2.535	0.976	16
Leaf tip no (Run 10)	NCo376_Oct_BH_Calib	21	18	0.846	0.997	-3	3	2.572	0.971	16
Leaf tip no (Run 4)	N31_Apr_BH	18	19	1.101	0.989	2	2	1.712	0.987	17
Leaf tip no (Run 7)	N31_Apr_BH_Calib	18	20	1.178	0.994	2	2	2.481	0.971	17
Leaf tip no (Run 5)	N37_Apr_BH	17	19	1.141	0.989	2	2	1.946	0.983	17
Leaf tip no (Run 11)	N37_Apr_BH_Calib	17	20	1.192	0.995	2	2	2.474	0.974	17
Leaf tip no (Run 6)	NCo376_Apr_BH	19	22	1.185	0.993	3	3	3.033	0.966	17
Leaf tip no (Run 12)	NCo376_Apr_BH_Calib	19	21	1.092	0.992	1	1	1.506	0.991	17
LAI (Run 1)	N31_Oct_BH	4.414	4.532	1.037	0.913	0.118	0.937	0.986	0.000	4
LAI (Run 8)	N31_Oct_BH_Calib	4.414	3.218	0.732	0.153	-1.2	1.195	1.283	0.211	4
LAI (Run 2)	N37_Oct_BH	3.868	4.554	1.21	0.224	0.686	1.128	1.405	0.213	4
LAI (Run 9)	N37_Oct_BH_Calib	3.868	3.612	0.936	0.412	-0.26	0.41	0.506	0.760	4
LAI (Run 3)	NCo376_Oct_BH	3.664	4.613	1.259	0.104	0.949	1.102	1.263	0.210	4
LAI (Run 10)	NCo376_Oct_BH_Calib	3.664	3.942	1.09	0.844	0.278	0.688	0.821	0.031	4
LAI (Run 4)	N31_Apr_BH	4.44	4.077	1	0.808	-0.36	0.65	0.774	0.913	10
LAI (Run 7)	N31_Apr_BH_Calib	4.44	3.648	0.946	0.753	-0.79	0.917	1.13	0.823	10
LAI (Run 5)	N37_Apr_BH	3.351	3.937	1.272	0.590	0.587	0.849	1	0.832	10
LAI (Run 11)	N37_Apr_BH_Calib	3.351	3.869	1.285	0.468	0.518	0.838	1.052	0.792	10
LAI (Run 6)	NCo376_Apr_BH	3.669	4.18	1.338	0.730	0.511	0.655	0.851	0.876	10
LAI (Run 12)	NCo376_Apr_BH_Calib	3.669	4.013	1.239	0.472	0.344	0.703	1.044	0.821	10
Stem wt kg/ha (Run 1)	N31_Oct_BH	20298	18315	0.892	0.992	-1983	1983	2286	0.986	4
Stem wt kg/ha (Run 8)	N31_Oct_BH_Calib	20298	19718	0.99	0.992	-580	1012	1245	0.996	4
Stem wt kg/ha (Run 2)	N37_Oct_BH	14272	17975	1.223	0.989	3702	3702	4365	0.929	4
Stem wt kg/ha (Run 9)	N37_Oct_BH_Calib	14272	14525	0.919	0.992	252	1712	2007	0.983	4
Stem wt kg/ha (Run 3)	NCo376_Oct_BH	13876	17671	1.386	0.995	3794	3794	3894	0.950	4
Stem wt kg/ha (Run 10)	NCo376_Oct_BH_Calib	13876	14714	1.027	0.997	837	1074	1146	0.995	4
Stem wt kg/ha (Run 4)	N31_Apr_BH	21499	24558	1.697	0.935	3059	3755	4612	0.898	9
Stem wt kg/ha (Run 7)	N31_Apr_BH_Calib	21499	19160	1.088	0.933	-2339	3449	4065	0.919	9
Stem wt kg/ha (Run 5)	N37_Apr_BH	17062	25996	1.705	0.810	8934	9349	10136	0.545	8
Stem wt kg/ha (Run 11)	N37_Apr_BH_Calib	17062	13112	0.834	0.807	-3950	4041	6236	0.635	8
Stem wt kg/ha (Run 6)	NCo376_Apr_BH	18456	25172	1.439	0.903	6716	6716	7288	0.575	8
Stem wt kg/ha (Run 12)	NCo376_Apr_BH_Calib	18456	13529	0.755	0.905	-4927	4927	5637	0.672	8
Tops wt kg/ha (Run 1)	N31_Oct_BH	33576	36492	1.084	0.981	2915	2915	3661	0.981	4
