THE RELATIONSHIP BETWEEN TILLER POPULATION DEVELOPMENT PARAMETERS AND CANE YIELD OF SUGARCANE

By

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Abstract

TILLERS are a major component of a sugarcane crop canopy and factors that affect tillering affect radiation interception and cane yield. The objective of this research was to examine the relationship between a number of parameters associated with tiller development and cane yield. Experiments were conducted at the Zimbabwe Sugar Association Experiment Station (ZSAES) and planted in autumn, mid-winter and spring viz. March, July and October, respectively. Cultivars ZN6, ZN7, N14, and NCo376 were studied. Tillers were counted from shoot emergence until 12 months crop age and parameters were derived from the tiller population curve. Tiller population development parameters studied were PTP (peak tiller population), FTP (final tiller population), TTTP (thermal time to peak tiller population), TTPT (thermal time per tiller) and TSR (tiller survival rate). Parameters TTTP, TTPT, PTP and TSR were highly correlated to cane yield while FTP was poorly correlated to cane yield. However, combined trendlines for all cultivars for TTTP and TSR showed poor correlations to cane yield. Strong cultivar controls exist for parameters TTPT, PTP, and TSR. PTP appears the most likely parameter with potential for use in yield selection, as it is highly correlated to cane yield and is quicker and easier to measure than the other parameters.

Introduction

Tillers form the above ground portion of the sugarcane plant that carries the leaves and the flowers (King et al., 1965; Singels and Smit, 2002). Tiller growth in sugarcane constitutes the major sink for photosynthate.

The tiller population supports the leaf canopy that generates the potential source of photosynthate. Factors that affect tiller population also affect light interception and consequently cane production.

Among these factors are crop nutrition, (Moberly, 1971; Moberly and Stevenson, 1971), trash management (Thompson, 1965), crop rotation (Garside et al., 2001), water (Thomas et al., 1978; Thompson and du Toit, 1965), genotype (SASEX, 2001; Zhou, 2003b), crop management (Braunack and Hurney, 2000), row spacing (Mali and Singh, 1988; Irvine et al., 1980) and seasons (Inman-Bamber, 1994).

Barnes (1964) noted that the extent of tillering and tiller survival to maturity is a clonal character that is influenced by climatic, soil and nutrient conditions.

Van Dillewijn (1952) identified light intensity and day length as the most important factors influencing tillering, and Inman-Bamber (1994) reported that higher order tillers would senesce rapidly when total radiant energy interception exceeds 70%.

The spatial dynamics of tillering, senescence, light interception and energy conversion is important to the understanding and modelling of the source-sink relationship.

The understanding of the seasonal effects on the tillering of cultivars would also improve the modelling of clonal differences in canopy development that should in turn improve the modelling of the source-sink relationships of different cultivars and possibly improve the prediction of cane yield.

Zhou et al. (2003) and Inman-Bamber (1994) defined the cultivar control of tillering. What is not clear is how the cultivar control of the tillering process affects cane yield. Zhou et al. (2003) defined peak tiller population (PTP), final tiller population (FTP), thermal time to peak tiller population (TTTP), thermal time per tiller (TTPT) and tiller survival rate (TSR) as tiller population development parameters. Table 1 defines these parameters.
Table 1—Description of tiller population development parameters.

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter description</th>
<th>Units</th>
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<tbody>
<tr>
<td>PTP</td>
<td>Peak tiller population</td>
<td>Number</td>
</tr>
<tr>
<td>FTP</td>
<td>Final tiller population at harvest</td>
<td>Number</td>
</tr>
<tr>
<td>TTTP</td>
<td>Thermal time required to reach peak tiller population</td>
<td>°C.day</td>
</tr>
<tr>
<td></td>
<td>accumulated from date of emergence (Tbase = 16°C)</td>
<td></td>
</tr>
<tr>
<td>TTPT</td>
<td>Thermal time required to produce one tiller (Tbase = 16°C)</td>
<td>°C.day</td>
</tr>
<tr>
<td>TSR</td>
<td>The number of millable tillers at harvest expressed as</td>
<td>Fraction</td>
</tr>
<tr>
<td></td>
<td>a fraction of the peak tiller population</td>
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The objective of this research was to examine the relationship between tiller population development parameters and cane yield of four cultivars grown under irrigation in the South East Lowveld of Zimbabwe.

