ANNUAL PROGRESS REPORT 2014/15

ISCM PROJECT ON

"MODELLING WORLD-WIDE GXE INTERACTION"

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June 2015

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Contents

1. GENERAL

The goal of the project 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:

- 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),
- determine model trait parameters (genetic coefficients) for each cultivar, derived from development, growth and water use measurements,
- identify and formulate underlying mechanisms of genotype response to environmental factors, and
- evaluate models' ability to simulate genotypic differences in crop performance.

The following organizations are participating in the project: SASRI, ZSAES, SIRC, and CIRAD and the following cultivars will be used in the trials: N41, R570, CP88-1762, HoCP96-540 and ZN7. In some cases NCo376 and Q183 will also be planted. The main activities in the project so far have been to generate and distribute genetically-true, disease-free seed material of the relevant cultivars to each of the participating countries, to propagate for the experiments, to plant experiments and to collect data on crop development, growth and yield. Plant crop experiments have been completed in three countries and captured data are currently being processed and analysed. Ratoon crop experiment have also commenced in these countries. Experiments have also been planted in Reunion Island. The modelling aspects of the project are due to start in 2016.

2. PROGRESS IN SOUTH AFRICA

2.1 Plant crop

Seedcane from the bulking plots from five varieties (N41, R570, ZN7, HOCP96-540, CP88-1762) was planted into plant crop and ratoon crop fields at the SASRI Research station in Pongola in March 2014. Seedcane from each variety was planted into four replicate plots (5 varieties x 4 replicates = 20 plots) that consisted of 5 rows per plot (with 1.5m row spacing) and each plot was 21m in length, with a 1m break between plots. Due to insufficient rainfall in the Pongola region (548 mm during the plant crop cycle), supplementary irrigation was applied with a surface drip irrigation system. The MyCaneSim crop simulation system was used to schedule irrigation and a total of 630 mm irrigation was applied in the 12 month cycle. The total crop water use for the plant crop is estimated at 1237 mm.

Climate data are shown in Figure 2.1

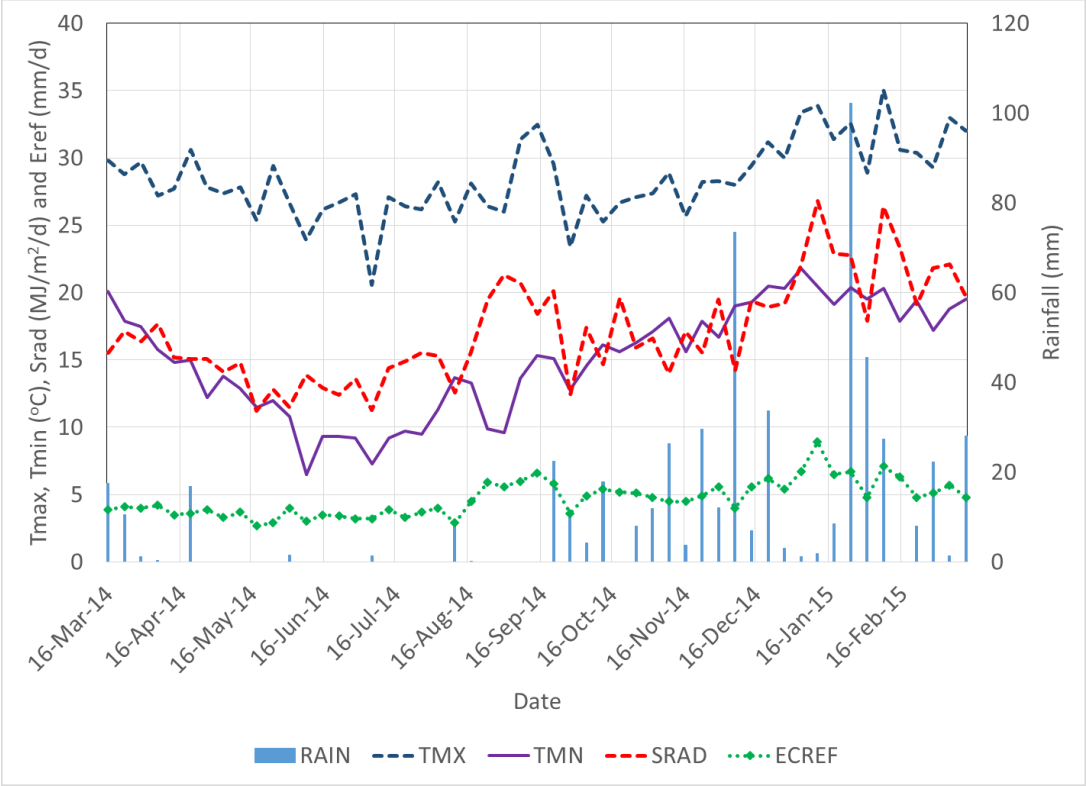

Figure 2.1 Weekly average maximum and minimum temperature (Tmax, Tmin), solar radiation (Srad) and sugarcane reference evaporation (Eref), and weekly total rainfall over the trial period at Pongola.

Non-destructive measurements of fractional interception (Fig 2.2), shoot population, stalk height and the total number of leaves were performed monthly until March 2015. Figure 2.2 shows fractional interception (FI, %) of PAR by the five varieties. FI was slightly different between the varieties for the first 5 months of the experiment, and HoCP96 appeared to maintain significantly lower FI for the duration of the plant crop experiment.

Destructive measurements of total fresh and dry mass of green leaves, stalks, sheath, tops and trash residue; and total leaf area were performed at 3, 6, 9 and 12 months after planting. Cane quality characteristics (dry matter content, fibre %, BRIX %, sucrose % and thus calculated non-sucrose %) were analysed at the Pongola millroom at 9 and 12 months after planting when the cane stalks were greater than 0.5m in length.

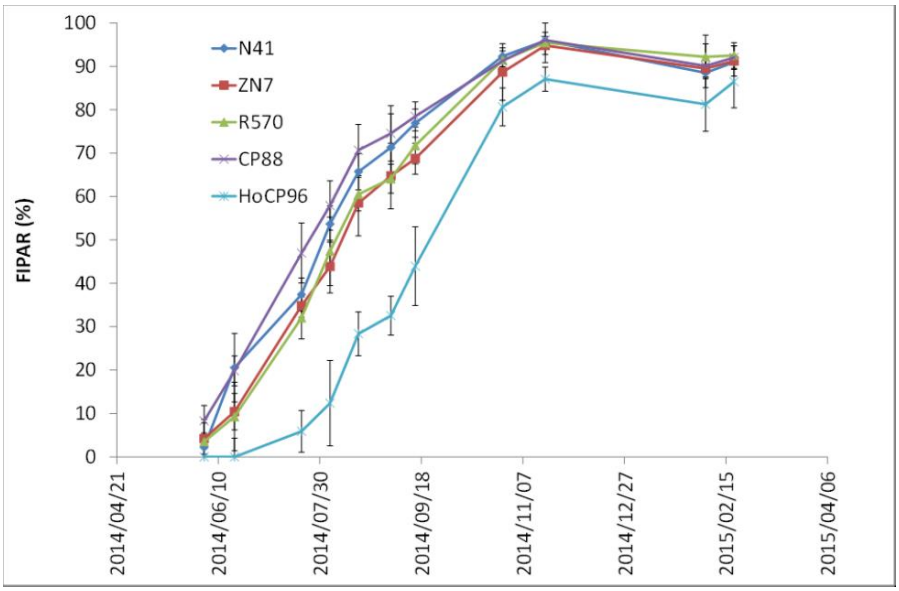

Figure 2.2: Fractional interception of photosynthetically active radiation (FIPAR) of the different sugarcane varieties grown at Pongola, South Africa during the plant crop season (2014_2015).

Figure 2.3 shows a collection of the destructive harvest operations at 12 months after planting for the plant crop season (2014_2015). Four meters of three rows (per plot) were cut and weighed in-field with a tractor fitted with a loadcell. Cane yield and sucrose yield (Fig 2.4) were calculated for each plot. Cane yield was approximately 140 t ha^{-1} for N41 and ZN7 for both the plant (Field 322) and "ratoon" field (Field 323) crop. N41 attained the highest sucrose yield of 17.4 t ha^{-1}, followed by CP88, which despite the lower cane yield, attained a sucrose yield of 16.5 t ha^{-1} because it had the highest sucrose content.

Two meters of the third row were subsampled for total dry biomass and biomass fractions (Fig 2.5). Concurrent with cane yield, N41 achieved the highest total dry biomass yield. Although the proportion of dry biomass allocated to stalk fibre was very similar between varieties, the proportion allocated to sucrose and non-sucrose differed widely. CP88 had the highest proportion of dry biomass allocated to stalk sucrose. R570 allocated a significantly higher proportion of it's dry biomass to green leaves, compared with the other varieties.

Figure 2.3: Destructive harvest operations for the different varieties at 12 months after planting at Pongola, South Africa for the plant crop season (2014_2015).

