SILICON FERTILISATION IN PLANT CANE AND FIRST RATOON: SOIL AVAILABILITY, PLANT UPTAKE, CROP YIELD AND STALK BORER DAMAGE

By

M.S. de CAMARGO¹ and G.H. KORNDÖRFER²

¹Agência Paulista de Tecnologia dos Agronegócios-APTA Pólo Centro Sul, Brazil
²Universidade Federal de Uberlândia, Brazil

¹mscamarg@yahoo.com.br; ²ghk@uber.com.br

KEYWORDS: Yield, Cultivar, Nutrition, Fertilisation, Monocots, Diatraea saccharalis.

Abstract

SILICON (Si) is a beneficial element in sugarcane, but there are few studies in Brazil. The objectives of this study were to evaluate the effect of calcium (Ca) magnesium (Mg) silicate applied in the furrow at planting on the available Si in the soil, sugarcane yield and stalk borer (Diatraea saccharalis F.) damage in two sugarcane cultivars. The experiments were carried out on plant cane from March, 2009 through to August, 2010 and first ratoon from August, 2010 through to August, 2011. The soil was a Rhodic Haplustox (soluble Si in 0.5 mol/L acetic acid = 6.9 mg/kg Si and in 0.01 mol/L CaCl₂ = 2.9 mg/kg Si). The experiment was a completely randomised factorial design with four replications, four Si rates (0, 55, 110 and 165 kg/ha Si) and two cultivars: IAC 86 3396, (resistant to stalk borer) and SP 89 1115 (susceptible to stalk borer). The source of silicon was Ca-Mg silicate (262.1 g/kg Ca; 56.8 g/kg Mg; 108.4 g/kg Si) applied in the furrow at planting. All plots received the same amount of Ca and Mg using additional lime and/or MgCl₂ when necessary. The silicate application increased soluble Si in the soil (0–25 cm), and reduced stalk borer damage in plant cane and first ratoon for both cultivars. Silicon extracted by both extractants (0–25 cm; 25–50 cm soil depth) and cane yield of SP 89 1115 were also increased with increasing rates of silicate, whereas borer damage was reduced in this cultivar in the first ratoon. Silicon fertilisation applied in the furrow at planting confirmed the possibility of increasing Si availability, sugarcane yield and reducing stalk borer damage with strong residual effects on these response variables in the first ratoon.

Introduction

Silicon (Si) is not an essential plant element (Epstein, 1999), but Si-accumulating plants such as sugarcane could exhibit reduced yields associated with intensive management and monoculture in soils with low silicon contents (Berthelsen et al., 1999). Several soils are used in sugarcane cropping in Brazil, including those characterised by low fertility and low Si contents, but there is little information about Si fertilisation.

Positive results have been obtained with silicon application to sugarcane in many countries, including Brazil (Savant et al., 1999; Kingston et al., 2005; Silveira et al., 2003). Most of these results were not exclusively due to silicon because the high rates of silicate can improve pH, Ca, and Mg contents. Silicate fertilisation applied in the furrow at planting could be useful to provide Si to plants and to reduce the cost of this product used at rates similar to lime (>2 or 3 t/ha) covering the whole area.

Another benefit of silicon for sugarcane is the possibility of reducing insect damage as already shown for ‘African stalk borer’ Eldana saccharina Walker (Keeping and Meyer, 2006;
Kvedaras et al., 2005). Silicate applications could also reduce the damage of sugarcane stalk borer Diatraea saccharalis F. (Lepidoptera: Pyralidae) as shown by Elawad et al. (1982) but there is little information about this subject in Brazil.

The objectives of this study were to evaluate the effect of a Ca-Mg silicate applied in the furrow at planting on the available Si in the soil, sugarcane yield and stalk borer (D. saccharalis) damage in two sugarcane cultivars.

Materials and methods

The experiments were conducted in plant cane (March/2009 to August/2010) and first ratoon (August/2010 to August/2011) in a commercial area located at Piracicaba, São Paulo state, Brazil. Chemical analysis of the Rhodic Haplustox soil (0–25 cm depth) was performed and the results were: organic matter = 16 g/dm³; P extracted by anionic exchange resin = 14 mg/dm³; K = 1 mmolc/dm³; Ca = 22 mmolc/dm³; Mg = 7 mmolc/dm³; CEC = 55 mmolc/dm³; Base saturation = 55%; Si extracted by 0.5 mol/L acetic acid = 6.9 mg/kg Si; Si extracted by 0.01 mol/L CaCl₂ = 2.9 mg/kg Si. The physical analysis revealed clay = 160, loam = 20 and sand 820 g/kg.

A completely randomised factorial design was used with four replications, four Si rates (0, 55, 110 and 165 kg/ha Si) and two cultivars: IAC 86 3396, (resistant to D. saccharalis, Sugarcane Center, Agronomic Institute-IAC) and SP 89 1115 (susceptible to D. saccharalis, Sugarcane Technology Center-CTC). The source of silicon was a Ca-Mg silicate Harsco® (262.1 g/kg Ca; 56.8 g/kg Mg; 108.4 g/kg Si) applied in the furrow at planting. All plots received the same Ca and Mg quantities with additions of lime (320 g/kg Ca, 9.6 g/kg Mg) and/or MgCl₂ (11.9% Mg) when necessary.

During sugarcane planting (March, 2009), the treatments were applied in the furrow and the soil was fertilised based upon soil analysis (Raij et al., 1997). Rates of 40 kg/ha of N, 100 kg/ha of P₂O₅ and 100 kg/ha of K₂O (10-25-25) were used for planting fertilisation. Each plot had 5 rows measuring 10 m. The surface nitrogen (40 kg/ha of N; ammonium sulfate, 20% N) and potassium fertilisation (KCl, 60% K₂O) took place 30 days after planting. During the first ratoon, the surface fertilisation with N and K was performed according to Raij et al. (1997) for first ratoon.

Before harvest of both plant cane (01/07/09) and first ratoon (15/08/10), sugarcane samples were taken from one metre of two central rows in order to evaluate stalk borer damage. The evaluation of the percentage of bored internodes was performed in twenty stalks from central rows of sugarcane. The harvest of each plot was performed on July 01, 2009 (plant cane) and on August 13, 2010 (first ratoon) by weighing the chopped cane in a truck equipped with a scale.

The sugarcane yield (tonnes of sugarcane stalks per hectare) was estimated by weight of each plot. After harvesting, soil sampling (0–25; 25–50 cm depth) was done by collecting samples from the three central rows of each plot. The Si concentration in the soil was determined using the acetic acid (0.5 mol/L) and CaCl₂ (0.01 mol/L) extraction methods, according to Korndörfer et al. (1999). Data were subjected to analysis of variance by F test. The cultivars were compared by the Tukey test and rates by polynomial regression.

Results and discussion

The soluble silicon (Si) extracted by 0.5 mol/L acetic acid and CaCl₂ in samples collected after harvest of plant cane and first ratoon was influenced by rates of silicate (Figure 1); however, differences in soluble Si between cultivars were not observed. Thus means of both cultivars were used for soil Si graphs (Figure 1A-E). The application of silicate increased soil silicon extracted by 0.5 mol/L acetic acid in samples collected at 0–25 cm depth after harvest of the plant crop (Figure 1A). The Si extracted by both extractants in soil (0–25 cm; 25–50 cm) was also increased after the first ratoon (Figures 1B, 1C, 1D and 1E).
The CaCl₂ extraction showed no increase in soil Si concentration during the plant crop, which could be related to the lower extraction power compared to acetic acid (Camargo et al., 2007). Soluble Si content using both extractants were lower in the first ratoon, which could be related to high Si uptake by sugarcane, as already reported (Berthelsen et al., 1999; Camargo et al., 2011). These data show the importance of Si fertilisation in soils with low Si content to sugarcane.

Superior yield (tonnes cane/ha) was observed for SP89 1115 in plant cane (Table 1), despite the occurrence of orange rust, *Puccinia kuehnii* (W. Krüger) E.J. Butler, in both plant cane and first ratoon.

**Table 1**—Yield, stalk borer damage and fibre after harvest of plant cane and first ratoon.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Plant cane</th>
<th>First ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield</td>
<td>Bored internodes</td>
</tr>
<tr>
<td></td>
<td>t/ha</td>
<td>%</td>
</tr>
<tr>
<td>IAC873396</td>
<td>154.26b</td>
<td>4.69b</td>
</tr>
<tr>
<td>SP891115</td>
<td>166.02a</td>
<td>24.32a</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.02</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Means followed by the same letter in the column do not differ by Tukey test (p<0.05).
Rust incidence could explain the better productivity for IAC 87 3396 in the first ratoon. Rates of Si increased yield (tonnes cane/ha) in plant cane for both cultivars (Figure 1 F) and this trend was also true for SP89 1115 in the first ratoon crop (Figure 1G), showing a positive effect of silicon fertilisation on sugarcane productivity and a residual effect on yield, in agreement with earlier studies (Kingston et al., 2005; Korndörfer et al., 2000). An increase in sugarcane yield was also observed by Camargo et al. (2011) when sugarcane was grown in low soluble Si soil with silicate application (rates up to 165 kg/ha Si) in the furrow at planting. Although positive results were obtained on yield, no differences were observed on sucrose (data not shown).

The stalk borer incidence was higher in SP 89 1115 than IAC 87 3396 in both plant cane and first ratoon (Table 1). Despite the differences in fibre percentage between cultivars, silicon application reduced stalk borer damage in plant cane in both cultivars (Figure 1H, I. The effect of Si application in soil of decreasing stalk borer damage observed in this experiment was also reported by Elawad et al. (1982) to D. saccharalis and by Kvedaras et al. (2005) and Keeping and Meyer (2006) to E. saccharina

Conclusions

Silicon fertilisation applied in the furrow at planting confirmed the possibility of increasing Si availability in the soil, increasing sugarcane yield, and reducing stalk borer damage with a strong residual effect in the first ratoon.

Acknowledgements

The authors wish to thank the State of São Paulo Research Foundation (FAPESP) for financial support, COSAN (Costa Pinto Sugar Mill) for providing the experimental area, and Agronelli, Brazil for supplying silicate for the experiment.

REFERENCES


Silveira, E.G., Korndörfer, G.H., Penati, C. and Camargo, M.S. Silicato de cálcio e calcário na produção e qualidade da cana-de-açúcar. [Calcium silicate and lime on yield and quality of sugarcane]. In: Brazilian Soil Science Congress, 29., 2003, Ribeirão Preto, SP, Brazil. Proceedings. CD-ROM.
EVALUATION OF FROST DAMAGE AND COPING STRATEGIES ON SUGARCANE PRODUCTION IN IRAN

By

M.A. KARAMVAND\(^1\), L. ABDOLLAHI\(^2\), F. YARAHMADI\(^1\), M.R. GASEMI\(^1\) and A. SORAGHI\(^1\)

\(^1\)Applied Research Center, Deabel Khozaei Agro-industrial Co. Ahwaz, Iran
\(^2\)Aarhus Univ., Dep. of Agroecology, Blicher Allé 20, P.O. Box 50, DK-8830 Tjele, Denmark
Email: Mojtaba Abdi Karamvand, m.a.k.1354@gmail.com

KEYWORDS: Iran, Sugarcane, Frost, Quality Indicators of Syrup, Hilling-Up.

Abstract

SUGARCANE FIELDS IN IRAN suffer from irreparable frost damage. This study aimed to determine and describe the effects of frost on aerial plant parts, impacts of these adverse environmental factors on syrup quality in different cultivars, and provide coping strategies and reduce losses. This study was done over several years (2004–2012). Damage to aerial plant parts was evaluated in the study. Based on field observation and sampling, it was determined that several of the farms have been damaged by frost. In order to determine the frost effects on syrup qualitative and quantitative indicators, samples from sugarcane fields with different varieties were taken before and after frost. Also, under laboratory conditions, effects of temperatures below and above freezing (−0.5 and +0.5 degree Celsius for 2 hours) on the lateral buds of different cultivars (CP 69-1062, CP 57-614, CP 48-103) were evaluated. Results indicated that frost (down to −4.5 °C in winter 2012) resulted in serious damage to the aerial parts of cane plants especially on the apical meristem. Quality and quantity of syrup was also affected, with syrup purity and other quality parameters being reduced with frost damage. The results from laboratory studies indicated that lateral bud germination was reduced and delayed, but in total after three weeks on average more than 88% of buds germinated and continued to grow despite exposure to low temperatures. Irrigation 1–3 days before freezing will reduce cold damage by creating favourable conditions for heat exchange between the air and ground. Also, hilling up operations before frost were shown to reduce frost damage significantly by putting a thin layer of soil on the apex.

Introduction

Khuzestan is the origin of sugarcane planting in Iran. It is located in the south of Iran and has a dry and hot climate especially in summer. During the winter, short periods of frost have severe impact on sugarcane yield. Initial effects of frost appear on leaves (Tai and Lentini, 1985, Samuir et al., 2001; Roth, 1966). Sugarcane exposure to low temperatures for three weeks will reduce shoot number, height, weight, and ultimately stem sugar content (Tai and Lentini, 1985; Samuir et al., 2001). In partial freezing of (−1 °C) for a few hours, chlorosis or burned spots on leaf tips may appear which have no effect on lateral buds. Low temperatures between −2 to −4 °C for a few hours kill the lateral buds, while lower temperatures between −4 to −5 °C kill apical as well as all lateral buds. Frost below −6 °C resulted in the loss of all the leaves, buds and stem tissue near to the soil surface (Tai and Lentini, 1985). The effect of frost on ratoon crops is more severe than the plant crop (Ranger et al., 1969).

Frost damage is mainly related to the duration of freezing rather than the lowest temperature (Roth, 1966). Freezing also causes drastic changes in the quality of sugar cane syrup (Majid, 2007).
After freezing, the damaged cells are exposed to decomposing bacteria, *Leuconostoc mesenteroides*. The bacteria consume sucrose and produce dextran (Eggleston *et al.*, 2003) which reduces the quality of cane syrup.

The aim of this study was to determine and describe the effects of frost on the aerial parts of plants and syrup quality in Iran, and offer coping strategies to protect sugarcane against these adverse environmental impacts.

**Materials and methods**

During a 3-month period, cane stalks from 270 sugarcane farms (each farm 25 hectares) including different varieties (CP 69-1062, CP 57-614, CP 48-103), were sampled before and after a frost event (one month before to two months after the frost, December to February) on a daily basis.

Sample extracts were taken and analysed in the laboratory for qualitative and quantitative indicators of syrup that include % Purity (the percentage of sucrose in the total solids in a sample), POL factor (a measure of the concentration of sucrose %), BRIX (dissolved solid material in the juice), QR, % Yield (yellow sugar resulting from 100 tonnes sugarcane), % RS and % Syrup.

Results were averaged and compared for each week and each month before and after the frost event. In addition, in different farms, the effect of frost on the appearance of the sugarcane plant following different field operations, including irrigated or not irrigated, hilling up or no hilling up, ratooned or not ratooned and with trash or without trash, were studied.

Also, under laboratory conditions, effects of temperatures below and above freezing (–0.5 and +0.5°C for 2 hours) on the lateral buds of different cultivars (CP 69-1062, CP 57-614, CP 48-103) were evaluated.

**Results and discussion**

**Field observation**

Results indicated that frost (down to –4.5°C in winter 2012) resulted in serious damage to the aerial parts of cane plants especially on the apical meristem (Table 1).

**Syrup and cane quality**

Results indicated that, two months after the frost event, syrup quality factors including the Pol factor, Purity, Brix, Yield %, RS % and Syrup % were reduced in CP 69-1062 and CP 48-103 varieties, from 7.1–18.7% and 2.1–14.3% for both varieties, respectively.

Quality decreases in variety CP 69-1062 were 57–70% more than that for variety CP 48-103 (Table 2), meaning that variety CP 69-1062 was more susceptible to frost than CP 48-103. Additionally, two months after the frost event, the ratio of invert sugar to sucrose (a factor calculated from Acidity % and Invert %) and QR factor increased in both varieties, indicating the detrimental impacts of frost on syrup quality as well (Table 2). The comparison of the percent of extracted juice from cane samples also indicated the adverse effects from frost.

Results showed a 13% and 8.2% decrease in the amount of juice per kg of cane stalk in CP 69-1062 and CP 48-103, respectively. The comparison of the loss in stalk weight before and two months after the frost indicated 15.7% and 14.3% weight loss in CP 69-1062 and CP 48-103, respectively. This finding corresponds to the results from Majid (2007).

**Coping strategies**

Results of this study showed irrigation 1–3 days before freezing will reduce frost damage by creating favourable conditions for heat exchange between the air and ground (Table 1). However, the protective effect of irrigation varied among different soil types and varieties (Figure 1). Also, hilling up operations supplemented with irrigation before frost was shown to reduce frost damage from 85 to 25% (Table 1) by putting a thin layer of soil on the apex.
Hence, disturbing soil structure after ratooning and hilling up operations increased the adverse effects of frost due to increasing porosity and diminishing heat exchange. Considering this result, one of the coping strategies would be avoiding soil disturbing operations prior to any foreseeable frost unless a preceding irrigation operation is applicable.

**Table 1**—frost damage to sugarcane aerial parts and apical meristem in different field operations.

<table>
<thead>
<tr>
<th></th>
<th>Ratooning</th>
<th>Hilling up</th>
<th>Irrigation</th>
<th>Trash</th>
<th>Aerial damage %</th>
<th>Meristem damage %</th>
<th>Stalk length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Harvested field</strong></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>60%</td>
<td>40%</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>√</td>
<td>–</td>
<td>20%</td>
<td>5%</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>√</td>
<td>90%</td>
<td>60%</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>Plant crop</strong></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>100%</td>
<td>70%</td>
<td>5</td>
</tr>
<tr>
<td>(new cultivation)</td>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>90%</td>
<td>80%</td>
<td>26.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
<td>70%</td>
<td>52%</td>
<td>22.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
<td>90%</td>
<td>80%</td>
<td>26.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>25%</td>
<td>15%</td>
<td>23.1</td>
</tr>
<tr>
<td><strong>Seed cane fields</strong></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
<td>100%</td>
<td>79%</td>
<td>27.8</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>√</td>
<td>–</td>
<td>80%</td>
<td>90%</td>
<td>25.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
<td>100%</td>
<td>80%</td>
<td>32.6</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>√</td>
<td>–</td>
<td>60%</td>
<td>20%</td>
<td>33.4</td>
</tr>
</tbody>
</table>

Sugarcane harvesting without burning leaves large quantities of trash on the field surface. It was hypothesised that leaving this mass of trash on the field surface hinders heat exchange and strengthens the negative effects of frost. Results of this study validated this hypothesis (Table 1). Removing the trash resulted in better cane growth and leaving the trash increased the adverse effect of the frost (Figure 2).

**Table 2**—Comparison of syrup quality indicators (averaged) before and after frost in two commercial varieties CP69-1062 and CP48-103.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Before frost</th>
<th>1 month after frost</th>
<th>2 months after frost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CP 69-1062</td>
<td>CP 48-103</td>
<td>CP 69-1062</td>
</tr>
<tr>
<td>Pol</td>
<td>17.6</td>
<td>16.6</td>
<td>16.8</td>
</tr>
<tr>
<td>Brix</td>
<td>19.8</td>
<td>18.9</td>
<td>19.4</td>
</tr>
<tr>
<td>Pty%</td>
<td>88.5</td>
<td>88.1</td>
<td>86.5</td>
</tr>
<tr>
<td>Stalk weight (kg)</td>
<td>0.70</td>
<td>0.60</td>
<td>0.63</td>
</tr>
<tr>
<td>QR</td>
<td>7.7</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Yield %</td>
<td>13.2</td>
<td>12.4</td>
<td>12.4</td>
</tr>
<tr>
<td>RS %</td>
<td>10.9</td>
<td>10.3</td>
<td>10.3</td>
</tr>
<tr>
<td>Syrup</td>
<td>36.7</td>
<td>37.1</td>
<td>34.6</td>
</tr>
<tr>
<td>Invert %</td>
<td>0.29</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td>Acidity%</td>
<td>1.12</td>
<td>1.01</td>
<td>1.43</td>
</tr>
</tbody>
</table>
Laboratory studies
The results from laboratory studies indicated that lateral bud germination was reduced and delayed, but in total after three weeks on average more than 88% of buds germinated and continued to grow despite exposure to low temperature.

Minimum and maximum percentage of germination for varieties CP 69-1062, CP 57-614, and CP 48-103 for the low temperature treatments were 66% and 75%, 100% and 100%, and 100% and 92%, respectively.

Conclusions
Considering the effects of frost on the qualitative and quantitative features of different commercial varieties revealed that variety CP 69-1062 was more sensitive to frost than other varieties. Hence, in the case of a frost event, it is recommended to harvest CP 69-1062 prior to other varieties to avoid adverse effects of frost.

REFERENCES
BIOMETRIC ANALYSIS OF MID-EARLY MATURING SUGARCANE VARIETIES

By

L.C. TASSO JUNIOR¹,², D.A.S. ROSA¹, D. MARQUES², G.A. NOGUEIRA¹, R.V. BRANCO², H.F. SILVA NETO² and M.O. MARQUES²

¹Canaoeste – PO Box 142; Sertãozinho-São Paulo -Brazil; ²UNESP University
¹aragaodaniela@yahoo.com.br; danielaaragao@canaoeste.com.br

KEYWORDS: Variety, Sugarcane, Performance, Productivity.

Abstract

THIS WORK AIMED to assess biometric variables in mid-early maturing sugarcane varieties. The experiment was located on an Eutrudox soil located on the Experiment Station – UNESP University, Jaboticabal, SP, Brazil in 2009. The biometric determinations were assessed in plots consisting of 3 sugarcane lines. The experimental design was a split-plot randomised block, with sugarcane varieties as the main treatments. The results were submitted to analysis of variance by F-test and means compared by a Tukey test at 5% probability. In relation to different periods analysed, for diameter there was no statistical significance. Relating to height, the varieties CTC 15 and RB855536 gave the best performance, with 2.81 m and 2.72 m, respectively, and varieties IACSP94-4004, IAC91-1099, IACSP95-5000 had the worst performance, with 2.31 m, 2.35 m and 2.40 m, respectively. Variety IACSP94-4004 had thicker stalk diameter than the others with 31.00 mm and the variety IAC95-5000 had a smaller diameter. In relation to tillering, variety IAC91-1099 excelled in relation to others. The variety IAC91-1099 produced the highest productivity, 118.29 t/ha, with tillering the most important factor. It is possible to conclude with the results of this experiment that IAC91-1099 showed better performance and higher productivity. Tonnes cane per hectare (TCH) was positively correlated with both stalk height and tillering but not with stalk diameter.

Introduction

Brazil is the world's largest producer of sugarcane, with the State of São Paulo being the most important with about 4 691 255 ha of planted area in 2010, with a production of 22 350 200 tonnes of sugar and 15 541 285 cubic metres of alcohol (Conab, 2011).

The study of varieties of sugarcane is of utmost importance to provide information to plant breeding programs and to guide producers on which varieties are more productive in certain regions and seasons.

Biometric parameters are those that enable the estimation of agricultural productivity. Components of sugarcane productivity include the diameter, length and number of stalks per area, associated with the tillering capacity and stalk density (Landell and Silva, 1995).

According to Vasconcelos (1998), biometric parameters also have great importance in the estimation of commercial production, allowing the planning of delivery of raw materials in the industry.

Therefore, the objective of this work was to study biometric variables of cultivars of sugarcane with maturation in the middle of the harvest cycle.
Materials and methods

The experiment was installed in the city of Jaboticabal in the macro-region of Ribeirão Preto, São Paulo, on the farm of teaching, research and production FCAVJ/UNESP.

Experimental design and statistical analysis

The experiment was planted in randomised blocks, on plots subdivided, with the treatments in 2 harvest dates in 2009.

The results were submitted to variance analysis by F-test and averages compared by Tukey test at 5% probability (Table 1). The Pearson correlation analysis was performed among the dependent variables (Table 2).

Results and discussion

Table 1—Average values for biometric characters and agricultural productivity (TCH) for cultivars of sugarcane with maturation cycle in the middle of harvest, analysed at 11 months after harvest.

<table>
<thead>
<tr>
<th>Varieties (V)</th>
<th>Average</th>
<th>Height (m)</th>
<th>Diameter (mm)</th>
<th>Tillering (culms/metre)</th>
<th>TCH (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAC91-1099</td>
<td></td>
<td>2.35 b</td>
<td>29.86 b</td>
<td>10.74 a</td>
<td>118.29 a</td>
</tr>
<tr>
<td>IACSP94-4004</td>
<td>2.31 b</td>
<td>31.00 a</td>
<td>10.00 ab</td>
<td>99.67 ab</td>
<td></td>
</tr>
<tr>
<td>IACSP95-5000</td>
<td>2.40 b</td>
<td>27.93 c</td>
<td>9.34 abc</td>
<td>92.11 b</td>
<td></td>
</tr>
<tr>
<td>SP81-3250</td>
<td>2.57 ab</td>
<td>29.24 b</td>
<td>7.93 c</td>
<td>92.11 b</td>
<td></td>
</tr>
<tr>
<td>CTC 15</td>
<td>2.81 a</td>
<td>29.67 b</td>
<td>8.99 bc</td>
<td>116.81 a</td>
<td></td>
</tr>
<tr>
<td>RB855536</td>
<td>2.72 a</td>
<td>29.54 b</td>
<td>9.34 abc</td>
<td>116.48 a</td>
<td></td>
</tr>
<tr>
<td>DMS (5%)</td>
<td></td>
<td>0.26</td>
<td>0.72</td>
<td>1.67</td>
<td>20.78</td>
</tr>
</tbody>
</table>

Harvest dates

- April
  - 2.25 b
  - 29.52 a
  - 8.99 b
  - 92.15 b
- September
  - 2.80 a
  - 29.56 a
  - 10.01 a
  - 127.83 a

DMS (5%)

- 0.09
- 0.79
- 0.68
- 6.45

Statistics

- F Test Blocks: 0.45NS
- F Test (V): 14.26**
- F Test (E): 174.77**
- F Test (CxE): 268NS
- C. V. % (C): 5.31
- C. V. % (E): 4.89

Table 2—Correlation coefficients between height, tillering, diameter and TCH, in six varieties of sugarcane with precocious maturation cycle.

