Tillage and Soil Fertility to Drip Irrigated Sugarcane

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Maceió-Alagoas
08/05/2011
Yield maximum theoretical to sugarcane

If the discrimination of carbon is equal to 0 (theoretical stress 0). Yield will 106 Mg ha$^{-1}$ of dry stalks. These values to 70% moisture will yield of 353 Mg ha$^{-1}$. Values close to those reported by Irvine (1983) equal to 380 Mg ha$^{-1}$.

\[
S_{dm} = 106.9 - 15.70^{*13}C \\
R ^2 = 0.47 \\
\text{Significative p}<0.05
\]

Yield maximum theoretical to sugarcane

Climate (water availability)

Genetics:
(genotypes of high productivity)

Soil

- Physical properties
  (sand, silt, clay and Compaction …)

- Chemical properties
  (Nitrogen, phosphorus, potassium, calcium and gypsum …)
Schematic of Subsurface Drip Irrigation System

- Pump Station
- Backflow Prevention Device
- Flowmeter
- Chemical Injection System
- Filtration System
- Submain
- Dripline Laterals
- Zones 1 and 2
- Flushline
- Air & Vacuum Release Valve
- Pressure Gage
- Flush Valve
- Zone Valve

Gava, et. al. (2011).
Experimental Station Jau, SP - APTA
Lat. 22 ° 17 ' S, Long. 48 ° 34 ' W and altitude 580 m
Average precipitation 1,350 mm
Oxisol (Dark red)
Irrigation in sugarcane

Automatic weather station

Data Plotter

Radiometer

Temperature sensor and RU

PENMAN-MONTEITH, ALLEN et al. (1998)

\[
ETP = \frac{0.408_s(Rn - G) + \gamma 900U_2 (e_s - e_a)}{t + 273} \frac{\gamma}{S + \gamma(1 + 0.34U_2)}
\]
Results

Drip irrigation (average two crop cycles 1.797 mm)
Dry system (average two crop cycles 1.437 mm)

Drip - Dry = 29 t.ha⁻¹
Average

Drip - Dry = 17 t.ha⁻¹
Average

Drip - Dry = 45 t.ha⁻¹
Average

Gava, et. al. (2011).
Simple Model of How Sugarcane Might Respond to Stress

Aboveground stress:
- light
- insects
- temperature

Belowground stress:
- nutrients
- water
- oxygen

Carbon Storage → Carbon Production → Leaf Growth → Root Growth → Water & Nutrient Uptake → Water & Nutrient Utilization

Leaf Growth: Carbon Production

Carbon Storage: Nutrient Utilization
GENETIC: (Phenotyping $^{13}\text{C}$)

Mass spectrometer (ANCA – CNS)
$^{13}C_{\Delta} \% \text{ isotope fingerprint of varieties}$

Gava, et al. (2010)
$^{13}\text{C}_\Delta \%$ isotope fingerprint of varieties

Gava, et. al. (2010)
$^{13}\text{C}_\Delta$ %. Isotope fingerprint of varieties

Gava, et al. (2010)
Genotypes of high productivity

**GENETIC: (Phenotyping $^{13}$C)**

- **RB855536** (line), $Y = 94.48 - 13.31^\circ X$, $R = 0.72$, significative ($p < 0.05$)
- **RB867515** $Y = 124.10 - 18.72^\circ X$, $R = 0.51$, significative ($p < 0.05$)
- **SP80-3280** $Y = 141.48 - 23.58^\circ X$, $R = 0.83$, significative ($p < 0.05$)

RB855536 (line), RB857515 (points) and SP80-3280 (dashed) — Gava, et. al. (2011)
SOIL: physical properties

- Soil Texture
- Three sizes of soil particles
  - Sand, 2.00-.05 mm
  - Silt, .05-.002 mm
  - Clay, <.002 mm
  - Particle size affects surface area
SOIL: physical properties

Textural Triangle

- Percent Sand
- Percent Silt
- Percent Clay

Types of soil:
- Sand
- Loam
- Silt
- Clay
- Silty

Soil classifications:
- Sandy
- Clay
- Loamy
- Silty Clay
- Sandy Clay
- Loam
- Clay Loam

Soil properties:
- 60%
- 75%
- 90%
- 35%
- 20%
- 10%
- 20%
- 75%
- 90%
SOIL: physical properties