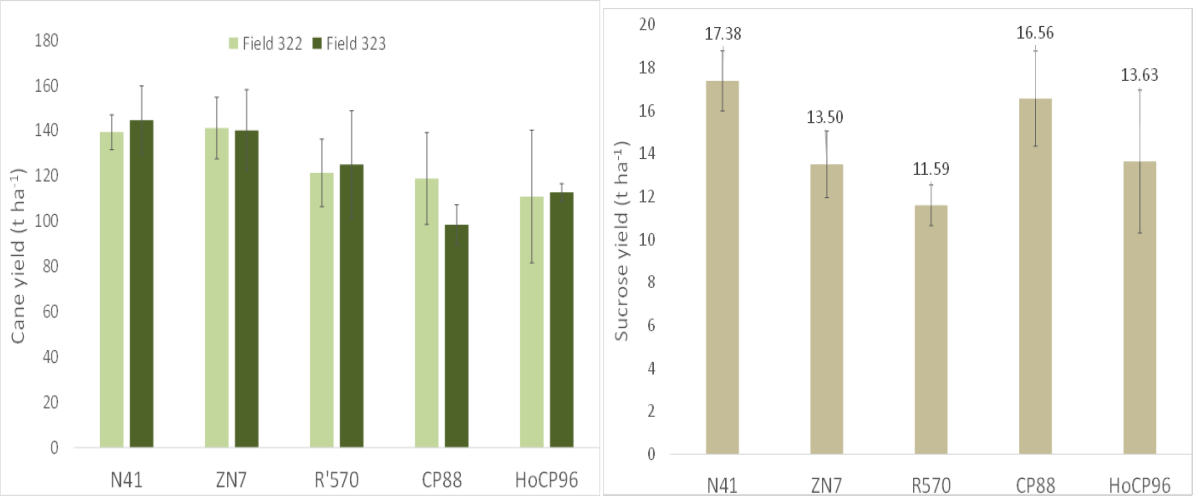

Figure 2.4: Sugarcane yield and sucrose yield for the different varieties at Pongola, 12 months after planting for the plant crop.

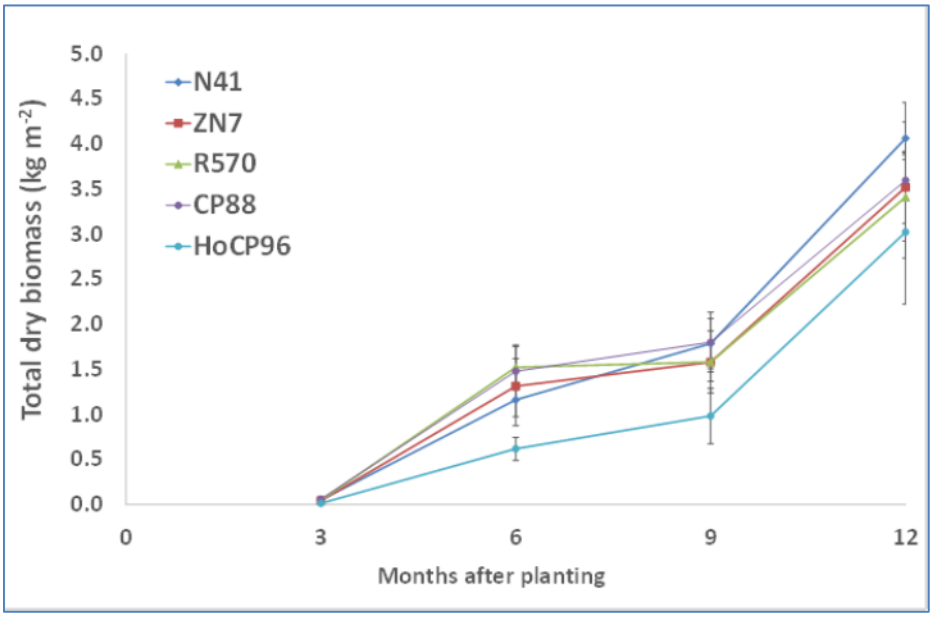

Figure 2.5: Dry biomass time series for the different varieties at Pongola, South Africa for the plant crop.

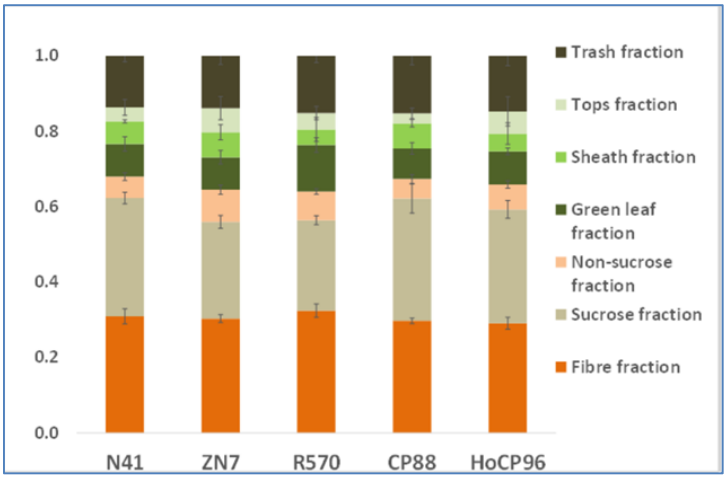

Figure 2.6 Biomass fractions at the final harvest for the different varieties at Pongola.

Challenges

HoCP96 was a poor germinating variety for the plant crop trial during 2014_2015. HoCP96 was eaten by rabbits, then by Sesamia spp (dead hearts) and one plot (Plot 5) received residual herbicide spray as a result of wind drift from the neighbouring field being sprayed with glyphosate. Growth and yield was negatively affected by these factors.

The number of dead leaves counted was not accurate throughout the trial, and for this reason, the calculated number of green leaves is unreliable after November 2014. This will be corrected in consultation with the technical team for the ratoon crop.

It was also discovered during the 9 month harvest (December 2014) that the sub-sampled plant components (green leaves, tops, sheath, but particularly stalks) were not fully dry after 3 days of drying in an oven at 80°C. At the 12 month harvest (March 2015) all the sub-sampled plant components were dried in the millroom oven for 7 days at 80°C, and the difference in dry weight between day 3 and day 7 was calculated. The dried day 7 measurement calculation was applied to all sub-sampled plant components for all four harvests (at 3, 6, 9, 12 months after planting). During the ratoon crop, the sub-sampled plant components will be dried for 7 days and the dry matter content of the stalks from the millroom sampling will be used for determining dry biomass (kg m^{-2}).

2.2 Ratoon crop

The ratoon crop has emerged well and are being irrigated according to recommendations from weather and soil water measurements. Phenology measurements have commenced.

3. PROGRESS IN REUNION ISLAND (Cirad)

3.1 Plant Crop

Land Preparation took place in December 2014 and consisted of chiselling and deep ploughing. The field was disked beginning of February 2015 and furrows were drawn on 17 and 18 February 2015. Soil sampling took place on 17 February 2015.

Planting of 5 varieties was carried out on the 25 February 2015 with N41, Q183, CP881762, NCO376 and R570 using 4 setts (of 3 buds) per row meter with row spacing of 1.5m. The trail layout is shown in Fig. 3.1. Each cultivar plot consists of 9 rows spaced at 1.5 m, 10.5m long. Inside each cultivar plot, there are 4 destructive sampling areas. Each destructive sampling area consists of 3 rows 4m long.

Irrigation is applied using sprinklers with 15m x 15m spacing. The following chemicals were applied:

- Biopesticide Betel against white grubs applied in the furrow
- Fertilizer aplication of 800 Kg/Ha of 9-23-30 applied in the furrow
- 2 herbicides applications on 16/03/2015 and 21/04/2015

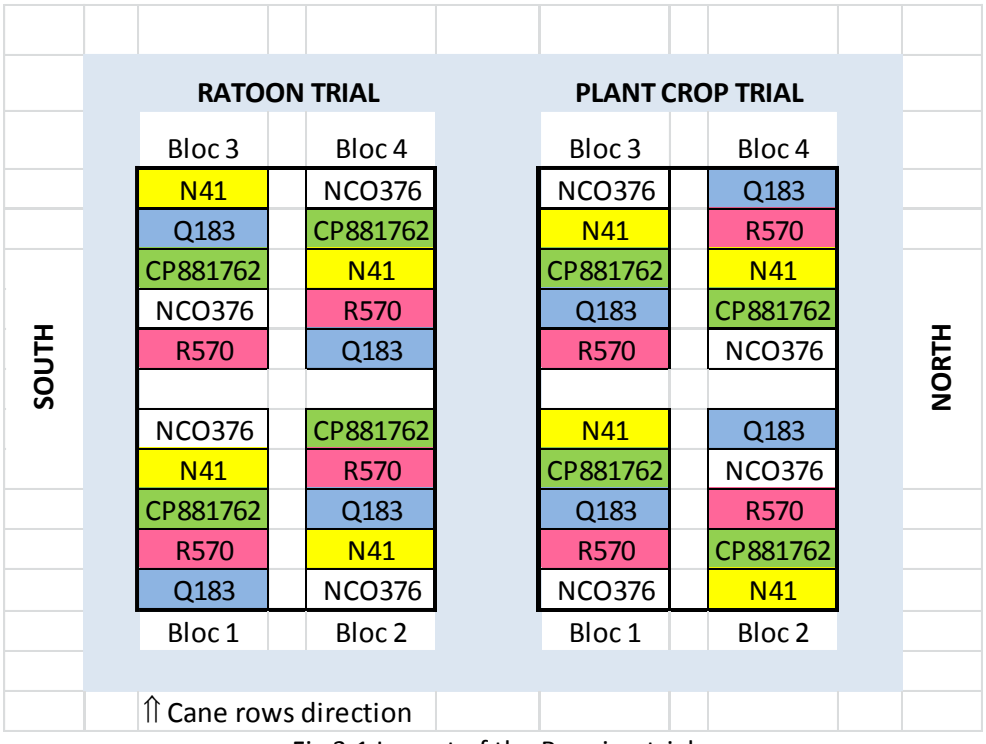

Fig 3.1 Layout of the Reunion trial

The following non-destructive measurements have been conducted:

