Suitable Biomass for a **Sustainable Sugarcane** Industry

UPDATE 3:
Mid-season crop composition

This project is supported by CRC for Developing Northern Australia , Far Northern Milling Pty Ltd, Sugar Research Australia and The University of Queensland

Introduction

In the first update, we addressed the need for a biomass dependent industry such as sugarcane to follow a 'zero wastage' policy and an approach to extract maximum economic value from the biomass. We highlighted that a lack of knowledge and diversification options are major constraints for a prosperous and sustainable future.

In response to these challenges, the objectives of the project are to identify genotypes that could contribute to increased total biomass production per unit land area. This would be achieved through evaluating the biomass production from a range of commercial and near commercial varieties, and Energycanes. As part of the process of identifying suitable sugarcane to diversify income and add value.

In this update, we present the information gathered from these trails, in relation to growth conditions, shoot emergence, canopy development and canopy health.

Sugarcane trials

Fifteen sugarcane genotypes were included in the trials at Mossman and Atherton Tablelands in Northern Queensland. These included 6 current commercial varieties and 9 non-commercial genotypes. At the Tablelands site, SRA26 that was released to the industry in 2019 was included in the genotype mix. The trials were planted in a completely randomised design including three replicate plots per treatment. Each replicate consists of 4 x 10 meters of cane. Billets obtained from disease-free stalks were used as planting material.

The Mossman trial was established at the Mango Park Cane Farm Company, Farm number: 5185 (16°28'38.16"S 145°20'59.16"E). The clones were planted on 2 September 2020. The plant crop was harvested on 29 July 2021. The Tablelands trial was established at the Salvetti Farming Company, Farm number: 6207 (17°6'8"S 145°20'28"E). The clones were planted on 28 August 2020 and will be harvested in July 2021.

Germination and crop establishment data was collected through a combination of on-ground measurements and aerial photography using drones. Data analysis was

In this update

- Growth conditions
- Shoot emergence
- Canopy development
- Phyllochrons
- Canopy health

In the picture above Dr Sijesh Natarajan and Johan Deutschenbaur are preparing the M600 drone equipped with a multispectral sensor for a flight to capture key crop growth attributes.

undertaken using specific algorithms developed by Sugar Research Australia [2].

An unmanned aerial vehicle (UAV) equipped with multispectral and thermal sensors was used to determine canopy cover, canopy height, canopy temperature, and a normalised vegetation index. Two UAV surveys at 90 and 210 days after planting (DAP) were done at a flight height of 60 m and a flight speed of 6 m s^{-1}.

Environmental conditions

Daily maximum and minimum air temperatures, rainfall, daily global incoming radiation for each of the trial sites were extracted as previously described [5]. Photosynthetic active radiation was calculated [9].

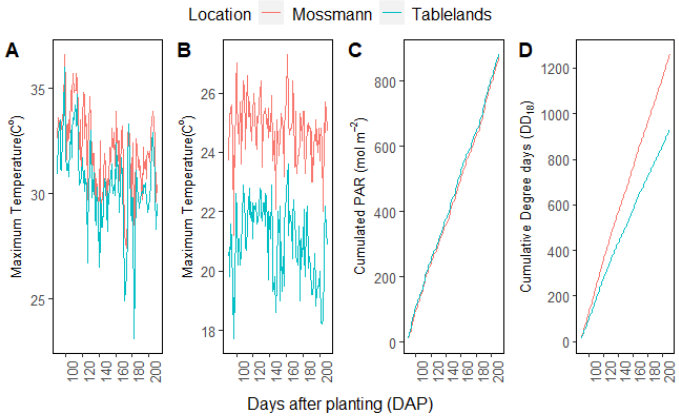

Figure 1: *Temperature and photosynthetic active radiation (PAR) at the two trial sites. (A) maximum temperature, (B) minimum temperature, (C) accumulated PAR and (D)accumulated degree days with 18°C as a base*.

In sugarcane the base temperatures for germination is 12°C, leaf appearance is 9°C and internode elongation (growth) is 18°C. The thermal time for leaf appearance and internode elongation was calculated from

$$\left(\frac{Max\ temp+Min\ temp}{2}\right) - t_{base}\ )$$

The major difference between the two locations is the daily minimum temperature (Fig. 1B). As a result, of this the Mossman site accumulate heat units more rapidly than the Tablelands site (Fig. 1D). The accumulation of photosynthetic active radiation is similar at the two research sites (Fig. 1C).