Clayey Soil (fine textured)
SOIL: physical properties

Loamy/Silty Soils (medium textured)
SOIL: physical properties

Sandy Soils
(coarse textured)
SOIL: physical properties

- Volume of small pores
- Volume of large pores
- Amount of pore space

Graph showing:
- Total pore space
- Volume of small pores
- Volume of large pores

X-axis: sand, loam, clay
Y-axis: Large amount, Small amount

Amount of pore space decreases from sand to clay, while total pore space increases.
• Soil Water Release Curve
  – Curve of matric potential (tension) vs. water content
  – Less water $\rightarrow$ more tension
  – At a given tension, finer-textured soils retain more water (larger number of small pores)
SOIL: physical properties

- Determines how water penetrates the soil.
- Determines how much water remains in the soil.
Argilossolos: (Ultisols)

26% Brazil

Argillic horizon (B textural).
Low activity clay or with high activity clay.
Increased water retention.
High and medium fertility.
Latossolos: (Oxisols)

Yellow, Red and Purple

50 % Brazil

Rich in iron and aluminum oxides.
Loam textured.
Average water retention.
High retention of phosphorus.
Average fertility.
Soil acidity.
NEOSSOLOS
QUARTZARÊNICOS (Entisols)

6% Brazil

Sandy texture.
Essentially quartz.
Low fertility.
Low water retention.
Brazil soils
Soil compaction

• Causes include combinations of:
  - Machines traffic
  - Tillage
  - Precipitation
Soil Tillage (Subsoiler)
Disc plow

Heavy harrow
Light harrow
Evolution of the planting of sugarcane

500 years...

10 years of mechanized planting...

24 months Plene
### Evolution of the planting of sugarcane

<table>
<thead>
<tr>
<th>Manual Planting</th>
<th>Mechanized Planting</th>
<th>Plene Planting (mini stalks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-14 t / ha</td>
<td>18-20 t / ha</td>
<td>1,5-2 t / ha</td>
</tr>
</tbody>
</table>

Mini stalks (Plene) requires the equivalent of 10 to 15% of a manual or mechanized planting.

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**Manual planting**
- High need for manpower
- High consumption of sugar: 12 t / ha
- Low performance: 140 people for 20 ha / day
- High soil compaction by intensive tillage

**Mechanized planting**
- High demand for heavy equipment
- High sugar consumption: 18 t / ha
- Low performance: 6 ha / day
- High soil compaction and intensive tillage
# Evolution of the planting of sugarcane

<table>
<thead>
<tr>
<th></th>
<th>Mechanized Planting</th>
<th>Manual Planting</th>
<th>Mini stalks (Plene)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 planters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 tractors (240 hp)</td>
<td></td>
<td></td>
<td>2 planters,</td>
</tr>
<tr>
<td>1 tractor (95 hp)</td>
<td></td>
<td></td>
<td>2 Tractors (120/180 hp)</td>
</tr>
<tr>
<td>18 equipment.</td>
<td></td>
<td>32 equipment.</td>
<td>5 equipment.</td>
</tr>
<tr>
<td>16 trucks</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 8 tractors (240 hp)
- 3 tractors (135 hp)
- 1 tractor (95 hp)
Mechanized sugarcane harvesting
Mechanized sugarcane harvesting

Conventional Planting
Compaction
Mechanized sugarcane harvesting
Mechanized sugarcane harvesting

Pineapple Row Planting

PLANTIO COMBINADO 40 X 1.40 (PLANTIO ABACAXI)
Mechanized sugarcane harvesting
Mechanized sugarcane harvesting

![Graph showing the relationship between crop yield and level of compaction](image)

- **Crop Yield**
- **Level of Compaction**

- Too Low
- Optimum
- Too High
Limiting factors

Previously..... Today!!!