<table>
<thead>
<tr>
<th>Variability</th>
<th>Height</th>
<th>Tillering</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCH</td>
<td>0.70**</td>
<td>0.65**</td>
<td>0.20NS</td>
</tr>
<tr>
<td>Diameter</td>
<td>-0.13NS</td>
<td>-0.15NS</td>
<td>-</td>
</tr>
<tr>
<td>Tillering</td>
<td>0.10NS</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

NS, and ** - not significant and significant at 1% level of probability, respectively.

Feliciano (2009), found similar values for the varieties CTC 15, IACSP94-4004 and IAC91-1099, with 121.97 t/ha, 120.50 t/ha and 116.81 t/ha, respectively, and worst performance for the variety RB855536, with 106.93 t/ha.

Pauli et al. (2009) also found reduced height for variety IACSP95-5000 and greater height for the variety CTC 15, with 2.25 m and 2.29 m, respectively.

In relation to the harvest dates reviewed, the interaction was not significant, concluding that the cultivars showed development throughout the year. On the other hand, Marchiori (2004) found variations during the performance of crop cultivars of sugarcane for the production of culms per hectare.
Conclusion

From the results obtained in the experiment, it was possible to draw the following conclusions:

Sugarcane variety IAC91-1099 had the best performance and highest productivity of all the cultivars.

TCH was positively correlated to height and tillering. The correlation between TCH and stalk diameter was not significant.

REFERENCES


ACCUMULATION OF NITROGEN AND BIOMASS IN AN IRRIGATED RATOE SUGARCANE CROP UNDER VARYING RATES OF N

By
O.T. KÖLLN¹, G.J.C. GAVA², H. CANTARELLA³, H.C.J. FRANCO¹, E. MARIANO⁴, L.E. PANNUTI⁵ and P.C.O. TRIVELIN⁶

¹Brazilian Bioethanol Science and Technology Laboratory – CTBE, rua Giuseppe Maximo Scolfaro, 10.000, Campinas/SP; ²Agência Paulista de Tecnologias dos Agronegócios, Polo Centro Oeste – Jau/SP; ³Instituto Agronômico de Campinas – IAC – Campinas/SP; ⁴Escola Superior de Agricultura Luís de Queiroz-USP- Piracicaba/SP; ⁵Universidade Estadual Paulista Julio de Mesquita Filho – UNESP- Botutucu/SP; ⁶Centro de Energia Nuclear na Agricultura – CENA/USP- Piracicaba/SP

oriel.kolln@bioetanol.org.br

KEYWORDS: Analysis of Growth, Above Ground, N Fertiliser.

Abstract

SUGARCANE IS A MAJOR crop in subtropical and tropical regions around the world. Brazil is the world’s largest producer of sugarcane, which is used to produce sugar and ethanol. The use of sugarcane growth analysis could improve some management practices, such as fertilisation, which is one of the most important for the crop and has caused concerns regarding environmental impacts and biofuels sustainability. The objective of this study was to assess the biomass and N accumulation of sugarcane (second ratoon of SP80-3280 variety) using drip irrigation with varying N-fertiliser rates. The experiment was carried out in Jau, São Paulo State, Brazil in a Rhodic Eutrudox soil. A randomised block design was used, with five treatments and four replications. The treatments were four N doses (50, 100, 150 and 200 kg/ha) and a control treatment without N application. Dry matter evaluations were performed at 38, 121, 208, 291 and 381 days after previous harvest. There was a significant linear response of dry matter production with the increasing N rate. The use of 200 kg N/ha increased dry matter production by 20 t/ha and N accumulated by 95 kg/ha. Hence, our conclusion was that N-fertiliser applied by drip irrigation increased sugarcane dry matter production and aboveground N accumulation.

Introduction

Sugarcane (Saccharum spp.) is an important crop in tropical and subtropical regions around the world, mainly used for ethanol and sugar production. Further, Brazil is the world’s largest producer of sugarcane (FAO, 2011). Sugarcane can produce high biomass under optimal growing conditions (Wiedenfeld, 2000). However, sugarcane yields in some Brazilian sugarcane fields remain low due to several limiting factors such as water (mainly) and nitrogen which reduce sugarcane performance (Inman-Bamber and Smith, 2005; Gava et al., 2011).

In contrast to sugarcane grown under dryland conditions, when sugarcane is grown with irrigation it shows high response to nitrogen fertilisation. Ng Kee Kwong et al. (1999) highlighted the importance of irrigation to N-fertiliser effects in sugarcane, with increased sugarcane production attributable to irrigation and N fertilisation.

Growth analysis can be used to improve some of these agricultural practices in sugarcane management, for instance to enhance fertilisation effectiveness (Gava et al., 2001). This analysis may be done by biomass sampling throughout the sugarcane crop cycle or by physiologic and biometric crop indices measured throughout sugarcane growth.

The objective of this study was to assess sugarcane biomass accumulation related to drip irrigation and N rates applied in a sugarcane ratoon crop.
Material and methods

The study was performed in Jaú, São Paulo state, Brazil (22°17' S, 48°34' W) using sugarcane variety SP80-3280. The treatments were 5 N rates (0, 50, 100, 150 and 200 kg/ha) applied throughout the crop cycle by drip irrigation. A randomised block design was used. During the crop cycle 1435 mm of rain was recorded, and only 390 mm of water was applied by drip irrigation which was calculated according to 100% of crop evapotranspiration rate by the Penman-Monteith method.

Crop biomass was evaluated at 38, 121, 208, 291 and 381 days after last harvest (DALH) using all biomass above ground in 2 m of row. Each sample after weighing was chopped and sub-samples were collected for dry matter determination in the laboratory (oven with free air circulation at 65°C). After that, dry samples were ground and N content (g/kg) was determined by the Kjeldahl method as described in Malavolta et al. (1997).

Growth analysis was performed as described by Lucchesi (1984) and crop index was obtained using the same methods as Machado et al. (1982).

Results and discussion

Dry matter and N accumulated above-ground by sugarcane were increased by N fertilisation at all sampling dates during a 2nd ratoon crop (Table 1). These results confirm previous research by Ng Kee Kwong et al. (1999) and Wiedenfeld (2000).

<table>
<thead>
<tr>
<th>N Rate Kg/ha</th>
<th>38 DALH</th>
<th>121 DALH</th>
<th>208 DALH</th>
<th>291 DALH</th>
<th>381 DALH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DM t/ha</td>
<td>NA kg/ha</td>
<td>DM t/ha</td>
<td>NA kg/ha</td>
<td>DM t/ha</td>
</tr>
<tr>
<td>0</td>
<td>0.37</td>
<td>5.6</td>
<td>4.1</td>
<td>24.1</td>
<td>13.2</td>
</tr>
<tr>
<td>50</td>
<td>0.45</td>
<td>7.4</td>
<td>4.8</td>
<td>29.6</td>
<td>15.7</td>
</tr>
<tr>
<td>100</td>
<td>0.58</td>
<td>12.3</td>
<td>8.3</td>
<td>49.2</td>
<td>24.8</td>
</tr>
<tr>
<td>150</td>
<td>0.67</td>
<td>9.6</td>
<td>11.3</td>
<td>77.5</td>
<td>25.1</td>
</tr>
<tr>
<td>200</td>
<td>0.80</td>
<td>12.7</td>
<td>10.6</td>
<td>81.8</td>
<td>25.5</td>
</tr>
<tr>
<td>CV (%)</td>
<td>14.8</td>
<td>19.7</td>
<td>16.9</td>
<td>16.1</td>
<td>13.6</td>
</tr>
<tr>
<td>R² L. R.</td>
<td>0.99**</td>
<td>0.71**</td>
<td>0.88**</td>
<td>0.94**</td>
<td>0.82**</td>
</tr>
<tr>
<td>R² Q. R.</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>0.91*</td>
<td>ns</td>
</tr>
</tbody>
</table>

**p<0.01, *p<0.05, DM= dry matter above ground, NA: Nitrogen accumulation, ns=not significantly different, (DALH) = days after last harvest, CV= coefficient of variation; (L. R.)= linear regression, (Q. R.) = quadratic regression.

Growth analysis methodology was used to model biomass and nitrogen accumulation by sugarcane during its crop cycle. These were sigmoid models following the equation \( y = y_{\text{max}}/1 + \exp(-B*(\text{DALH}-x_0)) \) which represents the three phases of sugarcane growth (Figures 1A and 2A), where \( y \) = growth or accumulation, \( y_{\text{max}} \) = maximum accumulation or growth b and \( x_0 \) = coefficients of the equation and \( \text{DALH} \) = days after last harvest.

The first phase took place until 90 DALH encompassing approximately 10% (4 t/ha) of total above-ground biomass accumulation. During this phase, sugarcane usually has high tillering, which permits good crop reestablishment, but small dry matter production (Oliveira, 2011).

The second phase occurred from 90–291 DALH during which the sugarcane crop had the highest dry matter accumulation (approximately 80% of total produced). Others Brazilian studies have verified this behaviour of the sugarcane crop across N rates (Gava et al., 2001; Oliveira, 2011). The biggest dry matter production during this phase was stalk formation, which at the end of the sugarcane crop cycle represents around 85% of total above-ground biomass (Franco et al., 2010). During the last phase, only 10% of total above-ground biomass was produced and this occurred between 291 and 381 DALH.
Fig. 1—Dry matter accumulation (A) and dry matter production rate (RDMP) (B) in sugarcane above ground biomass related to days after last harvest.

The dry matter production rate was obtained by the derivation of the sigmoid equation: 
\[ y = \frac{y_{max}}{1+e^{-(B*(DALH-x_0))}} \] 
with the same variables as equation 1 (Machado et al. 1982). This rate was low at the beginning of ratoon growth, increasing very quickly to reach the peak (maximum production rate) and then decreased sharply (Figure 1B). The maximum dry matter production rate of each treatment took place at different DALH, such as: 170 DALH (11.5 g/m²/day), 192 DALH (15.6 g/m²/day), 180 DALH (22.5 g/m²/day), 186 DALH (19.9 g/m²/day) and 207 DALH (22.2 g/m²/day), respectively for 0, 50, 100, 150 and 200 kg N/ha (Figure 1B).

Regarding N accumulation, it was possible to classify three phases as well. In general, only 15 kg/ha N was accumulated by the crop until 50 DALH (first phase) (Figure 2A). During the second phase (50 DALH to 300 DALH) approximately 80% of total N by the ratoon crop was accumulated. During the third phase, substantial differences were observed between the control treatment and the treatment with 200 kg N/ha, such that N accumulation increased from 1.5% to 10% as N rate increased from 0 to 200 kg N/ha (Figure 2A).
Growth analysis verified differences between the maximum rates of dry matter and nitrogen accumulation. The maximum nitrogen accumulation rate (Figure 2B) took place 59, 11, 11, 22 and 23 days earlier than the maximum dry matter rate (Figure 1A) for the 0, 50, 100, 150 and 200 kg N/ha treatments, respectively. This difference can be explained by N availability in sugarcane management with irrigation. According to Dourado-Neto et al. (2010), mineral fertiliser has higher availability to plants than other nutrient sources. Further, as split N application was adopted using drip irrigation, this increased the N effectiveness and suitable N uptake, because the N rates applied at each time were smaller than those used in just a single application as is usually done in Brazilian sugarcane fields. Other research has verified the beneficial effect of N-fertiliser applied side-dressed as an irrigation supplement for sugarcane production (Singh and Mohan, 1994; Ng Kee Kwong et al., 1999).

Conclusion

This study indicates that N-fertiliser applied by drip irrigation increased sugarcane dry matter production and N accumulation in Brazil.

REFERENCES


THE EFFECT OF THREE PHYSIOLOGICAL AGES 
AND SIX SUGARCANE VARIETIES ON THE QUANTITY 
AND QUALITY OF SEED CANE PRODUCTION

By

O. DE SOUSA-VIEIRA, R. BRICEÑO, 
C. TORIN and A. DÍAZ

Instituto Nacional de Investigaciones Agrícolas (INIA), INIA Yaracuy, Venezuela
saccharum@hotmail.com

KEYWORDS: Saccharum spp., Seed Nurseries, Biomass, Sugarcane Propagation, Trash.

Abstract

In Venezuela, sugarcane (Saccharum spp. hybrids) is propagated through stem cuttings (three bud setts). Planting material should come from well established nurseries. To easily manage and transport seed cane, the stem cuttings should be tied into bundles (30 setts each). For farmers, in order to obtain the maximum amount of quality seed per area, it is important to know at what physiological age a specific variety should be harvested for seed. We assessed total biomass, amount of trash (green tops and green and dry leaves), stalk weight, stalk number, buds per stalk, and number and weight of bundles of six recently-released varieties (CR87-339, V84-8, V98-62, V98-120, V99-236, and V00-50) at three different physiological ages (seven, eight, and nine months of age). On average, total biomass, stalk weight, stalk number, buds per stalk, and number of bundles were age and variety dependent. The average value of those variables increased with age. No significant change in the amount of trash was found, averaging 52.1 t/ha across ages. The percentage of trash in relation to the total biomass significantly decreased as age increased from 35.7% at seven months to 29.9% at nine months. Weight per bundle was variety dependent, but did not increase with age. Average effective number of buds per stalk significantly varied according to variety and age. The average effective number of buds per stalk irrespective of varieties was 10.7, 12.1, and 13.0 at seven, eight, and nine months of age, respectively. CR87-339 was the variety with the highest number of effective buds per stalk. As age increased, stalks were prone to lodging, breaking, and the presence of aerial roots which diminished the quality and quantity of seed cane. Results suggested that, irrespective of varieties, nine months old seed cane nurseries will maximise seed cane production while maintaining seed cane quality.

Introduction

Sugarcane (Saccharum spp. hybrids) is commercially propagated through the use of stem cuttings known as setts. Propagating crops vegetatively, as is done with sugarcane, entails certain disadvantages such as bulkiness of the cane seed pieces, short shelf life, and low multiplication ratio (Tew, 1987; Moyo et al., 2004). A major constraint in sugarcane production is the poor quality of the seed cane used (Jalaja et al., 2008).

One of the major drawbacks in Venezuelan sugarcane cultivation is the neglect of seed nurseries. Usually, sugarcane produced for the commercial crop is also used for seed purposes. Until now, when releasing new sugarcane varieties, not enough importance has been given to how to properly produce seed nurseries for a particularly variety.
Once newer varieties are released, it is essential to determine at what physiological age a new clone can provide both quantity and quality seed cane. Thus, the objective of this study was to assess total biomass, amount of trash (green tops and green and dry leaves), stalk weight, stalk number, effective number of buds per stalk, and number and weight of bundles of six recently released varieties (CR87-339, V84-8, V98-62, V98-120, V99-236, and V00-50) at three different physiological ages (seven, eight, and nine months of age).

Materials and methods

Six recently released varieties, five from the Venezuelan Sugarcane Variety Development Program (V84-8, V98-62, V98-120, V99-236, and V00-50) and one from the breeding program at Central Romana, Dominican Republic (CR87-339) were used in this study. Seed cane for planting the experiments was obtained from pure stand nurseries strategically established (nine months in advance) for the purpose of the study.

Each age test was set up as a randomised complete block design with three replications. Varieties were planted by hand using seed pieces or setts, generally 30–40 cm long, each with three buds. Seeding density was four three budded setts per linear metre of furrow. Each plot was 3 rows wide by 6 m long with 1.5 m row spacing. Experiments were planted on 23 August 2011 at the Yaritagua Research Station, Yaracuy state, Venezuela (10° 02’ 38” latitude N, 69° 05’ 20” longitude W, 336 m altitude).

Experiments were manually harvested and data collected in plant cane, seven, eight, and nine months following planting. Total biomass, amount of trash, stalk weight, stalk number, buds per stalk, and number and weight of 30 sett bundles were recorded for each variety and physiological age. Data were analysed for each physiological age separately and analyses were also conducted with the combined data across ages.

Results and discussion

On average, the magnitude of total biomass, stalk weight, stalk number, effective buds per stalk, and number of bundles significantly increased with age while the amount of trash was not age dependent (Table 1). The amount of trash averaged 52.1 t/ha across ages while the percentage of trash in relation to the total biomass significantly decreased as age increased, from 35.7% at seven months to 29.9% at nine months. Slightly lower cane growth was observed at eight months of age than at seven or nine months of age. This difference in growth resulted in cane with shorter internodes at eight months of age which may explain the differences in average weight of bundles.

Average number of buds per stalk significantly varied according to variety and age. The average effective number of buds per stalk irrespective of varieties was 10.8, 12.1, and 13.0 at seven, eight, and nine months of age, respectively. Across ages, CR87-339 was the variety with the highest number of effective buds per stalk averaging 12.8 (Table 2).

### Table 1—Sugarcane total biomass, trash, stalk weight, stalk number, effective buds per stalk, number of bundles, and bundle weight for three physiological ages averaged across six varieties.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Physiological Age</th>
<th>C.V. %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 months</td>
<td>8 months</td>
</tr>
<tr>
<td>Total Biomass (t/ha)</td>
<td>146.7 b</td>
<td>147.7 b</td>
</tr>
<tr>
<td>Trash (t/ha)</td>
<td>52.4 a</td>
<td>51.7 a</td>
</tr>
<tr>
<td>Stalk weight (t/ha)</td>
<td>94.2 b</td>
<td>96.0 b</td>
</tr>
<tr>
<td>Stalk number/ha</td>
<td>102 551 b</td>
<td>106 379 a</td>
</tr>
<tr>
<td>Effective buds per stalk</td>
<td>10.8 c</td>
<td>12.1 b</td>
</tr>
<tr>
<td>Number of bundles/ha</td>
<td>12 228 c</td>
<td>14 221 b</td>
</tr>
<tr>
<td>Bundle weight (kg)</td>
<td>6.8 a</td>
<td>6.3 b</td>
</tr>
</tbody>
</table>

1For each variable, means within a row followed by the same letter are not significantly different (P<0.05)
Weight per bundle was variety dependent (Table 2), but did not increase with age. Since the number of seed pieces (setts) is a constant of 30 per bundle, bundle weight would depend mostly on stalk diameter and internode length.

**Table 2**—Average sugarcane total biomass, trash, stalk weight, stalk number, effective buds per stalk, number of bundles, and bundle weight of six sugarcane varieties at three physiological ages.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Variables</th>
<th>Total biomass (t/ha)</th>
<th>Trash (t/ha)</th>
<th>Stalk weight (t/ha)</th>
<th>Stalk number/ha</th>
<th>Effective buds per stalk</th>
<th>Number of bundles/ha</th>
<th>Bundle Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seven months of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V84-8</td>
<td></td>
<td>141.8ab</td>
<td>49.6b</td>
<td>92.2bc</td>
<td>101 482c</td>
<td>11.1abc</td>
<td>12 495bc</td>
<td>6.5cd</td>
</tr>
<tr>
<td>V98-62</td>
<td></td>
<td>133.9b</td>
<td>52.1ab</td>
<td>81.6c</td>
<td>98 765c</td>
<td>10.8bc</td>
<td>11 799cd</td>
<td>6.1e</td>
</tr>
<tr>
<td>V98-120</td>
<td></td>
<td>153.0a</td>
<td>59.0a</td>
<td>93.4b</td>
<td>105 062bc</td>
<td>9.3d</td>
<td>10 877d</td>
<td>7.4b</td>
</tr>
<tr>
<td>V99-236</td>
<td></td>
<td>154.7a</td>
<td>59.0a</td>
<td>95.7ab</td>
<td>114 691a</td>
<td>10.6c</td>
<td>13 485ab</td>
<td>6.2de</td>
</tr>
<tr>
<td>V00-50</td>
<td></td>
<td>155.2a</td>
<td>48.6b</td>
<td>106.6a</td>
<td>111 975ab</td>
<td>11.2ab</td>
<td>14 007a</td>
<td>6.8c</td>
</tr>
<tr>
<td>CR87-339</td>
<td></td>
<td>141.4ab</td>
<td>45.5b</td>
<td>95.9ab</td>
<td>83 333d</td>
<td>11.6a</td>
<td>10 707d</td>
<td>7.9a</td>
</tr>
<tr>
<td>Eight months of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V84-8</td>
<td></td>
<td>137.7c</td>
<td>45.3c</td>
<td>92.4a</td>
<td>107 161b</td>
<td>12.3bc</td>
<td>14 617a</td>
<td>5.9d</td>
</tr>
<tr>
<td>V98-62</td>
<td></td>
<td>144.1abc</td>
<td>51.8b</td>
<td>92.3a</td>
<td>103 704b</td>
<td>12.7ab</td>
<td>14 663a</td>
<td>5.8d</td>
</tr>
<tr>
<td>V98-120</td>
<td></td>
<td>155.5a</td>
<td>60.5a</td>
<td>95.0a</td>
<td>109 136b</td>
<td>10.5d</td>
<td>12 683b</td>
<td>6.9b</td>
</tr>
<tr>
<td>V99-236</td>
<td></td>
<td>157.1a</td>
<td>56.9a</td>
<td>98.2a</td>
<td>118 642a</td>
<td>11.9c</td>
<td>15 725a</td>
<td>5.8d</td>
</tr>
<tr>
<td>V00-50</td>
<td></td>
<td>139.7bc</td>
<td>43.0c</td>
<td>96.7a</td>
<td>109 136b</td>
<td>12.1bc</td>
<td>14 657a</td>
<td>6.2c</td>
</tr>
<tr>
<td>CR87-339</td>
<td></td>
<td>152.1ab</td>
<td>50.7b</td>
<td>90 494c</td>
<td>101.5a</td>
<td>12.9a</td>
<td>12 980b</td>
<td>7.3a</td>
</tr>
<tr>
<td>Nine months of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V84-8</td>
<td></td>
<td>151.7d</td>
<td>39.1d</td>
<td>112.6b</td>
<td>105 556b</td>
<td>13.4ab</td>
<td>15 803ab</td>
<td>6.3c</td>
</tr>
<tr>
<td>V98-62</td>
<td></td>
<td>170.2bcd</td>
<td>51.7bc</td>
<td>118.5b</td>
<td>110 124ab</td>
<td>13.4ab</td>
<td>16 543a</td>
<td>6.3c</td>
</tr>
<tr>
<td>V98-120</td>
<td></td>
<td>187.5ab</td>
<td>64.0a</td>
<td>123.6b</td>
<td>112 346ab</td>
<td>11.3c</td>
<td>14 074b</td>
<td>7.6b</td>
</tr>
<tr>
<td>V99-236</td>
<td></td>
<td>179.5abc</td>
<td>57.7ab</td>
<td>121.8b</td>
<td>119 012a</td>
<td>12.8b</td>
<td>17 037a</td>
<td>6.1c</td>
</tr>
<tr>
<td>V00-50</td>
<td></td>
<td>163.2cd</td>
<td>45.1cd</td>
<td>118.0b</td>
<td>116 667a</td>
<td>13.1ab</td>
<td>17 037a</td>
<td>6.3c</td>
</tr>
<tr>
<td>CR87-339</td>
<td></td>
<td>193.0a</td>
<td>54.9b</td>
<td>138.1a</td>
<td>94 198c</td>
<td>13.8a</td>
<td>14 444b</td>
<td>8.5a</td>
</tr>
</tbody>
</table>

1For each variable, means within a column and crop age followed by the same letter are not significantly different (P<0.05)

Average bundle weight of CR83-339, a variety with thick stalks and medium internode length, was significantly higher than the other five Venezuelan varieties with an average weight of 7.9 kg per bundle across ages.

Because of the bulkiness of the seed cane, seed bundles of thicker and heavier varieties are more difficult to handle and transport than thinner and lighter varieties.

Irrespective of the physiological age, V84-8 and V00-50 produced the least amount of trash with an average of 44.7 and 45.6 t/ha, respectively, while V98-120 and V99-236 produced the highest amount with 61.3 and 58.5 t/ha, respectively.

A dense leaf canopy and strong adherence of the leaf sheath contributed to the most amount of trash. As age increased, stalks were prone to lodging, breaking, and the presence of aerial roots which diminished the quality and quantity of the seed cane.

Nine months old canes produced 6.9% and 3.1% more stalks/ha than canes with seven and eight months of age, respectively. They also produced 29.4% and 11.3% more bundles/ha than canes with seven and eight months of age, respectively.

