

IN SEARCH OF PARAMETERS TO MODEL CULTIVAR-SPECIFIC CANOPY DEVELOPMENT

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Introduction

The primary role of a crop canopy is to capture sunlight that can be converted to biomass, including sucrose stored in stalks. Canopy development also has a bearing on the amount of water used by the crop and how soon weeds are shaded out. Cultivars are known to differ in the rate of canopy closure in the field, and also differ in traits that determine canopy development, such as leaf size and shoot density.

Crop simulation models have proven to be valuable tools in optimising management practices and they may also be useful in plant breeding programmes for identifying ideal cultivars for a range of environments (Yin *et al.*, 2003), provided they adequately capture cultivar differences. Accurate simulations of biomass (and sucrose) production are dependent on how well canopy development and light interception is mimicked. Singels and Donaldson (2000) have shown that the Canegro model (Inman-Bamber, 1991) does not adequately capture differences in canopy development between cultivars. Experiments were therefore conducted at Pongola and Mount Edgecombe to study selected aspects of canopy development of different cultivars at different times of the year.

Sugarcane develops a canopy of leaves that are subtended by internodes along the stalks of each shoot. In a ratoon crop, shoots develop from buds on stubble left after harvesting the previous crop. The tillering process produces secondary and tertiary shoots, and their survival depends on the light environment in which they exist (Hay and Walker, 1989; Inman-Bamber, 1994). The rate of tiller appearance is dependent on temperature (Bezuidenhout *et al.*, 2003).

Leaves are produced at the stalk apex and the size of successive leaves increase up to a maximum, after which leaf size remains stable or may decline. Leaf appearance rate is dependent on temperature and, according to Inman-Bamber (1994), two distinct rates of leaf appearance are apparent.

It has been postulated that the completion of phenological events (e.g. the production of a leaf) or phases (e.g. the tillering phase) requires the accumulation of a given amount of thermal time (units of °C.d). Thermal time is derived from the mean daily temperature minus the base temperature. The minimum temperatures required for leaf and shoot development are 10 and 16°C (Inman-Bamber, 1994), respectively. The thermal time required to produce one leaf on a tiller is called a phyllochron interval.

It is believed that the cultivar characteristics that govern the underlying components of canopy development, namely leaf appearance, leaf size and shoot appearance, can be captured in biological meaningful parameters. These parameters are also referred to as 'genetic coefficients' (Boote *et al.*, 2003). The numeric value of these parameters should ideally be stable across environments (locality, season and time of year).

The objective of this study was to investigate the suitability of parameters to capture cultivar traits that regulate leaf and tiller phenology of selected varieties grown in different environments.

Keywords: sugarcane, modelling, Canegro, simulation

Methods

The first ratoon crops of nine cultivars were started in June and December 2000 at Mount Edgecombe (29°42'S, 31°02'E, 96 m asl). At Pongola (27°24'S, 31°35'E, 308 m asl), First (1998) and second ratoon (1999) crops of nine cultivars were started in March, April, May/June, August and December. The cultivars NCo376, N17 and CP66/1043 were present at both sites. The crops were kept free of moisture stress and were supplied with adequate amounts of nutrients.

Leaf numbers were counted on primary shoots at regular intervals and the number of shoots in 2 or 4 m sections were counted. In the Mount Edgecombe experiment, leaf area was estimated by multiplying the product of leaf length and width with a cultivar-specific factor (approximately 0.7). In the Pongola experiment, an electronic planometer was used to measure leaf areas of primary shoots. A ceptometer (1 m line quantum sensor, Li-Cor, Lincoln, NE, USA) was used to measure the amount of photosynthetically active radiation (PAR) intercepted by the green leaf canopy. Measurements done on lodged cane and outliers in the data have been excluded from further analysis.

Temperature was recorded in automated weather stations situated within 100 m of the experiment sites at both locations. Daily mean temperature was calculated as the mean of the daily maximum and minimum temperature.

The following parameters were determined for each crop:

- leaf area of the youngest largest leaves (L_{Amax})
- sequence number of the youngest largest leaf (L_{Nmax})
- the first (PI1) and second (PI2) phyllochron intervals, and the leaf sequence number separating PI1 and PI2, also named the phyllochron switch (L_{Nps})
- peak shoot density (SD_{max})
- the fraction of light intercepted at the time of peak shoot density (L_{Imax})
- thermal time requirement to reach peak shoot density (TT_{SDmax}).

