

ASPECTS OF DRY MATTER PARTITIONING IN SUGARCANE

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Introduction

Partitioning of dry matter (DM) in sugarcane is of interest for two fundamental reasons. Firstly sugar production depends directly on partitioning of biomass to the stalk and then to sucrose stored in the stalk. Secondly, various DM components of the stalk and particularly sucrose concentration are used to calculate the value of cane consignments delivered to the mill (Berding, 1997). The value of cane consignments is reduced by leaf and trash and by non-sucrose constituents of the stalk, even if the total mass of sucrose in the consignment is not reduced (Culverwell, 1996). In the case of the Australian sugar industry the payment formula is designed to accentuate the value of sucrose content of cane consignments and this has led to a heightened awareness of variations in sucrose content due to cultivar, harvest season, crop age and many other factors. The moisture, fibre and juice purity components of the payment formulas are also important but will not be considered in this paper.

The objective of this work was to gain a better understanding of the factors influencing dry matter partitioning in sugarcane as a basis for improving functional responses in sugarcane simulation models.

Keywords: dry matter partitioning, sucrose content, temperature, leaf number, model

Methods

Data from two growth analysis experiments in South Africa and 14 similar experiments conducted in Australia were re-analysed.

South African data

The two South African growth experiments were conducted at La Mercy on the KwaZulu-Natal (KZN) North coast (29.5 °S, 30.1 °E, 72 m altitude) on a sandy clay, Swartland soil form. The first experiment was established in 1988 to compare growth of crops of two cultivars (NCo376 and N12) ratooning at eight times over a period of two years (Treatments 1 to 8). The second experiment was planted in 1992 at the same site after a 10-month fallow period. Cultivars NCo376, N12, N16, N17 and N19 were planted in randomised sub-plots within two replicate blocks on 2 December 1992, 27 January 1993 and on 24 March 1993. The 1988 and 1992 La Mercy experiments will be abbreviated as LMY88 and LMY92. The establishment and sampling procedure for LMY88 was described by Inman-Bamber (1994). Five destructive samplings were conducted on each plot of LMY88 during the first week of alternate months, starting eight months after ratooning. Each plot of LMY92 was sampled on eight occasions starting at 16 weeks after planting and at 8-week intervals thereafter. Dry matter yield of green leaves, green sheaths, immature stalk, millable stalk in 20 cm segments and trash were determined with each sampling. Sucrose content and mass were also obtained for each 20 cm stalk segment. Total leaf number (TLN) per stalk and leaf area index (LAI) were also obtained by destructive sampling.

Australian data

The 14 Australian experiments and 110 sampling operations providing data for this paper have been described by (Inman-Bamber *et al.*, 2002). Q117 was the predominant cultivar in these experiments but Q96 (11 samplings) and Q124 (8 samplings) were used in some trials. Half the experiments were conducted in the Herbert and half in the Burdekin region. Experimental crops were sampled 4 to 16 times during the growth cycle to determine crop components as in the South African experiments but stalks were not segmented. The sampling procedure was described by Muchow *et al.* (1993). The trash component was derived by collecting dead material (method 1 as in the South African experiments) and sometimes by counting nodes from which leaves developed that were now dead (method 2). Dry mass of dead leaves was also obtained for method 2 so that trash mass could be derived from mass per leaf, nodes per stalk and stalks per square meter.

Results and Discussion

It is important to note that variation in biomass in these experiments arose largely from sampling crops during their development over time, however variation in growing conditions also influenced biomass yields regardless of crop age.

Partitioning to trash

LMY88 experienced reasonably good rainfall (1098 mm per annum) and LMY92 experienced very dry conditions (669 mm per annum). The trash fraction was as high as 0.36 (Figure 1). Trash fraction for Q117 determined by method 1 was as low as 0.04 in young cane and only as high as 0.08 when biomass approached a maximum.

After correcting for unrecovered trash (method 2), the trash component of Australian cultivars more than doubled but was still lower than the trash component of South African cultivars (Figure 1). From this it can be concluded that about half the trash component was not recovered by normal sampling (method 1) in Australia. About 15 to 20% of dry mass accumulated by sugarcane ends up in trash in moderate to high rainfall or irrigated conditions. In dry conditions up to 35% of the biomass could be in the trash component.