Tops wt kg/ha (Run 8)	N31_Oct_BH_Calib	33576	36491	1.084	0.982	2915	2915	3690	0.981	4
Tops wt kg/ha (Run 2)	N37_Oct_BH	31565	35486	1.188	0.934	3922	5028	5353	0.963	4
Tops wt kg/ha (Run 9)	N37_Oct_BH_Calib	31565	35941	1.219	0.929	4376	5458	5805	0.956	4
Tops wt kg/ha (Run 3)	NCo376_Oct_BH	29422	36495	1.323	0.982	7073	7073	7314	0.927	4
Tops wt kg/ha (Run 10)	NCo376_Oct_BH_Calib	29422	36227	1.315	0.978	6806	6806	7090	0.931	4
Tops wt kg/ha (Run 4)	N31_Apr_BH	33577	42325	1.62	0.827	8747	9336	11219	0.887	10
Tops wt kg/ha (Run 7)	N31_Apr_BH_Calib	33577	43254	1.681	0.830	9677	9951	11936	0.876	10
Tops wt kg/ha (Run 5)	N37_Apr_BH	25827	41220	2.116	0.816	15393	15393	16737	0.738	10
Tops wt kg/ha (Run 11)	N37_Apr_BH_Calib	25827	41592	2.119	0.809	15766	15766	17145	0.729	10
Tops wt kg/ha (Run 6)	NCo376_Apr_BH	27919	42913	2.312	0.792	14994	14994	16573	0.768	10
Tops wt kg/ha (Run 12)	NCo376_Apr_BH_Calib	27919	41658	1.98	0.803	13739	13739	15397	0.795	10

Tiller no #/m2	(Run 1)	N31_Oct_BH	27.4	20.8	0.793	0.271	-6.6	9.5	11.79	0.635	14
Tiller no #/m2	(Run 8)	N31_Oct_BH_Calib	27.4	21.9	0.831	0.580	-5.5	6.4	8.85	0.752	14
Tiller no #/m2	(Run 2)	N37_Oct_BH	19.1	19.7	1.093	0.431	0.6	6.2	7.503	0.809	17
Tiller no #/m2	(Run 9)	N37_Oct_BH_Calib	19.1	18.4	0.972	0.920	-0.7	1.8	2.618	0.975	17
Tiller no #/m2	(Run 3)	NCo376_Oct_BH	19.5	19.9	1.021	0.485	0.4	5	6.511	0.804	17
Tiller no #/m2	(Run 10)	NCo376_Oct_BH_Calib	19.5	17.8	0.892	0.893	-1.7	2.2	3.111	0.950	17
Tiller no #/m2	(Run 4)	N31_Apr_BH	25.6	19.6	0.74	0.500	-5.9	6.7	8.877	0.773	19
Tiller no #/m2	(Run 7)	N31_Apr_BH_Calib	25.6	21.5	0.888	0.641	-4.1	4.3	6.659	0.833	19
Tiller no #/m2	(Run 5)	N37_Apr_BH	27	19.4	0.732	0.572	-7.6	8.6	11.25	0.767	19
Tiller no #/m2	(Run 11)	N37_Apr_BH_Calib	27	18.4	0.704	0.833	-8.6	8.6	10.5	0.800	19
Tiller no #/m2	(Run 6)	NCo376_Apr_BH	22.1	19.8	0.848	0.880	-2.3	2.9	3.708	0.947	19
Tiller no #/m2	(Run 12)	NCo376_Apr_BH_Calib	22.1	17.9	0.781	0.686	-4.1	4.8	6.164	0.852	19
Sucrose kg/ha	(Run 1)	N31_Oct_BH	7801	7860	1.032	0.954	60	900	1070	0.988	4
Sucrose kg/ha	(Run 8)	N31_Oct_BH_Calib	7801	8409	1.25	0.951	608	1206	1249	0.984	4
Sucrose kg/ha	(Run 2)	N37_Oct_BH	8188	8051	1.185	0.902	-137	1379	1698	0.973	4
Sucrose kg/ha	(Run 9)	N37_Oct_BH_Calib	8188	6312	0.667	0.878	-1875	1875	2681	0.933	4
Sucrose kg/ha	(Run 3)	NCo376_Oct_BH	7019	7509	1.666	0.991	490	535	675.2	0.995	4
Sucrose kg/ha	(Run 10)	NCo376_Oct_BH_Calib	7019	6030	0.844	0.974	-989	989	1241	0.981	4
Sucrose kg/ha	(Run 4)	N31_Apr_BH	10857	12552	1.258	0.746	1695	2971	3237	0.618	7