A parameter was regarded as suitable for modelling cultivar traits when it was stable across environments and different among cultivars. As an initial test of parameter stability across locations and cycles, the range of each parameter was expressed as a percentage of the mean for a given cultivar. A parameter was regarded as stable when the range was less than 30% of the mean. Only instances that had more than four observations (n=5 or more) were used for determining stability of parameters across different environments. Cultivar differences were determined within crop cycles, and were regarded as significant when the range exceeded 30% of the mean.

Results and discussion

The progression of shoot density, leaf size and leaf number for selected crops are illustrated in Figure 1. These results confirm the patterns of development described in the introduction. Clear differences between the cultivars are also apparent.

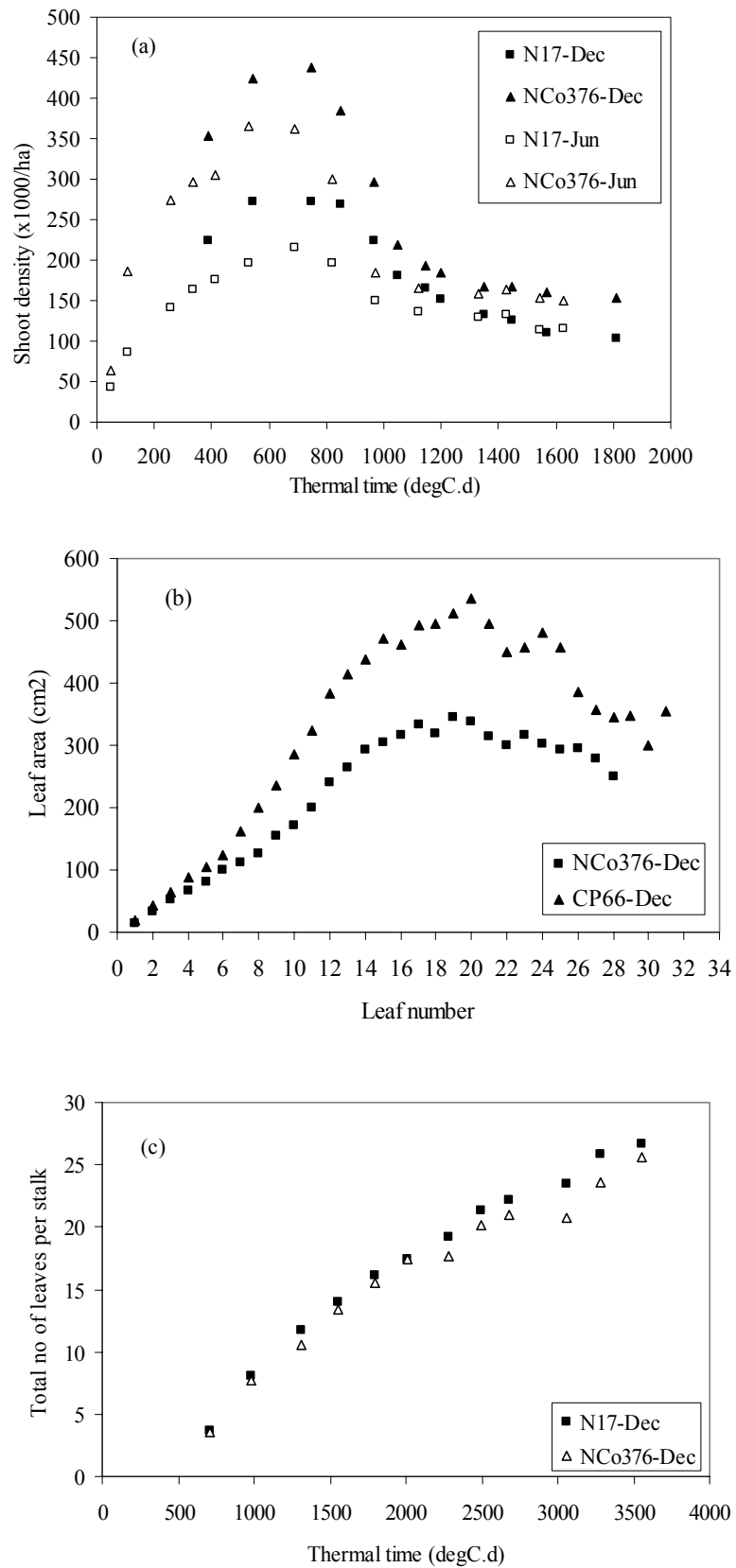


Figure 1. Canopy development of different cultivars started in June and December at Mount Edgecombe: (a) shoot density as a function of thermal time, (b) leaf size in sequence of appearance and (c) leaf appearance as a function of thermal time.