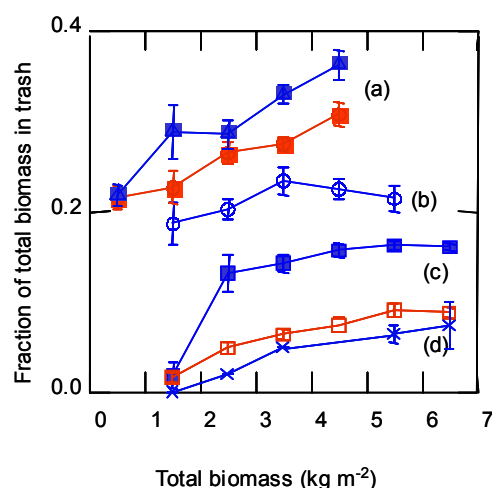


Figure 1. Fraction of aerial biomass in trash in relation to yield of aerial biomass a) for NCo376 (solid) and N17 (broken) in dry rainfed conditions in LMY92, b) for NCo376 (solid) and N12 (broken) in LMY88 with moderate rainfall, for Q117 (solid) and Q96 (broken) in largely well watered conditions in Australia, c) determined indirectly from node numbers and mass of dry leaves and d) determined directly from partitioning of whole plants. Bars show mean \pm one standard error. Data for Q96 were often insufficient to determine standard errors.

Partitioning to millable stalk

Having concluded that the amount of trash recovered in tropical conditions could be half the amount actually produced, this component was excluded when analysing other components of aerial biomass (green biomass). Stalk fraction reached a maximum of about 0.85 in all conditions and cultivars (Figure 2) although only data for NCo376 and Q117 are shown. In the dry conditions of LMY92, stalk fraction was close to the maximum when green biomass was 2 to 3 kg m⁻² and in the more favourable conditions of LMY88 stalk fraction reached a maximum when green biomass was 3 to 4 kg m⁻² (Figure 2). In Australia, maximum stalk fraction was achieved when green biomass was 5 to 6 kg m⁻². There was little justification for distinguishing between the 14 Australian experiments since they were mostly well watered. Earlier achievement of maximum stalk fraction in the dry conditions of LMY92 resulted from the loss of green leaves and sheaths to the trash component. Conversely in well watered tropical conditions in Australia, young crops with less than 4 kg m⁻² green biomass tended to have a relatively large proportion of biomass in green cabbage and leaf tissue.

The lack of variation across a limited number of cultivars in final partitioning to the stalk is not encouraging for yield improvements through this trait. However these data suggest that harvesting could be delayed to ensure that stalk fraction is as high as possible.

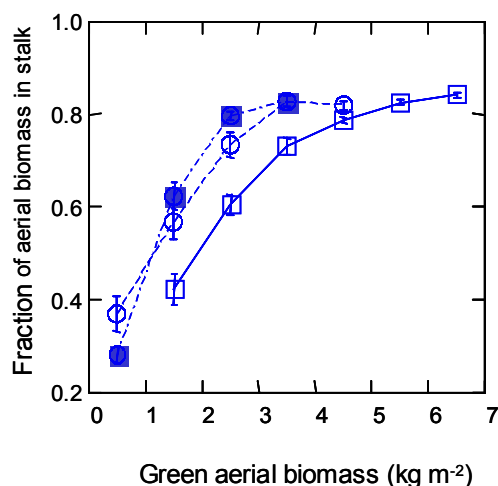


Figure 2. Fraction of aerial biomass in millable stalk, in relation to total green aerial biomass yield, for favourable rainfed or irrigated conditions of LMY88 and Australia and for dry rainfed conditions of LMY92 (bold lines).

Bars show mean \pm one standard error.

Partitioning to sucrose within stalk

In the LMY88 experiment, sucrose content (SC) of 20-cm stalk segments were grouped according to mean mass per stalk from which the segments were taken. It is easy to see from the means of segment and mass groups (Figure 3) how SC increased with increasing stalk mass. At the base of the stalk SC increased markedly with the first two 50-g increments in stalk mass and then mean SC per segment reached a maximum of about 0.55 g g⁻¹. The gradient in SC toward the top of the stalk was similar for each stalk mass class. It is therefore the length of stalk with near maximum SC that determines the SC of whole stalks. Maturation in sugarcane could be described in two phases, one in which SC of basal internodes is increasing and the other in which SC of basal internodes has reached a maximum. In the second phase, further increments in SC of whole stalks depends mostly on ripening of distal internodes. Once the crop is through the first phase, seasonal variation in SC of whole stalks is largely due to partitioning to sucrose in distal internodes mediated by factors such as water and nutrient stress and temperature which affect expansive growth more than photosynthesis.

Data in Figure 3 suggests that there is little change in SC of basal internodes, once a ceiling value of about 0.55 is obtained for stalks weighing more than 150 g. However, seasonal effects on SC in 0 to 20 cm and 20 to 40 cm segments *were* evident in stalks weighing more than 150 g. SC of basal sections of the stalk was lowest in Autumn, highest in Spring and it decreased during Summer (data not shown). The mass of sucrose per segment was subject to the same seasonal variation as SC indicating that changes in SC were due to changes in sucrose mass per segment rather than dilution by other solutes and cell wall constituents. Export of sucrose from basal segments would then augment the ‘dilution’ concept described above.