**Conclusion**

The results of this study suggest that, irrespective of varieties, nine month old seed cane nurseries will maximise seed cane production while maintaining seed cane quality in Venezuela.
Growers will benefit from better understanding how to appropriately manage seed nurseries of these recently-released varieties in order to ensure sugarcane and crop cycle productivity.

Acknowledgments

The authors wish to extend special thanks to the personnel at Yaritagua Research Station (José R. George, Milagros Niño, Gustavo Palencia, Argenis Rivero, and Alexis Perez) for their help in field work and data collection.

REFERENCES


MACRONUTRIENT ACCUMULATION AND EXPORT IN SUGARCANE AS AFFECTED BY N RATE UNDER SUBSURFACE DRIP IRRIGATION

By


1Brazilian Bioethanol Science and Technology Laboratory – CTBE, rua Giuseppe Maximo Scolfaro, 10.000, Campinas/SP; 2Agência Paulista de Tecnologias dos Agronegócios, Polo Centro Oeste – Jaú/SP; 3Agronomic Institute of Campinas- IAC – Campinas/SP; 4Universidade Estadual Paulista Julio de Mesquita Filho – UNESP- Botucatu/SP; 5Centro de Energia Nuclear na Agricultura – CENA/USP- Piracicaba/SP.

oriel.kolln@bioetanol.org.br

KEYWORDS: Nutrient, Uptake, Fertiliser Management, Accumulation.

Abstract

MINERAL REQUIREMENTS for sugarcane and nutrient uptake by the crop are important information for fertiliser management. The aim of this work was to assess accumulation and export of macronutrients by sugarcane with changes in N rate under drip irrigation management. The experiment was carried out in Jaú, São Paulo State, Brazil, in a Rhodic Eutrudox. A randomised block design was used, and five treatments in four replications were assessed. The treatments were five N rates (0, 50, 100, 150 and 200 kg/ha). Crop biomass was evaluated at 381 days after last harvest (DALH), as whole above ground weight in a 2 m row. Dry samples were ground and N, P, K, Ca, Mg and S content (g/kg) were determined. The order of accumulation in above ground biomass was K>N>Ca>Mg>S>P. There was an increase in nutrient accumulation with N rate applied, which may be explained by synergistic interactions among nutrients. There was an increase in amount of nutrients accumulated by the crop when 200 kg N/ha was applied compared to 100 kg N/ha. The increase was 170, 95, 9, 10, 15 and 20 kg/ha, respectively, for N, P, K, Ca, Mg and S. Each plant part of sugarcane had a different ratio of nutrient accumulation with the most nutrients taken up by the stalks. Considering that no burning was undertaken before sugarcane harvest, approximately 40% of all nutrients were retained in the field in dry leaves and stalks, while 60% was exported to the sugar mill with the stalks. N and K were accumulated in larger amounts than other macronutrients by the crop showing the importance of N and K fertiliser management in sugarcane.

Introduction

Many factors interact in sugarcane production and maturation, such as environmental conditions, crop management and sugarcane variety. Among environmental factors, solar radiation, temperature and water have the highest impact. In addition, soil is one of those complex factors which contribute to sugarcane production and its properties are essential for plant nutrition.

The mineral nutrient requirements of sugarcane as well as the amounts of nutrients accumulated in its dry matter are important knowledge for sugarcane technicians and farmers, because they define nutrient supply (Coletti et al., 2006).

According to Ceotto and Castelli (2002), each sugarcane variety has a specific nutrient requirement, and nutrient uptake by the crop depends on crop cycle, soil management and nutrient availability.
Research aimed at better exploiting the extraction and export of macronutrients in sugarcane grown in different soil and climatic conditions must be undertaken to improve sugarcane crop management. Therefore, the aim of this study was to evaluate the macronutrient accumulation and export by sugarcane above ground parts with different N fertiliser rates under drip irrigation.

Material and Methods

The trial was performed in Jaú, São Paulo state, Brazil (22°17'S, 48°34'W) using variety SP80 3280. The treatments were 5 N rates (0, 50, 100, 150 and 200 kg/ha) applied throughout the crop cycle by drip irrigation. All treatments received a dose of 150 kg/ha of K (K₂O) applied during the cycle by subsurface drip irrigation. A randomised block design was used. During the crop cycle, 1435 mm of rain were received and only 390 mm of water was applied by drip irrigation to meet the crop water requirement, which was calculated according to 100% of crop evapotranspiration rate by the Penman-Monteith method.

Crop biomass was evaluated on 381 days after last harvest (DALH) as whole above ground weight in a 2 m row. Each sample was chopped after weighing and sub-samples were collected for dry matter determination in laboratory (oven drying with free air circulation at 65 °C). After that, dry samples were ground and N, P, K, Ca, Mg and S content (g/kg) were determined as described in Malavolta et al. (1997).

The results were submitted to an analysis of variance (ANOVA), at $p>0.05\%$, and the averages were compared by regression analysis.

Results and discussion

Sugarcane plant parts had differing amounts and relative order of macronutrient accumulation, in the following order of importance: N>Ca>K>Mg>S>P in dry leaves, K>N>Ca>P>Mg in tops and K>N>Ca>Mg>S>P in stalks (Tables 1, 2 and 3). These results are related to the mobility and function of these nutrients in plant nutrition (Maathuis, 2009). Regarding the order of nutrient accumulation in stalks, (K> N> Ca> Mg> S> P), similar results were obtained by Coale et al. (1993) with variety CL 61-620 grown on Histosols in Florida, USA. However, Oliveira et al. (2010) obtained different results of nutrient magnitude extraction (K> Ca> N> Mg> P) by a group of sugarcane varieties grown under full irrigation in Brazil.

Table 1—Sugarcane nutrient accumulation in dry leaves.

<table>
<thead>
<tr>
<th>N rate kg/ha</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6.1</td>
<td>0.64</td>
<td>3.0</td>
<td>8.9</td>
<td>2.1</td>
<td>1.6</td>
</tr>
<tr>
<td>50</td>
<td>9.9</td>
<td>0.85</td>
<td>3.2</td>
<td>10.5</td>
<td>2.8</td>
<td>1.8</td>
</tr>
<tr>
<td>100</td>
<td>13.2</td>
<td>0.76</td>
<td>5.6</td>
<td>13.8</td>
<td>3.4</td>
<td>2.4</td>
</tr>
<tr>
<td>150</td>
<td>18.4</td>
<td>0.92</td>
<td>6.7</td>
<td>17.7</td>
<td>4.2</td>
<td>2.7</td>
</tr>
<tr>
<td>200</td>
<td>23.8</td>
<td>1.41</td>
<td>28.5</td>
<td>15.9</td>
<td>4.8</td>
<td>3.9</td>
</tr>
<tr>
<td>R² L. R.</td>
<td>0.98*</td>
<td>0.73*</td>
<td>0.90*</td>
<td>0.83*</td>
<td>0.99*</td>
<td>0.90*</td>
</tr>
<tr>
<td>R² Q. R.</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>CV (%)</td>
<td>27</td>
<td>27</td>
<td>30</td>
<td>26</td>
<td>12</td>
<td>24</td>
</tr>
</tbody>
</table>

*Significant $p<0.01$, ns= not significantly different, R² L. R. = R² linear regression, R² Q. R. = R² quadratic regression, CV= coefficient of variation;

There was more Ca accumulated in dry leaves than P and K, which is expected due to the high mobility of P and K into the phloem, which leads to high remobilisation of these macronutrients to the youngest parts of sugarcane.

There was an increase in amount of nutrients accumulated by the crop when 200 kg N/ha was applied compared to 100 kg N/ha which is currently applied in Brazilian sugarcane under...
irrigation management. In fact, in Brazil there is no specific recommendation for N fertilisation in sugarcane under irrigation.

The increase was 170, 95, 9, 10, 15 and 20 kg/ha, respectively, for N, P, K, Ca, Mg and S. These data may be explained by sugarcane management used in this trial: the irrigated regime improved nutrient uptake by plants as well as the split fertiliser application used. Split fertiliser management is widely known to increase nutrient use efficiency, mainly with N-fertiliser.

<table>
<thead>
<tr>
<th>N rate</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22.9</td>
<td>4.5</td>
<td>40.1</td>
<td>8.6</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>50</td>
<td>22.8</td>
<td>4.8</td>
<td>60.1</td>
<td>10.9</td>
<td>3.0</td>
<td>4.6</td>
</tr>
<tr>
<td>100</td>
<td>30.6</td>
<td>4.8</td>
<td>63.3</td>
<td>12.5</td>
<td>3.6</td>
<td>4.2</td>
</tr>
<tr>
<td>150</td>
<td>41.8</td>
<td>7.7</td>
<td>93.5</td>
<td>16.4</td>
<td>4.9</td>
<td>6.2</td>
</tr>
<tr>
<td>200</td>
<td>39.7</td>
<td>5.6</td>
<td>84.0</td>
<td>17.0</td>
<td>5.3</td>
<td>8.0</td>
</tr>
</tbody>
</table>

R² L. R. 0.85* ns 0.83* 0.96* 0.96* 0.90*
R² Q. R. ns ns ns ns ns ns
CV (%) 25 26 20 28 30 30

*Significant p<0.01. ns= not significantly different. R² L. R.= R² linear regression. R² Q. R.= R² quadratic regression. CV= coefficient of variation.

There was an increase in nutrient accumulation with N rate applied, which may be explained by synergistic interactions among nutrients. In the literature, this effect has been observed with positive interactions, such as: nitrogen and water (Gava et al., 2010), nitrogen and sulfur, (Brown et al., 2000) and nitrogen and phosphorus (Iqbal and Iqbal, 2001).

Considering that no burning was undertaken before sugarcane harvest, it is possible to predict that those nutrients contained in dry leaves and tops will be recycled in the soil-plant system.

Based on nutrients present in sugarcane straw (dry leaves and tops), approximately 36, 34, 41, 51, 27 and 34%, respectively, of total N, P, K, Ca, Mg and S of sugarcane will be recycled (Figure 1). Hence, the amounts of nutrients exported with the millable stalks were 64, 66, 59, 49, 73 and 66% of N, P, K, Ca, Mg and S, respectively.

These results are different from those obtained by Coale et al. (1993) who found that exports were above 50% only for the primary macronutrients N, P and K. However, Oliveira et al. (2010) reported that more than 50% of macronutrients accumulated by sugarcane were exported in stems, similar to our results.

Conclusions

There were linear increases in macronutrients accumulated by sugarcane stalks with N rates applied. Each plant part of sugarcane had a different order of nutrient accumulation, with most
nutrients taken up by the sugarcane crop being exported in stalks. N and K were accumulated in larger amounts than other macronutrients.

Fig. 1—Nutrient accumulation percentage in sugarcane plant parts.

**REFERENCES**


COMPARISON OF DAYCENT-SIMULATED AND MEASURED N\textsubscript{2}O FROM CONTRASTING SOILS CULTIVATED WITH SUGARCANE IN BRAZIL

By

V.P. VARGAS\textsuperscript{1}, S.J. DEL GROSSO\textsuperscript{2}, M. REYES-FOX\textsuperscript{2} and H. CANTARELLA\textsuperscript{1}

\textsuperscript{1}Agronomic Institute, IAC; \textsuperscript{2}Soil Plant Nutrient Research, SPNR/ARS/USDA

vitorpvargas@hotmail.com

KEYWORDS: Modelling, N\textsubscript{2}O Daily Fluxes, Cane Productivity, Mineral N.

Abstract

Since measurements to characterise N\textsubscript{2}O emission patterns are limited, time consuming, laborious and expensive, modelling can be an important tool to understand the temporal and spatial variability of N\textsubscript{2}O fluxes in sugarcane fields from Brazil. We used the DayCent (Daily Century) model to predict N\textsubscript{2}O fluxes from two sugarcane areas, with contrasting soils, and to compare measurements performed throughout the first ratoon cycle. Both areas (Jau – sandy loam soil site and Piracicaba – clayey soil site) are located in Sao Paulo state and have similar climate, mean air temperature and annual precipitation. Primary model inputs are soil features by horizon, daily weather information and land cover/use data. To establish soil organic C equilibrium, we modelled 1900 years of native vegetation followed by 110 years of sugarcane plantations. Different schedule files were created for each treatment and site to represent management events and their respective dates during plant-cane and first ratoon (2010-2012). We tested the model with three N levels applied 3 months after harvest of the plant-cane: without N, medium N (100 kg/ha), and high N (150 kg/ha). First ratoon-crop overall emissions were calculated. Observed and predicted daily N\textsubscript{2}O fluxes showed a better agreement for the clayey soil (Piracicaba), while no correlation was detected for the sandy loam soil site. The model underestimated the daily fluxes and cumulative emissions for plots without N in clayey and sandy loam sites by 80 and 83%, respectively when assuming that 0.35% of nitrified N is lost as N\textsubscript{2}O and by 68 and 44% when the loss was 0.7%. Averaging the other two N levels (medium and high), the model underestimated by 16% in Piracicaba and by 3% in Jau and overestimated by 39% in Piracicaba and by 94% in Jau, respectively for 0.35 and 0.7% of nitrified N lost as N\textsubscript{2}O. This study indicates that the model can be used for estimating N\textsubscript{2}O emission from cane sites with restrictions and estimates are better when cumulative-represented.

Introduction

Nitrous oxide (N\textsubscript{2}O) emission related to N fertilisation during the growth of bioenergy crops is of concern to the scientific community and production sector because it is a potent greenhouse gas (GHG) and is currently the main ozone-depleting substance (Ravishankara \textit{et al.}, 2009).

According to Crutzen \textit{et al.} (2008), high N losses as N\textsubscript{2}O from feedstock production could offset the benefits achieved with the replacement of fossil fuels by biofuels. Estimates have been performed worldwide to better characterise spatial and temporal emission patterns of this GHG.

However, many of these measurement techniques are limited, laborious and expensive. Therefore, modelling may be an important tool to understand the temporal and spatial variability of N\textsubscript{2}O fluxes as well to estimate N\textsubscript{2}O losses from sugarcane fields in large scales of space and time.
Several process-based models have been developed to estimate local, regional and national soil GHG fluxes (Smith et al., 2004; Del Grosso et al., 2006) and to compare the impact of different land management practices on emissions (Del Grosso et al., 2005; Li et al., 2005). However, it is desirable to continually compare model outputs with observed data to identify model capabilities or weaknesses and spur model development.

This study examined the DayCent model, a biogeochemical model that simulates fluxes of C and N among the atmosphere, vegetation and soil (Del Grosso et al., 2001), to predict N₂O fluxes from two sugarcane areas, with contrasting soils, and to compare model outputs with measurements performed during the 1st ratoon of sugarcane in the south-eastern area of Brazil.

**Materials and methods**

The DayCent model simulations were compared to measurements performed in cane fields located in Sao Paulo state, south-eastern region of Brazil, over two contrasting soil types: a clayey (Piracicaba – 22°41'6” S and 47°38’55” W) and a sandy loam soil (Jau – 22°15’10” S and 48°34’7” W). Both soils are classified as Rhodic Hapludox and main characteristics are displayed in Table 1. Sugarcane was planted in April, 2010 at both sites and the plant crop was harvested after 16 months, and the first ratoon 12 months later.

<table>
<thead>
<tr>
<th>Table 1—General soil physical and chemical properties of the studied sites in Brazil.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>cm</td>
</tr>
<tr>
<td>Clayey soil</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Sandy loam soil</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

To calibrate the model, we used stalk yields from the plant-cane cycle and soil C content in 0–20 cm top soil layer. NO₃⁻ and NH₄⁺ concentrations, water filled pore space in 0–10 cm top layer and N₂O daily fluxes were analysed during the 1st ratoon. These data were obtained from plots with three regimes of N fertilisation: 0, 100 and 150 kg N ha⁻¹ applied approximately three months after ratoon sprouting out. N fertiliser was applied as ammonium sulfate in a single banded application in October, almost three months after plant-cane was harvested.

N₂O fluxes, temperature and soil water content were evaluated three times per week up to 60 days after N fertilisation, and once a week in the following month. Estimates of N₂O emissions between sampling days were made through linear interpolations between sampling dates throughout the season.

To establish soil organic C equilibrium, we modelled 1900 years of native vegetation (subtropical forest + shrubs), followed by 110 years of sugarcane plantations in order to properly initialise the C and N pools. We simulated the perennial sugarcane crop as a tree (as opposed to a crop) using the tree.100 sub-model due to its greater flexibility for parameterisation. For example, there is only one above-ground component in the crop.100 file but in the tree.100 sub-model we can represent stalks (large wood), leaves and tops (branches), whose growth patterns and C:N ratios are different. Moreover these above-ground components are managed differently (e.g. stalks are harvested; leaves and tops were historically burned but currently are kept on soil surface as trash).
To better represent sugarcane, we considered three different time periods to account for the plant breeding during more than a century of cane cultivation in Brazil. This improvement was represented through the prdx parameter in the model which controls maximum potential plant growth rate. Model outputs from 2009 were saved and used as initial conditions for the six sets of simulations to represent experimental treatments: two soils and three N rates.

The DayCent files that schedule management events were based on records of these events that were implemented in the field. Model outputs for C removal, daily N2O emissions, daily NH4+ and NO3−, SOC and soil water content were saved and compared with measured values of these variables. Simulations were conducted assuming that 0.35 and 0.7% of nitrified N was emitted as N2O.

**Results**

The DayCent model was suitable in estimating the stalk yield of sugarcane (Figure 1) after altering the value for the prdx (1) parameter. The adjustment between observed data averaged for four replicates and estimated data was greater than 0.9 (R²). Sometimes the observed stalk yields for replicates were different from estimated values, but considering the natural infield variation, the model satisfactorily simulated the observed data. Moreover, the DayCent model differentiated between the SOC concentrations from both the Piracicaba site (clayey with higher C content than at Jau) as well the Jau site (sandy loam).

![Fig. 1—Observed and Daycent-predicted sugarcane stalk yields of plant-cane as a function of N rate and soil type in Brazil.](image)

On average, the model presented good agreement between daily measured and estimated soil water content data (data not shown). In general, the model predicted with high accuracy the difference between the two extreme soil types. DayCent underestimated the NH4+-N and NO3−-N concentrations in plots where no N was applied and in the fertilised areas over the periods before N was applied (data not shown).

Although the model has predicted some peaks related to native SOM mineralisation and mineral N availability, which occurred when the soil moisture started to increase, the levels were always lower than measured.

On the other hand, in periods near to N application the model satisfactorily predicted the effect of applied N on increasing the concentration of mineral N fractions for both N rates having a good agreement for NH4+-N and NO3−-N levels in the sandy loam soil (Jau) and NO3−-N in the clayey soil (Piracicaba).

There was a delay (underestimation) between the predicted and observed maximum NH4+-N level for Piracicaba just after N fertilisation on the 1st ratoon cane cycle. Independent of the amount of nitrified N lost as N2O we observed the same pattern for the mineral N turnover in both soils. The agreement between estimated and observed mineral N fractions was in general better in Jau, with R² equal to 0.54 and 0.24 for NH4+-N and NO3−-N, respectively.
The DayCent model also did not satisfactorily predict the daily N\textsubscript{2}O fluxes from a control treatment without N fertiliser (Figures 2a and 2d). This response seems to be related to underestimation of soil mineral N in these plots. In fertilised plots, the model was able to simulate the increase of daily N\textsubscript{2}O fluxes after N application regardless of N amount in the clayey soil site (Figures 2e and 2f).

We observed that the magnitude of daily fluxes was also better estimated when the factor of 0.35% was used to account for the loss of nitrified N as N\textsubscript{2}O, especially just after N application. However, even with the low factor of nitrified N lost as N\textsubscript{2}O (0.35%), predicted fluxes were higher than measured just after N fertilisation, in sandy loam soil site (Figures 2b and 2c), and then they were lower than some fluxes observed after rainfall events for both sites.

Jarecki \textit{et al.} (2008) also found underestimation of peak flux events following rainfall events. The model did not estimate well the daily fluxes throughout the first two months after N fertilisation in the sandy loam soil site (Figures 2b and 2c).

During this period we observed only a small peak which occurred just after a 200-mm rainfall event three weeks after N fertilisation. On the other hand the model predicted several small peaks in the first days after application of fertiliser. After two months of N fertilisation, the model was good in predicting the background emissions of both soil types.

In the clayey soil site was a better agreement detected between observed and predicted N\textsubscript{2}O fluxes with a correlation coefficient and R\textsuperscript{2} equal to 0.41 and 0.2, respectively. This magnitude of agreement has been determined as acceptable in past studies (Jarecki \textit{et al.}, 2008). The model underestimated the daily fluxes and cumulative emissions (Table 2) for plots without N in Piracicaba and Jau, respectively, by 80 and 83% when assuming that 0.35% of nitrified N is lost as N\textsubscript{2}O and by 68 and 44% when the loss assumption was 0.7%.

Averaging the other two N levels (medium and high), the model underestimated by 16% in Piracicaba and by 3% in Jau and overestimated by 39% in Piracicaba and by 94% in Jau, respectively, for 0.35 and 0.7% of nitrified N lost as N\textsubscript{2}O. These differences are in accord with those already published (Del Grosso \textit{et al.}, 2008). Higher differences between predicted and observed results were verified in the sandy loam soil site because there was no big effect of N
fertilisation on observed N\(_2\)O emission while the model is very responsive to N supply. The absence of response in this site was explained by Vargas et al. (2012) due to high drainage capacity and low water accumulation.

### Table 2—Observed and predicted N\(_2\)O emission throughout the first ratoon cane cycle in two sites of Brazil as a function of N fertiliser application and assuming two rates of loss of nitrified N (0.35 and 0.7%).

<table>
<thead>
<tr>
<th></th>
<th>N(_2)O-N emission (gN/ha)</th>
<th>Nitrified N lost as N(_2)O (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Predicted</td>
</tr>
<tr>
<td>Clayey soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without N</td>
<td>599</td>
<td>121</td>
</tr>
<tr>
<td>Mean N rate</td>
<td>1040</td>
<td>724</td>
</tr>
<tr>
<td>High N rate</td>
<td>1145</td>
<td>1407</td>
</tr>
<tr>
<td>Sandy loam soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without N</td>
<td>356</td>
<td>61</td>
</tr>
<tr>
<td>Mean N rate</td>
<td>364</td>
<td>269</td>
</tr>
<tr>
<td>High N rate</td>
<td>370</td>
<td>446</td>
</tr>
</tbody>
</table>

In this study we highlighted the potential issues related to the performance of the DayCent model when modelling data for N\(_2\)O emissions in a sugarcane plantation. In general, the performance of the DayCent model to estimate the fluctuations of the concentrations of inorganic N in the soil was somewhat poor, especially for the unfertilised plots, where N concentrations and N\(_2\)O emissions were underestimated.

The presence of high amounts of sugarcane residues (about 10 t/ha dry mass) after harvest may create conditions for soil N mineralisation that may not be capturable by the model. The overestimation of N\(_2\)O emissions just after N fertilisation is probably also associated with particular aspects of sugarcane crop: plants grow fast under rainy and warm weather and may deplete rapidly the soil available N.

Other authors also reported low correlations between estimated and measured values of N\(_2\)O emissions for crops other than sugarcane (Stehfest and Müller, 2004; Jarecki et al., 2008). This is not surprising taking into consideration the complex interactions and the multitude of factors that affect N\(_2\)O emissions.

However, DayCent predictions were, in several cases, quite acceptable and it may be improved if some specific characteristics of the sugarcane crop are built into the model. Further studies in tropical cane fields with high sampling intensity are required to better validate the model comparisons.

### REFERENCES


NITROGEN FERTILISATION FOR SUGARCANE 
BASED ON FOUR CONSECUTIVE RATOONS

By
H.A.W. JORIS, H. CANTARELLA, A.C. VITTI and R. ROSSETTO

Instituto Agronômico (IAC)
hwjoris@yahoo.com.br

KEYWORDS: Sustainability, Green Cane System, Ratoon Cane, Nitrogen.

Abstract

NITROGEN (N) FERTILISATION in sugarcane for bioenergy production is important to achieve high yields. In Brazil, recent results have pointed to higher responses to N fertilisation than previously observed. This study involved N application in consecutive years (2007 to 2012) in order to study the effects of N rates on yield, energy balance, N balance and economic factors, using a sugarcane variety highly responsive to N. N rate treatments were applied to each ratoon (0, 60, 120 and 180 kg/ha) for four years. Overall, considering all ratoons, N uptake was increased by N rates. This improvement in N nutrition resulted in increases in stalk yield in all ratoons. The highest stalk yields were obtained applying 180 kg/ha, which was the most profitable rate. On the other hand, this rate is almost 2-fold higher than the customary rates in Brazilian sugarcane ratoons, and almost 50% of the N applied was not exported by stalks in this treatment. Overall, there were few differences between N rates in energy ratios. To achieve adequate stalk yield in N responsive varieties, more N is required than is usually applied; however, these high application rates result in surplus N in the soil system.

Introduction

Nitrogen fertilisation in bioenergy crops has been widely discussed as a function of the great expenditure of energy to produce nitrogen fertilisers. Compared to other countries, in Brazil the amount of N applied is lower, and these amounts have resulted in N exports in harvested sugarcane higher than the N addition from N fertiliser (Cantarella et al., 2007).

f N applications do not meet the amount of N exported, soil N storage and biological fixation of N are possibly other sources. Constant use of soil-N may result in decreases in cane yield in the long-term, especially considering the use of new varieties, which are highly productive and N-demanding. There are recent studies concerning nitrogen fertilisation in sugarcane, with regards to plant-cane and ratoon-cane responses to N application.