- Light interception with ceptometer (3 dates)

- Shoots and tillers emission, stalk and canopy heights (10 dates)
- TVD leaf number and height on labelled stalks (2 dates)

Destructive samplings will be conducted according to the schedule indicated in Fig 3.2

		2015											2016										
	Month	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Plant Crop Trial	Age	0	1	2	3	4	5	6	7	8	9	10	11	12										
	ED	PL			DS1			DS2			DS3			DS4										
Ratoon Trial	Age	0	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	11	12
	ED	PL										Harvest			DS1			DS2			DS3			DS4

Fig. 3.2 Destructive sampling schedule for the Reunion experiment

Crop development are depicted in Fig 3.3.

One Month after planting

Two Months and half after planting

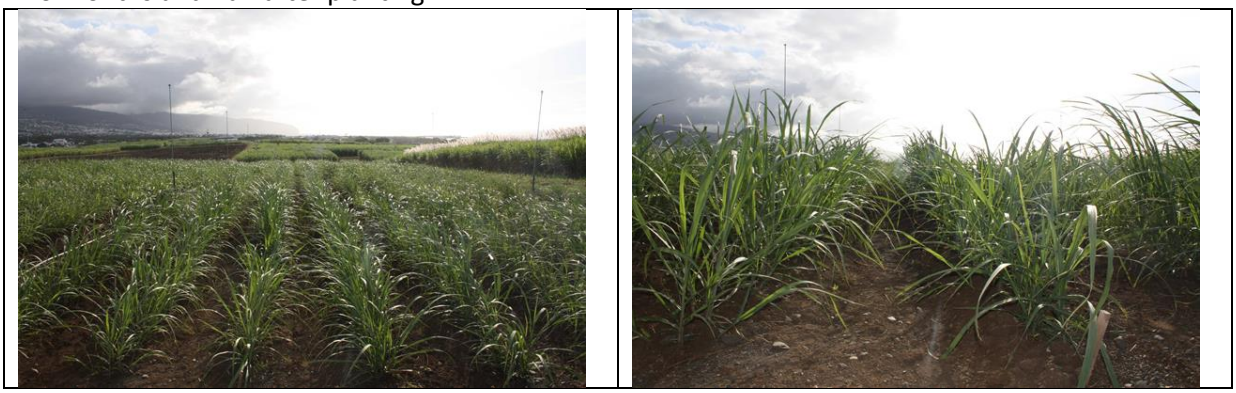

Figure 3.3 Crop development in the Reunion experiment

3.2 Ratoon crop

The block planted to become the ratoon trial will be harvested In December 2015, at the age of 10 months.

4. PROGRESS IN ZIMBABWE

4.1 Plant crop

Hardened tissue cultured plants from six varieties namely R570, Q183, ZN7, CP88-1762, HoCP96-540, and N41, were planted into the field on 15 December 2011 at the ZSAES. The varieties were cut and planted out on 2 November 2012 for further bulking to produce the amount of seedcane required for planting out the trials. The trial was planted out on 30 October 2013 in Field L3, Sable Block (plant crop) and was harvested on 26 November 2014.

Destructive sampling

Measurements of total fresh and dry mass of green leaves, stalks, sheath, tops and trash residues and total leaf area were performed at 3, 6, 9 and 12 months after planting using destructive sampling. The dry mass of CP88-1762 and HoCP95-540 increased sharply in winter [i.e. May to July] while accumulation of dry mass in R570 remained depressed. The other three test varieties also accumulated DM throughout the winter period. Only two varieties, ZN7 and R570, had sharp increases in total DM after 9 months from planting

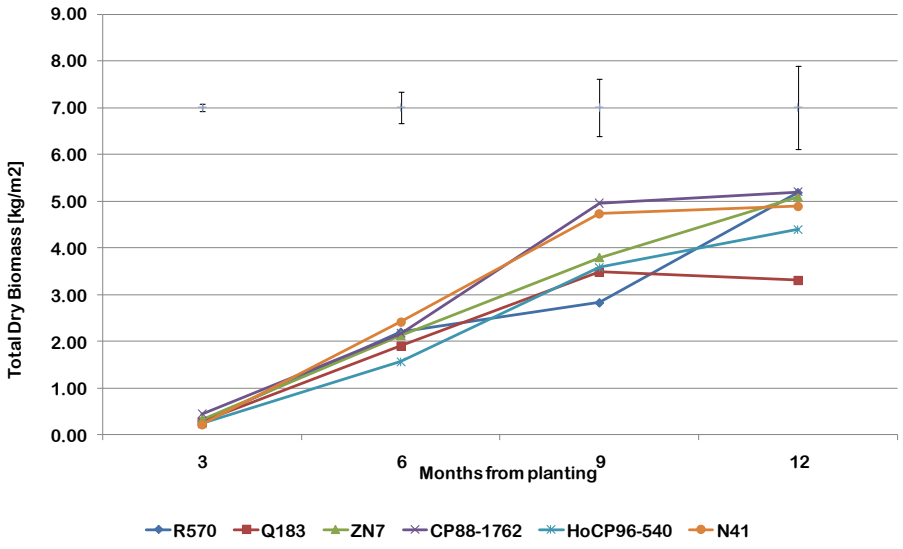

Figure 4.1 Dry biomass for varieties R570, Q183, ZN7, CP88-1762, HoCP96-540, and N41 at 3, 6, 9 and 12 months from planting.

Leaf Area Index (LAI)

The LAI reached a peak at around 9 months after planting and declined thereafter. Dry-off was done at 12 months hence senescence of the leaves increased resulting in reduced LAI. Variety CP88-1762 had the highest LAI at three months but thereafter R570 recorded the highest LAI.

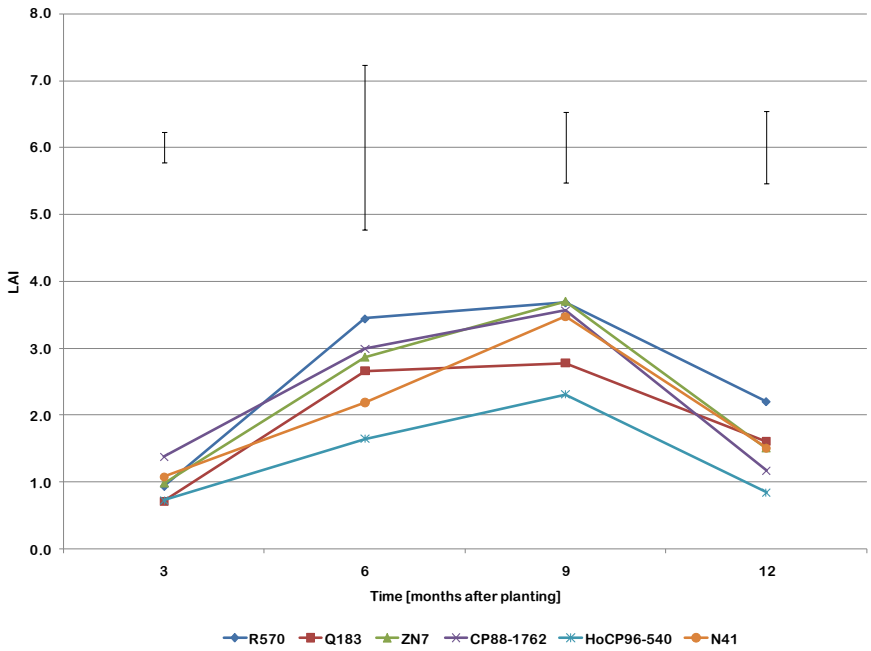

Figure 4.2. Leaf Area Index [LAI] for varieties R570, Q183, ZN7, CP88-1762, HoCP96-540, and N41 at 3, 6, 9 and 12 months from planting where destructive samplings were done.