Materials and methods

Experimental details

Data were collected from experiments at the Zimbabwe Sugar Association Experiment Station (ZSAES) 21°01'S Lat., 28°38' E Long., and 430 m altitude. The experiments were conducted on a sandy clay loam soil (24% clay, 7% silt, and 69% sand) and the crop was furrow irrigated. Water was applied to avoid water stress. All the experiments were in the plant crop cycle.

Experiments 1 and 3 were replicated; Experiment 2 was not. The designs for Experiments 1 (5 replicates) and 3 (3 replicates) were randomised blocks. Experiment 1 was planted on 19 October 2001 (late season planting), Experiment 2 on 20 March 2002 (early season planting) and Experiment 3 on 6 July 2002 (mid-season planting).

The plot sizes were 13 rows 1.5 m wide by 12 m long. Rows 1 to 6 were used for pre-harvest destructive sampling while rows 7 to 13 were harvested and weighed after 12 months of crop development.

Fig. 1—The long-term means (1970–2003) for minimum and maximum air temperature °C for Zimbabwe Sugar Association Experiment Station.
The cultivars were planted using two cane setts laid side by side in the bottom of the planting furrows. Single superphosphate (18% P₂O₅) fertiliser was applied in the furrow at a rate of 100 kg P₂O₅/ha before planting. Potassium was applied as muriate of potash (60% K₂O) at 60 kg K₂O/ha four weeks after crop emergence. Nitrogen was applied as ammonium nitrate (34.5% N) at 140 kg N/ha, in split applications of 60 kg N/ha at four weeks after emergence and 80 kg N/ha at eight weeks after emergence.

Data collection
Weather data for maximum and minimum temperatures were collected from a weather station at ZSAES and located 700 m from the experimental site. Long-term weather data for the site are in Figure 1 to show the temperature through which each crop developed.

The sampling units, marked with wooden pegs, were pre-determined and randomly scattered in the sampling rows of each plot. The sampling units were randomly scattered in the sampling plot. The sampling unit consisted of one running metre in the cane row with one metre guard area on all sides of the sampled area. All the cane in the one metre was cut and taken to a shed where the number of tillers per sample was counted. Sampling was done every 14 days until the crop was harvested. Care was taken to avoid uprooting setts during early sampling.

Calculations
The peak tiller population (PTP) was determined as the peak of the tiller population development curve. Thermal time to reach peak tiller population (TTTP) was determined as the thermal (Tbase = 16°C) from 50% emergence of planted eyes to the peak of the fitted polynomial equation. The final tiller population (FTP) was determined as the tiller population at 12 months from the fitted tiller population curve. The thermal time per tiller was calculated as the thermal time between 50% emergence of planted eyes and TTTP divided by the number of tillers produced during that period. Tiller survival rate (TSR) was calculated as the FTP divided by PTP. The cane yield means for each cultivar-planting date were regressed against the tiller population development parameters.

Results and discussions
Thermal time required to reach peak tiller population (TTTP)
The TTTP was greatest in October and lowest in July for all cultivars, except for N14 (Table 2). There was a negative correlation in TTTP and cane yield (Figure 2 and Table 2).

![Graph](image-url)
The ability of a cultivar to attain peak tiller population quicker might be important for producing high cane yield. Low population cultivars (ZN6 and ZN7) had higher correlations between TTTP and cane yield. The combined cultivar trendline was lower, the R² between TTTP and cane yield indicating possible cultivar control of the relationship between TTTP and cane yield. Generally, the cane yield of all cultivars appeared to decrease as the TTTP increased.

**Thermal time per tiller (TTPT)**

The TTPT increased from March to October planted crops. The October planted crops had almost double the TTPT of the July crop (Table 2). The conditions conducive to rapid tillering are likely to occur to March planted crops, while the October planted crops had the least favourable. There was a high and negative correlation between TTPT and cane yield for all cultivars (Figure 3 and Table 2).

The combined trendline showed high negative correlation between TTPT and cane yield indicating that generally faster tillering may result in higher cane yield. This may also be indicating the possible seasonal influence on both TTPT and cane yield. However, the combined correlation had much lower R² than that of individual cultivar correlation indicating possible cultivar control of the relationship between TTPT and cane yield.

![Graph showing correlation between cane yield and thermal time per tiller (TTPT)](image)

**Peak tiller population (PTP)**

The peak tiller population (PTP) decreased from March to October planted crops for all cultivars (Table 2). This indicates the date of planting resulted in subsequent seasonal influence on tillering of sugarcane, which in turn determined the maximum number of tillers that can be produced by a cultivar. There were strong positive correlations between PTP and cane yield for all cultivars (Figure 4).