Yield of sugarcane

<table>
<thead>
<tr>
<th></th>
<th>Previously</th>
<th>Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>t ha⁻¹</td>
<td>70</td>
<td>150</td>
</tr>
</tbody>
</table>

Chemical properties

N  P  K  Mg  Micr.
## Chemical properties

### Nutricional requirement of sugarcane

<table>
<thead>
<tr>
<th>Ciclo</th>
<th>Macronutrientes</th>
<th>Micronutrientes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Cana Planta</td>
<td>1,24</td>
<td>0,15</td>
</tr>
<tr>
<td>Cana Soca</td>
<td>1,55</td>
<td>0,21</td>
</tr>
</tbody>
</table>

**Cane Plant Crop:**
- K > N > Ca > Mg = S > Fe > P > Mn > Zn > B > Cu

**Ratoon Crop:**
- K > N > Ca > S > Mg > Fe > P > Mn > Zn > B > Cu

Genotype: SP81 - 3250, an average of three Oxisols

Oliveira et al. (2011)
Biomass and nutrients accumulation

\[ \frac{dN}{dt} = \frac{\alpha N}{1 + \exp\left(-\frac{x - \beta}{\gamma}\right)} \]

**T\textsubscript{1}\textsuperscript{\textsuperscript{st}}\textsuperscript{fase}**: Significant gains initiation;

**T\textsubscript{2}\textsuperscript{nd}\textsuperscript{fase}**: End of the large accumulation;

**MAR**: Maximum accumulation rate;

**TMAR**: Time of MAR;

**DMAR**: Duration of TMAR

Venegas et al. (1998); Greef et al. (1999)
Relative biomass production and nutrients accumulation

- Relative accumulation - ReA (kg ha\(^{-1}\)):
  \[ AR_{e} = A_{f} - A_{i} \]

- Relative accumulation percentage:
  \[ AR_{e} (%) = \frac{AR_{e}}{At} \times 100 \]

\( AR_{e} \) - Relative Accumulate / Sugarcane phases
\( A_{f} \) and \( A_{i} \) - Final and Begin Accumulate
\( At \) - Total accumulate by sugarcane
Biomass Production and Nitrogen Accumulation (Plant Cane Crop)

\[ y = 258.17 \times \left[ 1 + \exp \left( \frac{DAP - 234.04}{4.53} \right) \right], R^2 = 0.944 \]

\[ y = 90.356 \times \left[ 1 + \exp \left( \frac{DAP - 314.94}{9.44} \right) \right], R^2 = 0.975 \]

Oliveira et al. (2011)
### Chemical properties

**Phases of nutrients accumulation (Cane Plant Crop)**

<table>
<thead>
<tr>
<th></th>
<th>1° fase</th>
<th></th>
<th>2° fase</th>
<th></th>
<th>3° fase</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Período</td>
<td>AR%</td>
<td>Periodo</td>
<td>AR%</td>
<td>Periodo</td>
<td>AR%</td>
</tr>
<tr>
<td>MS</td>
<td>0 - 191</td>
<td>8,0</td>
<td>12</td>
<td>245</td>
<td>53,0</td>
<td>80</td>
</tr>
<tr>
<td>N</td>
<td>0 - 117</td>
<td>24,7</td>
<td>12</td>
<td>237</td>
<td>157,7</td>
<td>78</td>
</tr>
<tr>
<td>P</td>
<td>0 - 148</td>
<td>3,1</td>
<td>12</td>
<td>224</td>
<td>20,0</td>
<td>80</td>
</tr>
<tr>
<td>K</td>
<td>0 - 130</td>
<td>57,2</td>
<td>12</td>
<td>230</td>
<td>365,8</td>
<td>78</td>
</tr>
<tr>
<td>Ca</td>
<td>0 - 130</td>
<td>9,4</td>
<td>12</td>
<td>160</td>
<td>60,0</td>
<td>74</td>
</tr>
<tr>
<td>Mg</td>
<td>0 - 131</td>
<td>7,0</td>
<td>13</td>
<td>331</td>
<td>45,0</td>
<td>84</td>
</tr>
<tr>
<td>S</td>
<td>0 - 120</td>
<td>5,4</td>
<td>12</td>
<td>194</td>
<td>34,7</td>
<td>78</td>
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<td></td>
<td>313</td>
<td>276,6</td>
<td></td>
<td></td>
<td>436 - 483</td>
<td>5,0 8</td>
</tr>
<tr>
<td></td>
<td>236</td>
<td>943,8</td>
<td></td>
<td></td>
<td>354 - 483</td>
<td>20,0 10</td>
</tr>
<tr>
<td></td>
<td>260</td>
<td>125,2</td>
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<td></td>
<td>372 - 483</td>
<td>1,9 8</td>
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<tr>
<td></td>
<td>245</td>
<td>2138,9</td>
<td></td>
<td></td>
<td>360 - 483</td>
<td>44,1 10</td>
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<tr>
<td></td>
<td>210</td>
<td>528,2</td>
<td></td>
<td></td>
<td>290 - 483</td>
<td>11,5 14</td>
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<tr>
<td></td>
<td>293</td>
<td>171,8</td>
<td></td>
<td></td>
<td>462 - 483</td>
<td>1,3 3</td>
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<tr>
<td></td>
<td>234</td>
<td>257,7</td>
<td></td>
<td></td>
<td>314 - 483</td>
<td>9,4 10</td>
</tr>
</tbody>
</table>