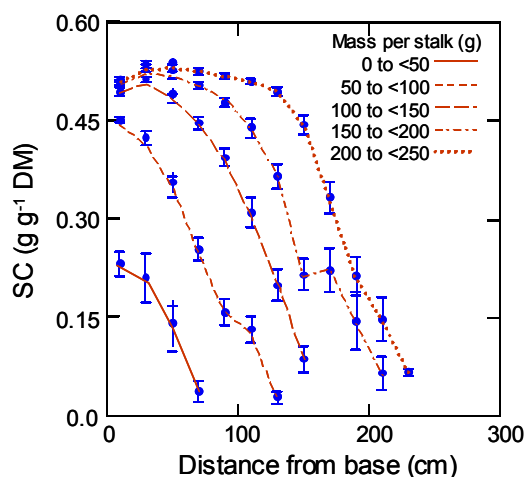


Figure 3. Mean sucrose content (SC) 20-cm stalk segments from LMY88 samples (cultivar NCo376 only) grouped by dry stalk yield, versus stalk height. Bars show mean \pm one standard error.

Empirical model for sucrose content (SC)

Several simple correlations of plant and climatic parameters with SC of whole stalks of treatments 1 to 4 (June 89 to Dec 89 ratoons) of the LMY88 experiment, were found to be significant. SC was positively correlated with TLN, a measure of physiological age, and dry stalk yield (W , $t\ ha^{-1}$) and was negatively correlated with green leaf number per stalk and LAI. LAI depends partly on number of green leaves per stalk which in turn depends on available soil water content (Inman-Bamber, 1991) and leaf water potential (Inman-Bamber and de Jager, 1986). A stepwise regression procedure (SYSTAT, SPSS Inc, Chicago,IL) selected TLN, LAI, W and mean temperature minus 10 (T , $^{\circ}C$) of a 14-d period before sampling as the most influential variables ($n=37$, $R^2 = 0.78$).

$$SC = 0.405 + 0.00455\ TLN - 0.01827\ LAI + 0.00267\ W - 0.01009\ T \pm 0.026\ (g\ g^{-1}) \quad (2)$$

Although SC for treatments 5 to 8 (Feb. 90 to Aug. 90 ratoons) were not involved in the development of Eq. 2, the agreement between SC of these treatments and model predictions were as good as for treatments 1 to 4 apart from four low (<0.3) SC values. When these four low values were omitted, intercept ($a=0.059$) and slope ($b=0.862$) coefficients were not significantly different from 0 or 1 respectively ($n=36$, $r^2 = 0.79$, $SEy=0.033$).

The empirical model developed from LMY88 data accounted for 75% of the variation in SC of Q117 in the Australian data set ($n=140$, $r^2 = 0.75$, $SEy=0.044$). As with the independent data, the intercept (-0.029) and slope (0.97) were not significantly different from 0 or 1 respectively. It can be inferred from this that SC of Q117 grown in Australia responded to the same climatic and developmental processes as SC of NCo376 and N12 grown in South Africa. The simple multiple linear model therefore has application across a wide range of conditions. This is not to deny the importance of genotype by environment interactions in regard to SC.

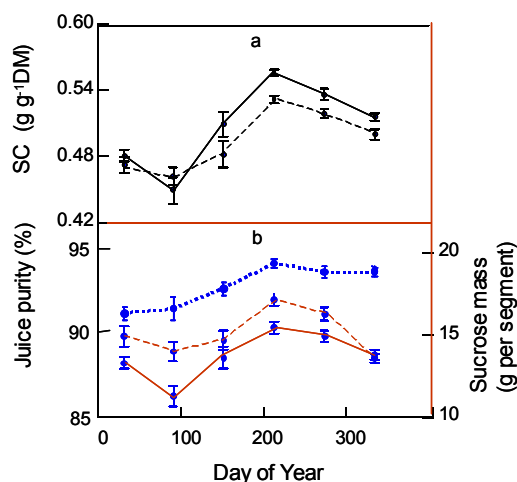


Figure 4a). Sucrose content and (b) mass of stalk segments, 0 to 20 cm (dashed line) and 20 to 40 cm (solid line) and juice purity of 0 to 40 cm segment (dotted line) of NCo376 for stalks weighing more than 150 g DM and sampled at 2-month intervals. Stalks were segmented from the base upwards. Bars show mean \pm one standard error.

The empirical equation is offered only as an interim step while waiting for the development of a fully mechanistic model such as that proposed by O'leary (2000).

Acknowledgements

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