High population cultivars (N14 and NCo376) had high correlations between PTP and cane yield compared to low population cultivars (ZN6 and ZN7). This could mean that the effect of PTP on cane yield could be more predictable on high population cultivars (N14 and NCo376) than low population cultivars.
(ZN6 and ZN7). The combined trendline showed high correlation that was less than the individual cultivars. This meant that generally, as PTP increased, cane yield was likely to be increased. The lower correlations compared to individual cultivars indicated the possible cultivar control of the relationship between PTP and cane yield.

\[ y = 1.47x + 71.24 \]
\[ R^2 = 0.81 \text{ (ZN6)} \]
\[ y = 1.61x + 84.57 \]
\[ R^2 = 0.84 \text{ (ZN7)} \]
\[ y = 1.81x + 92.60 \]
\[ R^2 = 0.99 \text{ (N14)} \]
\[ y = 0.87x + 105.07 \]
\[ R^2 = 0.91 \text{ (NCo376)} \]
\[ y = 1.54x + 84.53 \]
\[ R^2 = 0.62 \text{ (combined)} \]

![Graph of cane yield and peak tiller population](image)

**Fig. 4—Cane yield of cultivars ZN6, ZN7, N14 and NCo376 plotted against peak tiller population.**

**Final tiller population (FTP)**

The final tiller population (FTP) for cultivars ZN6 and ZN7 decreased from the March to the October planted crops. Cultivars N14 and NCo376 had their lowest FTP in July and increased towards March and October planted crops (Table 2).

The cane yield of low-population cultivars (ZN6 and ZN7) was more correlated to FTP than that of high population cultivars (N14 and NCo376) (Figure 5 and Table 2). This may indicate that the low cane yield of low population cultivars was more likely to be sensitive to fluctuations in final tiller population than high population cultivars.

The tiller survival rate of high population cultivars increased by 88% compared to 54% for low population cultivars from July to October, indicating that the final tiller population of high population cultivars was less sensitive to times of planting than the low population cultivars. Therefore, with high population cultivars, more tillers were likely to survive under unfavourable conditions and, therefore, result in potentially high cane yield production. Zhou (2003a) showed that high stalk population was associated with high cane yield.

The high population cultivars increased their stalk population in late harvests and thus minimised yield reduction. The poor correlation of the combined trendline indicated the possible cultivar control of the relationship between FTP and cane yield.

Generally, Figure 5 showed that as the FTP increased, cane yield increased. The low population cultivars generally produced lower cane yield than high population cultivars in this study (Table 2 and Figure 5). The scatter of the trendlines for all cultivars reaffirms the strong cultivar control of FTP reported by Inman-Bamber (1991, 1994) and Zhou et al. (2003).
The tiller survival rate (TSR) increased from March to October. The October planted crops had at least 50% greater TSR than those of the July planting while the difference between the March and July TSR was smaller (Table 2).

The higher TSR in October was caused by the lower PTP while the March TSR is lowered by the higher PTP.

It appears the relationship between TSR and cane yield is controlled by seasonal effects through the seasonal control on PAR and PAR control on movement of plant growth regulations that control tillering (van Dillewijn, 1952).

There were strong correlations between TSR and cane yield with low population cultivars (ZN6 and ZN7) showing greater correlations compared to high populations cultivars (N14 and NCo376). The consistent decline in FTP observed in low population cultivars (ZN6 and ZN7) (Figure 5) explained this pattern.

There were negative correlations between TSR and cane yield for all cultivars (Figure 6). High tiller survival rates are associated with low PTP that occurred in October planted crops where low cane yields were measured.

The combined trendline had lower correlations compared to individual cultivars indicating the possible cultivar control of the relationship between TSR and cane yield.

The decrease in cane yield associated with an increase in TSR indicated the strong seasonal influence on the relationship between TSR and cane yield.
Conclusions

The data showed that parameters TTPT, PTP and TSR were strongly correlated with cane yield for individual cultivars. The low correlations between the parameters and cane yield of combined data indicated the possible cultivar control of these parameters. TTPT and FTP had low correlations to cane yield for combined data indicating possibly unclear seasonal effects and cultivar control. Rapid tillering and
high peak tiller population appear to be important for producing high cane yield. TSR appears important in determining the FTP compensation ability of cultivars and, possibly, the cane yield compensation ability under unfavourable tillering conditions.