The values of the different parameters are shown in Table 1.

The analysis suggests the following:

- LA_{max} is a stable parameter for most cultivars, and significant differences exist between cultivars within cycles.
- LN_{max} appears not to be a stable parameter. The values were different for the two localities and also varied between cycles. Values for crops started in winter were higher than for crops started in summer.
- The PI1 parameter appears unstable across environments but has similar values for different cultivars within cycles. The PI2 parameter also appears unstable across environments. Although differences were not evident among cultivars in crops of the second ratoon crop and those started in June, August and December of the first ratoon crop at Pongola, PI2 was different amongst the cultivars at Mount Edgecombe and in crops started in March and April of the first ratoon crop at Pongola.
- LN_{ps} (phyllochron switch) was unstable across environments, but were similar for all cultivars within cycles. These results suggest that the phyllochron concept used in Canegro might not be suitable to accurately model leaf appearance of different cultivars.
- SD_{max} is not a stable parameter and varies significantly between cultivars. This confirms previous knowledge that complex interactions between genotype and environment determine shoot density.
- LI_{max} appears to be a stable parameter. Although there were no differences between cultivars, this parameter holds promise for simulating a feedback process that determines shoot density.
- TT_{SD_{max}} appears to be unstable across environments. Cultivars have similar values for this parameter within cycles.

Table 1. Parameter values for different cultivars grown at different locations (see text for explanation of abbreviations).

Location:		Mount Edge combe						Common to both			Pongola					
Cultivar:		N12	N14	N16	N21	N27	N29	NCo 376	CP66/ 1043	N17	N19	N22	N24	N25	N26	Q124
Parameter	Unit															
LA _{max}	cm ²	414-497	458-466	403-414	427-452	383-525	417-508	310-424	453-535	337-463	391-535	353-356	336-406	288-424	430-509	381
LN _{max}	Number	19-22	26-28	19-29	20-28	17-29	24-25	12-25	17-27	16-29	13-18	12-16	15-16	12-18	11-17	14
PI1	°C.d/leaf	110-112	100	85-94	81-93	91-98	96-99	60-103	53-98	82-90	78-105	81-103	59-92	60-103	60-105	94-164
PI2	°C.d/leaf	217-270	213-227	139-167	141-147	133-159	200-213	129-196	126-213	130-164	121-137	128-159	103-145	113-208	109-270	137-158
LN _{ps}	Number	15	16	15	17	16	16	12-17	11-16	13-17	14-18	13-17	11-15	11-18	11-19	16-17
SD _{max}	×1000/ha	338-462	272-287	295-369	223-245	304-353	304-353	365-652	163-226	215-311	300-448	403-579	324-465	321-394	207-341	183-184
LI _{max}	%	75-80	69-71	64-70	81	74-83	74-83	67-93	69-84	68-82	77	72-93	84	75-96	65-87	81
TT _{SD_{max}}	°C.d	690-749	532-543	532-543	690-749	532-543	532-543	399-749	440-848	543-563	450-749	458-644	440-584	440-665	440-665	665-883
No. of crops:		2	2	2	2	2	2	7 to 12	4 to 6	3 to 4	4	4	4	5 to 10	5 to 10	1 to 2

Conclusion

The values of various physiological parameters were determined for different cultivars and evaluated for their suitability to model cultivar-specific canopy development. Among the parameters investigated only maximum leaf size satisfied the requirement for being a useful parameter by being cultivar-specific and stable across environments. The light interception threshold for tillering was stable across environments, suggesting that this could be a useful parameter for simulating shoot dynamics. However, no differences were found for the cultivars tested here. The data obtained from this work will be investigated further to establish the physiological basis of G x E interaction in canopy dynamics.

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