Cane quality

Cane stalks were analyzed for fibre % cane, brix % cane and sucrose % cane [quality characteristics] at ZSAES Agric Chemistry lab at 6, 9 and 12 months after planting when some cane stalks were greater than 0.5 m in height. Varieties CP88-1762, Q183 and HoCP96-540 had higher ERC % Cane compared to R570, ZN7 and N41 at 6 months. Beyond 9 months from planting CP88-1762, Q183 and HoCP96-540 did not record big increases in ERC % Cane. At 12 months however, ERC % Cane from R570, ZN7 and N41 was comparable to CP88-1762, Q183 and HoCP96-540 that accumulated sucrose earlier in the growing period [Figure 4.3].

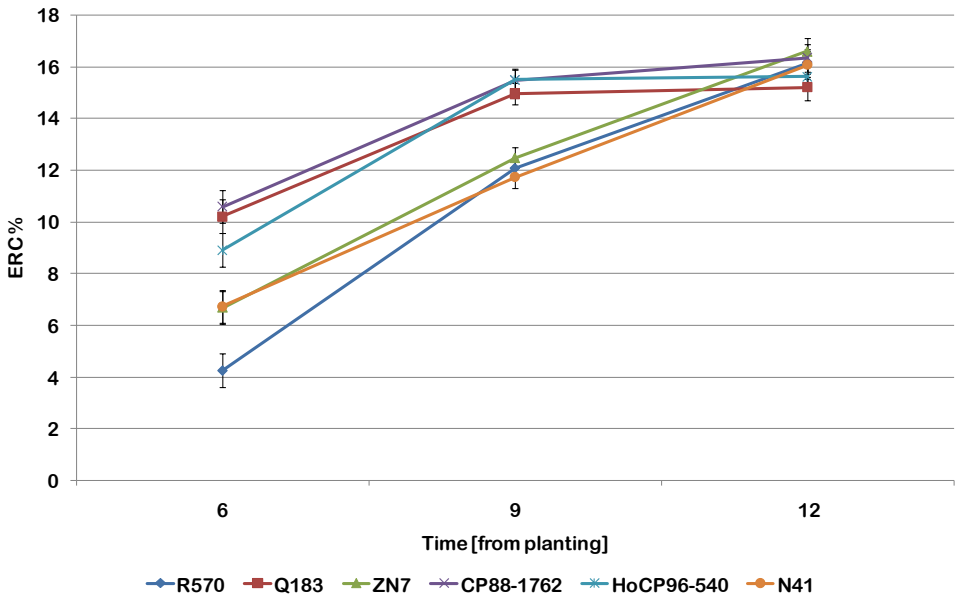

Figure 4.3: ERC% cane for the different varieties at 6, 9 and 12 months after planting.

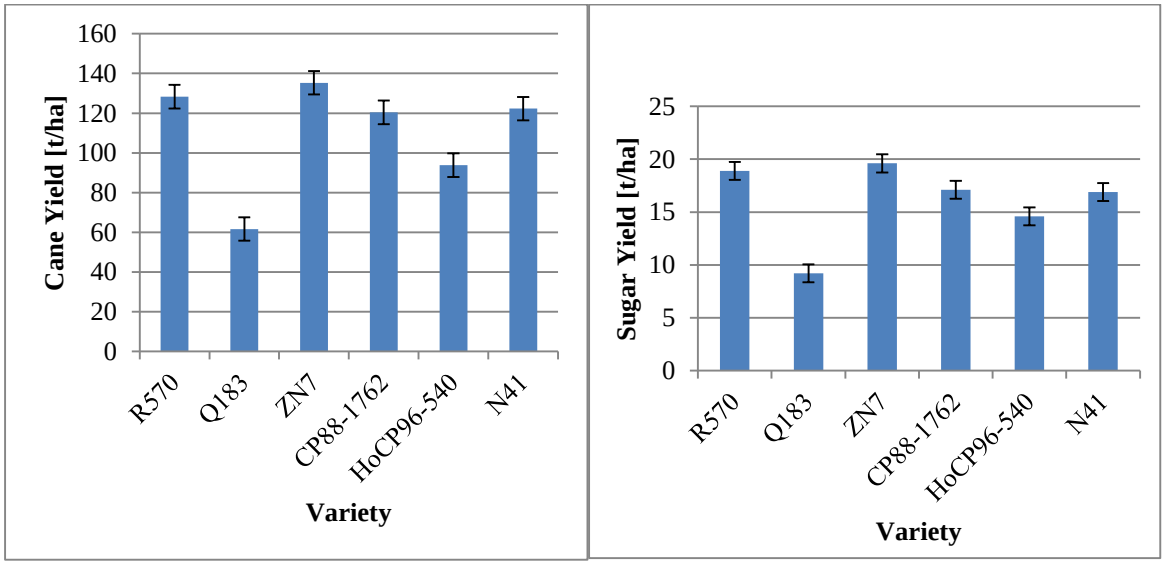

Figure 4.4: Sugarcane and sugar yield [t/ha] of the different varieties at L3, Sable Block, ZSAES. Varieties were planted on 30 October 2013 and harvested on 26 November 2014 at 12.9 months of age.

Variety ZN7 had the highest cane yield [135.3 t/ha] followed by R570 with 128.3 t/ha while Q183 had the lowest cane yield [61.6 t/ha]. N41 and CP88-1762 had comparable cane yields of respectively 122.3 and 120.4 t/ha. ZN7 and R570 had the highest sugar yields of respectively 19.6 and 18.9 t/ha. N41 and CP88-1762 had sugar yields of respectively 17.1 and 16.9 t/ha indicating that CP88-1762 had higher sugar content.

The highest yielders, ZN7 and R570 had respectively the longest or tallest [2.9 m and 2.6 m] and thickest stalks [2.5 and 2.6 cm] but had the least number of stalks [86,000 and 76,000 stalks]. N41 had many thinner stalks followed by CP88-1762 [Figure 4.5]. The local environment was not favorable for Q183 that exhibited the lowest cane and sugar yields as well as the lowest stalk lengths.

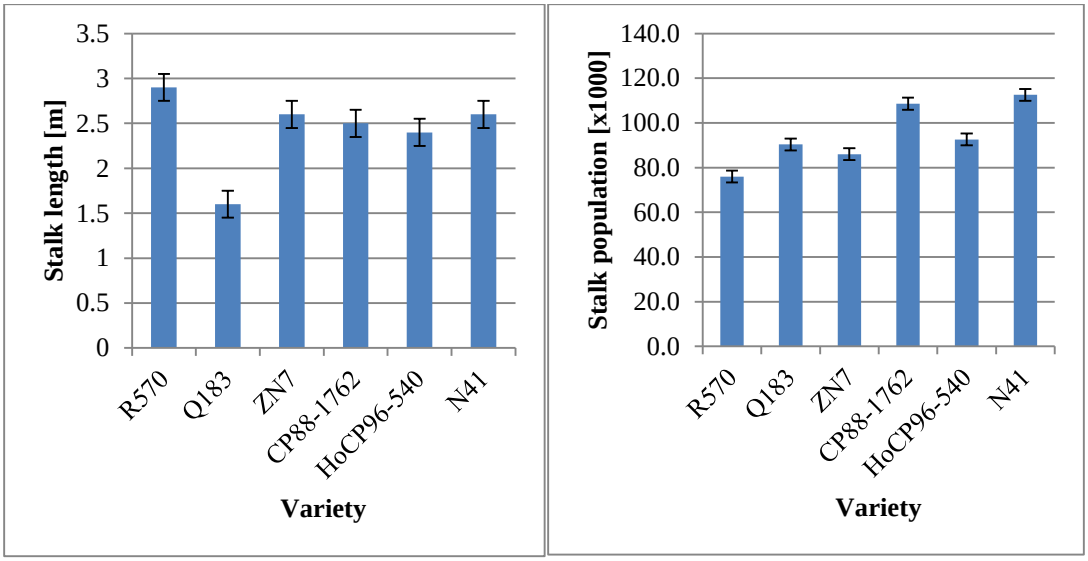

Figure 4. 5: Length of stalks [m] and stalk population of R570, Q183, ZN7, CP88-1762, HoCP96-540, and N41 harvested at 12.9 months of age at L3, Sable Block, ZSAES.

4.2 Ratoon crop

The ratoon crops are still to be harvested because the mills were closed from 4 December, 2015 to 22 April, 2015.

4.3 Challenges

Insect pests: Yellow aphid (*Sipha flava*) attack as reported earlier on many varieties was a challenge. Also reported ealier were the presence of natural enemies that ensured the densities of *Sipha flava* remained low. No spraying was done but the cane was able to grow out of the attack.

Diseases: Leaf scald symptoms reported on Q183 during the bulking phase could have affected the variety. Unlike in the bulking phase, no deaths of shoots were recorded on the variety in the plant crop trial phase.

Data capture: Some of the data collected manually during the plant crop is still to be captured electronically, more than 6 months after harvesting the plant crop data. Efforts are underway to procure Handheld Computers or Personal Digital Assistants [PDA] for data capturing within the fields.