These studies have shown positive responses of sugarcane to nitrogen fertiliser applications in the plant crop, and in greater magnitude, in the ratoon crops (Cantarella et al., 2007; Prado and Pancelli, 2008; Franco et al., 2010).

Therefore, the use of N fertilisers is becoming increasingly essential, in part due to more productive varieties. The increased need for N fertilisers is also a function of the phasing out of burning at harvesting, since the post-harvest residue (trash) from green-cane harvesting has a high C:N ratio.

If the input of N by fertiliser is higher than the output through harvest, N remains in the soil system, and it might be a source for N lost by leaching and denitrification, among others. On the other hand, if the increase in N rate results in higher biomass production, there is more C sequestration. Therefore, high N rates may represent a more efficient agriculture, producing high amounts of biomass, and using less land area for bioenergy production.
In order to make better N recommendations, it is important to carry out long-term studies, with consecutive fertiliser applications.

**Methods**

The sugarcane experiment was established in March 2008, on a Rhodic Kandiudox. It was located in Piracicaba, State of São Paulo, Brazil (22°4’S; 47°38’W), 580 m above sea level, 250 km inside the continent from the Atlantic Ocean. The sugarcane variety IAC 91-1099 was planted with rows 1.4 m apart.

After the harvest of plant-cane, in July 2008, four treatments of nitrogen fertiliser were applied: 0, 60, 120 and 180 kg/ha of N, as ammonium nitrate, in a randomised block design, with 4 replications. The treatments were applied on four consecutive sugarcane ratoons. The entire aboveground plant biomass along 2 m of the sugarcane row was collected at randomly chosen positions.

The masses of plant material (dry leaves, tops and stalk) from each plot were obtained directly in the field using an electronic scale. The dried subsamples were ground in a Wiley-type laboratory mill before determining the total N content (g/kg of N). With the moisture content and N concentration (g/kg of N) of samples, the N uptake (kg/ha of N) in the sugarcane aboveground biomass was calculated.

Only the stalks were removed from the field. Therefore, the accumulation of N (kg/ha) in the stalks was the export of N. The calculations of N balance were based on the measure of nitrogen output subtracted from nitrogen input.

In our work, inputs were considered as being the nitrogen fertilisation in different treatments, whereas the output is the export of N from stalks.

**Results and discussion**

In all evaluated ratoons, there was a linear response in stalk yield as a function of nitrogen application (Figure 1). These results indicate that even high N rates up to 180 kg/ha/y can result in biomass production increases.

In all raton crops, N uptake was increased with increasing N rates, resulting in an increase in N contained in the stalks. This improvement in N nutrition resulted in increases in stalk yield in all ratoons. In the four treatments, approximately 50% of the nitrogen taken up was removed with the stalks and 50% remained in tops and dry leaves, which is in agreement with other studies (Wood...
et al., 1996; Vitti et al., 2008). With the increase observed in stalk yield, the highest rate (180 kg/ha) was the more profitable rate.

On the other hand, this rate is almost 2-fold higher than the usual rate in Brazilian sugarcane ratoons, and almost 50% of the N applied was not exported by stalks in this treatment, which may result in environmental problems. However, this increase in biomass production means that less land can be used to produce the same amount of energy under high N applications.

The nitrogen balance (Figure 2) showed that, in the control treatment and at the low rate (60 kg/ha), the amount of N applied was not sufficient to replace the N removed by stalks, which may result in soil degradation in the long-term.

On the other hand, higher rates (120 and 180 kg/ha) resulted in N addition higher than N exports, mainly with 180 kg/ha. In conditions with deep soils, without problems of nitrate leaching and water contamination, or high nitrous oxide emissions, this may not be a problem. However, soil type should be evaluated in terms of nitrogen concentrations, so that N recommendations will have minimal environmental impact.

REFERENCES


ARSENAL GEN 2® (IMAZAPYR) PROVIDES MORE THAN FOUR MONTHS OF WEED CONTROL ON SUGARCANE FIELD ROADS AND NON-CROP LANDS

By

S. SEERUTTUN, C. BARBE
and A. GAUNGOO

Mauritius Sugarcane Industry Research Institute,
Réduit, Mauritius

suman.seeruttun@msiri.mu

KEYWORDS: Cynodon dactylon, Woody Shrub, Glyphosate, Post-Emergence.

Abstract

WEED MANAGEMENT ON roads along sugarcane fields in Mauritius is currently achieved by several applications of herbicide treatments, often consisting of glyphosate and diuron. Imazapyr, a non-selective herbicide with a good post-emergence efficacy followed by a long residual activity and used in non-crop lands in several countries, has been tested as an alternative for cost-effective control of weeds on sugarcane field roads and adjacent non-crop lands. Arsenal Gen 2 (imazapyr), at rates varying between 0.25 and 1.25 kg a.i./ha, has proved to be very effective on a large spectrum of weeds including some tough grass species like Cynodon dactylon, Panicum maximum and Chloris barbata. The level of control increased appreciably as from 0.75 kg a.i./ha. The only weakness of Arsenal Gen 2 has been observed on the woody shrubs Desmanthus virgatus and Eupatorium pallescens. As from 0.75 kg a.i./ha, Arsenal Gen 2 outclassed the standard glyphosate tank-mixed with atrazine or diuron with a residual activity exceeding 16 weeks. This study indicates that the rates of Arsenal Gen 2 which should be recommended for commercial use in Mauritius will vary between 0.75 and 1.125 kg a.i./ha.

Introduction

Weed control on sugarcane field roads and non-crop lands is currently achieved by several herbicide applications, often consisting of glyphosate alone or in tank-mixes with diuron. However, these are not economically viable as they require several interventions. ARSENAL GEN 2® contains 250 g of imazapyr per litre.

Its effectiveness has been demonstrated in a strategy to manage weeds in fallow sugarcane lands before planting the succeeding crop (Liu et al., 1992).

The objective of this work was to determine the optimum rate of ARSENAL GEN 2® for use on sugarcane field roads and non-crop lands in Mauritius.

Materials and methods

Two trials were established in non-crop lands at Riche Terre and Union Park, and two on sugarcane field roads at Riche en Eau. The various rates of Arsenal Gen 2 tested and the three standards are given in Table 2.

Spraying was carried out using hand-operated knapsack sprayers, delivering 350 litres of
spray solution per hectare at a working pressure of 300 kPa. The statistical design was a randomised complete block with three replicates and a plot size of 64 m².

**Table 2**—Pre-post-emergence herbicide treatments.

<table>
<thead>
<tr>
<th>Tmt. Nos.</th>
<th>Herbicides</th>
<th>Dosage – kg a.i./ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arsenal Gen 2</td>
<td>0.250</td>
</tr>
<tr>
<td>2</td>
<td>Arsenal Gen 2</td>
<td>0.500</td>
</tr>
<tr>
<td>3</td>
<td>Arsenal Gen 2</td>
<td>0.750</td>
</tr>
<tr>
<td>4</td>
<td>Arsenal Gen 2</td>
<td>1.000</td>
</tr>
<tr>
<td>5</td>
<td>Arsenal Gen 2</td>
<td>1.125</td>
</tr>
<tr>
<td>6</td>
<td>Arsenal Gen 2</td>
<td>1.250</td>
</tr>
<tr>
<td>7</td>
<td>Glyphosate + diuron (Std. 1)</td>
<td>1.0 + 2.0</td>
</tr>
<tr>
<td>8</td>
<td>Glyphosate + atrazine (Std 2)</td>
<td>1.0 + 2.4</td>
</tr>
<tr>
<td>9</td>
<td>Glyphosate + diuron (Std. 3)</td>
<td>1.7 + 2.0</td>
</tr>
<tr>
<td>10</td>
<td>Control (Untreated)</td>
<td>–</td>
</tr>
</tbody>
</table>

Data collection comprised an assessment of the percentage weed cover before spraying and at 16 weeks after spraying (WAS), with visual observations at four and eight WAS. The pre-emergence efficacy was assessed from the final survey.

The data were then arcsine transformed for analysis of variance (Gomez and Gomez, 1984) and the treatment means were compared using the Duncan’s Multiple Range Test (DMRT).

**Results and discussion**

**Non-crop lands**

At spraying, grasses and a woody shrub, *Desmathus virgatus*, were predominant at Riche Terre. Observations showed a fairly good knock-down of grasses with the lowest rate of Arsenal Gen 2, the effect improving with increase in dosage. *D. virgatus* proved resistant to Arsenal Gen 2. From the final survey, the post-emergence effect with Arsenal Gen 2 outclassed the three standards (Figure 1).

![Fig. 1—Post-emergence efficacy of herbicide Arsenal Gen 2 in non-crop lands at Riche Terre and Union Park. Means followed by a common letter are not significantly different at the 5% level.](image-url)
The final weed survey revealed that Arsenal Gen 2 has a superior residual activity to the standard treatments (Figure 2).

At Union Park, the predominating weeds at spraying consisted of *Digitaria horizontalis*, *D. timorensis* and a few broad-leaved species. A fairly good knock-down of the two *Digitaria* spp. was observed with the lowest rate of Arsenal Gen 2; the level of control improved with increase in dosage and the three higher rates were more effective than the standards. This was confirmed at the final survey (Figure 1). The only weakness of Arsenal Gen 2 was on the woody shrub *Eupatorium pallescens* which appeared to be quite resistant.

The residual activity of Arsenal Gen 2, observed at Union Park, was significantly superior at the two higher rates (Figure 2).

**Sugarcane field roads**

Grasses were the predominating weeds before spraying at Riche en Eau 1; *Cynodon dactylon* being the main one. A fairly good knock-down of most weeds except *C. dactylon* was noted at 4 WAS with the lowest rate of Arsenal Gen 2; the effect improved with increase in dosage. Arsenal Gen 2 was in general superior to the three standards, the best one being the higher rate of glyphosate tank-mixed with diuron where severe scorching of *C. dactylon* and other weeds were noted. These were confirmed in the final weed survey carried out 16 WAS (Figure 3).
The residual activity of the various treatments at the final survey showed the superiority of Arsenal Gen 2 at rates of 1.125 and 1.25 kg a.i./ha (Figure 4).

At Riche En Eau 2, all treatments gave a good knock-down of most weeds. The final survey showed a good level of control of most grasses with the three lower rates of Arsenal Gen 2; however, some young broad-leaved weeds had started to emerge in these plots (Figure 3). At the three higher rates, almost complete eradication of most weeds except *Eleusine indica* was obtained.

The superiority of Arsenal Gen 2 with respect to its residual activity was not apparent from the final survey as some broad-leaved weeds had emerged at the time of the final survey (Figure 4). However, the Arsenal Gen 2 plots appeared cleaner.

**Conclusion**

Arsenal Gen 2 tested in non-crop lands and field roads have proved to be very effective on a broad spectrum of weeds and with a relatively longer residual activity than glyphosate tank-mixed with atrazine or diuron. The rates of Arsenal Gen 2 which will be recommended for commercial use in Mauritius will vary between 0.75 and 1.125 kg a.i./ha.

**REFERENCES**


A BASELINE SURVEY ON THE STATUS OF SUGARCANE PRODUCTION TECHNOLOGIES IN WESTERN KENYA

By
J.E. JAMOZA, R.A. AMOLO and S.M. MUTURI
Kenya Sugar Research Foundation P.O. BOX 44-40100 Kisumu, Kenya
japheth.jamoza@kesref.org; risper.amolo@yahoo.com

KEYWORDS: Sugarcane Productivity, Improved Varieties, Farmers.

Abstract
OVER THE PAST DECADE, low sugarcane productivity has persisted in all production zones in Kenya. The objectives of this study were to determine current sugarcane yields in various zones, assess the extent of adoption of best sugarcane management practices, establish the area of commercial sugarcane varieties and determine the reasons for low cultivation of improved varieties. The study was conducted between March and April, 2011. Sugarcane yields were low and varied both across and within zones. Average sugarcane yield was 64 t/ha as opposed to a potential yield of more than 100 t/ha under rain-fed conditions. Old varieties, namely Co 945 (42.7%), Co 421 (20.4%), Co 617 (13.4%) and N14 (12.7%), were still dominant with improved varieties accounting for only 6% of the area. Primary data analysis indicated that current sugarcane management practices in Kenyan production included conventional tillage (54% of respondents), minimal soil tests prior to planting (25%), use of poor quality seedcane (over 80%), manual weed control (over 60%), lack of seedcane of new varieties (57%), and lack of awareness (31%). The study results show that sensitisation and training of farmers on new varieties and use of best management practices should be performed. In addition, an effective seedcane multiplication and distribution framework should be instituted urgently to improve technology uptake.

Introduction
The sugar industry is a source of income for over 260 000 farmers, 11 700 employees, and directly or indirectly supports over 6 million Kenyans (Wawire et al., 2011). The Kenya Sugar Research Foundation (KESREF) has been researching technological solutions to low sugarcane productivity reported in all sugarcane zones in western Kenya.

The European Union (EU) has also provided KESREF with additional resources to conduct research to improve Kenyan growers’ sugarcane productivity. Since 2002, KESREF has developed and released 13 improved varieties (Jamoza, 2005, 2011) but their adoption is still very low (Odenya et al., 2010).

In addition, KESREF has developed best management practices (BMPs) for sugarcane farmers in western Kenya. The BMPs are site-specific practices, which provide optimum production potential, improve input efficiency and provide environmental protection (CSIRO, 2007).

Some BMPs developed and recommended by Rono et al. (2010) include early maturing varieties, soil tests prior to planting, and appropriate fertiliser use. Cultivation of early, medium and late maturing varieties in suitable proportions has been reported to increase sugar yields and gross margins (Jackson et al., 1999; Anon., 2008).

Soil tests lead to improved nutrient use, thereby sustaining yields and reducing nutrient loss to the environment (Legendre et al., 2000). However, in Mauritius, 75% of sugarcane farmers do not use soil testing despite this service being provided free (Payandi Pillay et al., 2010).
In Kenya, soil tests are charged as little as USD 1.18 for soil pH to USD 10 for the basic elements (N,P,K) due to high costs of chemicals used for sample analysis.

Information on the status of adoption of BMPs in the sugar industry in western Kenya is limited. A baseline survey was conducted to determine the status of production technologies in various sugarcane-growing zones and identify possible interventions to improve sugarcane productivity.

Specific objectives of this study were to:
1. determine current sugarcane yields in various zones,
2. assess the extent of adoption of sugarcane BMPs,
3. establish area of commercial sugarcane varieties, and
4. assess the reasons for low adoption of improved sugarcane varieties in western Kenya.

Materials and methods
The study was contacted in the Mumias-West Kenya/Butali-Nzoia, Chemelil-Muhoroni-Soin, and South Nyanza-Transmara-Sukari sugar zones in western Kenya covering about 157,500 ha. A multidisciplinary team of scientists from KESREF undertook the study between March and April 2011.

The study entailed a review of the available secondary information in the KESREF sugar database and sugar industry reports, followed by primary data collection.

Through stratified random sampling, 366 sugarcane farmers drawn equally from the various sugar zones were interviewed using a pre-designed questionnaire containing 28 questions. The data collected were analysed using the SPSS version 17 (2008 release) statistical package.

Results and discussions
Secondary information indicated that sugarcane yields were low, and varied within and across the zones (Figure 1). The average yield was 64 t/ha in 2010 (KSB, 2010). Sugarcane yield was a function of various factors including soil type, climatic condition, variety and crop management practices.
More than 80% of the respondents used untreated seedcane (Figure 2). Planting untreated seedcane may lead to build-up of sugarcane diseases such as smut, mosaic and ratoon stunting (Tucker et al., 1981).

![Fig. 2—Use of treated seedcane by farmers in western Kenya.](image)

Only 25% of respondents tested their soils prior to planting (Figure 3). This finding was similar to Payandi Pillay et al. (2010) who reported that 75% of the respondents were not testing soils even when the services were free. Legendre et al. (2000) reported that soil tests prior to planting lead to improved nutrient use, reduced nutrient loss to the environment and sustained cane yields.

![Fig. 3—Use of soil testing prior to planting in western Kenya.](image)

Manual weed control was a common practice (over 60% respondents) in the industry (Figure 4). Weeds compete with sugarcane for nutrients, water and light especially during the first 6 months after planting before sugarcane canopy closure.
Integrated weed control is one of the BMPs recommended by KESREF to provide management of troublesome perennial weeds such as couch grass (*Cynodon dactylon* L).

Sugarcane smut was the major disease (79% respondents) in all zones (Figure 5). The high sugarcane smut incidence could be associated with use of untreated seedcane (Tucker *et al.*, 1981). Nzioki *et al.* (2006) reported a 21–38% cane yield loss due to smut in Kenya.

The most common varieties cultivated were Co 945 (42.7%), Co 421 (20.4%), Co 617 (13.4%) and N14 (12.7%). Only 6% of the respondents had adopted newer, improved varieties, with D8484, KEN 83-737 and KEN 82-472 the most popular.
There was poor variety mix with old late-maturing varieties being more popular than improved early-maturing ones. This finding is contrary to a proposed variety mix of 30:40:30 for early, medium and late maturing varieties (Jackson et al., 1999; Anon., 2008) which results in increased sugar yields and profitability.

The reasons for low adoption of improved sugarcane varieties were lack of seedcane (60% of the respondents) and awareness (30% respondents) (Figure 6). This was attributed to lack of an effective seedcane development and distribution framework.

![Figure 6—Reasons for low adoption of improved varieties in the sugar industry in western Kenya.](image)

**Conclusions**

Average cane yield was 64 t/ha against the potential of at least 100 t/ha under rain-fed conditions in Kenya. Most farmers still applied old technologies on their farms. The most popular varieties were Co 945, Co 421, Co 617 and N14. Among the new varieties, D8484, KEN 83-737 and KEN 82-472 were popular.

Lack of seedcane was the major limitation to adoption of new varieties. An effective seed cane multiplication and distribution framework is urgently required to promote the adoption of improved varieties. Farmers’ training on the following BMPs is required in order to improve productivity: soil tests prior to planting to guide fertiliser use, planting high quality seedcane, and integrated weed management.

**Acknowledgements**

The authors are grateful to the European Union and KESREF for funding the project and to our research colleagues for assistance in data collection and analysis.

**REFERENCES**


EVALUATION OF ORGANIC SUGARCANE FARMING AND ITS EFFECT ON SOIL PROPERTIES, PLANT GROWTH AND YIELD

By

A. SORAGHI, K. MASUDIAN, F. YARAHMADI
and M. MOSTOFI

Applier Recherché Center of Deabel Khozaei Agro-industrial CO., Ahvaz, Iran
Am_srg@yahoo.com

KEYWORDS: Sugarcane, Organic Farming,
Bagasse, Filter Mud, Manure.

Abstract

Organic farming is a system of farm management to create an eco-system which can achieve sustainable production without the use of artificial external inputs such as chemical fertilisers and pesticides. The potential of organic farming in generating socially and environmentally beneficial effects is impressive. In order to determine the production of organic sugar from organic sugarcane, an experiment was conducted at Deabel Khozaei research center in Iran. The experiment was designed as a randomised complete block with 3 replications and 5 treatments. The treatments were: T1: control (chemical fertiliser and herbicide), T2: 50 t/ha bagasse, T3: 50 t/ha filter mud, T4: 20 t/ha manure, and T5: 25 kg/ha clover. The results showed that the effect of different treatments on soil physical properties including bulk density, permeability and organic matter was not significant. Also the effect of treatments on soil cation and anion concentration, the amount of available phosphorus and soil PH, ESP and ECe was not significant. However, the percentage of nitrogen in the soil at different times was significant. The results also showed that treatments had significant effect on cane height. The control treatment and manure had highest and lowest heights, respectively. None of the treatments had a significant effect on sugarcane yield. None of the treatments had a significant effect on sugar quality factors except brix. In this study, there was no significant difference in yield between inorganic and organic sugarcane farming treatments.

Introduction

Organic farming differs from conventional farming in a number of ways. In conventional farming, synthetic chemicals are used to increase growth. However, in organic farming, it is preferable to use organic wastes and compost in the form of fertilisers, which can result in increasing the nutrients supplied to plants.

Recently, due to the environmental pollution caused by chemical fertilisers and pesticides and their consequences, organic farming has been followed in many advanced countries. The extent of this type of agriculture is expanding and is one way of increasing soil organic matter (Mozardelan and Savabeqy, 2002).

Adding filter cake to soil was found to enrich soil organic matter (Juan, 1989). Also, liquid manure applications increased soil organic matter content from 5% to 9% (Tsa-pou, 1968).

Research showed that, among the organic fertilisers, light weight and porous organic matter caused a decrease in soil bulk density (Kaurichev et al., 1963).

The purpose of this project was to study the effect of organic farming through application of bagasse, filter cake, and clover on soil properties and yield of sugarcane.
Materials and methods

In order to investigate the possibility of producing organic sugar devoid of chemical fertilisers, pesticides and herbicides, an experiment was conducted in a randomised complete block design with five treatments and three replications.

The treatments were: T1: control (chemical fertilisers and herbicides), T2: 50 tonnes per hectare of bagasse, T3: 50 tonnes per hectare of filter cake, T4: 20 tonnes per hectare of manure, and T5: 25 kg/ha of clover.

Results and discussion

Effect of different treatments on soil physico-chemical properties

Table 1 shows the results of soil physico-chemical analysis in each treatment, 10 months after planting. None of these properties was significantly different among treatments.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Treatment</th>
<th>pH</th>
<th>EC</th>
<th>Cl⁻</th>
<th>Na⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>P₂O₅</th>
<th>N%</th>
<th>OM%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ms/cm</td>
<td>Meq/L</td>
<td>Meq/L</td>
<td>Meq/L</td>
<td>Meq/L</td>
<td>mg/kg</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>8.19</td>
<td>3.61</td>
<td>21.83</td>
<td>22.30</td>
<td>15.56</td>
<td>8.83</td>
<td>10.90</td>
<td>0.046</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>8.14</td>
<td>3.87</td>
<td>20.43</td>
<td>20.87</td>
<td>23.52</td>
<td>9.80</td>
<td>14.33</td>
<td>0.040</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>8.17</td>
<td>3.69</td>
<td>19.44</td>
<td>18.29</td>
<td>21.17</td>
<td>8.75</td>
<td>9.63</td>
<td>0.043</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>T4</td>
<td>8.18</td>
<td>3.19</td>
<td>13.47</td>
<td>14.69</td>
<td>18.33</td>
<td>7.67</td>
<td>15.70</td>
<td>0.041</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>8.28</td>
<td>2.37</td>
<td>11.81</td>
<td>11.88</td>
<td>11.61</td>
<td>4.47</td>
<td>14.00</td>
<td>0.045</td>
<td>0.77</td>
</tr>
</tbody>
</table>

The results of the analysis of variance and Duncan's comparison test shows that among the factors measured, only the nitrogen content of soil varied significantly at the 5% level over time. N content increased with increasing crop age and the highest percentage of nitrogen in the soil was at the final sampling (Figure 1).

Effect of different treatments on yield and quality of sugarcane

Sugarcane height in different treatments was significantly different (Figure 2). Maximum and minimum stalk height were observed in T1 (chemical fertiliser control) and T4 (manure), respectively. Lower stalk height in T4 may be due to low nutrient content and high salinity of manure.
Stalk length in T3 (filter cake) was not significantly different from the control.

**Sugar cane quality**

The effect of different treatments on % RS, % PTY and % POL were not significant. But the effect of different treatments on brix was significant and the means separated in 3 different groups (Figure 3).

The results of this study indicate that different treatments had no significant effect on the juice quality except brix. Due to the short time interval of the experiment, the decomposition of the organic material might have been slow and would not show any impact on juice quality.

**Discussion**

Serious doubts have been raised about the ability of organic farming to attain the productivity levels achieved under conventional agriculture (Bhattacharyya and Chakraborty, 2005; Das and Biswas, 2002). It has been noted that the change from conventional intensive farming to organic farming reduces yields, at least during the initial years (IFAD, 2005; Rajendran et al., 2000).
In this study, there was no significant difference in yield between inorganic and organic sugarcane farming treatments. But organic treatments (T2, T3, T4 and T5) had 35.8, 19.8, 39.8 and 43.3% lower yield, respectively than an inorganic farmer treatment (T1).

However, it has been reported that, in subsequent years, organic farming is able to reduce this yield gap (Rajendran et al., 2000) and sometimes has given higher yields also (Thakur and Sharma, 2005).

It was observed in Karnataka that, by the end of the third year, the sugarcane yields were stabilised and, from the fourth year, the yields became higher with organic sugarcane farming than inorganic farming (IFAD, 2005).

The results of this study indicate that economic profits were 20 per cent higher from organic sugarcane farming than inorganic sugarcane farming. This could be attributed to lower cost of cultivation in organic sugarcane farming and higher prices for organic sugar.

The covariance of gross profits was also substantially higher in organic farming than inorganic farming. Thus, this analysis shows that not only profitability was higher but was much more stable under organic farming than inorganic farming.

The higher cost efficiency observed in organic sugarcane farming was also reflected in higher gross returns per rupee of total cost.