Shoot emergence

The germination of the sugarcane genotypes in the Tablelands trial is presented in Table I. Five of the genotypes germinated better and had a higher stalk

"Temperature is the key driver of all stages of sugarcane development and growth. The time taken for the plant to develop organs or complete processes such as germination, flowering, etc. decreases as temperature increases. This phenomenon that any plant development process must accumulate a certain amount of heat units (t_i) for completion is generally called the heatsum or degree days (DD). The units for degree days are °C d-1. Most physiological processes stop at temperatures well above 0°C and this is referred to as the base temperature"

"The thermal time for any physiological process can be calculated from the following equation:

$$\sum_{\text{max length}}^{\text{initiation}} (t_i - t_{base}) = k$$

Where t_i is the accumulated average daily temperature, t_{base} is the threshold temperature below which the process does not proceed, and k is the day degrees or heat sum for the process."

TABLE 1: Shoot emergence after planting of 15 sugarcane genotypes in the Tablelands

Clone	Shoot emergence								
	28 DAP[1]			42 DAP[1]			56 DAP[1]		
	Shoots[2]	sd	TUKEY[3]	Shoots[2]	sd	TUKEY[3]	Shoots[2]	sd	TUKEY[3]
QS10-7123	33.3	14.6	b	76.0	14.8	abc	172.7	37.6	a
QS08-8662	34.0	6.4	b	93.0	1.6	a	147.0	6.5	ab
QS10-8770	36.3	1.2	b	80.3	7.3	ab	144.0	12.8	ab
SRA3	52.3	3.8	a	77.7	1.7	ab	135.3	31.5	abc
QN13-173	26.7	7.4	bcd	54.0	8.6	cd	117.7	31.4	bcd
KQ228	33.7	8.3	b	73.3	15.4	abcd	113.3	15.2	bcd
WSRA24	34.3	3.3	b	68.0	7.3	bcd	100.7	9.3	cd
QS09-8348	28.3	10.0	bc	69.3	16.0	bcd	98.0	18.1	cd
Q240	14.3	4.5	cde	52.3	12.3	d	94.0	18.4	d
Q208	12.7	9.4	de	56.7	19.2	cd	92.7	24.1	d
QS09-8404	26.7	1.9	bcd	59.0	4.3	bcd	92.7	4.6	d
QS08-7370	12.7	4.2	de	61.7	13.7	bcd	91.0	17.1	de
QS07-9185	24.0	8.5	bcd	53.3	8.2	d	87.3	13.6	def
QN13-609	3.3	2.1	e	25.7	8.4	e	50.3	13.7	ef
QN12-512	8.7	5.4	e	28.7	7.8	e	47.0	15.9	f

[1] Days after planting

[2] Shoots per 20 meters

[3] TUKEY HSD ($P_{0.05}$)

population than KQ228. Two genotypes (QN13-609 and QN12-512) germinated poorly.

The information captured during the UAV surveys were used to also determine the row length of each plot int the Mossman and Tablelands trials. The data confirms the high variability in the germination of the genotypes at both sites (Fig. 1). In the Mossman trial the germination of QN12-520 and QN-512 were particularly poor.

Canopy development

Stalk elongation and leaf development were measured throughout the first six months of crop development.

Canopy height was measured from the base of the stalk to the first visible dewlap [10]. In addition, canopy height was derived from the visual images after constructing a digital surface model (DSM) and a digital terrain model (DTM). Canopy height was determined as

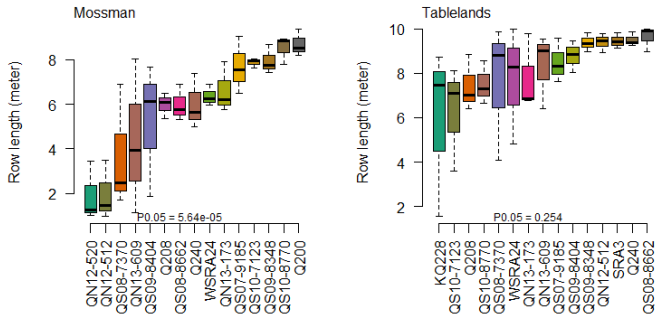

Figure 2: Estimated row length of the sugarcane genotypes included in the field trials in Mossman and Tablelands based of the RPA surveys 90 days after planting (DAP). *Varieties were sorted with the highest value on the right.*