The described procedure of drying the samples [Drying samples at 80^{o}C for 3 days and then 105 ^{o}C for 3 hours] including the modified method communicated later were not followed. The maximum temperature achievable with the ovens at ZSAES is 65^{o}C. Drying of stalks mainly involved chopping stalks into pieces and slicing them longitudinally to increase surface area. The process took on average from just above one week to four weeks to achieve constant dry mass of different sugarcane components.

5. PROGRESS IN FLORIDA, USA

5.1 Plant crop

Field operations

Varieties N41, NCo376, CP 88-1762, R 570, Q183, and HoCP 96-540 were planted manually on Dec 12, 2013 at the Everglades Research and Education Center (EREC) of the University of Florida at Belle Glade, FL. Seed cane was harvested from the plots planted for seed bulking in the fall of 2012.Two trails were planted in a randomized complete block design (RCBD) with four replications, each for data collection from plant-cane crop and from first-ratoon crop. For plantcane crop, data were collected only from one trial (other trial is currently being used for first ratoon crop data). Each plot consisted of 9 rows, each 11m long with 1.5m row spacing. Standard management practices for sugarcane cultivation on high organic soils of south Florida were employed during the season. These trails were planted on a Lauderhill muck (euic, hyperthermic Lithic Haplosaprist) soil type. Field was under sub-surface irrigation with drainage ditches surrounding the field. Moisture level in the field was kept optimum by pumping water in and out of the ditch. Weather data for 2014 and 2015 seasons are presented in Figure 5.1. No hard freeze was observed during both years of the study except for Jan 19, 2014 (38 DAP) when temperature was -0.9 ^{o}C.

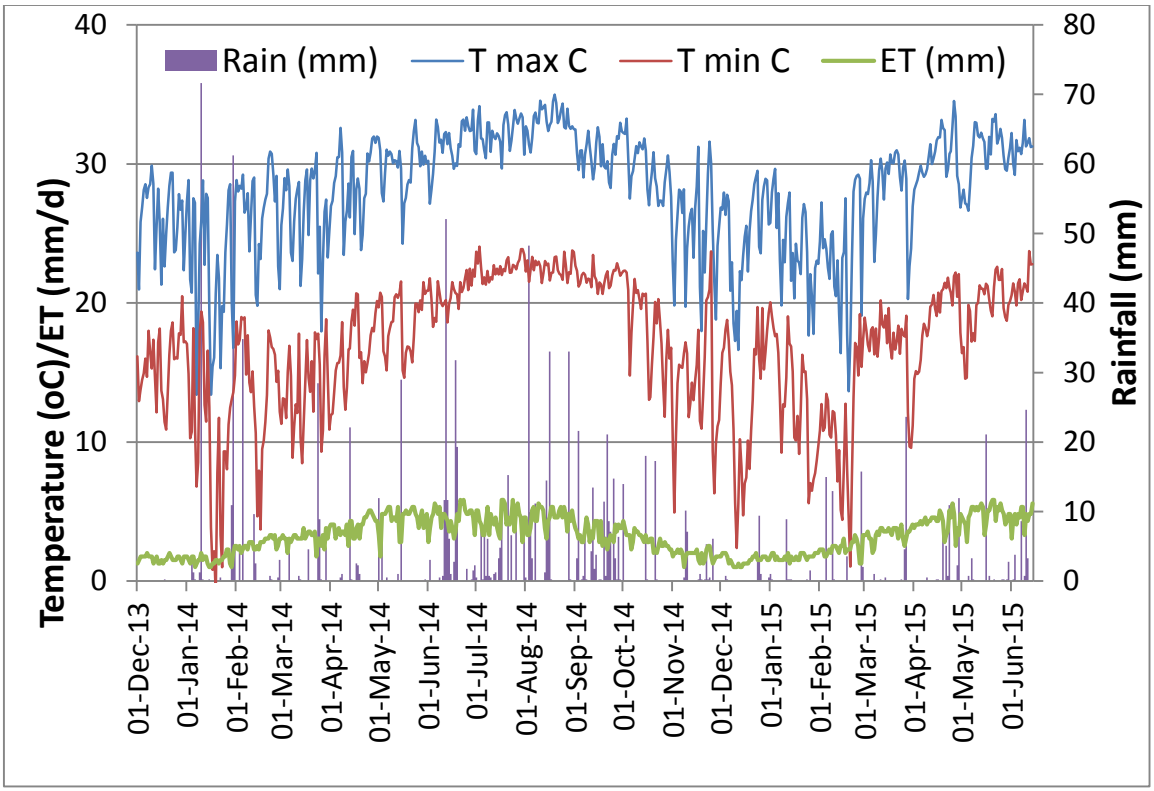

Figure 5.1 Daily maximum and minimum temperature (Tmax, Tmin), daily evapotranspiration (ET) and daily total rainfall (mm) over the study period at Belle Glade, FL, USA.

Data were collected on sugarcane emergence, tiller count, stalk height, and total number of leaves in all the varieties throughout the season. LAI and canopy cover data were not measured because of instrument problems. Additionally data were also collected on various physiological variables in all the varieties. Variety Q183 showed earliest emergence and time to reach to 90% emergence compared to all other varieties. Variety R570 showed the slowest emergence rate. At 120 DAP, all varieties had greater than 85% emergence, enabling uniform plant stand. Eight plants were tagged in each plot (in the section marked for final harvest) to collect data on green leaf count and stalk height.

Destructive harvests were performed on April 10 (119 DAP), July 9 (209 DAP), September 25 (287 DAP), and December 16 (369 DAP) during the plantcane crop. During these harvests, data were collected on total fresh biomass and biomass partitioning to stalks, green leaves, tops, and dead leaves. Subsamples were dried to calculate data on total dry biomass and biomass partitioning to various plant parts. Data were also collected on number of green leaves, nodes, stalk height, and stalk diameter during each of these harvests on 10-subsampled plants.

Data on destructive harvests

Data on various destructive harvests is shown in Table 5.1 and Figures 5.2-5.6. A 2m row section was harvested to measure total fresh biomass yield. A 10-plant subsample was collected for biomass partitioning on fresh and dry weight basis and for count data on green leaves, nodes, stalk length and

diameter. All individual subsamples (green leaf, dead leaf, tops, and stalks) were weighed fresh and dried in oven at 80 ^{o}C until constant weights were achieved to determine dry matter content. Stalk weights were used to calculate TCH (tonnes of cane per hectare). Subsampled stalks were juiced using a roller press and juice analyzed for Brix and POL. Commercial recoverable sucrose (CRS, g per kg) was calculated based on brix, POL, fiber, and theoretical recoverable sucrose. Sucrose yield (TSH, tonnes of sucrose per hectare) was calculated from TCH and CRS.

CP 88-1762 showed the highest cane yield and was statistically similar to other varieties except HoCP 96-540 (Table 5.1 and Figure 5.2), resulted from lower stalk count and stalk weight in the latter variety. NCo376 attained highest stalk count but lowest stalk weight. Similar to cane yield, highest sucrose yield was attained in CP 88-1762 and was statistically similar to R570 and Q183 but greater than HoCP 96-540, NCo376, and N41 (Table 5.1, Figure 5.3). Both CRS and TCH were higher in CP 88-1762 compared to HoCP 96-540, resulting in 79% greater sucrose yield in CP 88-1762.

Table 5.1. Sugarcane yield parameters (stalk number, stalk weight, TCH: tonnes of cane per hectare, CRS: commercial recoverable sucrose, and TSH: tonnes of sucrose per hectare) for six varieties in plantcane, planted on December 12, 2013 and harvested on December 16, 2014 at Belle Glade, FL, USA. Numbers with different letters within a column signify a difference at P <0.05.

Variety	Stalk no.	Stalk wt.	TCH	CRS	TSH
	stalk m^{-2}	kg $stalk^{-1}$	Mg ha^{-1}	g kg^{-1}	Mg ha^{-1}
N41	100066ab	1.36ab	136ab	89.4ab	12.3b
NCo376	112369a	1.22b	136ab	84.2b	11.4b
CP 88-1762	104987ab	1.79ab	187a	102.2a	19.2a
R 570	88583ab	1.87a	165ab	95.5ab	15.8ab
Q183	96785ab	1.49ab	144ab	93.9ab	13.5ab
HoCP 96-540	75459b	1.52ab	110b	96.4ab	10.7b
P value	*0.04*	*0.02*	*0.01*	*0.02*	*0.008*