REFERENCES


Tsa-pou, Y. (1968). Comparison of the effect of compost, solid and liquid manure on sugarcane yields and on physico-chemical properties of the soil. TSE Soil Research Institute, China.
EFFECT OF NUTRIENT SOURCES AND LEVELS ON SUGARCANE SEED PRODUCTION

By
R.R. KUMAR¹, S. NATARAJAN², S. PANEERSELVAM² and J.S. GAWANDER¹

¹Sugar Research Institute of Fiji, Drasa, Lautoka, Republic of Fiji Islands
²Department of Agronomy, Faculty of Agriculture, Annamalai University, Tamil Nadu, India

renil@srif.org.fj

KEYWORDS: Saccharum officinarum, Chip Bud, Shade Net, Diammonium Phosphate, Urea.

Abstract
A NURSERY AND A FIELD experiment were conducted from 2010 to 2012 to study the response of various levels and sources of nutrients on sugarcane chip buds and their effects in the field. The experiment was designed and planted at the Department of Agronomy trial site at Annamalai University, Annamalainagar, Tamil Nadu, India. A split plot design with three replications was used. The two main plot treatments were: seedlings raised with shade net (M₁) and without shade net (M₂). There were eight treatments in each sub plot: control (coir pith) (T₁), 0.5 g urea per chip bud (T₂), 0.5 g diammonium phosphate per chip bud (T₃), 3% panchagavya foliar spray (T₄), 5 g vermicompost per chip bud (T₅), 0.5% urea foliar spray (T₆), 1% DAP foliar spray (T₇) and 1% 19:19:19 complex foliar spray (T₈). In the field, conventional fertiliser rates (275:63:113 kg/ha N, P₂O₅ and K₂O, respectively) were applied uniformly in all treatments. Nursery results indicated that chip bud seedlings raised under shade net with fertiliser application rate of 0.5 g DAP or urea per chip bud showed encouraging results in terms of plant height, leaf area index (LAI), root length and seedling vigour index at 25 days after planting. In the field seedlings raised under shade net with direct application of 0.5 g DAP or urea per chip bud recorded higher growth and yield attributes viz., tiller count, millable cane, cane length, individual cane weight and seed cane yield of 93 t/ha at 210 days after planting. Higher economic returns were observed under these treatments which is beneficial in the current scenario for sugarcane seed production in India.

Introduction
The sugar industry is the main livelihood of 35 million farmers in India with an area of 4.2 million ha under cane and a production of 335 million tonnes per year. Different technologies are used to produce seed cane for the industry. Sustainable Sugarcane Initiative appears to result in lower usage of seed cane and irrigation water. In India, the average requirement of seed material per year is approximately 40 million tonnes (Gujja et al., 2009).

With the adoption of chip bud technology, there is a possibility of savings of approximately 20 million tonnes of seed cane that could be sent for milling, thus benefitting both the farmers and the millers. Well-nurtured seedcane can lead to the establishment of good plant and ratoon crops. As chip buds have minimum amounts of mother tissue attached to the bud, a suitable management technique for developing a healthy seedling is imperative.

Taking these factors into consideration, a field study was undertaken to study the response of chip buds to various nutrient sources and their effects in field trials using Sustainable Sugarcane Initiative (SSI) technology.
Materials and methods

A nursery and a field study were conducted on a sugarcane seed crop (2010 – 2012) using chip bud production techniques at the experimental farm of the Department of Agronomy, Annamalai University, Annamalainagar, Tamil Nadu (11° 24’ N, 79° 44’ E 5.79 masl). This site represents a tropical climate with moderately warm and hot summer months. Mean annual rainfall is approximately 1200 mm and nearly 80% of the total rainfall is received through the north-east monsoon. Total rainfall during the growing seasons was 362.3 mm and 1421.8 mm.

The soil can be characterised as a clay loam, with high organic C (0.63%) and low available N (229 kg/ha), medium P availability (19.30 kg/ha) and high in K (325 kg/ha). Soil Ec was 0.28 dS/m and its pH was 7.9. Chip buds were chipped from healthy, 7 month old seed cane and planted in plastic trays with coir pith medium during the 2-year (2010–2012) trial. A split plot design with three replications was used. The main treatments were trays planted inside the nursery with a shade net (M1) and outside the nursery (M2). Sub plot treatments included: control (coir pith) (T1), 0.5 g urea per chip bud (T2), 0.5 g diammonium phosphate per chip bud (T3), 3% panchagavya foliar spray (T4), 5 g vermicompost per chip bud (T5), 0.5% urea foliar spray (T6), 1% DAP foliar spray (T7) and 1% 19:19:19 complex foliar spray (T8) were applied at 12 days after planting (DAP).

Transplanting of the seedlings to the field was done 25 days after planting the chips and, throughout the program, the SSI methodology was adopted. Growth measurements of the chip buds were recorded: including germination percentage at 12 DAP, plant height, leaf area index (LAI), root length and seedling vigour index at 25 DAP in the nursery. In the field experiment, observations were made on per cent establishment of seed cane, tiller count, number of stalks, stalk height and individual cane weight. Seed cane yield was recorded 210 DAP. The prevailing market prices of inputs and outputs were taken into account for economic analysis of different treatments. Values were subjected to Statistix 9 package statistical analysis, and means were separated at the 5 % probability level.

Results and discussion

Nursery (2010–12)

The results recorded indicated that the seedlings raised under a shade net had increased plant height, root length and vigour index (Table 1). These shade net benefits could be ascribed to a more appropriate temperature for germination and planting development growing under shade.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>2010-2011</th>
<th>2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height (cm)</td>
<td>Root length (cm)</td>
</tr>
<tr>
<td>Shade net effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shade net effect</td>
<td>20.94a</td>
<td>20.95a</td>
</tr>
<tr>
<td>Without shade net</td>
<td>18.15b</td>
<td>16.44b</td>
</tr>
<tr>
<td>SE_0</td>
<td>0.2</td>
<td>0.61</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.41</td>
<td>1.62</td>
</tr>
<tr>
<td>Nutrients applied in the nursery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>14.71d</td>
<td>14.34g</td>
</tr>
<tr>
<td>0.5g Urea/chip bud</td>
<td>23.01a</td>
<td>20.18b</td>
</tr>
<tr>
<td>0.5g DAP/chip bud</td>
<td>23.43a</td>
<td>21.54a</td>
</tr>
<tr>
<td>3% Panchagavya foliar spray</td>
<td>17.36c</td>
<td>16.35f</td>
</tr>
<tr>
<td>5g Vermicompost/chip bud</td>
<td>17.41c</td>
<td>17.51e</td>
</tr>
<tr>
<td>0.5% Urea foliar spray</td>
<td>19.98b</td>
<td>18.75d</td>
</tr>
<tr>
<td>1% DAP foliar spray</td>
<td>19.47bc</td>
<td>19.55c</td>
</tr>
<tr>
<td>1% 19:19:19 complex foliar spray</td>
<td>20.51b</td>
<td>21.25a</td>
</tr>
<tr>
<td>SE_0</td>
<td>1.18</td>
<td>0.25</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>2.36</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Means in the same column and treatment group followed by the same letter are not significantly different (P < 0.05). N/A – Not statistically analysed; B:C ratio – benefits cost ratio
In Annamalainagar, temperatures are high (>35°C) and according to many researchers, optimal temperatures for germination ranged between 18–30°C (Whiteman et al., 1963; Keating et al., 1999; Romero et al., 2001). Temperatures above 34°C causes growth disorder in sugarcane plants and low temperature reduces tillering and affects sprouting of the buds. Thus, shade nets play an important role in protecting the seedlings from heat stress and physical protection. Perez et al. (2006) explained that shade nets which can be used outdoors as well as in greenhouse conditions provided physical protection (birds, snail, insects, excessive radiation), affected environmental conditions (humidity, shade, temperature) and increased the relative proportion of diffused (scattered) light. Regarding the nutrient treatments, applications of 0.5 g DAP and urea significantly influenced all the growth parameters in the nursery (Table 1).

**Main field (2010–11)**

Seedlings that were raised under a shade net performed better with higher growth parameters. The increase in plant height under a shade net was 24 cm at 210 DAP, whereas LAI was 5% greater compared to plants that were not grown under a shade net. A similar increase in tiller count and dry matter production (DMP) was noticed.

Among the various sources of nutrients tested, application of 0.5 g of DAP per chip bud, significantly influenced all the measured growth parameters. It is noteworthy to observe that 0.5 g of urea per chip bud led to similar growth increases to sugarcane treated with 0.5 g of DAP. The seedlings in the nursery that exhibited better performance, continued to do so in the field as well.

As a result seedlings established well, which resulted in favourable growth. In the field experiments, additional quantities of urea, DAP and muriate of potash application resulted in further improved growth. Similar establishment of a good quality plant crop occurred when 40 day old chip buds were transplanted and uniform early tillers and increased cane length was reported by Tamil Selvan (2000). These healthy seedlings from treatments T2 and T3 recorded faster growth and high tiller production in the field.

**Yield attributes and seed cane yield**

Yield is a function of yield attributes. As observed in growth and yield attributes, the same treatment (0.5 g DAP or 0.5 g urea with shade net) resulted in higher seed cane yield (Table 2).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>2010-2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tillers (000/ha)</td>
</tr>
<tr>
<td>Shade net effect</td>
<td></td>
</tr>
<tr>
<td>Shade net effect</td>
<td>153a</td>
</tr>
<tr>
<td>Without shade net</td>
<td>132b</td>
</tr>
<tr>
<td><strong>SE&lt;sub&gt;D&lt;/sub&gt;</strong></td>
<td>4.76</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>9.52</td>
</tr>
<tr>
<td>Nutrients applied in the nursery</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>115e</td>
</tr>
<tr>
<td>0.5g Urea/chip bud</td>
<td>164a</td>
</tr>
<tr>
<td>0.5g DAP/chip bud</td>
<td>166a</td>
</tr>
<tr>
<td>3% Panchagavya foliar spray</td>
<td>127d</td>
</tr>
<tr>
<td>5g Vermicompost/chip bud</td>
<td>130d</td>
</tr>
<tr>
<td>0.5% Urea foliar spray</td>
<td>143c</td>
</tr>
<tr>
<td>1% DAP foliar spray</td>
<td>140c</td>
</tr>
<tr>
<td>1% 19:19:19 complex foliar spray</td>
<td>153b</td>
</tr>
<tr>
<td><strong>SE&lt;sub&gt;D&lt;/sub&gt;</strong></td>
<td>4.94</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>9.88</td>
</tr>
</tbody>
</table>

Means in the same column and treatment group followed by the same letter are not significantly different (P < 0.05)
Earlier Pannu et al. (1985) demonstrated the importance of phosphorus in promoting root growth as well as tillering ability. Sathyavelu et al. (1999) showed the importance of nitrogen in increasing sugarcane yield, thus supporting our present findings.

The Benefit Cost Ratio (BCR) was favourable with the application of 0.5 g DAP per chip bud under shade net conditions. High seed cane yield resulted in higher profit. The 0.5 g DAP treatment was followed by 0.5 g urea per chip bud with shade net which also gave reasonable BCR, which is beneficial for both farmers and millers.

**Conclusions**

Seedlings raised in the nursery under a shade net with application of 0.5 g of DAP per chip bud gave healthier seedlings and higher seed cane yield in the field with the highest monetary returns.

**REFERENCES**


EFFECT OF SUGARCANE HARVEST RESIDUE ON NUTRIENT RECYCLING AND CANE YIELD

By

H.S. SANDHU1, R.A. GILBERT1, G. KINGSTON2, J.F. SUBIROS3,
K. MORGAN4, R.W. RICE5, L. BAUCUM6, J.M. SHINE, JR.7 and L. DAVIS8

1University of Florida, Everglades Research and Education Center, Belle Glade, Florida
2Formerly BSES Limited, Bundaberg, Australia; now Sugron Pty Ltd, Australia
3Azucarera El-Viejo, Guanacaste, Costa Rica
4University of Florida, Southwest Florida Research and Education Center, Immokalee, Florida
5University of Florida, Palm Beach County Extension Service, West Palm Beach, Florida
6University of Florida, Hendry County Extension Service, La Belle, Florida
7Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida
8United States Sugar Corporation, Clewiston, Florida

Contact author: hsandhu@ufl.edu

KEYWORDS: Green Cane, Burnt Cane, Trash Blanket, Histosol, Nitrogen, Phosphorus, Potassium.

Abstract

SUGARCANE HARVEST METHODS include both green and burnt cane harvest. With green-cane harvest, thick layers of residue (7.55 to 23.30 t/ha) remain on the soil surface after harvest. With burnt cane harvest, most of the leafy biomass is burned away, resulting in considerably smaller quantities of soil surface residues (0.87 to 4.73 t/ha). The amount of nutrients in the residue left after green or burnt cane harvesting and their effect on yield in different soil types is not fully elucidated. A three-year study was conducted in Florida and Costa Rica on three soil types, including a muck Histosol (EREC, Florida), a sandy-textured Entisol (Hilliards, Florida) and a clay loam Inceptisol (El Viejo, Costa Rica) to determine the effects of harvest method on trash nutrients (N, P, K, Ca, Mg, Zn, Mn, Cu, and Fe) and cane yield. Due to a significantly greater amount of harvest residue in green-cane than burnt-cane harvest, all harvest residue nutrients were significantly greater in green-cane. However, cane yield was greater in burnt-cane harvest by 7.8, 3.9, and 1.7 t/ha at El-Viejo, EREC, and Hilliards, respectively. These trends suggest that, while trash fractions associated with green-cane harvest can potentially add significantly greater quantities of nutrients to the soil, these nutrients may not be immediately available to support increases in cane yield.

Introduction

In both Florida and Costa Rica, increasing urbanisation pressures near agricultural regions, combined with a general desire to return organic residues to agricultural soils, have led to an increased interest in green-cane harvesting options. The short- and long-term impacts of burnt vs green-cane harvesting on sugarcane production dynamics in both Florida and Costa Rica are not well understood. The objectives of this study were to compare green vs burnt-cane harvest systems for differences in nutrient levels within harvest ‘trash’ residues, the potential return of these nutrients to the soil, and the effect this might have on yields in sugarcane grown on three different soil types.

Materials and methods

A three-year study was conducted on an organic muck Histosol [University of Florida/IFAS Everglades Research and Education Center (EREC) in Belle Glade, Florida], a sandy Entisol [Hilliard Brothers (Hilliards) in Clewiston, Florida], and a clay loam Inceptisol (Azucarera, El-
Viejo in Guanacaste, Costa Rica). Sugarcane varieties grown at EREC, Hilliards and El-Viejo were CP 80-1743, CP 78-1628, and B 80-689, respectively.

Each experiment included two harvest treatments (pre-harvest burnt and green-cane harvest), with three to six replications arranged as a randomised complete block design. Plot sizes at all locations were at least 12 m wide × 300 m long to allow for adequate burning, efficient commercial-scale mechanical harvest operations, and uniform harvest residue deposition in the green-cane treatments.

Immediately after harvest, the trash was collected and weighed from a 3 × 3-m quadrant, replicated two times in each plot. A trash sub-sample was collected and dried for 2–3 weeks in preparation for nutrient composition analysis. Post-harvest trash residue quantities and crop yields were measured at all three sites for three crop cycles.

Data on trash nutrients are presented for plant cane and first ratoon from EREC and El-Viejo. Sugarcane biomass yields or cane yield (tonnes of cane per hectare, t/ha) were calculated from trailer or rail car weights recorded at the mill.

Results and discussion

Averaged across three annual crops (plant cane, first ratoon and second ratoon), trash from green cane harvest was greatest in muck soil (ERE; 17.3 t/ha) followed by sandy soil (Hilliards; 16.2 t/ha) and clay soil (El-Viejo; 11.3 t/ha) (Table 1).

In general, greatest trash quantities were recorded in plant cane followed by first ratoon and second ratoon. Low first ratoon trash at El-Viejo likely reflects the low cane yields that occurred during extended drought conditions (Table 1).

<table>
<thead>
<tr>
<th>Table 1—Least square means of harvest residue (trash) dry weights and cane yield for green and burnt cane treatments in all three crops at EREC, Hilliards, and El-Viejo.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>Trash residues</th>
<th>Cane yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>Green</em></td>
<td><strong>Burnt</strong></td>
</tr>
<tr>
<td></td>
<td>t/ha</td>
<td>t/ha</td>
<td>t/ha</td>
</tr>
<tr>
<td>EREC</td>
<td>PC</td>
<td>23.3Aa</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>1R</td>
<td>17.1Ab</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>2R</td>
<td>11.6Ac</td>
<td>3.82</td>
</tr>
<tr>
<td>Hilliards</td>
<td>PC</td>
<td>20.8Aa</td>
<td>4.73</td>
</tr>
<tr>
<td></td>
<td>1R</td>
<td>14.5Ab</td>
<td>2.99</td>
</tr>
<tr>
<td></td>
<td>2R</td>
<td>13.2Ab</td>
<td>2.61</td>
</tr>
<tr>
<td>El-Viejo</td>
<td>PC</td>
<td>12.9Ba</td>
<td>3.19</td>
</tr>
<tr>
<td></td>
<td>1R</td>
<td>7.6Bb</td>
<td>1.49</td>
</tr>
<tr>
<td></td>
<td>2R</td>
<td>13.6Aa</td>
<td>2.84</td>
</tr>
</tbody>
</table>

*Letters are used to show interactions between location and crop in amount of trash residues and cane yield; Different upper case letters in the same column indicate significant differences among locations for the same crop; Different lower case letters indicate significant difference among crops at the same location.

** In burnt cane, interactions between location and crop were not significant.

Across all three locations, green-cane harvest had greater trash than burnt-cane harvest. Trash levels at EREC and Hilliards exceeded the 10 t/ha reported in Louisiana (Viator and Wang, 2011), 7–16 t/ha in Argentina (Romero et al., 2007) and 7–12 t/ha in Australia (Robertson and Thorburn, 2007). Residue levels recorded at El-Viejo were similar to those reported in the aforementioned studies.

Due to greater amounts of trash in green-cane harvest, nutrient quantity per unit of land (kg/ha) was greater in green-cane than burnt-cane in both plant cane and first ratoon at all three locations (Table 2).
Table 2—Least square means of trash nutrients (kg/ha) for green and burnt cane treatments in plant cane and first ratoon at EREC and El-Viejo.

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>Treat</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Zn</th>
<th>Mn</th>
<th>Cu</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>EREC</td>
<td>PC</td>
<td>Green</td>
<td>148.4</td>
<td>12.3</td>
<td>84.7</td>
<td>96.3</td>
<td>19.6</td>
<td>0.29</td>
<td>1.13</td>
<td>0.04</td>
<td>3.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Burnt</td>
<td>4.4</td>
<td>0.5</td>
<td>5.2</td>
<td>2.5</td>
<td>0.6</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.21</td>
</tr>
<tr>
<td>1R</td>
<td>Green</td>
<td>109.8</td>
<td>15.0</td>
<td>109.5</td>
<td>102.5</td>
<td>22.1</td>
<td>0.47</td>
<td>1.12</td>
<td>0.09</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burnt</td>
<td>1.4</td>
<td>0.3</td>
<td>2.9</td>
<td>1.2</td>
<td>0.3</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>El-Viejo</td>
<td>PC</td>
<td>Green</td>
<td>91.7</td>
<td>15.3</td>
<td>99.0</td>
<td>32.2</td>
<td>24.6</td>
<td>0.11</td>
<td>0.65</td>
<td>0.07</td>
<td>8.42</td>
</tr>
<tr>
<td></td>
<td>Burnt</td>
<td>20.1</td>
<td>4.6</td>
<td>37.0</td>
<td>6.7</td>
<td>6.2</td>
<td>0.04</td>
<td>0.10</td>
<td>0.02</td>
<td>2.15</td>
<td></td>
</tr>
<tr>
<td>1R</td>
<td>Green</td>
<td>41.5</td>
<td>7.7</td>
<td>95.9</td>
<td>20.5</td>
<td>15.4</td>
<td>0.10</td>
<td>0.90</td>
<td>0.08</td>
<td>35.95</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burnt</td>
<td>9.6</td>
<td>2.2</td>
<td>23.6</td>
<td>3.1</td>
<td>3.2</td>
<td>0.03</td>
<td>0.10</td>
<td>0.02</td>
<td>5.31</td>
<td></td>
</tr>
</tbody>
</table>

Standard Error at EREC: N=11.37, P=1.23, K=9.67, Ca=5.86, Mg=1.75, Zn=0.038, Mn=0.088, Cu=0.007, Fe=1.90
Standard Error at El-Viejo: N=9.85, P=1.06, K=8.38, Ca=5.08, Mg=1.52, Zn=0.033, Mn=0.076, Cu=0.006, Fe=1.64

Averaged across plant cane and first ratoon, green-cane trash would potentially add 66.6 kg/ha N per year to the cane production system at El-Viejo. Similarly, addition of P (13.7 kg/ha/year) and K (97.1 kg/ha/year) at EREC could potentially reduce P and K fertiliser requirements in muck soils. However, trash-derived nutrients are not necessarily immediately available. Van Antwerpen et al. (2001) reported that it took several years before substantial fertiliser savings were realised from trash decomposition nutrient inputs.

In general, burnt-cane had greater cane yield than green-cane harvest except in second ratoon at EREC where cane yields were similar across both treatments, and in plant cane at Hilliards where green-cane yield exceeded burnt-cane harvest (Table 1).

Overall, burnt-cane harvest resulted in average cane yield increases of 7.8, 3.9, and 1.7 t/ha at El-Viejo, EREC and Hilliards, respectively.

Similarly, Viator and Wang (2011) reported that pre-harvest burning supported 7.4 t/ha more cane yield than green-cane harvest. However, results from our study differ from a South African study where green-cane harvest yields exceeded burnt cane harvest by 8.16 t/ha (Van Antwerpen et al., 2001).

Conclusions

Thick trash residues from green-cane harvest contain significantly greater quantities of plant nutrients than burnt-cane harvest residues.

However, lower green-cane harvest yields in first and second ratoon crops suggest that nutrient availability is either not quickly available for improved growth or this nutrient supply simply cannot overcome any yield losses that occur due to green-cane harvest.

Other abiotic factors (e.g. temperature, moisture etc.) may also be influencing the reductions in green-cane harvest yields.

REFERENCES


ASSESSMENT OF BIO-ACTIVATORS IN SUGARCANE IN TUCUMÁN, ARGENTINA

By

L.G. ALONSO, E.R. ROMERO, P.E. FERNÁNDEZ GONZÁLEZ, M.F. LEGGIO, S. FAJRE and J. SCANDALIARIS

Estación Experimental Agroindustrial Obispo Colombres
lgalonso@eeaoc.org.ar

KEYWORDS: Bio-activator, Water Stress.

Abstract

WE EVALUATED THE USE of a foliar bio-activator at the beginning of the rainy season, as a strategy to accelerate sugarcane recovery after it had undergone the negative effects of water deficits at the onset of the crop cycle. Three trials were carried out in commercial fields planted with variety LCP 85-384 in the first and second ratoon crops, located in areas with different water stress levels and with soils with different organic matter content. Four treatments were evaluated: 1) a control; 2) bio-activator: 2 L/ha (B); 3) conventional fertilisation at a rate of 115 kg of N/ha (CF) and 4) CF + B. At harvest, stalk population and stalk weight were measured and yield was estimated for each treatment. These assessments were complemented with sugarcane factory yield analyses. All the data were analysed with an ANOVA and a Fisher’s test (at 5 and 10% levels of statistical significance). All treatments had significant differences compared to the control regarding stalk population, but the greatest stalk population was obtained with the CF + B treatment (16% > control). All treatments had significantly greater stalk weight (P< 0.10) than the control, but stalk weights did not differ among fertiliser or bio-activator treatments. Weight increases measured in treatments with bio-activators (B and CF + B) amounted to 12%. All treatments had significantly greater cane yield when compared to the control treatment, with the greatest increases attained with the CF + B treatment (29.2% > control). The use of bio-activators influenced yield components in two different ways: when the sugarcane crop was fertilised with N, the bio-activator significantly increased stalk population, whereas in the case of crops without fertilisation, the effect was evident in both stalk population and weight.

Introduction

In Tucumán, the beginning of the sugarcane growing season coincides with a period of low rainfall. As a result, and on account of the fact that 80% of plantations are not irrigated, the crop undergoes significant water stress at this stage. Under these conditions, it is of great importance to accomplish a rapid recovery of sugarcane crop in order to ensure high yields. Hence, the use of metabolic bio-activators in sugarcane crops constitutes a tool of great agricultural interest, since they allow the crop to recover rapidly, thus ensuring that plantations will have higher yields.

There is limited information about the use of bio-activators in sugarcane. Garcia et al. (2001) observed that, when they applied a bio-stimulator named Agrispon on sugarcane crops, they observed positive effects on stalk population, sugar content, increases in sugarcane weight/stalk, length, juice purity, and pol % in cane.

The objective of this study was to evaluate the performance of a bio-activator made from seaweed extracts, applied at the beginning of the rainy season. This bio-activator was a liquid organic product, which contained amino-acids, hormones, polysaccharides, macronutrients (NPK 5-5-4) and traces of micronutrients (Mg, B, Fe and Zn) in its composition. (PSW SA, 2012).
Materials and methods

For this study, three trials were conducted in commercial plots planted with cultivar LCP 85-384 in the first and second ratoon crops. These plots were located in areas where different water stress levels were found, and where soil presented different organic matter content levels.