Sucrose kg/ha	(Run 7)	N31_Apr_BH_Calib	10857	9313	0.926	0.749	-1544	2350	3158	0.618	7
Sucrose kg/ha	(Run 5)	N37_Apr_BH	8674	13087	1.681	0.940	4413	4413	4835	0.542	7
Sucrose kg/ha	(Run 11)	N37_Apr_BH_Calib	8674	5141	0.627	0.940	-3534	3534	4017	0.603	7
Sucrose kg/ha	(Run 6)	NCo376_Apr_BH	9073	11979	1.537	0.794	2906	2978	3755	0.573	7
Sucrose kg/ha	(Run 12)	NCo376_Apr_BH_Calib	9073	5247	0.64	0.788	-3826	3837	4485	0.574	7
Stalk height m	(Run 1)	N31_Oct_BH	1.914	1.876	0.97	0.922	-0.04	0.16	0.176	0.969	4
Stalk height m	(Run 8)	N31_Oct_BH_Calib	1.914	1.871	0.987	0.884	-0.04	0.152	0.162	0.966	4
Stalk height m	(Run 2)	N37_Oct_BH	1.544	1.591	1.015	0.957	0.047	0.119	0.155	0.966	4
Stalk height m	(Run 9)	N37_Oct_BH_Calib	1.544	1.69	1.096	0.915	0.146	0.146	0.198	0.938	4
Stalk height m	(Run 3)	NCo376_Oct_BH	1.274	1.406	1.105	0.929	0.132	0.143	0.184	0.946	4
Stalk height m	(Run 10)	NCo376_Oct_BH_Calib	1.274	1.444	1.159	0.896	0.17	0.17	0.208	0.921	4
Stalk height m	(Run 4)	N31_Apr_BH	1.843	2.198	1.745	0.909	0.355	0.355	0.447	0.918	10
Stalk height m	(Run 7)	N31_Apr_BH_Calib	1.843	2.051	1.52	0.950	0.208	0.209	0.31	0.959	10
Stalk height m	(Run 5)	N37_Apr_BH	1.477	1.841	1.937	0.920	0.363	0.363	0.417	0.899	10
Stalk height m	(Run 11)	N37_Apr_BH_Calib	1.477	1.849	1.78	0.952	0.372	0.372	0.403	0.911	10
Stalk height m	(Run 6)	NCo376_Apr_BH	1.279	1.708	1.973	0.933	0.428	0.428	0.457	0.859	10
Stalk height m	(Run 12)	NCo376_Apr_BH_Calib	1.279	1.636	1.728	0.955	0.357	0.357	0.38	0.901	10
Frac. intercpt	(Run 1)	N31_Oct_BH	0.79	0.77	0.801	0.984	-0.02	0.06	0.073	0.990	5
Frac. intercpt	(Run 8)	N31_Oct_BH_Calib	0.79	0.71	0.743	0.990	-0.08	0.08	0.091	0.983	5
Frac. intercpt	(Run 2)	N37_Oct_BH	0.78	0.76	0.798	0.984	-0.02	0.05	0.063	0.993	5
Frac. intercpt	(Run 9)	N37_Oct_BH_Calib	0.78	0.66	0.693	0.976	-0.12	0.12	0.133	0.964	5
Frac. intercpt	(Run 3)	NCo376_Oct_BH	0.75	0.77	0.845	0.988	0.02	0.05	0.066	0.992	5
Frac. intercpt	(Run 10)	NCo376_Oct_BH_Calib	0.75	0.69	0.754	0.985	-0.06	0.06	0.072	0.989	5
Frac. intercpt	(Run 4)	N31_Apr_BH	0.78	0.83	1.069	0.887	0.05	0.07	0.104	0.961	6
Frac. intercpt	(Run 7)	N31_Apr_BH_Calib	0.78	0.79	0.971	0.940	0.01	0.07	0.087	0.977	6
Frac. intercpt	(Run 5)	N37_Apr_BH	0.75	0.82	1.129	0.855	0.07	0.08	0.132	0.946	6
Frac. intercpt	(Run 11)	N37_Apr_BH_Calib	0.75	0.71	0.853	0.990	-0.04	0.05	0.087	0.983	6
Frac. intercpt	(Run 6)	NCo376_Apr_BH	0.71	0.86	1.444	0.697	0.15	0.15	0.236	0.842	6
Frac. intercpt	(Run 12)	NCo376_Apr_BH_Calib	0.71	0.7	0.887	0.987	-0.01	0.04	0.064	0.992	6