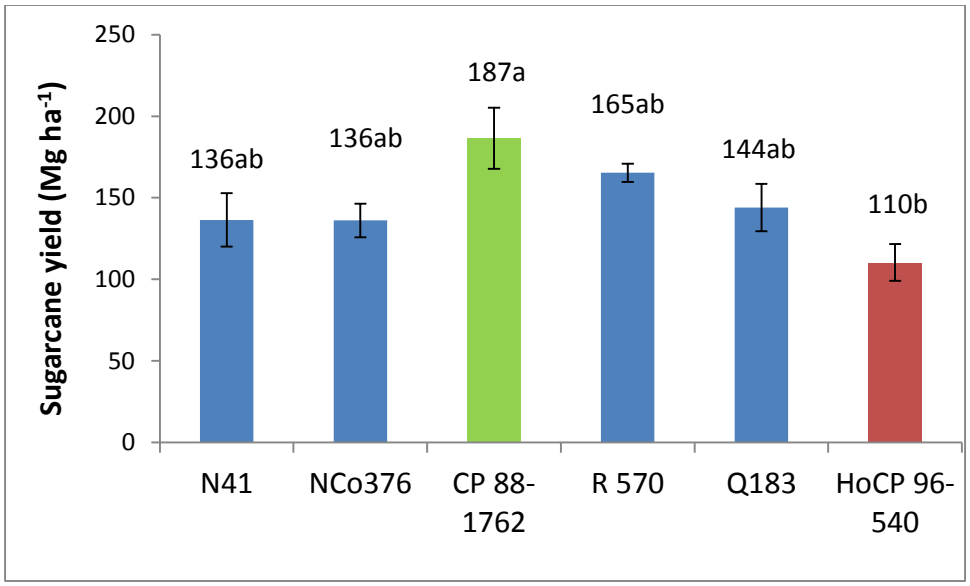

Figure 5.2: Sugarcane yield (TCH, tonnes of cane per hectare, Mg ha^{-1}) for six varieties in plantcane, planted on December 12, 2013 and harvested on December 16, 2014 at Belle Glade, FL, USA. Bars with different letters signify a difference at P <0.05.

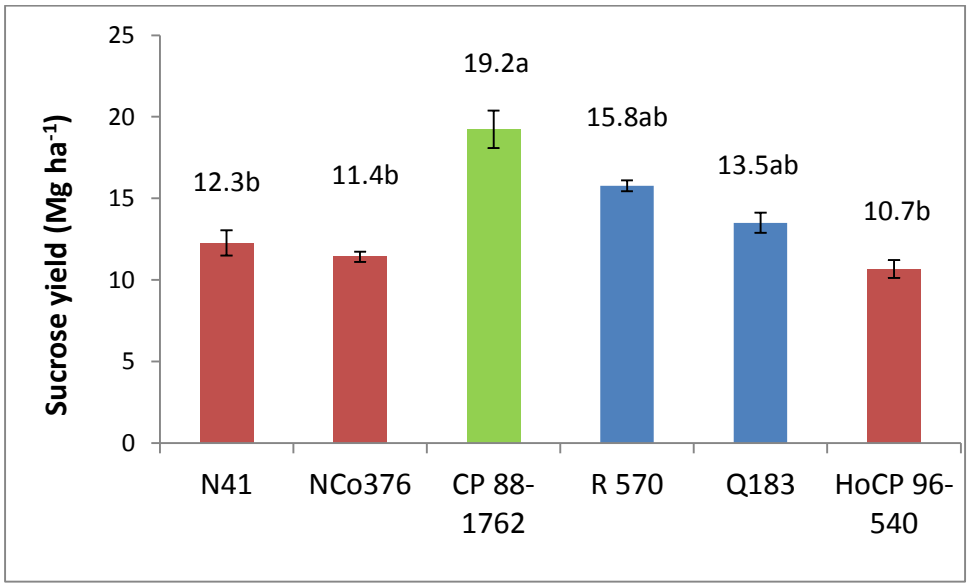

Figure 5.3: Sucrose yield (TSH, tonnes of sucrose per hectare, Mg ha^{-1}) for six varieties in plantcane, planted on December 12, 2013 and harvested on December 16, 2014 at Belle Glade, FL, USA. Bars with different letters signify a difference at P <0.05.

Similar to final cane and sucrose yield, CP 88-1762 attained the highest dry biomass yield throughout the growing season (Figure 5.4). This was driven primarily by the highest stalk dry biomass in this variety

along with the green leaf dry biomass (Figure 5.5). HoCP 96-540 showed a decline in dry biomass as the season progressed. Decline in photosynthetic capacity due to brown rust, lodging and some rat damage observed in this variety later in the season could explain some of this decline.

The proportion of the dry biomass allocated to various plant parts did not change considerably between varieties throughout the growing season (Figure 5.6). At final harvest, HoCP 96-540 and CP 88-1762 had the highest proportion of dry biomass allocated to stalks (0.86 and 0.84, respectively) while NCo376 and R570 had the lowest allocation to stalks (0.77 and 0.76, respectively; Figure 5.6). None of the variety differed in total fiber content in the stalk at final harvest, ranging from 11.7% in CP88-1762 to 13.3% in NCO376.

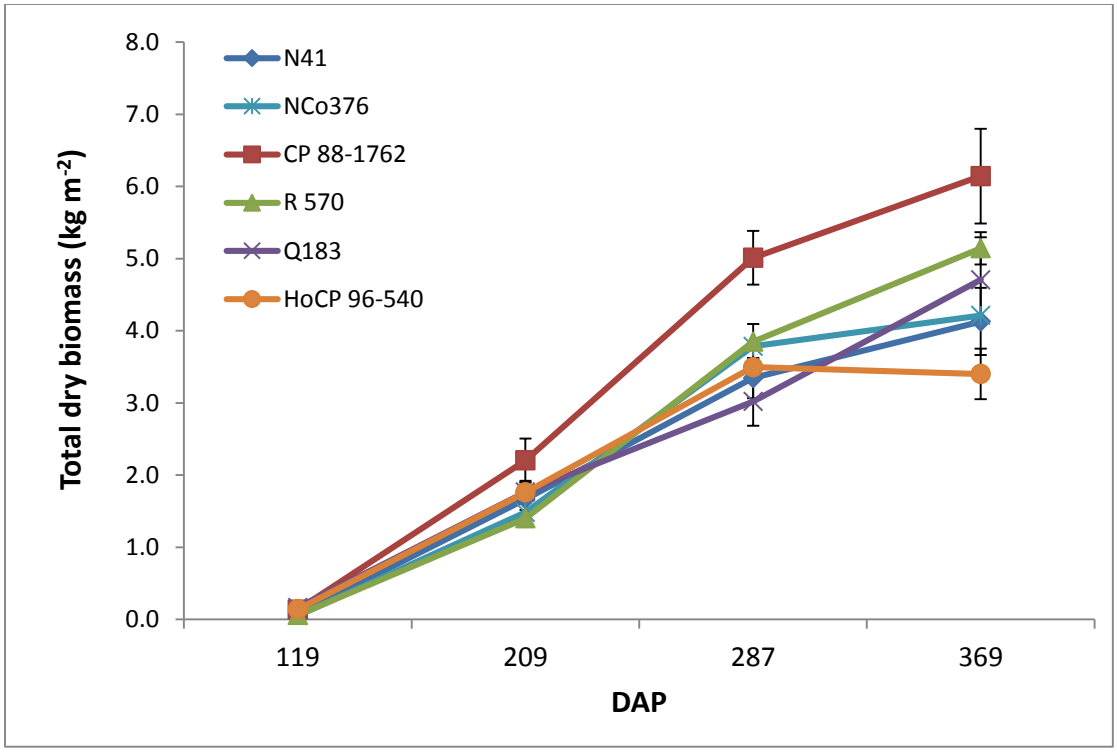

Figure 5.4: Total dry biomass for six varieties in plantcane, planted on December 12, 2013 and harvested on December 16, 2014 at Belle Glade, FL, USA.