Two of these plots had soils with 1.1% and 1.7% organic matter content and were located in areas where average annual rainfall averaged 930 mm. By contrast, the remaining site had soils with high organic matter content (4.2%) and was located in an area with a higher annual rainfall mean (1450 mm).

The experimental design was a randomised block design, where plots had five 100-metre rows (a total area of 800 m²).

The following treatments were evaluated:

1. Control
2. Bio-activator 2 L/ha (B).
3. Urea conventional dose = 115 kg of N/ha – (CF)
4. Urea conventional dose + bio-activator 2 L/ha (CF + B)

The application of the bio-activator was performed with a carbon dioxide backpack with a volume of 75 L/ha, after fertilisation with nitrogen and when the crop had 6 to 8 expanded leaves.

At harvest, stalk population was evaluated in 10 m of row, as well as the weight of individual millable stems. With these data, yield for each treatment in the plots was estimated. Also, in the laboratory of the EEAOC Chemistry Department, factory quality of cane juice obtained with the different treatments was analysed.

Data analysis was performed using ANOVA, and Fisher's test (at P< 0.05 and 0.10 significance levels).

Results

The CF + B treatment led to a higher average sugarcane stalk population, with 2.8 stalks/m of row increase compared with the control, and 1.3 stalks/m of row increase with respect to CF. The B treatment showed an average increase in the number of stalks of 1.8 stems/m of row compared with the control. In all cases except CF, differences with the control were significant (Table 1).

Regarding stalk weight, treatment B showed an average 0.088 kg increase in comparison with the control, while treatment CF + B had no stalk weight increase with the addition of bio-activator with respect to CF. (Table 1).

| Table 1—Effects of treatments on population and individual weight of stalks of variety LCP 85-384. Average data of three trials evaluated. Tucumán, Argentina. |
|---------------------------------|----------------|----------------|----------------|----------------|
| Treatments | Population (stalk/m) | Fisher’s test (5%) | Individual stalk weight (kg) | Fisher’s test (5%) |
| Control | 17.2 | B | 0.75 | A | B |
| B | 19.1 | A | 0.84 | A | A |
| CF | 18.7 | AB | 0.84 | A | A |
| CF+B | 20.0 | A | 0.84 | A | A |
| CV% | 4.5 | | 6.3 | | |
| LSD | | | 1.6 | | 0.10 | 0.08 |

When analysing cane yield, all treatments were significantly different from the control. The highest yields were observed in plots where bio-activator was applied as a urea supplement (CF + B), with an increase of 23.7 t/ha compared to control, and 7.7 t/ha more than CF treatment (Figure 1). Treatment B had 19.1 t/h over the control and 3.1 t/ha more than CF (Figure 1).
However, it should be noted that treatments B, CF and CF + B did not differ significantly from each other. This indicates that the addition of the bio-activator, when applied without nitrogen fertiliser, can lead to yields similar to those generated by traditional fertilisation.

![Cane yield (t/ha)](chart.png)

**Fig. 1**—Effects of treatments on cane yield of variety LCP 85-384. Data were averaged over three trials evaluated. Tucumán, Argentina.

Although this paper does not show the data for each trial evaluated, it was observed that bio-activator treatments showed a tendency to generate greater production increases in areas with low organic matter content and low rainfall.

When analysing juice factory quality, no significant differences were observed among treatments (Table 2).

**Table 2**—Effect of treatments on pol % cane of variety LCP 85-384 variety. Average data of three trials evaluated. Tucumán, Argentina.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Pol% cane</th>
<th>Fisher’s test (5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>14.38</td>
<td>A</td>
</tr>
<tr>
<td>B</td>
<td>14.18</td>
<td>A</td>
</tr>
<tr>
<td>CF</td>
<td>14.27</td>
<td>A</td>
</tr>
<tr>
<td>CF + B</td>
<td>14.32</td>
<td>A</td>
</tr>
<tr>
<td>CV%</td>
<td>6.41</td>
<td></td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>1.73</td>
</tr>
</tbody>
</table>

**Conclusions**

The use of the bio-activator resulted in increases in sugarcane production, as stalks established better before the beginning of the harvest season, in both plots with nitrogen fertilisation and without. When sugarcane fields were not fertilised with nitrogen, there was an increase in stalk weight with the addition of a bio-activator.

In this study, the use of bio-activators without additional N fertilisation led to similar sugarcane yields to traditional fertilisation. The use of the bio-activator did not affect the quality of sugarcane juice.

**REFERENCES**


http://www.biblioteca.idict.villaclara.cu/biblioteca/articulos/ciencia/art91

CHEMICAL RIPENING ADVANCES IN TUCUMAN, ARGENTINA

By

M.F. LEGGIO NEME, S. FAJRE, E.R. ROMERO,
L.G. ALONSO and A. SANCHEZ DUCCA
Estación Experimental Agroindustrial Obispo Colombres, Tucumán-Argentina
fleggio@eeaoc.org.ar

KEYWORDS: Sugarcane, Pre-Harvest Practice, Herbicides, Plant Growth Regulators, Mineral Nutrients.

Abstract
THE NEED TO MAXIMISE potential for both the environment and sugarcane varieties has resulted in an increase in sugarcane area treated with ripeners in Tucuman from 3000 ha in 1997, to approximately 115 000 ha currently. This advancement was promoted by researchers at the Estación Experimental Agroindustrial Obispo Colombres (EEAOC) in Tucumán, Argentina, who issued recommendations for the use of glyphosate as a ripener in 1997. Similarly, fluazifop-p butyl was released for use as a ripener in 2001. In searching for new alternative ripeners, graminicides (clethodim, haloxyfop-r methyl) and imazapyr have been evaluated since 2000. After these trials, only clethodim was released for commercial use in 2005. Imazapyr, despite being efficient, was discarded because of its high cost. In 2006, EEAOC scientists started evaluating trinexapac-ethyl. This plant growth regulator (PGR) has shown potential to replace herbicide ripeners. Trinexapac-ethyl is already used as a ripener in Brazil, along with sulfometuron-methyl. The latter was evaluated in 2007 in Tucumán, but sugarcane response was highly variable and inconsistent. Since 2010, the effect of ethephon, a PGR that releases ethylene, has been evaluated with and without a graminicide. So far, sugarcane responses have been satisfactory (average increment Pol % cane of 0.41 and 0.62, respectively). Mineral nutrients application (phosphorus, potassium and boron) were also evaluated showing in some cases considerable sucrose content increases. In conclusion, this paper is a review of extensive studies conducted since 1994 by EEAOC researchers in order to provide a great number of products for growers to be used as sugarcane ripeners under different agro-ecological situations.

Introduction
Chemical ripening hastens crop maturity, thus making available high quality sugarcane for processing at an earlier stage of growth. This is particularly important in achieving the goal of expanding the sugarcane production area into regions not traditionally planted with sugarcane, especially those with high probability of freeze occurrence.

In Tucumán, chemical ripening is the only pre-harvest practice available that leads to significant increases in sugar recovery levels, bringing about important economic benefits (Leggio Neme et al., 2009).

This technology has been studied and promoted by scientists at the Estación Experimental Agroindustrial Obispo Colombres (EEAOC) since 1994, with excellent results. Adoption of chemical ripening technology has resulted in an increase of sugarcane area treated with ripeners from 3000 in 1997 to 115 000 ha presently in Tucumán.

A review of chemical ripening in Tucumán, Argentina
The EEAOC started chemical ripening studies in 1994 and, in 1997, after conducting several trials and commercial scale demonstrations, issued a series of recommendations for use of glyphosate as a sugarcane ripener.
In 1997, research on fluazifop-p butyl as a ripener began at the EEAOC, which resulted in its recommendation (Rufino et al., 2001). Later, evaluations of graminicides (clethodim and haloxyfop-r methyl) and imazapyr, continued.

In 2005, after 6 years of studies, the use of clethodim was finally recommended for commercial fields (Leggio Neme et al., 2005). However, haloxyfop-r methyl use did not provide acceptable results.

In contrast, imazapyr was very efficient and resulted in very satisfactory results. However, further research on imazapyr was discontinued because its use was not economically feasible due to high cost (Table 1).

Table 1—Indices of response to ripeners (averages for cultivars, rates, and application stages) obtained by the Estación Experimental Agroindustrial Obispo Colombres (EEAOC) in Tucumán, Argentina, throughout the period when they were evaluated.

<table>
<thead>
<tr>
<th>Ripener</th>
<th>Response indices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total response(1)%</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>81.2</td>
</tr>
<tr>
<td>(0.22,0.24 and 0.29 L ia/ha)</td>
<td>(1994–2000)</td>
</tr>
<tr>
<td>Fluazifop-p butyl</td>
<td>89.5</td>
</tr>
<tr>
<td>(25,40 and 45 g ia/ha)</td>
<td>(1997–2000)</td>
</tr>
<tr>
<td>Imazapyr</td>
<td>80</td>
</tr>
<tr>
<td>(150 and 200 g ia/ha)</td>
<td>(2000–2007)</td>
</tr>
<tr>
<td>Clethodim</td>
<td>92</td>
</tr>
<tr>
<td>(60,72 and 96 g ia/ha)</td>
<td>(2000–2007)</td>
</tr>
<tr>
<td>Haloxyfop-r methyl</td>
<td>37</td>
</tr>
<tr>
<td>(20,30 and 40 g ia/ha)</td>
<td>(2000–2007)</td>
</tr>
<tr>
<td>PK</td>
<td>35</td>
</tr>
<tr>
<td>(3.4 and 6.8 kg/ha)</td>
<td>(2006–2011)</td>
</tr>
<tr>
<td>Boron</td>
<td>19</td>
</tr>
<tr>
<td>(6 and 9 L/ha)</td>
<td>(2006–2011)</td>
</tr>
<tr>
<td>Trinexapac-ethyl</td>
<td>66</td>
</tr>
<tr>
<td>(0.6,0.8 and 1.2 L/ha)</td>
<td>(2006–2011)</td>
</tr>
<tr>
<td>Sulfometuron-methyl</td>
<td>39</td>
</tr>
<tr>
<td>Ethephon</td>
<td>100</td>
</tr>
<tr>
<td>(1.5 L/ha)</td>
<td>(2010–2011)</td>
</tr>
<tr>
<td>Ethephon+graminicide</td>
<td>100</td>
</tr>
<tr>
<td>(2010–2011)</td>
<td></td>
</tr>
</tbody>
</table>

(1): Total positive response tests (increases > 0.3 Pol % cane)
(2): Total high positive response tests (increases > 0.5 Pol % cane)
(3): Average increases for the following cultivars:
  - Glyphosate: CP 65-357, NA 63-90, TUC 71-7, LCP 85-376, TUCCP 77-42 and TUC 72-16.
  - Fluazifop, like Glyphosate and LCP 85-384 and RA 87-2.
  - Imazapyr, Clethodim, and Haloxyfop: LCP 85-384, CP 65-357, RA 87-3 and TUCCP 77-42.
  - PK, B, Trinexapac, Sulfometuron, Ethephon and Ethephon+graminicide: LCP 85-384 and TUCCP 77-42.

*OHT: optimal harvest time expressed as weeks after application.
In 2006, evaluation of a new plant growth regulator (PGR), trinexapac-ethyl as a potential ripener began. Trinexapac-ethyl inhibits the synthesis of gibberellic acid (Rademacher et al., 2000) thus delaying growth. Trinexapac-ethyl was already being used in Brazil as a ripener along with sulfometuron-methyl (Dalley and Richard, 2010). The latter has been evaluated since 2007, with variable and inconsistent results (Table 1).

Furthermore, since 2010, the effects of ethephon, a PGR that releases ethylene (Marrero et al., 2004), has been evaluated when used alone or in combination with fluazifop–p butyl. Responses have been satisfactory and consistent (Table 1); therefore, this PGR continues to undergo further evaluation to determine the ideal use rate.

The growing concern for risks posed by the use of chemical products and their effects on the environment and humans (Montano Martínez, 2002), has led to the search for other alternatives that would successfully replace these products.

Since 2006, the use of mineral nutrients like phosphorus, potassium and boron have been considered as an alternative that would cause changes in the nutritional balance favouring maturation. In general, we observed that, over five years, the use of mineral nutrients as ripeners produced considerable sucrose content increases, although in some cases significant differences were not observed (Table 1).

In Tucuman, early applications were performed between mid-March to mid-April, intermediate applications mid to late April, and late applications until mid-May. In general, best responses were observed with early applications (minimum temperature 14.8°C and maximum 23.7°C, historical temperature data (from Agrometeorology Section, EEAOC) coinciding with the end of the great growth period. Under these conditions, ripeners restrain vegetative growth rates resulting in increased sucrose storage (Leggio Neme et al., 2009).

In conclusion, this paper reviews the extensive work made by EEAOC researchers in order to have a great number of products that could be efficiently used as sugarcane ripeners under different agro-ecological conditions. This has allowed the establishment of a technological package to be used according for each situation.

REFERENCES


PLANTING, DISTRIBUTION OF NEW VARIETIES, AND SANITARY CONDITIONS OF REGISTERED NURSERIES IN THE 2011 SEASON, TUCUMÁN-ARGENTINA

By

J.A. GIARDINA, P.A. DIGONZELLI, D. DUARTE, F. PÉREZ ALABARCE, C. FUNES, R. BERTANI, A. SANCHEZ DUCCA and J. SCANDALIARIS

Estación Experimental Agroindustrial Obispo Colombres
Av. William Cross 3150, Las Talitas, Tucumán, R. Argentina.
jgiardina@eeaoc.org.ar

KEYWORDS: Registered Nurseries, Ratoon Stunt Disease, Leaf Scald, Sugarcane.

Abstract

HIGH QUALITY SEED cane is necessary to improve sugarcane production in Tucumán, Argentina. In 2000/2001, Obispo Colombres Agroindustrial Experimental Station created the Vitroplantas Project to produce and propagate such seed. The material, produced through meristem culture and micropropagation, is multiplied in basic, registered and certified nurseries. This work reports on varieties, planted area, multiplication rates, ratoon stunt disease (RSD) and leaf scald (LS) in registered nurseries in 2011. Ten hectares of the basic nursery were planted with the main varieties in Tucumán. This material was reproduced in 28 registered nurseries of 170 ha (17:1 multiplication rate). Together with those planted in 2010, registered nurseries totalled 50 (260 ha) across 11 departments in Tucumán, particularly Famaillá, Cruz Alta and Monteros, with 24%, 23% and 20% of the total planted area, respectively. TUC 95-10, a variety released in 2011, was planted in 75 ha of the registered nurseries, which supplied material for planting 750 ha of certified nurseries (2012) and approximately 6000 ha in commercial plantations (2013). RSD and LS levels in registered nurseries averaged 0.35% and 0.77% (below thresholds accepted in Argentina). The project has provided growers with great quantities of high quality seed cane for their plantations.

Introduction

The sugarcane agro-industry in Tucumán has recently embraced processes to improve cane and sugar production. Average sugarcane yield has risen from 35 to 62 t/ha (Pérez et al., 2009), and other productivity improvements derived from the introduction of new technologies into the cropping system have been undertaken (Cuenya et al., 2010).

Since 2000/2001, Obispo Colombres Agroindustrial Experimental Station (EEAOC) has been conducting the Vitroplantas Project, in order to obtain high quality seed cane of the most important varieties planted in Tucumán as well as recently released varieties. The project aims to ensure true-to-type propagation material free of pathogens or pests, or seedcane with minimum pathogen or pest incidence (Digonzelli et al., 2006).

Sanitary conditions are fundamental to secure seed cane quality, especially when considering systemic diseases, like Sugarcane mosaic virus, Sorghum mosaic virus, leaf scald (LS, Xanthomonas albilineans), sugarcane smut (Sporisorium scitamineum) and ratoon stunt disease (RSD, Leifsonia xyli subsp. xyli) (Glyn, 2005).

The Vitroplantas Project has established a nursery network, which comprises a Basic Nursery and Registered and Certified Nurseries, where micropropagated seedlings are multiplied.
The present work reports on variety distribution, planted area, multiplication rates, and RSD and LS incidence in registered nurseries in 2011.

Materials and methods

This work was based on data collected in 2011, concerning seed cane availability, varietal distribution, row number and area planted with each variety in the basic nursery, as well as seed cane tonnes of each variety, supplied for registered nurseries. Details such as seed cane amount requested from the basic nursery, planted row numbers per variety, plantation densities (buds/m), geographical position of nurseries and their planted areas, were measured.

Multiplication rates were calculated on the basis of the area planted with each variety in the basic nursery, seed cane of each variety distributed for registered nurseries, and area effectively planted in the latter.

RSD and LS incidence in registered nurseries was determined by taking samples consisting of 20 stalks/ha, taking into account variety, age and management. These samples were analysed by means of Tissue Blot Immunostain (TBIA) to determine if the pathogens were present. Disease incidence was calculated as number of infected stalks/total number of stalks.

Results

Registered nurseries in 2011

With a total area of 10 ha, the basic nursery multiplied six different varieties for planting in registered nurseries in 2011: LCP 85-384, TUCCP 77-42, RA 87-3, TUC 95-37, TUC 97-8 and TUC 95-10.

Twenty-eight registered nurseries, which had a total 170 ha, were planted with these varieties. These nurseries, together with ones planted in 2010 (22 nurseries), totalled 50 registered nurseries, totalling 260 ha throughout the Argentinian sugarcane industry (Figure 1).

![Fig. 1—Distribution of registered nurseries in the Tucumán, Argentina sugarcane region in 2011.](image)
These nurseries were located in 11 departments in Tucumán, primarily in Famaillá, Cruz Alta and Monteros, with 24%, 23% and 20% of the total nursery planted area, respectively. Burruyacú had 14% of the nursery planted area, whereas the remaining departments had percentages between 1% and 7%.

TUC 95-10 was the most widely planted variety in the registered nurseries, with 75 ha (44% of total area). This seed cane will be used for planting approximately 750 ha in certified nurseries in 2012. Subsequently, with seed cane produced in these nurseries, 5250 to 6000 ha will be planted in commercial fields from 2013 onwards, thus promoting the rapid spread of this new variety.

Mean multiplication rates in registered nurseries varied according to varieties, crop growth stage, and freeze occurrence. The highest multiplication rate (20:1) corresponded to TUC 95-10, followed by TUCCP 77-42, TUC 97-8 and LCP 85-384 (17:1). The lowest rate (15:1) was recorded for both TUC 95-37 and RA 87-3, which suffered from frost effects that made it necessary to increase planting density (Table 1).

**Table 1**—Average multiplication rates of different varieties planted in registered nurseries during the 2011 season in Tucumán, Argentina.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean multiplication rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCP 85-384</td>
<td>17:1</td>
</tr>
<tr>
<td>RA 87-3</td>
<td>15:1</td>
</tr>
<tr>
<td>TUCCP 77-42</td>
<td>17:1</td>
</tr>
<tr>
<td>TUC 97-8</td>
<td>17:1</td>
</tr>
<tr>
<td>TUC 95-37</td>
<td>15:1</td>
</tr>
<tr>
<td>TUC 95-10</td>
<td>20:1</td>
</tr>
<tr>
<td>Average</td>
<td>17:1</td>
</tr>
</tbody>
</table>

**Sanitary conditions of registered nurseries in 2011**

RSD and LS mean incidence levels recorded in registered nurseries in 2011 were 0.35% and 0.77%, respectively (considering all varieties and nursery plots) (Figure 2).

In 2011, RSD levels in the nurseries were lower than in 2010, when a 0.65% incidence was recorded. The highest disease incidence was observed in RA 87-3 (0.49%), and the next highest was TUC 95-37 (0.42%), whereas the remaining varieties showed values that ranged between 0.33% and 0%.

The highest incidence of LS recorded in 2011 was in TUCCP 77-42 (1.24%) followed by TUC 97-8 (1.05%), TUC 95-37 (0.6%), LCP 85-384 (0.59%), CP 65-357 (0.54%) and RA 87-3 (0.43%).
These disease means are below tolerance thresholds considered acceptable in Argentina, which are 1% and 2.5% for RSD and LS, respectively.

**Conclusion**

In 2011 the Vitroplantas Project produced seed cane to plant 170 ha of registered nurseries. It is worthwhile mentioning that TUC 95-10, a new variety released that year, was planted in 75 ha of these nurseries. Multiplication rates were high, with an average rate of 17:1.

Disease incidence in the registered nurseries was low, with RSD and LS means below tolerance thresholds accepted in Argentina.

**REFERENCES**


EFFECTS OF POTASSIUM FERTILISERS ON SUGARCANE SUCROSE CONTENT IN JAPAN

By

K. WATANABE, J. TOMINAGA, F. KOJYA, M. OSHIRO, R. SUWA, M. UENO and Y. KAWAMITSU

Faculty of Agriculture, University of the Ryukyus, Okinawa 903-0213, Japan
kawamitu@agr.u-ryukyu.ac.jp

KEYWORDS: Counter Ion, Kcl, K2SO4, Potassium Fertiliser, Sugar Content.

Abstract

Potassium (K) is an essential nutrient that promotes sugarcane growth, but there is a negative correlation between K and sucrose content in juice in Okinawa, Japan. In addition, there is a possibility that counter ions to K (Cl\(^-\), SO\(_4^{2-}\)) affect sugar accumulation. The objectives of this study were to investigate effects of two kinds of K fertiliser (KCl and K\(_2\)SO\(_4\)) on sugar accumulation in sugarcane. Pot experiments with type and level of K fertiliser treatments were conducted using Saccharum spp. cv. NiF8 in Okinawa, Japan. We set up eight plots in Exp. 1 (KCl and K\(_2\)SO\(_4\); 0.19, 0.75, 1.50, and 7.50 g/pot) and 12 plots in Exp. 2 (KCl, K\(_2\)SO\(_4\), and KCl+K\(_2\)SO\(_4\); 1, 5, 10, and 20 g/pot). At early harvest stages, sucrose content in juice tended to increase with an increase of K content regardless of K types. At later stages, however, sucrose content decreased with increase of K in KCl plots. We did not observe a clear result between K and sucrose content in K\(_2\)SO\(_4\) and KCl+K\(_2\)SO\(_4\) plots. Cl\(^-\) content was positively correlated with K contents in all K types, and the highest KCl plots had the highest Cl\(^-\) contents. Sugar yield was affected by sucrose content; therefore, the highest KCl plots had lower sugar yields. Sucrose content decreased with increase of K in KCl plots but not in K\(_2\)SO\(_4\), suggesting that higher sugar yields could be attained by using K\(_2\)SO\(_4\) or decreasing KCl amount.

Introduction

Okinawa, which is located in the SW part of Japan, has a subtropical climate. Because of its C\(_4\) photosynthesis, sugarcane exhibits a high growth rate under both high light and temperature conditions.

In addition, sugarcane is partially resistant to damage due to typhoon or drought. Thus, sugarcane has had an important role as a stable crop in Okinawa.

Since the sugarcane price is determined by its quality based on sugar content, appropriate management practices which enhance both cane yields and sugar content of sugarcane are necessary.

There have been many reports that K, one of the essential nutrients for plant growth, has a highly negative correlation with sucrose contents in juice of sugarcane (Kawamitsu et al., 1997).

In examining the quality factor in sugarcane payment systems, our objective was to define the causes of sucrose reduction by K and suggest alternative K management.

We hypothesised that there was a possibility that the ions (Cl\(^-\) and SO\(_4^{2-}\)), as well as K itself, are related to the decrease of sugar content.

The objective of this study was to evaluate the effects of ions on sucrose accumulation and sugar yield under different K fertilisers (KCl and K\(_2\)SO\(_4\)).
Materials and methods

Experiment 1

A pot experiment using *Saccharum* spp. cv. NiF8 was conducted under greenhouse conditions at the University of the Ryukyus in Okinawa, Japan. We started seedling cultivation on Apr 15, 2010 and transplanted them into pots filled with 10 kg of mixed soil (dark-red soil: sea sand: peat moss = 1:1:1 (v/v)) on May 12.

We applied 2.50 and 0.75 g/pot of nitrogen and phosphorus, respectively and set up eight plots with two types of K (KCl and K₂SO₄) and four levels of K (0.19, 0.75, 1.50 and 7.50 g/pot). Each plot consisted of 12 pots with the same treatment. Three pots for each plot were sampled on Aug 20, Oct 31, and Dec 20, 2010 and Feb 22, 2011. We measured stalk weights and K, Cl⁻, SO₄²⁻, and juice sucrose content.

Experiment 2

The same variety (NiF8) was used for Exp. 2. We started seedling cultivation on Nov 26, 2010 and transplanted them on Dec 29, following the same procedure as Exp. 1. We applied 3 and 1 g/pot of nitrogen and phosphorus, respectively and set up 12 plots with three types of K (KCl, K₂SO₄, and KCl+K₂SO₄) and four levels of K (1, 5, 10 and 20 g/pot). Three pots for each plot were sampled on Aug 21 and Oct 26, 2011, and Jan 12, 2012. Each plot consisted of nine pots with the same treatment. The same parameters as Exp. 1 were measured.

Results and discussions

Experiment 1

As K level increased, K content in juice also increased, ranging from 0 to 3500 ppm. In August, sugar content increased with increase of K content in both KCl and K₂SO₄ plots (Figure 1). However, sugar content was affected differently by K type in Oct and Dec.