*TMAC-MS: kg ha\(^{-1}\)dia\(^{-1}\); *TMAC-Macronutrientes: g ha\(^{-1}\)dia\(^{-1}\); **AR-MS: Mg ha\(^{-1}\); **AR-Macronutrientes: kg ha\(^{-1}\)

Genotype: SP81 - 3250, an average of three Oxisols

Oliveira et al. (2011)
### Phases of nutrients accumulation (Ratoon Crop)

<table>
<thead>
<tr>
<th></th>
<th>1° fase</th>
<th>2° fase</th>
<th>3° fase</th>
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<tbody>
<tr>
<td></td>
<td>Período</td>
<td>AR (%)</td>
<td>Período</td>
</tr>
<tr>
<td><strong>Período</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MS</strong></td>
<td>0 - 151</td>
<td>4,5</td>
<td>197</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>0 - 72</td>
<td>13,2</td>
<td>190</td>
</tr>
<tr>
<td><strong>P</strong></td>
<td>0 - 78</td>
<td>1,8</td>
<td>195</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>0 - 90</td>
<td>28,4</td>
<td>134</td>
</tr>
<tr>
<td><strong>Ca</strong></td>
<td>0 - 117</td>
<td>6,2</td>
<td>163</td>
</tr>
<tr>
<td><strong>Mg</strong></td>
<td>0 - 118</td>
<td>3,8</td>
<td>219</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>0 - 95</td>
<td>3,2</td>
<td>153</td>
</tr>
</tbody>
</table>

*TMAC-MS: kg ha⁻¹ dia⁻¹; TMAC-Macronutrientes: g ha⁻¹ dia⁻¹; **AR-MS: Mg ha⁻¹; **AR-Macronutrientes: kg ha⁻¹*

Genotype: SP81 - 3250, an average of three Oxisols

Oliveira et al. (2011)
### Low nutrient use efficiency

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Efficiency (%)</th>
<th>Cause of low efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>30-50</td>
<td>Immobilization, volatilization, denitrification, Leaching</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>15-20</td>
<td>Fixation in soils Al – P, Fe – P, Ca – P</td>
</tr>
<tr>
<td>Potassium</td>
<td>70-80</td>
<td>Fixation in clay - lattices</td>
</tr>
<tr>
<td>Sulphur</td>
<td>8-10</td>
<td>Immobilization, Leaching with water</td>
</tr>
<tr>
<td>Micro nutrients</td>
<td>1-2</td>
<td>Fixation in soils</td>
</tr>
<tr>
<td>(Zn, Fe, Cu, Mn, B)</td>
<td></td>
<td></td>
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</tbody>
</table>
### Chemical properties (Soil pH)

<table>
<thead>
<tr>
<th>pH Range</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
<th>Sulphur</th>
<th>Calcium</th>
<th>Magnesium</th>
<th>Iron</th>
<th>Manganese</th>
<th>Boron</th>
<th>Copper &amp; Zinc</th>
<th>Molybdenum</th>
</tr>
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<tbody>
<tr>
<td>4.0-4.5</td>
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<td>5.5-6.0</td>
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<td>6.5-7.0</td>
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<td>7.0-7.5</td>
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<td>7.5-8.0</td>
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<td>8.0-8.5</td>
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<td>8.5-9.0</td>
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<td>9.0-9.5</td>
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</tbody>
</table>
Role & consequences of excess Al

- Not essential or beneficial
- Toxic to some species (roots) & in Acid Sulfate soils
- Sugarcane has high tolerance of Al compared to species such as maize and most legumes
  - Ca must be adequate
- Al involved in P sorption/fixation in acid soils <pH5.5

Effect of Al on roots of sugarcane - photographs Andersen & Bowen, (1991)
Correction of soil acidity