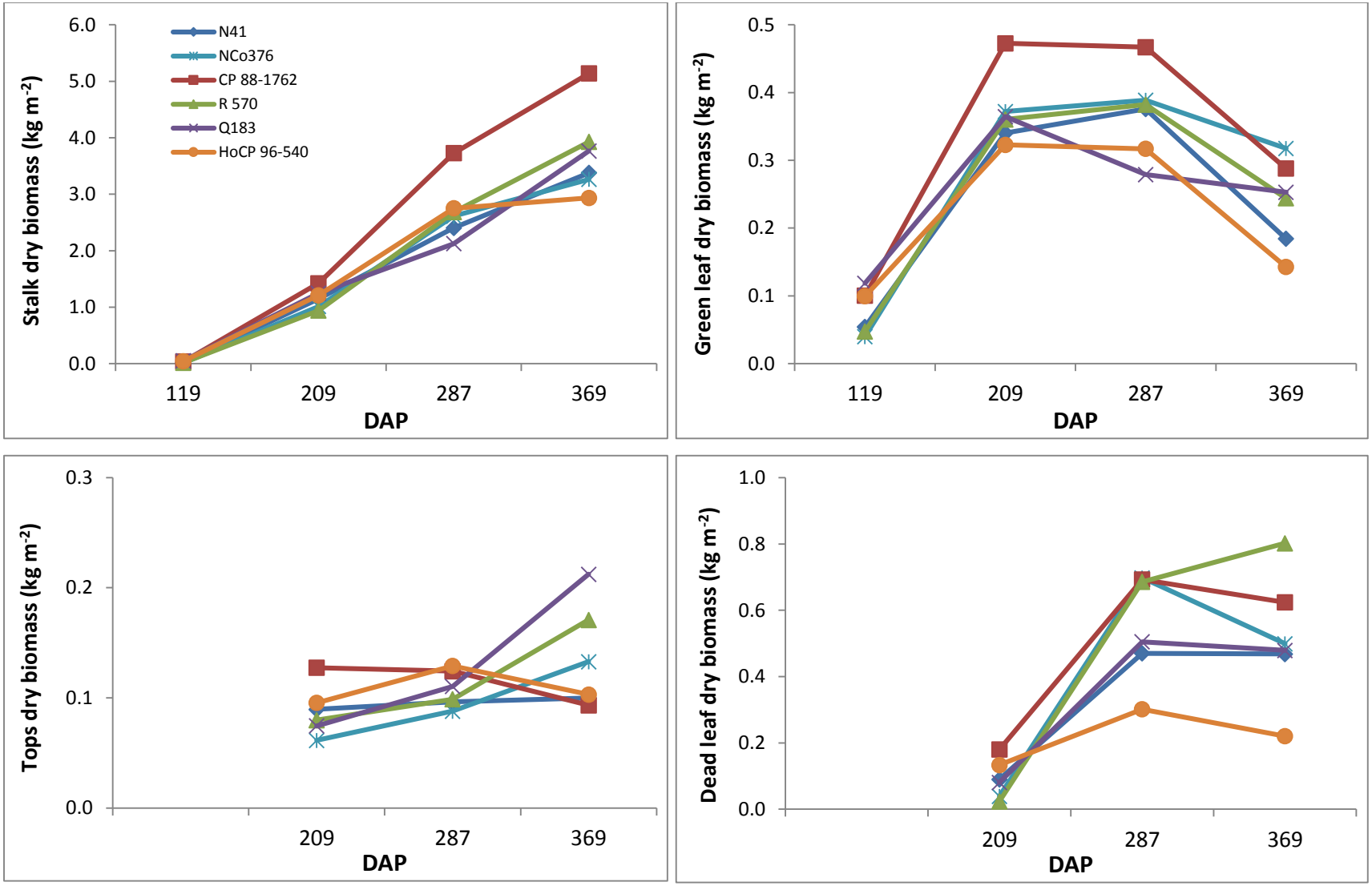

Figure 5.5: Partitioning of dry biomass to various plant parts (stalks, green leaves, tops, and dead leaves) at various harvests for six varieties in plantcane at Belle Glade, FL, USA.

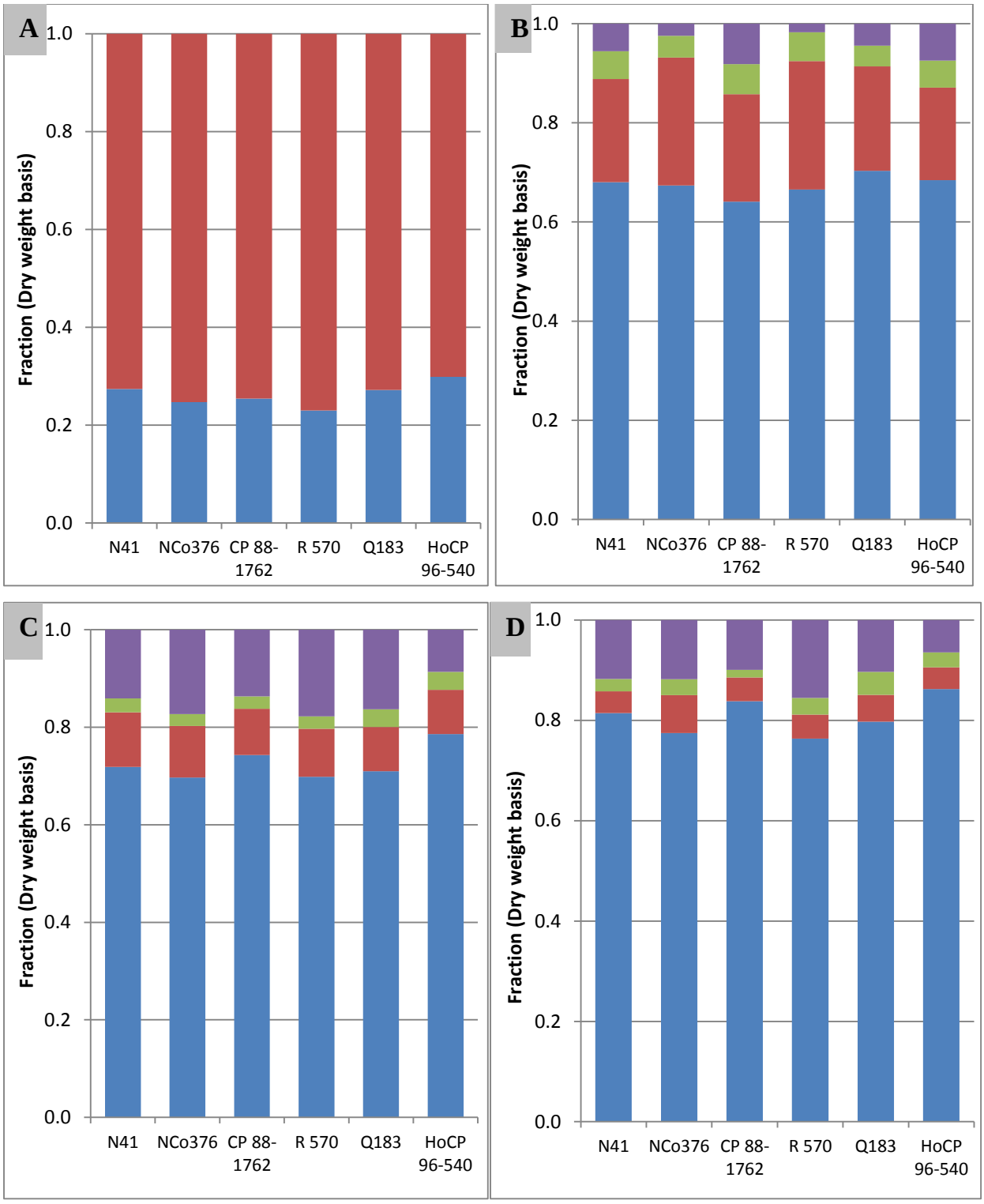

Figure 5.6: Dry matter partitioning for six varieties in plantcane at Belle Glade, FL, USA. (A) April 10- 119 DAP; (B) July 9- 209 DAP; (C) Sept. 25- 287 DAP; (D) Dec. 16- 369 DAP. Legend: Stalk fraction, Green leaf fraction, Tops fraction, Dead leaf fraction

Challenges faced

Due to limited resources available, we were unable to harvest large sections (4 m sections in 3 marked rows) for the destructive harvest. Instead, we collected samples from a representative 2m section in one row (except for first harvest where 2m sections were harvested in 2 rows). Also, we did not collect leaf sheaths separately in the biomass partitioning due to the same reason. For dead leaves, sheaths were mostly part of leaves while for green leaves, sheaths were part of the stalk. Allocations to sucrose and non-sucrose fraction were also not calculated due to unavailability of the equipment and samples later on.

We also faced some issues with data collection on number of leaves on the tagged plants. Loss of tag on the marked tiller, death of marked tiller, disappearance of color marking on the leaf, and tall plants later in the season all played a role in making it difficult to collect this data non-destructively. We are using plastic and metal tags this year to avoid some of these issues.

Due to mild winters during 2013-14, we had seen early initiation of brown and orange rust symptoms in sugarcane in south Florida. In this trial, variety HoCP 96-540 had shown most severe symptoms of brown rust (Figure 5.7, left panel), mostly in plantcane. Fungicide Headline (Pyraclostrobin) was sprayed to control brown rust. Minimal to no symptoms were seen in other varieties. Manganese nutrient deficiency symptoms were observed in varieties Q183 (Figure 5.7, right panel), NCo376, and N41 in this trial, due to inherent low Mn levels in high organic soils.

Figure 5.7: Brown rust on HoCP 96-540 (leaf panel) and Manganese deficiency in Q183 along with some brown spotting (right panel).

5.2 Ratoon Crop

Field operations

Plantcane trial plots were mechanical harvested with sugarcane harvester on January 23, 2015 and allowed to ratoon. Plots used for collecting plantcane destructive harvest samples will not be used for the ratoon crop. Data will be collected from the plots where no harvest or data were collected during

the plantcane crop. Standard management practices for sugarcane cultivation on high organic soils of south Florida will be employed to maintain these plots. By early April, all varieties except R570 showed good emergence and initial growth (Figure 5.8).

Progress on data collection

Data were collected on sugarcane emergence and tiller count in all the varieties (Figures 5.9 and 5.10). All varieties except R570 showed faster initial growth. However, R570 lagged behind all other varieties in the early emergence and growth (Figure 5.8 and 5.9). Tiller count data was collected in two 4m row section in the area marked for final destructive harvest. Again, variety R570 showed lowest tiller count in the early phase of growth (Figure 5.10). Eight plants were tagged in each plot (in the section marked for final harvest) and data will be collected on leaf count and stalk height. Some data have already been collected on these parameters. Also, first destructive harvest was conducted on April 30, 2015.