As K content increased, sugar content in KCl plots decreased, whereas those in K₂SO₄ plots increased. In February, there was no clear relationship between K and sugar content. Significantly Cl⁻ content had positive correlations with K content in both KCl and K₂SO₄ plots, but the slope of the regression line of KCl plots was higher than that of K₂SO₄ plots (Figure 2). There were no significant correlations between SO₄²⁻ and sugar content. In December, sugar yields of 7.50 g/pot of KCl and 0.19 g/pot of K₂SO₄ were lower than those of the other plots because of lower stalk weights and sucrose content (data not shown).

In February, the plot with 7.50 g/pot of K₂SO₄ had the highest stalk weight and sucrose content and thus the highest sugar yield (Table 1). Because all the plots had approximately the same sucrose content, sugar yields were directly related to stalk weights, and consequently the plots with 7.5 g/pot of KCl and 0.19 g/pot of K₂SO₄ had lower sugar yields (Table 1).
Fig. 2—Relationship between K and Cl⁻ content in sugarcane juice. (See Fig. 1 for the symbols).

Table 1—Effects of K fertiliser type on stalk weight, sucrose content, and sugar yield in Exp. 1. (Harvested Feb., 2011).

<table>
<thead>
<tr>
<th>Type</th>
<th>Plot (g/pot)</th>
<th>Stalk weight (g/plant)</th>
<th>Sucrose (%)</th>
<th>Sugar yield (g/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>0.19</td>
<td>752 ± 77</td>
<td>24.5 ± 0.5</td>
<td>161 ± 13</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>787 ± 122</td>
<td>23.5 ± 0.7</td>
<td>161 ± 30</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td>744 ± 104</td>
<td>23.1 ± 0.6</td>
<td>149 ± 25</td>
</tr>
<tr>
<td></td>
<td>7.50</td>
<td>667 ± 29</td>
<td>23.5 ± 0.4</td>
<td>136 ± 5</td>
</tr>
<tr>
<td>K₂SO₄</td>
<td>0.19</td>
<td>635 ± 54</td>
<td>22.9 ± 1.0</td>
<td>126 ± 15</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>703 ± 139</td>
<td>23.6 ± 0.8</td>
<td>145 ± 35</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td>785 ± 77</td>
<td>23.7 ± 0.3</td>
<td>162 ± 15</td>
</tr>
<tr>
<td></td>
<td>7.50</td>
<td>865 ± 75</td>
<td>24.4 ± 0.1</td>
<td>184 ± 16</td>
</tr>
</tbody>
</table>

**Experiment 2**

K content in juice increased with increase in K level and ranged from approximately 700 to 5000 ppm. In August and October, sugar content tended to increase with increase of K content in all the plots. In January, however, sucrose content of KCl-treated plants decreased with increase in K content, while no trend was observed in K₂SO₄ and KCl+K₂SO₄ plots (Figure 3).

Fig. 3—Relationship between K and sucrose content in sugarcane juice. (Exp. 2; ● Aug, □ Oct, ▲ Jan).

Cl⁻ content was positively correlated with K content in all plots, but the order of increasing regression line slopes were KCl, KCl+K₂SO₄, and K₂SO₄. SO₄²⁻ content had a negative correlation with K content in KCl plots and positive correlations to K₂SO₄ and KCl+K₂SO₄ plots in January (Figure 4). In January, the plot with 5 g/pot of KCl had the highest sugar yield and the plot with 20 g/pot of KCl had the lowest. Sugar yield was affected by sugar content rather than by stalk weight (Table 2).
Fig. 4—Relationship between K and SO₄²⁻ content in sugarcane juice. (See Fig. 3 for the symbols).

Table 2—Effects of K fertiliser type on stalk weight, sucrose content, and sugar yield in Exp. 2. (Harvested Jan., 2012).

<table>
<thead>
<tr>
<th>Type</th>
<th>Plot (g/pot)</th>
<th>Stalk weight (g/plant)</th>
<th>Sucrose (%)</th>
<th>Sugar yield (g/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>1</td>
<td>1025 ± 22</td>
<td>22.9 ± 0.5</td>
<td>166 ± 10</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1063 ± 54</td>
<td>23.2 ± 0.1</td>
<td>174 ± 7</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1139 ± 83</td>
<td>21.1 ± 1.2</td>
<td>165 ± 23</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1161 ± 18</td>
<td>19.4 ± 1.8</td>
<td>145 ± 23</td>
</tr>
<tr>
<td>K₂SO₄</td>
<td>1</td>
<td>1117 ± 55</td>
<td>21.2 ± 1.0</td>
<td>163 ± 11</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1135 ± 17</td>
<td>21.1 ± 2.2</td>
<td>164 ± 24</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1143 ± 16</td>
<td>21.0 ± 0.6</td>
<td>165 ± 4</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1154 ± 63</td>
<td>20.8 ± 1.1</td>
<td>164 ± 20</td>
</tr>
<tr>
<td>KCl + K₂SO₄</td>
<td>1</td>
<td>1130 ± 18</td>
<td>22.1 ± 1.8</td>
<td>170 ± 16</td>
</tr>
<tr>
<td>KCl + K₂SO₄</td>
<td>5</td>
<td>1158 ± 26</td>
<td>20.3 ± 2.0</td>
<td>153 ± 22</td>
</tr>
<tr>
<td>KCl + K₂SO₄</td>
<td>10</td>
<td>1083 ± 30</td>
<td>22.1 ± 2.0</td>
<td>160 ± 20</td>
</tr>
<tr>
<td>KCl + K₂SO₄</td>
<td>20</td>
<td>1085 ± 49</td>
<td>21.9 ± 0.2</td>
<td>161 ± 9</td>
</tr>
</tbody>
</table>

At later harvest dates, different K fertilisers had different effects on sugarcane, and sucrose content decreased in KCl plots but not in K₂SO₄ and KCl+K₂SO₄ plots. A likely factor in sucrose reduction with KCl application may be increase of Cl⁻ and/or decrease of SO₄²⁻, though we could not explain it in the present paper.

Tallat (2002) investigated growth, yield, and quality of sugarcane when using KCl and K₂SO₄ K and reported that both K fertilisers improved cane parameters and were equally effective for sugarcane cultivation in Pakistan.

In that experiment, however, the original K amount in the soil was insufficient and only positive aspects might have been obtained.

Also Khadr et al. (2004) concluded there were slight differences with types and levels of K. Considering that we performed pot experiments, it is supposed that the samples of our experiment were affected by K more easily than those of previous experiments.

In Exp. 2, although stalk weight of 20 g/pot of KCl was the highest, sugar yield was the lowest because it had the lowest sugar content; therefore, we can say that sugar content has a great influence on sugar yield and that a sucrose reduction results in a lower income.

These results indicate that KCl, which is commonly included in the compound fertiliser sugarcane growers use in Japan, may decrease sucrose content and eventually sugar yield. Sugarcane growers are recommended to use 60 kg/ha of KCl for spring planting and 80 kg/ha for summer planting, which is much less than the amounts of K fertiliser we used in these experiments.

Considering that we performed pot experiments, we cannot simply compare the rates used by farmers with those in this study; however, there is a possibility that sugar content and sugar yield can be improved by lowering K fertiliser rates.
This study indicates that field experiments should be conducted to confirm these observations on K fertiliser type and rate on sugarcane sucrose content.

REFERENCES


COMPETITION AND FACILITATION EFFECTS OF WEED MANAGEMENT IN SUGARCANE

By

J. MARTIN\textsuperscript{1}, M. CHABALIER\textsuperscript{2}, E. ARHIMAN\textsuperscript{2},
P. LETOURMY\textsuperscript{3} and D. MARION\textsuperscript{2}

\textsuperscript{1}Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), 97400 La Réunion
\textsuperscript{2}eRcane, 97494 La Réunion
\textsuperscript{3}CIRAD, 34000 Montpellier, France

jose.martin@cirad.fr

KEYWORDS: Sugarcane, Differential Weed Management, Competition, Facilitation.

Abstract

DIFFERENTIAL INTRA- AND inter-row weed management can be a means to reduce herbicide use in sugarcane. A field experiment was conducted in 2011 in La Reunion Island to assess inter-row weed competition. Four inter-row weed competition treatments for a duration of one (T1), two (T2), three (T3) and four (T4) months after planting were imposed in a randomised complete block design with 5 replications; treatment plots were paired with non-weeded inter-row control plots. Row spacing was 1.5 m and space allocated to intra-row and inter-row was equally divided. All intra-rows where kept weed-free all season long. Weeds covered 100\% of the inter-rows by three months after planting. Sugarcane grew far above the weed canopy, completely closing the canopy between the rows for all treatments. Overall, sugarcane tillering and production was significantly reduced by weed competition. Sugarcane yield decreased by 13 t/ha/month of early competition. However, the control yield, expected to be lower than T4, was similar to the T3 treatment. This suggests a late facilitation effect of the inter-rows vegetation in control plots which partially compensates for its early competition effect. This may be due to the particular flora of our experiment, with high populations of N-fixing weeds and broomweeds. Obviously, additional research is needed to corroborate this singular result.

Introduction

Differential intra- and inter-row weed management can be a means to reduce herbicide use in sugarcane. For example, herbicides could be applied as a band over the rows and mechanical cultivation implemented between the rows. Inter-cropping of non-creeping legumes as cover-crops or managing the spontaneous vegetation between the rows can be further options.

Most studies show that the critical period of weed competition for sugarcane is the period of crop establishment, from spiking to the ‘out-of-hand stage’ (McMahon \textit{et al.}, 2000), i.e. mainly between one and four months after planting for plant-cane crops (Marion and Marnotte, 1991; Azania \textit{et al.}, 2010).

During this period before canopy closure, yield losses commonly range between 10 and 12\% per month of weed competition. These results were obtained from conventional trials with mixed weed populations and without separation of intra- and inter-row competition.

A field experiment was designed in La Reunion Island to assess inter-row weed competition on sugarcane. The weediness and weed flora of sugarcane fields in Reunion Island are quite well known (Le Bourgeois \textit{et al.}, 2004; Lebreton \textit{et al.}, 2009). Weed management relies mainly on chemical control (Marnotte \textit{et al.}, 2010).
Materials and methods

The experiment was conducted in 2011 in sub-humid lowlands to assess sugarcane yield losses from inter-row weed competition by keeping the intra-rows free of weeds. The experiment was established in a field left as a weedy fallow for 10 years, submitted to moderate grazing, where broadleaf weeds became dominant.

Conventional cultivation was used for soil preparation. According to soil testing recommendations, 91-185-168 kg/ha of NPK fertilisers were pre-plant applied in the furrows.

The sugarcane cultivar used was ‘R579’. The field was sprinkler-irrigated as needed throughout the growing season.

Four treatments T1, T2, T3, and T4 were compared, with inter-row weed competition occurring for (and stopped at) one, two, three and four months after planting, respectively in a randomised complete block design with 5 replications. Each of these 20 plots was paired at random with an adjacent control plot, whose inter-rows were not weeded for the entire season.

Just after planting, a broadcast application of a non residual, contact herbicide (Basta F1 at 4 L/ha) killed the first emergence of weed seedlings before planting, in order to measure effect of weed competition from planting to harvest. Row spacing was 1.5 m and space allocated to intra- and inter-rows was equally divided.

All intra-rows (including those of the control plots) where kept weed-free all season long, using labeled PRE and POST herbicides in band applications over the rows (three applications at 14, 43 and 65 days after planting: firstly, Merlin at 100 g/ha plus Prowl 400 at 3 L/ha; secondly, Sencoral ultradispersible at 1 kg/ha plus Chardol 600 at 1 L/ha; thirdly, Camix at 2.5 L/ha plus Chardol 600 at 1 L/ha).

By mid-season, intra-row colonisation by weeds coming from inter-rows in T4 and control plots was prevented by removing weeds, mainly vines from sugarcane (up to three times on control plots).

For T1 to T4 treatments, inter-row weed competition was stopped at the respective treatment time and kept weed-free by hand hoeing and hand pulling after weed removal.

Weeds species present in the field are listed in Table 1. The percentage of ground covered by weeds in the inter-rows and the percentage of each weed species were assessed visually in each plot, every month until the seventh month (with the exception of the sixth month).

The weed biomass in the inter-rows was assessed by harvesting and measuring the dry weight of 3.75 m² areas for T2, T3 and T4 treatments at the end of their respective time of weed competition for cane.

Regarding the control plots, dry weight of weeds was also assessed in a lateral inter-row at five, six and seven months after planting. The most abundant species were weighted separately as far as possible.

Tillering and stalk elongation were measured monthly; sugarcane was harvested 9.5 months after planting and cane yields were assessed by weighing the two central rows of each plot.

Tillering, stalk elongation, cane yield (and difference with control plots) were statistically analysed with linear models (analysis of variance or covariance and regression analysis), using the GLM procedure of SAS software (SAS Institute Inc. 2002–2011).

Results

Weeds covered 96% of the inter-rows two months after planting, reaching 100% cover at around 4 months and then declining to 96% at 7 months in non-weeded treatments (Figure 1).

Weed composition was quite diverse (Table 1), but at 4 months N2-fixing weeds (9 among 10 Fabaceae) and broomweeds (4 among 5 Malvaceae) became dominant, accounting for approximately 30 and 32% of total coverage at 7 months, respectively (Figure 1).
Table 1—Botanical names and family of weeds present at the study location. Functional groups are relative to their contribution to global coverage (Figure 1) and global biomass (Table 2).

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Family</th>
<th>Functional grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cyperus rotundus</td>
<td>Cyperaceae</td>
<td>Geophyte plant (as sedge)</td>
</tr>
<tr>
<td>2 Brachiaria nana</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>3 Cenchrus biflorus</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>4 Digitaria ciliaris</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>5 Eleusine indica</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>6 Melinis repens</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>7 Panicum maximum</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>8 Paspalum dilatatum</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>9 Rottboellia cochinchinensis</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>10 Sorghum verticilliflorum</td>
<td>Poaceae</td>
<td>Grasses</td>
</tr>
<tr>
<td>11 Commelina benghalensis</td>
<td>Commelinace</td>
<td>Commelina benghalensis</td>
</tr>
<tr>
<td>12 Achyranthes aspera</td>
<td>Amaranthaceae</td>
<td>Amaranthaceae + Solanaceae</td>
</tr>
<tr>
<td>13 Amaranthus dubius</td>
<td>Amaranthaceae</td>
<td>Amaranthaceae + Solanaceae</td>
</tr>
<tr>
<td>14 Amaranthus viridis</td>
<td>Amaranthaceae</td>
<td>Amaranthaceae + Solanaceae</td>
</tr>
<tr>
<td>15 Bidens pilosa</td>
<td>Asteraceae</td>
<td>Asteraceae + others broadleaf weeds</td>
</tr>
<tr>
<td>16 Parthenium hysterophorus</td>
<td>Asteraceae</td>
<td>Asteraceae + others broadleaf weeds</td>
</tr>
<tr>
<td>17 Siggseckia orientalis</td>
<td>Asteraceae</td>
<td>Asteraceae + others broadleaf weeds</td>
</tr>
<tr>
<td>18 Cleome viscosa</td>
<td>Brassicaceae</td>
<td>Cleome viscosa</td>
</tr>
<tr>
<td>19 Ipomoea eriocarpa</td>
<td>Convolvulaceae</td>
<td>Vines</td>
</tr>
<tr>
<td>20 Ipomoea hederifolia</td>
<td>Convolvulaceae</td>
<td>Vines</td>
</tr>
<tr>
<td>21 Ipomoea nil</td>
<td>Convolvulaceae</td>
<td>Vines</td>
</tr>
<tr>
<td>22 Ipomoea obscura</td>
<td>Convolvulaceae</td>
<td>Vines</td>
</tr>
<tr>
<td>23 Acalypha indica</td>
<td>Euphorbiaceae</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>24 Croton bonplandianus</td>
<td>Euphorbiaceae</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>25 Euphorbia heterophylla</td>
<td>Euphorbiaceae</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>26 Euphorbia hypericifolia</td>
<td>Euphorbiaceae</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>27 Phyllanthus amarus</td>
<td>Euphorbiaceae</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>28 Cajanus scarabaeoides</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>29 Centrosema pubescens</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>30 Crotalaria retusa</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>31 Desmanthus virgatus</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>32 Desmodium intortum</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>33 Desmodium tortuosum</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>34 Indigofera hirsuta</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>35 Mimosa invisa</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>36 Mimosa pudica</td>
<td>Fabaceae</td>
<td>N-fixing Fabaceae</td>
</tr>
<tr>
<td>37 Senna occidentalis</td>
<td>Fabaceae</td>
<td>within others broadleaf weeds</td>
</tr>
<tr>
<td>38 Hibiscus surattensis</td>
<td>Malvaceae</td>
<td>Vines (as creeping plant)</td>
</tr>
<tr>
<td>39 Malvastrum comormandelianum</td>
<td>Malvaceae</td>
<td>Broomweeds Malvaceae</td>
</tr>
<tr>
<td>40 Melochia pyramidata</td>
<td>Malvaceae</td>
<td>Broomweeds Malvaceae</td>
</tr>
<tr>
<td>41 Sida acuta</td>
<td>Malvaceae</td>
<td>Broomweeds Malvaceae</td>
</tr>
<tr>
<td>42 Sida glutinosa</td>
<td>Malvaceae</td>
<td>Broomweeds Malvaceae</td>
</tr>
<tr>
<td>43 Oxalis corniculata</td>
<td>Oxalidaceae</td>
<td>Geophyte plant</td>
</tr>
<tr>
<td>44 Argemone mexicana</td>
<td>Papaveraceae</td>
<td>Asteraceae + other broadleaf weeds</td>
</tr>
<tr>
<td>45 Passiflora foetida</td>
<td>Passifloraceae</td>
<td>Vines</td>
</tr>
<tr>
<td>46 Portulaca oleracea</td>
<td>Portulacaceae</td>
<td>Asteraceae + other broadleaf weeds</td>
</tr>
<tr>
<td>47 Cardiospernum halicacabum</td>
<td>Sapindaceae</td>
<td>Vines</td>
</tr>
<tr>
<td>48 Solanum americanum</td>
<td>Solanaceae</td>
<td>Amaranthaceae + Solanaceae</td>
</tr>
<tr>
<td>49 Solanum lycopersicum</td>
<td>Solanaceae</td>
<td>Amaranthaceae + Solanaceae</td>
</tr>
<tr>
<td>50 Solanum nigrum</td>
<td>Solanaceae</td>
<td>Amaranthaceae + Solanaceae</td>
</tr>
<tr>
<td>51 Striga asiatica</td>
<td>Scrofulariaceae</td>
<td>none (parasitic plant, scarce)</td>
</tr>
</tbody>
</table>

51 species 17 families 10 functional groups

Weed biomass (dry matter) reached a maximum of 1.8 kg/m² in the inter-rows of the control plots five months after planting; when adjusted to a curvilinear model and extrapolated, this
maximum value becomes 7.1 t/ha (Table 2). At 6 months, broomweeds and *Crotalaria retusa* accounted for 62 and 19% of weed biomass, respectively (Table 2). N₂-fixing Fabaceae other than *C. retusa* were not separated from other weeds because of their voluble, spiny or sticky traits.

![Fig. 1](image_url)

Fig. 1—Average composition and number of species of the inter-row weed coverage (i.e. treatment plots before their weeding at 1, 2, 3 and 4 months plus control plots). All intra-rows, including those of control plots, were kept weed-free using chemical plus manual control.

<table>
<thead>
<tr>
<th>Days after planting</th>
<th>Measured weed biomass (kg/m²)</th>
<th>Adjusted weed biomass to full area t/ha</th>
<th>Broomweeds Malvaceae (%)</th>
<th><em>Crotalaria retusa</em> (%)</th>
<th><em>Amaranthus dubius</em> + <em>A. viridis</em> (%)</th>
<th><em>Bidens pilosa</em> (%)</th>
<th><em>Commelina benghalensis</em> (%)</th>
<th><em>Cleome viscosa</em> (%)</th>
<th>Grasses (%)</th>
<th>Other weeds (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>0.30</td>
<td>1.5</td>
<td>19</td>
<td>12</td>
<td>11</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>47</td>
<td>20</td>
</tr>
<tr>
<td>90</td>
<td>0.89</td>
<td>4.6</td>
<td>13</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>9</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>121</td>
<td>0.75</td>
<td>6.6</td>
<td>25</td>
<td>10</td>
<td>11</td>
<td>–</td>
<td>21</td>
<td>–</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>149</td>
<td>1.85</td>
<td>7.1</td>
<td>28</td>
<td>15</td>
<td>21</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>185</td>
<td>0.52</td>
<td>5.9</td>
<td>62</td>
<td>19</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>19</td>
<td>46</td>
</tr>
<tr>
<td>220</td>
<td>0.18</td>
<td>2.7</td>
<td>54</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Sugarcane height was far above weed canopy by mid-season, completely closing the canopy between the rows for all treatments. Overall, sugarcane tillering (Table 3) and production were significantly reduced by weed competition. Stalk elongation and sugar content were not affected by weed competition (results not shown).

The effect of the duration of weed competition was highly significant on sugarcane tillering (*p < 0.0001* at 3 and 6 months after planting) despite one significant effect of the initial shoot emergence rate on tillering (*p = 0.006* and *p = 0.015*). Effects other than initial shoot emergence rate and duration of weed competition were not significant (not shown).
Table 3—Sugarcane tillering at 3 and 6 months after planting.

<table>
<thead>
<tr>
<th>Time after planting</th>
<th>Average (number of tillers / m)</th>
<th>Initial shoot emergence rate effect (covariance analysis)</th>
<th>Duration of weed competition effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 months</td>
<td>17.8</td>
<td>P = 0.006</td>
<td>P &lt; 0.0001</td>
</tr>
<tr>
<td>6 months</td>
<td>13.6</td>
<td>P = 0.015</td>
<td>P &lt; 0.0001</td>
</tr>
</tbody>
</table>

Sugarcane yield was 131 t/ha for T1 and significantly decreased by 13.5 t/ha for consecutive months of early competition through T4 (p = 0.0015, Figure 2). The yield differences between treatments and their respective control plots were tested and were significant for T1 (T1 > control, p = 0.0145) and almost significant for T4 (T4 < control, p = 0.0706) (Figure 2).

![Cane yields and differences to control](image)

Fig. 2—Sugarcane yields (blue and red bars), linear regression of treatment yields against time of weed control in months (regression line in blue) and statistical tests (p values) of differences from the unweeded control treatment (green bars).

Discussion and conclusion

Results from this study were similar to those of Marion and Marnotte (1991) in terms of weed and maximum cane biomass accumulation, despite the fact that their study was conducted in quite different conditions and harvested at 12.7 months versus 9.5 for this study.

The cane yield reduction documented with total intra-row weed control in this study is almost as high as Marion and Marnotte (1991) recorded without intra-row weed control (-13.5 versus –14.5 t/ha/month of exposure to weed competition).

Thus, mitigation of weed competition by intra-row weed control above ground is probably less than proportional to the space allocated to the intra-row: we observed in some soil profiles evidence that weed roots coming from inter-rows colonise intra-row space and meet sugarcane roots.
However, the average yield of our control plots, expected to be lower than T4, can be considered higher than T4 (p=0.07), reaching the yield level of T3. This finding suggests a late facilitation effect of the inter-row vegetation in control plots which partially compensated for an early competition effect.

This may be due to the particular flora of our study, with high populations of N₂-fixing weeds and broomweeds. Obviously, confirmation of this singular result is needed, and additional research is in progress for it.

Acknowledgments

This research was conducted by ERCANE and CIRAD in La Réunion. It was supported by funding from Europe (FEADER) and France (ONEMA) for MAGECAR Project, and from CIRAD and ERCANE.

REFERENCES


EVALUATION OF DIFFERENT ROW-SPACING IN SUGARCANE CULTIVATED IN THE MEDAK REGION OF ANDHRA PRADESH, INDIA

By

SURESH KONDUMAHANTHI¹, SHASHI BHUSHAN VEMURI² and VIJAY KUMAR MEDE³

¹Farmers’ Call Centre, A N G R Agricultural University, Hyderabad, India, ²Pesticide Residues Laboratory, A N G R Agricultural University, Hyderabad, India, ³Agril Research Station, Basanthpur, A N G R Agricultural University, Hyderabad, India

suresh.angrau@gmail.com

KEYWORDS: Sugarcane, Planting Geometry, Millable Canes, Yield.

Abstract

SUGARCANE IS EXTENSIVELY grown in the Zaheerabad region of the Medak district in the Telangana tract of Andhra Pradesh, India. Yield variations are high in the region with no defined agronomic packages, especially in planting geometry. Hence, an experiment was conducted during 2009–10 to evaluate different row-spacings (0.9, 1.2, 1.5 and 1.8 m) in sugarcane to standardise the spacing to be adopted in this region for a profitable crop. The soil of the experimental field was a red acidic lateritic with low organic carbon and available nitrogen, medium available phosphorus and high available potassium. Promising and widely adopted mid to late maturing variety Co 86032 was used as the test variety. Higher cane yield (145 t/ha) and juice sucrose content (19.6%) was recorded in 1.5 m spacing compared to other spacings. However, highest stalk height (3.4 m), stalk diameter (3.2 cm) and individual stalk weight (2.4 kg) were recorded in 1.8 m spacing. Yield increases (8%) with 1.5 m spacing were due to more millable canes (89 650) compared to 1.8 m spacing (84 000). Traditional methods of 0.9 m spacing resulted in lower yield components and yield (118 t/ha). Our study indicated 1.5 m row-spacing produced more cane than the other tested spacings.