High population cultivars appeared better at increasing FTP through increasing TSR than low population cultivars. The strong correlations of TTPT, PTP, and TSR to cane yield indicates the possibility of their use as selection parameters for cane yield in crop improvement programs. PTP appears the most likely candidate for use in selection programs, as it is easier and quicker to determine compared to other parameters. There is a possibility to use these parameters in modeling seasonal cultivar differences in tiller development.

Recommendations for further research

These data were limited to three planting dates and four cultivars. The challenge is to repeat the work with more clones/cultivars and more planting times to establish the ranges of seasonal and cultivar variations.

There is need to test the ability of these parameters to identify high cane yield clones at the single stool and single line stages of sugarcane selection programs where plots are not replicated. The heritability and repeatability of the above parameters need to be investigated.

REFERENCES


LA RELATION ENTRE LES PARAMÈTRES DE L'ÉVOLUTION DE LA POPULATION DES TIGES PENDANT LE TALLAGE ET LE RENDEMENT DE LA CANNE À SUCRE

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Résumé

LES TALLES sont une composante principale de la voûte foliaire d'une culture de canne et les facteurs contrôlant le tallage affectent aussi l'interception de la radiation solaire et le rendement. L'objectif de cette étude était d'examiner la relation entre un nombre de paramètres associés au développement des talles et au rendement de la canne. Des essais ont été entrepris au Zimbabwe Sugar Association Experiment Station (ZSAES) avec les variétés ZN6, ZN7, N14 et NCo376, plantées en automne, mi-hiver et au printemps, notamment en mars, juillet et octobre respectivement. Les talles ont été comptées dès leur émergence et ce jusqu'à l'âge de 12 mois et des paramètres ont été dérivés à partir de la courbe de tallage. Les paramètres étudiés sont la population maximale (PTP), la population finale (FTP), le besoin thermique pour atteindre la population maximale (TTTP), le besoin thermique d'une talle (TTPT) et le taux de survie des talles ( TSR). TTP, TTTP, PTP et TSR sont fortement corrélés au rendement de la canne tandis que FTP l'est faiblement. Toutefois, les tendances toutes paramètres confondues pour le TTP et le TSR démontrent une faible corrélation avec le rendement. Des variétés pouvant être utilisées avec fiabilité comme témoin existent pour le TTPT, FTP et TSR. FTP se présente comme le meilleur paramètre possédant un potentiel pour être utilisé dans la sélection pour le rendement car il lui est fortement corrélé et est rapidement ainsi que facilement mesurable comparé aux autres paramètres.

LA RELACIÓN ENTRE LOS PARÁMETROS DE DESARROLLO DE LA POBLACIÓN DE BROTES Y LA PRODUCCIÓN DE CAÑA DE AZÚCAR

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PALABRAS CLAVES: Brote, Población, Desarrollo, Parámetros, Cultivares.

Resumen

LOS BROSÜÈ son un componente importante de la cubierta foliar de la caña de azúcar que afectan el macollamiento, la interceptación de la radiación y la producción de caña. El objetivo de este estudio fue examinar la relación entre una serie de parámetros asociados con el desarrollo de los brotes y la producción de la caña. Los experimentos fueron realizados en la Estación Experimental de la Asociación del Azúcar de Zimbabwe (ZSAES) y sembrados en otoño, mitad de invierno y primavera o Marzo, Julio y Octubre, respectivamente. Los cultivares estudiados fueron ZN6, ZN7, N14, y NCo 376. Los brotes fueron contados desde su emergencia hasta los 12 meses de edad y los parámetros fueron derivados de la curva de la población de los brotes. Los parámetros sobre el desarrollo de la población de brotes estudiados fueron PTP (población máxima de los brotes), FTP (población final de los brotes), TTTP (tiempo termal de la población máxima de los brotes), TTPT (tiempo termal por brote) y TSR (tasa de supervivencia de los brotes). Los parámetros TTTP, TTPT, FTP y TSR estuvieron altamente correlacionados con la producción de caña mientras que el FTP tuvo muy baja correlación con la producción de caña. Sin embargo, las interacciones para todos los cultivares para TTTP y TSR mostraron correlaciones muy pobres con la producción de caña. Existen relaciones fuertes en los cultivares por los parámetros TTTP, FTP, y TSR. El parámetro de FTP parece ser el que tiene mayor potencial para usarlo en la selección por producción, puesto que están muy bien correlacionados con la producción de caña y son más rápidos y fáciles de medir que los otros parámetros.