SHORT COMMUNICATION

THE EFFECT OF ROW SPACING ON INTER-ROW COMPETITION IN SUGARCANE

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Abstract

Knowledge of yield response to row spacing in sugarcane is contradictory and lacks understanding of the underlying mechanisms. This communication reports on an investigation into the impact of competition for light on crop development and growth for row spacings ranging from 0.63 to 2.79 m, as observed in an experiment conducted at Mount Edgecombe.

Results show that intra-row interception of radiation peaked at the same time for all row spacings, and coincided with the occurrence of peak tiller population and peak green leaf number. Green leaf number declined sharply when inter-row interception of radiation exceeded 90%, which occurred progressively later as row spacing increased. Aboveground biomass and stalk yield were affected by competition at an early stage. The information obtained in this study could be used to refine and develop new concepts for modelling the effect of row spacing.

Keywords: tiller population, radiation interception, yield, competition, leaf senescence, thermal time, row spacing

Introduction

Information about crop response to row spacing (RS) in sugarcane is contradictory and there is a lack of understanding of the underlying mechanisms of competition between cane rows. For example, Bull and Bull (2000) found a 50% increase in cane yield when RS was reduced from 1.5 to 0.5 m, while others found much lower yield responses (see Singels and Smit, 2002).

This lack of knowledge extends to crop models, which causes uncertainty when these are used for RS sensitive applications. In the Canesim model (Singels and Donaldson, 2000) canopy development (and interception of photosynthetically active radiation, PAR) is driven by thermal time. The RS effect is simulated by adjusting the thermal time requirement to reach 50% canopy by 125ºCd per m change in RS. In the Canegro model (Inman-Bamber, 1991), a more complex approach is followed by simulating the development of individual leaves and tiller cohorts, both driven by thermal time. Leaf area index (LAI) is calculated by multiplying leaf area per tiller by tiller population. Fractional interception of PAR across cane rows (FI_{INTER}) is then calculated according to Beer's law. The RS effect is accounted for by simulating an increase in tiller appearance rate inversely proportional to RS. Tiller population is capped at $30/m^2$.

This communication reports on the impact of RS, through competition for light, on canopy development and yield formation. Field observations are compared with simulated responses from two crop models.

Methods

A field experiment was conducted at Mount Edgecombe (29º42’18,4”S, 31º02’48,5”E, 105 m a.s.l.) on a Mayo (USDA Mollisol) soil type with 35% clay and a 0.5-0.7 m depth. A wagon wheel design was used, with RS ranging from 0.25 to 3.00 m. Cultivar NCo376 was planted on 28 November 2002 and ratooned on 29 August 2003. The crop received adequate water and nutrients, and weeds, pests and diseases were not a factor. The experiment was a follow up from a similar experiment with a plant crop reported by Singels and Smit (2002) and, apart from a few additional measurements, a similar experimental procedure was followed. Briefly, the following parameters were measured regularly:

- The interception of PAR across the inter-row (FI_{INTER}) with a ceptometer. The interception of PAR within the row (FI_{INTRA}) was measured similarly, except for positioning the ceptometer next to and parallel to the cane row.
- The number of emerged leaf tips on a stalk. All leaves with more than 50% green area were counted as green leaves.
- Tiller population.
- Dry aboveground biomass and millable stalk yield on six occasions from 19 January 2004.

Thermal time was calculated as the cumulative (since emergence) sum of daily mean air temperature minus a base temperature of 10ºC (TT10) or 16ºC (TT16). Date of emergence was estimated by retrofit on tiller population data.

The response of the different variables to RS was expressed as the average change in the variable per metre reduction in RS (linear regression), relative to the value measured at the widest RS.

Observed responses in FI_{INTER}, and stalk yield were compared with responses simulated by the Canesim and Canegro models.

Results and Discussion

The TT16 required for FI_{INTER} to reach 50% is a good measure of canopy development rate. This entity’s relationship with RS is shown in Figure 1. The TT16 requirement decreased linearly by 170ºCd (37% per metre reduction in RS) per metre reduction in RS. The corresponding response observed by Singels and Smit (2002) for a plant crop was 230ºCd (33% per m reduction in RS), and took between 150ºCd and 250ºCd (depending on RS) longer to reach FI_{INTER}=50% than the ratoon crop.

The TT16 requirements observed here are higher than those used in the Canesim model (250ºCd at RS=1.4 m), while the response to RS is similar (see Figure 1). Canesim simulates no difference in TT16 requirements for FI_{INTER}=50% for plant and ratoon crops. The corresponding values for the Canegro model are between those observed for the plant and ratoon crop for typical RS, but the response was less than observed.

FI_{INTRA} measured was not affected by RS. The rate of increase over time was the same, and the maximum FI_{INTRA} (defined as values above 0.9) was reached simultaneously for all RS.

Inter-row competition could be identified by considering development and growth per unit row length. A decrease in leaf and/or tiller appearance rate, or an increase in leaf and/or tiller senescence rates, or decrease in biomass or stalk growth, implies increased competition effects from neighbouring rows. This could then be related to the light environment as quantified by FI_{INTER} and FI_{INTRA}.