"Stalk elongation and leaf development were non-destructively measured in-field. This was done to ensure minimal disruption to canopy development by not changing shoot and leaf numbers, leaf production rates, and numbers of senescing leaves"

"Germination at the Mossman site was more variable and slower than at the Tablelands site. Even 90 DAP some of the rows had seedlings in less than 50% of the row length"

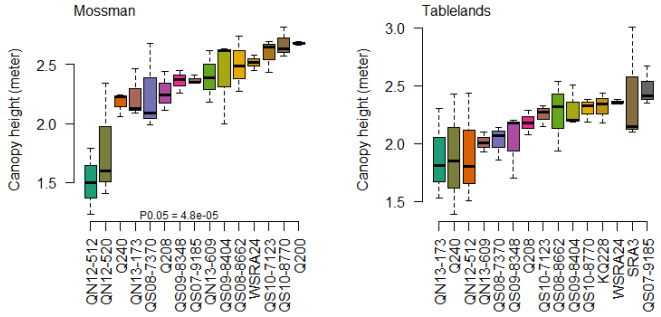

Figure 3: Canopy height of the 15 test genotypes at Mossman and Tablelands 210 DAP. *Varieties were sorted with the highest value on the right.*

the difference between DSM and DTM. Canopy height in this instance is estimated from the ground to the leaf edges. Unlike manual measurements where usually the height is measured up to the first dewlap.

"In all the grasses such as sugarcane, there is a strong correlation between stalk length, internode length and aboveground biomass [4, 6]. Cooler temperatures and reduced moisture availability lead to shorter internodes. [7]."

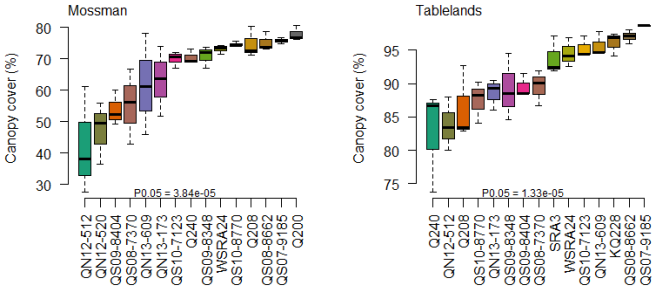

Figure 4: Canopy cover of the 15 test genotypes at Mossman and Tablelands 210 DAP. Canopy cover (%) was determined by classifying the images into vegetation or soil and determining the percentage vegetation within each plot. *Varieties were sorted with the highest value on the right.*

"In sugarcane a phytomer is a unit consisting of a leaf, associated axillary bud, node, and internode (Evans & Grover 1940). The culm is constructed by the sequential addition of phytomer units at the shoot apex."

Canopy cover (Fig. 4) was estimated using the RGB orthomosaic by classifying the orthomosaic to vegetation, soil, and other background pixels. The proportion of vegetation pixels within a plot was estimated as canopy cover.

Growth rate

The growth rate at Mossman tended to be higher than at Tablelands (Fig. 5). This is probably directly related to the difference in the accumulation of heat units (Fig. 1D).

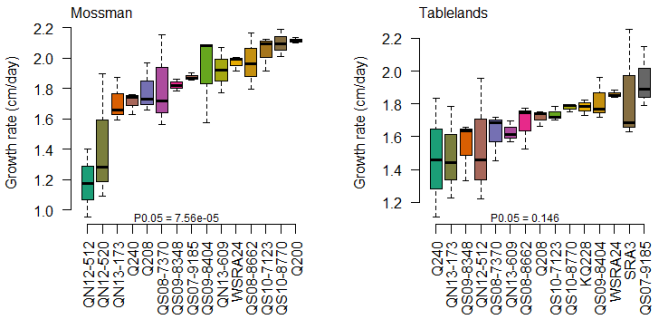

Figure 5: Stalk growth rate of the 15 test genotypes at Mossman and Tablelands 210 DAP. *Varieties were sorted with the highest value on the right.*

Phyllochrons

The phytomer [8, and references therein] is the fundamental building block of the crop canopy. The interval between leaf appearances can be recorded in both standard measurements of time as well as thermal time (e.g. growing degrees of day degrees). One phytomer unit is added over the course of one phyllochron.