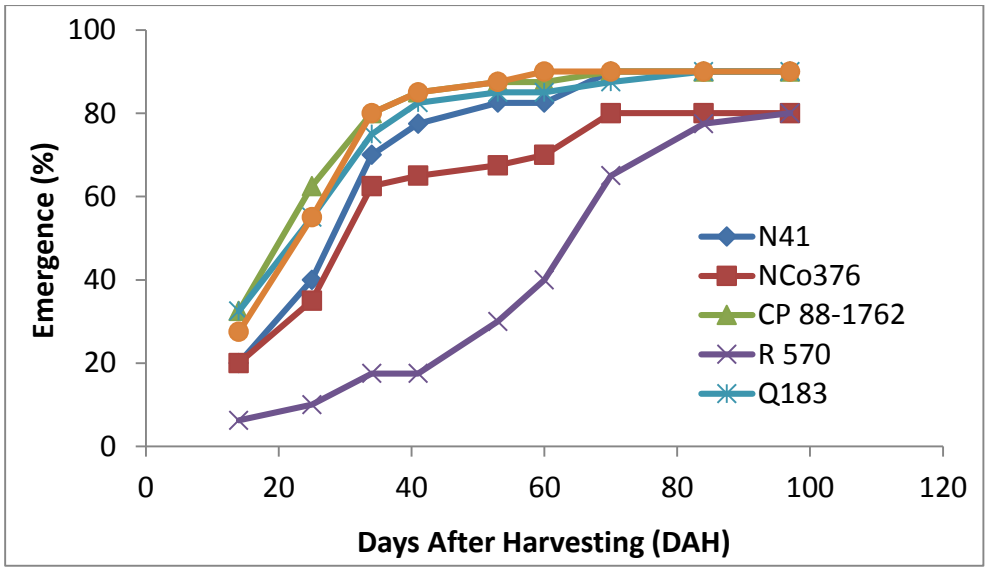

Figure 5.8: Sugarcane emergence (%) for all six varieties in first ratoon crop.

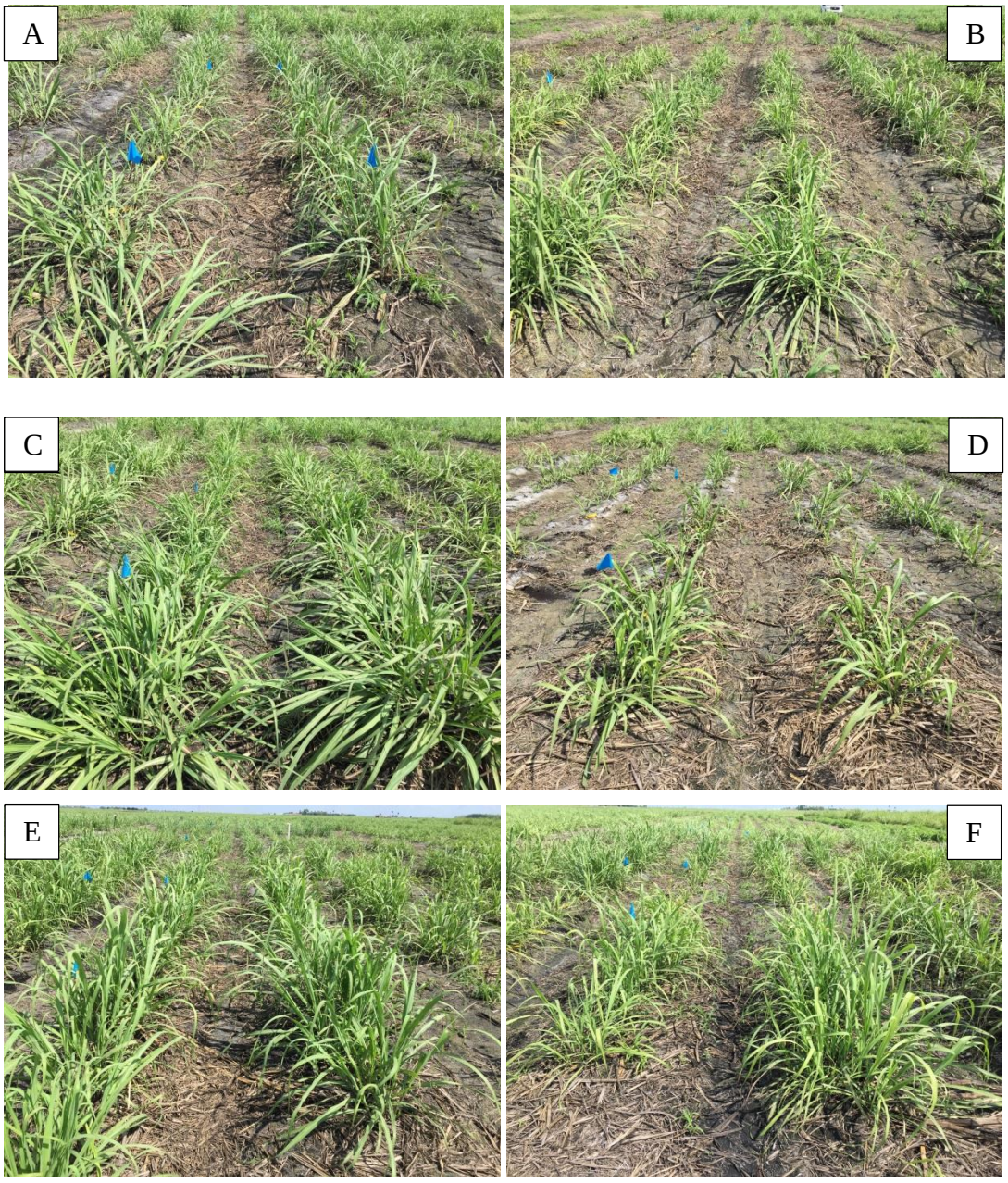

Figure 5.9: Sugarcane varieties in first ratoon crop: (A) N41, (B) NCo376, (C) CP 88-1762, (D) R 570, (E) Q183, and (F) HoCP 96-540. Pictures were taken on April 3, 2015 (70 days after harvest).

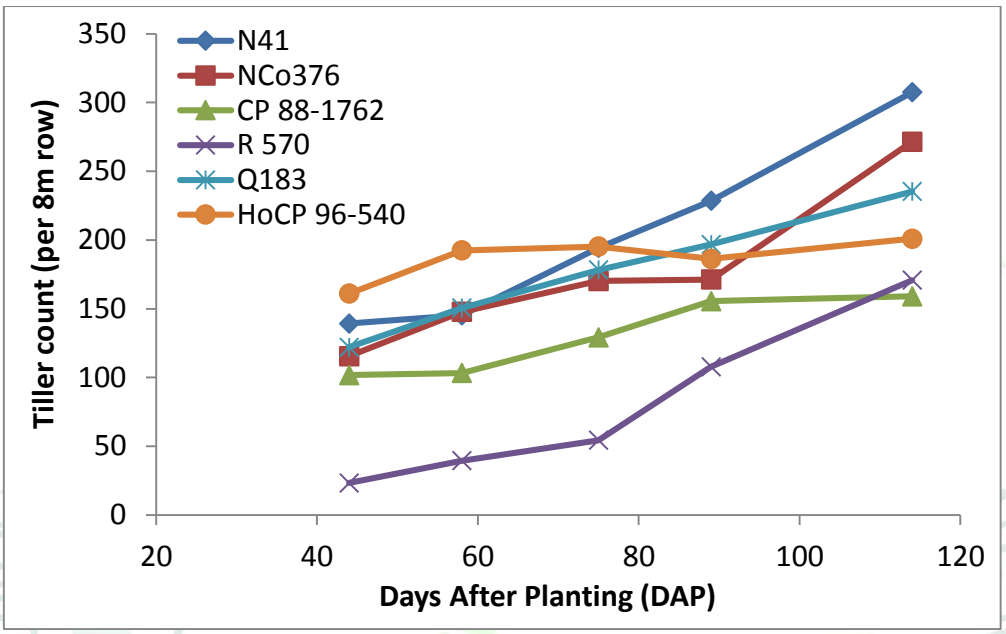

Figure 5.10: Tiller count data for all six sugarcane varieties in first ratoon crop (plantcane was harvested on Jan 23, 2015).

6. CONCLUSIONS

The project has progressed well with three plant crop experiment completed and the fourth started during the reporting period. Captured data are being checked and processed into a form suitable for analysis and interpretation. Some interesting preliminary findings are that the home grown varieties seem to perform the best in terms of yield, and that variety ranking differs widely between the different trials – an indication of strong GXE interaction. This provides the necessary challenge that this project aims to address, namely to mathematically predict genotype performance in diverse environments by simulating lower level yield contributing processes. Data interpretation and modelling will commence in 2016 and a Ph.D. student or post0doctoral fellow will have to be recruited for this purpose.

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