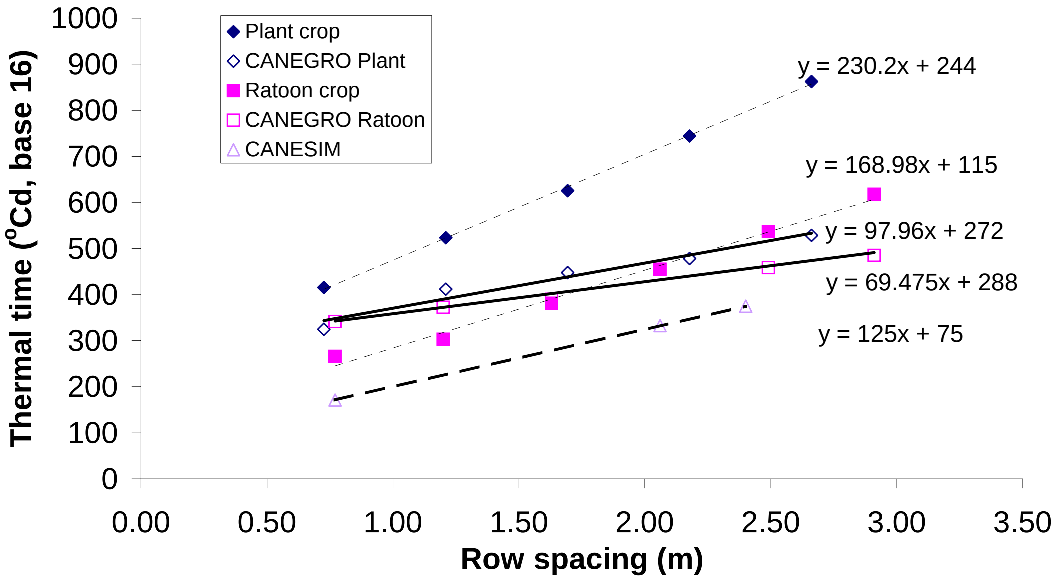

Figure 1. Observed and simulated thermal time requirements to reach 50% interception of PAR in the inter-row in a plant (Singels and Smit, 2002) and ratoon crop as a function of RS.

Leaf appearance rate decreased with decreasing RS (36% per m reduction). The average TT10 requirement for the appearance of a leaf decreased from 79.4ºCd for RS=0.64 m to 62.1ºCd for RS=2.79 m. The maximum number of green leaves was achieved at approximately TT16 = 430ºCd for all RS, which coincided with the occurrence of peak tiller population and maximum FI_{INTRA}. Thereafter the number of green leaves for all RS declined gradually (as is the norm) up to a stage where a drastic correction was observed. The timing of these corrections correlates strongly with the timing of maximum FI_{INTER}. The latter is an indication of when neighbouring rows impacted negatively on light conditions so that fewer green leaves could be maintained. The commencement of this stage occurred earlier as RS decreased (379ºCd (base 16) earlier per m reduction in RS). The size of the correction was inversely proportional to RS, as was the number of green leaves that was maintained after the correction.

Tiller population per metre row length increased at the same rate and reached peak population (Tpeak) at the same time for all RS (at approximately TT16=450ºCd). This was also the case for the plant crop observed by Singels and Smit (2002). The differences in initial tiller population per metre row length inherited from the preceding plant crop, was carried through to Tpeak in the ratoon crop. After Tpeak the narrow RS experienced greater tiller senescence and the survival rate decreased from 37% at RS=2.79 m to 22% at RS=0.64 m.

TPeak coincided with the time of maximum FI_{INTRA} and was independent of RS or FI_{INTER}. Inman-Bamber (1994) reported that Tpeak occurred when FI_{INTER} reached 0.7 in a 1.2 m RS. Instead, the authors postulate that FI_{INTER} is not an appropriate parameter to control tiller phenology across a range of RS, and that net tiller senescence commences when FI_{INTRA} exceeded 0.9.

Biomass and stalk yield per m row length decreased significantly with reduced row spacing from the first sampling onwards, indicating significant impacts on crop growth from inter-row competition between rows. Biomass and stalk yield, when expressed in t/ha, increased on average by 31% and 28% per m reduction in RS, respectively. The response in stalk yield is more than that observed by Singels and Smit (2002) (13% per m reduction in RS) and Boyce (1968) in a plant crop, and less than that measured by Bull and Bull (2000). The response of the Canegro model for the plant and ratoon crop was 11 and 4% per m reduction, respectively.

Conclusions

The main findings from this study are:

- The thermal time requirement to reach 50% canopy decreased by 170ºCd per m reduction in RS.
- Intra-row interception of PAR peaked at the same time for all RS, and coincided with the occurrence of peak tiller population and peak green leaf number.
- Green leaf number declined sharply when inter-row interception of PAR exceeded 0.9. This occurred progressively later as RS increased.
- Aboveground biomass and stalk yield were affected by competition at an early stage. However, both parameters responded positively to a reduction in row spacing when expressed per unit area.

The information obtained in this study could be used to refine and develop new concepts for modelling the effect of row spacing on crop growth and yield.

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