The rate of internode (phytomer) production is similar between the genotypes (Fig. 6). The variable germination rate, especially at the Tablelands site is reflected in the internode numbers in some of the genotypes (Fig 6). The number of new leaves produced in the period between

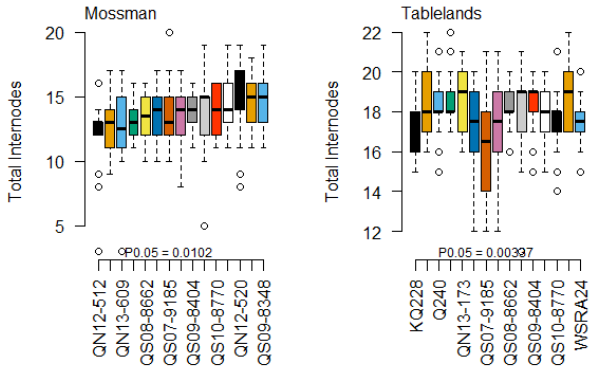

Figure 6: Total internodes produced per stalk in the 15 test genotypes at Mossman (124 DAP) and Tablelands (144 DAP).

90 to 200 DAP was used to calculate the average phyllochron interval of the genotypes (Table 2).

The data suggest that there is significant genetic variation for this trait among the genotypes. As only the top five to six internodes elongate [3], varieties with a long phyllochron interval will have a longer window for internode elongation.

"The phyllochron is the intervening period between the sequential emergence of the leaves on the stem. This measurement is used to describe the growth and development of the crop"

"As there was no significant difference in the phyllochron length of the genotypes between the two locations the data was combined"

"The variation in phyllochron interval is within that previously reported for sugarcane [1]. "

TABLE 2: Phyllochron interval of the 17 sugarcane genotypes in the Mossman and Tableland trials in the period 90 to 200 DAP.

Genotype	Phyllochron °C d^{-1}	sd	TUKEY[1]
Q200	117.5	9.3	a
QS08-8662	101.1	17.5	b
Q240	95.3	18.1	bc
QS09-8404	94.3	15.1	bcd
QS10-7123	94.2	13.0	bcd
QS09-8348	93.1	15.5	bcd
QS10-8770	92.8	14.6	bcde
QN13-173	92.7	15.7	bcde
QN12-512	91.8	22.6	bcde
WSRA24	91.6	12.4	bcde
QS08-7370	89.2	12.2	cde
QS07-9185	89.1	20.4	cde
QN13-609	88.3	16.5	cde
Q208	87.9	18.2	cde
SRA3	83.1	7.6	cde
QN12-520	80.2	7.9	de
KQ228	78.7	10.1	e

[1] = TUKEY HSD (P0.05)

Canopy Health

There is a significant difference in the chlorophyll content of the different genotypes at both locations (Fig. 7). The data suggest that QN12-512, QN12-520, QS09-8348, and QN13-609 are all under significant physiological stress and probably will perform poorly as the season progresses.

"Normalised Difference Red Edge (NDRE) is a sensitive measure of the chlorophyll concentration in the sugarcane leaves. This makes it particularly sensitive to changes in vegetation health and nitrogen status."

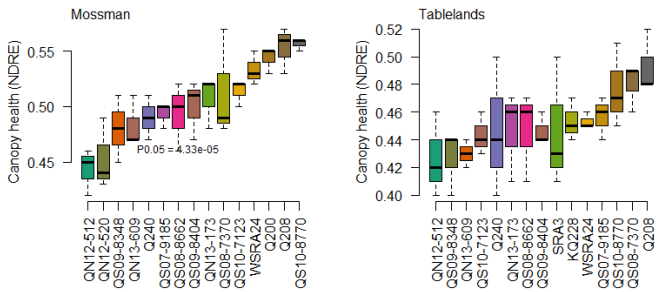

***Figure 7**:* Canopy health of the 15 test genotypes at Mossman and Tablelands 210 DAP.

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