Introduction

Sugarcane (a complex hybrid of Saccharum spp.) is a highly preferred cash crop in India due to high yield potential and assured marketing. However, the cost of cultivation, especially seed cost, water and fertiliser requirements are important factors in influencing sugarcane economics and area under its cultivation.

Row-spacing for sugarcane has been a subject of study for the past decade. Sugarcane in pre-history was originally a grassy weed, carpeting the soil, but has now been successfully planted to row-spacings of 45 cm, 75 cm, 80 cm, 90 cm, 120 cm and 150 cm in different parts of the world (Stephen Arul, 2011).

Sugarcane is an industrial crop in India, but its area in Andhra Pradesh has declined in recent years due to increased cost of cultivation. To prevent this decreasing trend in area, it is necessary to bring some changes in cultivation, which may improve profitability. As a C4 plant, sugarcane is considered as one of the most efficient converters of solar energy (Naidu, 2003), and has potential to produce huge amounts of biomass. The plant also can grow very quickly, is more efficient in using CO2 and is resistant to drought and high temperatures.

In Andhra Pradesh, sugarcane occupies nearly 300 000 ha of which Medak district has 23% of the cropped area and produces nearly 800 000 tonnes of cane. Cultivation of sugarcane is highly labour and time consuming and requires about 150 man-days per hectare in addition to
tractor/bullock power in conventional methods of cultivation. Sugarcane is normally planted with two or three-eye seed pieces placed manually in the furrows which require a lot of man-power and time.

Sugarcane yield is the function of number of millable stalks and stalk weight, and number of millable stalks represents population of millable stalks per hectare. Singh et al. (2001) reported that population per unit area and space between cane rows play significant roles in cane yield.

Normally sugarcane is planted in 80–90 cm row-spacing in India. However, previous literature indicates that wide row-spacing is better than traditional row-spacing (Sundara et al. 2002). Keeping this in view, this study was undertaken to evaluate different row-spacings that can be adopted for sugarcane plantings.

Material and methods

A field experiment was conducted at the Agricultural Research Station, Basanthpur, Medak district, Andhra Pradesh during 2009–10 to optimise the row-spacing for sugarcane. Four row-spacings (0.9, 1.2, 1.5, and 1.8 m) were assigned in a randomised block design with five replications, and plot size was 10 m x 10 m. The soil of the experimental field was red laterite with low organic carbon (0.47%), low in available N (182 kg/ha), medium in available P₂O₅ (28 kg/ha) and high in K₂O (279 kg/ha).

The total precipitation received during the crop growth period was 663.5 mm. Recommended management practices including need-based plant protection measures were followed for raising a healthy crop. Cane yield and yield attributes such as stalk height, stalk diameter, stalk weight, millable stalks, and percent juice sucrose were recorded at the time of harvest. Five samples of individual canes were sampled for cane yield and sucrose content from each plot. Sucrose per cent was recorded using standard procedures with a hand-held refractometer. Analysis of Variance (ANOVA) was performed for analysing data using PROC GLM to determine the differences in variables. The means were compared using Fisher’s protected least significant difference (LSD) at \( P = 0.05 \).

Results and discussion

Stalk height was significantly greater at 1.8 m row-spacing (3.4 m) than other spacings which were not significantly different from each other (Table 1). Stalk diameters at 1.8 m (3.2 cm) and 1.5 m (3.0 cm) spacing were significantly greater than 1.2 m (2.6 cm) and 0.9 m (2.2 cm) spacings.

Individual stalk weight (kg) at harvest also followed the same trend as that of cane diameter with 1.8 m (2.4 kg) and 1.5 m (2.3 kg) spacings which were significantly greater than 1.2 m (1.6 kg) and 0.9 m (1.3 kg) spacings. However, significantly greater number of millable stalks (thousands/ha) were recorded at a row spacing of 0.9 m (101.2) followed by 1.2 m (96.3), 1.5 m (89.6) and 1.8 m (84.9) owing to high density planting at 0.9 m (Table 1).

<table>
<thead>
<tr>
<th>Inter-row Spacing</th>
<th>Stalk height (m)</th>
<th>Stalk diameter (cm)</th>
<th>Stalk weight (kg)</th>
<th>Millable stalks ('000/ha)</th>
<th>Cane yield (t/ha)</th>
<th>Percent juice sucrose (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9 m</td>
<td>3.1</td>
<td>2.2</td>
<td>1.3</td>
<td>101.2</td>
<td>118</td>
<td>19.1</td>
</tr>
<tr>
<td>1.2 m</td>
<td>3.2</td>
<td>2.6</td>
<td>1.6</td>
<td>96.3</td>
<td>129</td>
<td>19.4</td>
</tr>
<tr>
<td>1.5 m</td>
<td>3.2</td>
<td>3.0</td>
<td>2.3</td>
<td>89.6</td>
<td>145</td>
<td>19.6</td>
</tr>
<tr>
<td>1.8 m</td>
<td>3.4</td>
<td>3.2</td>
<td>2.4</td>
<td>84.9</td>
<td>133</td>
<td>19.5</td>
</tr>
<tr>
<td>LSD – 0.05</td>
<td>0.12</td>
<td>0.26</td>
<td>0.28</td>
<td>2.8</td>
<td>6.20</td>
<td>NS</td>
</tr>
<tr>
<td>CV (%)</td>
<td>12.6</td>
<td>13.5</td>
<td>18.2</td>
<td>16.8</td>
<td>15.2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Although the number of millable stalks obtained in 0.9 m planting was highest, it did not reflect the cane yield (118 t/ha) because of lower individual stalk weight (1.3 kg).
Significantly higher cane yield was obtained at 1.5 m spacing (145 t/ha) due to comparatively greater stalk weight (2.3 m) than 0.9 and 1.2 m spacings, and greater number of millable stalks (89.6) than the 1.8 m spacing.

Despite having the highest individual stalk weight, stalk height and stalk diameter at 1.8 m spacing, lower number of millable stalks resulted in lower cane yield (133 t/ha) than 1.5 m spacing (145 t/ha) (Figure 1). Similar findings were also observed by Balaji Naik et al (2010).

Due to heavy inter-plant competition, cane planted at 0.9 m spacing had significantly lower cane yield (118 t/ha) than other spacings. Thompson and duToit (1965) also found that mean stalk weights were lower for narrow-spaced cane resulting in less cane per hectare. Per cent juice sucrose at harvest was not significantly influenced by the tested row spacings. It can be concluded that 1.5 m row-spacing is optimum to produce more cane under the evaluated conditions in India.

REFERENCES
USE OF SOIL CHARACTERISATION MADE BY RESISTIVITY SURVEYING FOR THE OPTIMISATION OF SUGARCANE PRODUCTION IN CAMEROON

By

T. VIREMOUNEIX¹, B. BISSOSSOLI MEKA² and S. LATRILLE DEBAT²

¹SOMDIAA, 39 rue Jean-Jacques Rousseau, 75001 Paris – France
²SOSUCAM, BP 857 Yaoundé - Cameroon
tviremouneix@somdiaa.com

KEYWORDS: Sugarcane, Electrical Resistivity, Soil Map, Crop Management, Planned Sustainable Agriculture.

Abstract
A GOOD KNOWLEDGE of soil properties and their agricultural suitability is a major requisite for managing agriculture in a planned, sustainable, and environmentally friendly manner. In order to optimise sugarcane production, the Cameroon Sugar Company (SOSUCAM) therefore decided in 2006 to use an innovative technology to characterise its soils. This technology is based on electrical resistivity measurements, which are correlated with soil properties and agricultural potential. Resistivity maps combined with a specific process, linking data processing and soil observation, make it possible to define precisely and quickly homogeneous zones and to obtain soil maps. Moreover, some trials were set up on different soil types in order to evaluate sugarcane response. Resistivity surveys were taken on more than 21 000 ha, and 7000 ha of soil maps were created. The precise knowledge of the soils was used to determine the best adapted agricultural practices for each homogeneous area. Thus, specific technical operations of land preparation were defined for each soil type and fertilisation was optimised by considering both soil potential and more representative leaf and soil samples. Finally, varietal trials were used to choose the varieties which were the most adapted to the different contexts. Resistivity surveying is a quick, precise and reliable technique which allows the mapping of the spatial variability of soil properties in sugarcane production areas. It is used to characterise and delineate homogeneous zones, on which better practices and operations are adopted.

Introduction
As a firm believer in integrating knowledge of soils in the management of its farming operations, SOSUCAM, a sugar agro-industrial complex covering about 25,000 ha in Central Cameroon, launched a soil characterisation project in 2006 based on electrical resistivity technology. This technology is faster, more reliable and more accurate than conventional auger testing technology (Viremouneix et al., 2007). Detailed soil maps generated from resistivity maps were used in various areas to adjust farm practices: to define cultural practices and land parcel management, to determine the most appropriate variety selection, to set up agronomic trials, and to optimise fertilisation.

Material and methods

Overview of the environment
SOSUCAM is located in central Cameroon, 150 km North-East of the national capital, Yaoundé, in an area once covered with grassy savannah. Most soils are listed as oxisoils, including oxidised ferralitic soils, gravelly soils (that can turn into laterite pans), hydromorphic soils and poorly developed soils (Vallerie, 1973), most often related to topography. In this context of high
agro-pedological heterogeneity, the implementation of a soil exploration and mapping project was initiated in 2004.

In 2006, after initially relying on conventional auger testing technology, SOSUCAM started to focus on electrical resistivity mapping technology – a faster, more reliable and more accurate approach.

**Overview of electrical resistivity technology**

Soil resistivity, expressed in ohms.m (Ω.m), is a measure of how much a soil resists the flow of electricity that goes through it.

Studies conducted in various pedological environments show that resistivity is closely linked to soil intrinsic and perennial properties (clay content, water holding capacity, stoniness, type of geological substrate as well as a number of more transient features (structure, temperature, water content) (Dabas *et al.*, 1989a; Benderitter and Shott, 1997; Goutouly, 2006).

Electrical resistivity was initially limited to geophysics and hydrology studies, but is now being applied in farming as a soil characterisation tool.

An initial series of trials conducted in 2005 showed that electrical resistivity was a high-performance tool in highlighting the spatial variability of specific features of SOSUCAM soils and of their agronomic value (Viremouneix *et al.*, 2007).

Subsequently, in partnership with Géocarta, a company that developed a technology to obtain continuous resistivity measurements at three depths, 0.5 m, 1.10 m and 2.10 m (Figure 1 and Figure 2), this technology started to be used on a larger scale, gradually covering every land parcel.

**Transforming resistivity maps into soil maps**

After acquiring land parcel-based electrical resistivity measurements, data are sent for computer processing to Géocarta, which returns them as electrical resistivity maps for soil depths.

SOSUCAM set up a specific procedure to turn those resistivity maps into soil maps (Viremouneix, 2009).

As a result, after analysing and processing the resistivity data on a computer in order to mark out homogenous areas (Figure 3), targeted field observations for each one of them help to characterise soil types accurately (Figure 4).
Results and discussions

Project status – mapping progress
This project, which was launched on an industrial scale in 2006 after being tested, has helped generate very fine-scale maps so far (Figure 5):

- Resistivity maps covering 21,000 ha.
- Soil maps covering 6000 ha.

Leveraging resistivity maps

Soil cultivation aids and land parcel management
Whereas in the past a unique soil cultivation procedure, i.e. subsoiling, diskng and drill
ploughing, was used for every land parcel to replant, accurate soil maps help determine the most appropriate sequence depending on soil texture and depth.

These include:

- drill ploughing only for shallow gravelly areas or sandy areas.
- disking limited to compacted clay-rich soils.
- soil loosening and drill ploughing for as many areas as possible.

As a result, farming practices have changed since 2007 with fewer machine passes (Fig. 6), leading to financial efficiencies (decreased fuel consumption, decreased operational time) and to better soil fertility conservation (decreased erosion, maintenance of organic matter).

Moreover, resistivity, which is used to identify land parcels with homogeneous properties, is applied to land parcel management with a view to matching crop and harvest units (2–3 hectares squares) with soil types.

**Establishing varieties depending on soil types**

Presently all five varieties grown on an industrial scale at SOSUCAM were planted independent of field pedological properties and potential. However, the behaviour of those varieties, depending on their ruggedness, varies from one soil type to the next. Thus, soil expertise now makes it possible to test the different varieties on the main soil types to compare their behaviour and yield in terms of tonnes of cane per hectare and tonnes of sugar per hectare. A test conducted in 2010 helped evaluate the respective capacities of varieties on the main soil types, showing significant differences in terms of production (Figure 7).
Based on these results the selection of varieties to plant on each land parcel now depends on the main soil type, which helps leverage variety capacities and optimise land parcel output. Although this trial needs to be continued, we could conclude that the best results are observed with the varieties Fr81258 and B82333 on deep red soils, with Fr81258 and Co997 on deep yellow soils, and B46364 and Fr81258 on gravelly soils.

**Fertilisation**

Learning about soils through resistivity and their related farming potential (Viremouneix *et al.*, 2007) helps optimise fertilisation. On the one hand, it improves soil sampling representativeness by targeting sampling across homogeneous areas; on the other hand, it helps adjust mineral fertiliser rates to farming potential.

**Establishing agronomic trials**

In order to improve sugar productivity, several trials are regularly implemented by SOSUCAM. Thanks to resistivity measurements and very accurate maps of soil potential trials can now be conducted in homogeneous areas, which helps reduce soil-related bias by decreasing the ‘block’ effect linked to soil heterogeneity.

This results in increased relevance and significance in terms of trial results.

**Conclusions**

Using electrical resistivity technology has helped SOSUCAM generate reliable and accurate soil and farming potential maps quickly. Land parcel identification and management as homogeneous farming management units facilitate the implementation of tailored and optimised crop protocols. These protocols involve soil preparation as well as variety planting and fertilisation. Thus, electrical resistivity mapping contributes to improving productivity and sustainability.

**REFERENCES**


TRANSPORT, ADSORPTION AND DESORPTION OF ATRAZINE AND METRIBUZIN IN SUGARCANE RESIDUE-AMENDED SOILS

By

H. MAGDI SELIM
School of Plant, Environmental and Soil Sciences
Louisiana State University Agricultural Center, Baton Rouge, LA 70803, USA
mselim@agctr.lsu.edu

KEYWORDS: Residue, Herbicide Movement, Retention.

Abstract

QUANTIFYING HERBICIDE RETENTION in soils is essential for their efficacy and minimising their runoff and contamination potential of surface and groundwater resources. In this study, the transport and adsorption-desorption characteristics of atrazine and metribuzin were carried out in soils amended with sugarcane (Saccharum spp. hybrids) residue grown on Sharkey clay and Commerce loam soils. The residue was sampled following combine harvest during 2000–2009 growing seasons. Miscible displacement experiments were carried out to quantify the mobility of the herbicides in columns where sugarcane residue was mixed with the soil. The incorporation of residue with the soil resulted in retarded atrazine mobility due to strong sorption and slow release during leaching. Metribuzin breakthrough curves (BTCs) indicated high mobility in residue-amended soils. Batch methods were used to quantify adsorption and desorption for a wide range of atrazine and metribuzin concentrations and reaction times. Atrazine and metribuzin isotherms for the sugarcane residue exhibited linear adsorption where a partitioning or affinity coefficient ($K_d$) increased with time. Release exhibited strong hysteresis indicative of time-dependent retention of herbicides by the residue. Limited metribuzin sorption kinetics were observed compared to atrazine. In addition, $K_d$ values for both soils were significantly higher than that measured for the sugarcane residue. Decreasing or increasing trends of atrazine and metribuzin retention by the sugarcane residue with time of residue decay was not observed. The use of an average $K_d$ to represent atrazine and metribuzin retention over an entire growing season is recommended. Therefore, we conclude that retention coefficients for retention of atrazine and metribuzin can be used to predict their movement in residue-amended soils for the entire growing season.

Introduction

The presence of mulch crop residue on the soil surface following harvest protects it from water and wind erosion and conserves soil water. The presence of crop residue such as wheat can be a temporary storage medium for herbicides when compared to conventional practices (Banks and Robinson, 1982; Dao, 1991).

In a field study, Selim et al. (2003) reported that significant amounts of applied herbicides were intercepted by the sugarcane residue. In addition, a reduction in runoff-effluent concentrations, as much as 50%, for atrazine and pendimethalin, was realised. Similar findings were found by Banks and Robinson (1982). In this study, we quantified the movement and retention of atrazine and metribuzin by the sugarcane residue in an effort to characterise their behaviour in soils. Changes in the characteristics of herbicide retention as a function of the age of the residue while decaying in the field were also investigated.
Methods

To quantify the extent of herbicide movement in residue-amended soils, transport and adsorption by sugarcane residue was carried out in the laboratory. The sugarcane was grown on Sharkey clay and Commerce loam soils at the St. Gabriel Sugarcane Research Station, St. Gabriel, Louisiana. The residue, which covers the soil surface following combine harvest, was sampled during the 2000–2009 growing seasons. Residue samples were randomly collected at 3–6 times following harvest during three growing seasons, and dried at 55 °C for 24-h and weighed and cut into 1 cm sections for herbicide transport and retention experiments.

To quantify the mobility of metribuzin and atrazine, miscible displacement column experiments were carried out (Zhu and Selim, 2009; Selim and Naquin, 2011). Acrylic columns were packed with Commerce loam or Sharkey soil. During packing, the sugarcane residue was uniformly mixed with the soil. Metribuzin and atrazine breakthrough curves (BTCs) were obtained by introducing a pulse solution and subsequent leaching with herbicide-free solution. Atrazine and metribuzin concentrations in the input pulse (C_o) were 30 and 100 mg/L, respectively. Radioactive atrazine and metribuzin (14C-UL ring labelled) were used as tracers to monitor the extent of retention of each herbicide.

To assess herbicide retention of the residue, adsorption by the residue was carried out in the laboratory using the batch method (Selim and Zhu, 2005). Adsorption was initiated by mixing 1 g of dried residue samples with 30 mL of various herbicide concentration solutions in a 40 mL Teflon centrifuge tube. Six initial atrazine/metribuzin concentrations ranging from 2.98 to 29.8 mg/L for atrazine and from 2 to 98 mg/L for metribuzin in 0.005 M CaCl₂ were used. All concentrations were spiked with radio-labelled atrazine/metribuzin.

Each mixture was shaken for 1–21 d reaction times, centrifuged, and a 0.5 mL aliquot sampled from the supernatant. Analyses for C-14 were carried out on sampled supernatants using liquid scintillation.

Results and discussion

Results of the movement of atrazine and metribuzin in soils amended with sugarcane residue are given by the BTCs presented in Figure 1. These results represent the relative concentration (C/ C_o) of the herbicide in the effluent solution versus pore volume (V/V_o). These results indicate that the incorporation of residue with the soil resulted in retarded atrazine mobility as indicated by the strong sorption and slow release or tailing of the BTC during leaching. Metribuzin BTCs indicated high mobility in residue-amended soil columns than atrazine. Metribuzin BTCs also exhibited gradual release during leaching.

Fig. 1—Atrazine and metribuzin breakthrough results (closed circles) from sugarcane residue–amended Commerce soil. Solid curves represent multireaction model predictions. The arrows indicate when 4-d flow interruption occurred.
A multireaction model which accounts for kinetic retention was successful in describing time-dependent adsorption-desorption behaviour and transport of both herbicides in soils where sugarcane residue was incorporated.

Adsorption results indicated that atrazine and metribuzin isotherms for the sugarcane residue exhibited linear adsorption where a partitioning or affinity coefficient ($K_d$) increased over time of retention. Release or desorption exhibited strong hysteresis indicative of time-dependent retention of both herbicides by the residue. Limited metribuzin sorption kinetics was observed compared to atrazine. These results are consistent with the transport data which indicated higher mobility of metribuzin compared to atrazine. The $K_d$ values for both soils were significantly lower than that measured for the sugarcane residue.

Results given in Table 1 for $K_d$ values of atrazine and metribuzin also indicate that decreasing or increasing trends of atrazine and metribuzin retention by the sugarcane residue with time of decay was not observed.

<table>
<thead>
<tr>
<th>Sugarcane season</th>
<th>Sampling date</th>
<th>Age of residue (days)</th>
<th>Metribuzin $K_d$ (mL/g)</th>
<th>Atrazine $K_d$ (mL/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000–2001*</td>
<td>4-Jan-01</td>
<td>26</td>
<td>10.00 ± 0.15</td>
<td>14.99 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>7-Feb-01</td>
<td>61</td>
<td>11.29 ± 0.49</td>
<td>16.52 ± 0.13</td>
</tr>
<tr>
<td></td>
<td>23-Mar-01</td>
<td>105</td>
<td>11.20 ± 0.20</td>
<td>15.90 ± 0.22</td>
</tr>
<tr>
<td></td>
<td>27-Apr-01</td>
<td>140</td>
<td>10.36 ± 0.10</td>
<td>18.09 ± 0.13</td>
</tr>
<tr>
<td>2001–2002*</td>
<td>30-Oct-01</td>
<td>12</td>
<td>9.23 ± 0.32</td>
<td>16.21 ± 0.36</td>
</tr>
<tr>
<td></td>
<td>26-Nov-01</td>
<td>39</td>
<td>9.47 ± 0.20</td>
<td>14.92 ± 0.39</td>
</tr>
<tr>
<td></td>
<td>20-Dec-01</td>
<td>63</td>
<td>10.47 ± 0.22</td>
<td>16.72 ± 0.27</td>
</tr>
<tr>
<td></td>
<td>22-Feb-02</td>
<td>127</td>
<td>11.11 ± 0.04</td>
<td>15.65 ± 0.16</td>
</tr>
<tr>
<td></td>
<td>20-Mar-02</td>
<td>153</td>
<td>10.07 ± 0.06</td>
<td>17.18 ± 0.31</td>
</tr>
<tr>
<td></td>
<td>23-May-02</td>
<td>217</td>
<td>10.97 ± 0.06</td>
<td>15.93 ± 0.18</td>
</tr>
<tr>
<td>2002–2003*</td>
<td>6-Dec-02</td>
<td>1</td>
<td>12.02±0.75</td>
<td>14.06 ± 0.23</td>
</tr>
<tr>
<td></td>
<td>6-Jan-10</td>
<td>30</td>
<td>12.87±0.57</td>
<td>15.54 ± 0.57</td>
</tr>
<tr>
<td></td>
<td>14-Feb-10</td>
<td>68</td>
<td>11.62±1.20</td>
<td>13.45 ± 0.40</td>
</tr>
<tr>
<td>2003–2004$</td>
<td>29-Oct-10</td>
<td>1</td>
<td>12.58±1.04</td>
<td>14.82 ± 0.40</td>
</tr>
<tr>
<td></td>
<td>4-Dec-10</td>
<td>37</td>
<td>13.02±0.91</td>
<td>18.20 ± 0.61</td>
</tr>
<tr>
<td></td>
<td>27-Jan-10</td>
<td>90</td>
<td>10.57±0.51</td>
<td>18.34 ± 0.25</td>
</tr>
<tr>
<td></td>
<td>2-Mar-10</td>
<td>128</td>
<td>10.15±0.16</td>
<td>19.51 ± 0.99</td>
</tr>
<tr>
<td></td>
<td>5-Apr-10</td>
<td>160</td>
<td>9.51±0.18</td>
<td>15.14 ± 0.63</td>
</tr>
<tr>
<td>2004–2005$</td>
<td>28-Oct-10</td>
<td>3</td>
<td>11.55±0.89</td>
<td>18.83 ± 0.69</td>
</tr>
<tr>
<td></td>
<td>3-Dec-10</td>
<td>45</td>
<td>11.81±0.67</td>
<td>15.26 ± 0.51</td>
</tr>
<tr>
<td></td>
<td>26-Jan-10</td>
<td>96</td>
<td>12.43±0.84</td>
<td>15.44 ± 0.48</td>
</tr>
<tr>
<td>2008–2009$</td>
<td>7-Nov-08</td>
<td>4</td>
<td></td>
<td>17.39 ± 0.72</td>
</tr>
<tr>
<td></td>
<td>8-Dec-08</td>
<td>37</td>
<td></td>
<td>18.69 ± 1.43</td>
</tr>
<tr>
<td></td>
<td>8-Jan-09</td>
<td>68</td>
<td></td>
<td>17.47 ± 0.99</td>
</tr>
<tr>
<td></td>
<td>4-Feb-09</td>
<td>105</td>
<td></td>
<td>16.82 ± 0.62</td>
</tr>
<tr>
<td></td>
<td>6-Mar-09</td>
<td>136</td>
<td></td>
<td>19.16 ± 0.61</td>
</tr>
</tbody>
</table>

* Sugarcane variety LCP 85-384 grown on Sharkey clay soil.
$ Sugarcane variety HoCP 91-555 grown on Commerce silt loam soil.

The use of an average $K_d$ to represent atrazine and metribuzin retention over an entire growing season is recommended. Therefore, application of atrazine or metribuzin by sugarcane growers can be made as needed regardless of the age of the residue.

**REFERENCES**


114