Before liming

After liming

Soil + H₂ + CaCO₃ \rightarrow \text{Soil} + \text{Ca} + \text{H₂O} + \text{CO₂}
Neutralization of $\text{Al}^{3+}$

$3\text{CaCO}_3 + 3 \text{H}_2\text{O}$

$+ 2 \text{Al(OH)}_3 + 3 \text{CO}_2$

Insoluble
Chemical properties (Soil pH)

Brazil

Base saturation \((V\%)\)

\[
L \text{ (ton/ha)} = \frac{(60 - V\%) \times CEC}{(PRNT \times 10)}
\]
CaSO₄₄

Promotes the reduction of acidity and improves root depth.

\[ 2\text{CaSO}_4\cdot2\text{H}_2\text{O} \rightarrow \text{Ca}^{2+} + \text{SO}_4^{2-} + \text{CaSO}_4^0 + 4\text{H}_2\text{O} \]
Benefits

Source of Ca and S
Correction of acidity in subsurface
Improvement of root environment
Reduction of toxic Al3 (AlSO4).
Sub-soils - use gypsum if Ca<0.6 cmol$_c$/L & Al%>40

When the rates of gypsum to be applied are based on soil texture, you can use the following recommendation (RAIJ, 1997): dose to be

$$QG \text{ (kg ha}^{-1}\text{)} = \text{clay (g kg}^{-1}\text{)} \times 6.0$$
Photosynthesis & Respiration
- ATP
- NADP
Phosphorus - P

Role

• Uptake as $\text{HPO}_4^{2-}$ or $\text{H}_2\text{PO}_4^{-}$ ions.

• Required for energy rich bonds (ADP, ATP)
  – $\text{CO}_2$ assimilation depends on P assimilation.

• Constituent of nucleic acids - cell division & heredity transfer - important in root & shoot growth.

• Helps crop maturation by biomass dilution of high N application.
P sorption

- P is “fixed” by Fe, Al & in acidic soils - also by humic-Al complexes
- <10% of applied P available in some high P fixing soils
- Implications for banding P, use of higher rates, pH adjustment

P sorption and ‘fixation’ at various values of soil pH

McLaren and Cameron, (1996)
### Measurement of P in soil

- Ion exchange resins
  - Brasil - closer theoretical basis to P uptake by roots

<table>
<thead>
<tr>
<th>Phosphorus fertilizer for sugarcane, based on availability of phosphorus with ion exchange resin (t ha(^{-1}))</th>
<th>Extracted Phosphorus (mg dm(^{-3}))</th>
<th>(&lt; 100)</th>
<th>(150)</th>
<th>(&gt; 150)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 6</td>
<td>7 - 17</td>
<td>16 - 40</td>
<td>(&gt; 40)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>---</td>
<td>80</td>
<td>44</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>&lt; 100</td>
<td>90</td>
<td>55</td>
<td>40</td>
<td>26</td>
</tr>
<tr>
<td>150</td>
<td>100</td>
<td>66</td>
<td>45</td>
<td>35</td>
</tr>
</tbody>
</table>

For transforming P into P\(_2\)O\(_5\), multiply the desired value by 2.29.

*Source: adapted from Raij (1997).*
Interaction N:P in sugarcane

TCH = 40,27 + 0,09*N_{dose} + 0,06*P_{dose}

R^2 = 0,89*

*Significativo (p<0,05)

Fonte: Iqbal & Iqbal, 2001
Effect of nitrogen fertilization and drip irrigation (H₂O) in the yield of sugarcane and accumulation of N.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Dry matter stalks (Mg.ha⁻¹)</th>
<th>Yield stalks (Mg.ha⁻¹)</th>
<th>Yield sugar (Mg.ha⁻¹)</th>
<th>Dry matter shoot (Kg.ha⁻¹)</th>
<th>Accumulation N (Kg.ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland-0 kg ha⁻¹ N</td>
<td>17.59 c</td>
<td>64.7 c</td>
<td>10.8 c</td>
<td>31.9 c</td>
<td>81.5 c</td>
</tr>
<tr>
<td>Irrigation-0 kg ha⁻¹ N</td>
<td>24.08 b</td>
<td>83.6 b</td>
<td>14.4 b</td>
<td>41.4 b</td>
<td>97.5 c</td>
</tr>
<tr>
<td>Dryland-140 kg ha⁻¹ N</td>
<td>26.90 b</td>
<td>91.3 b</td>
<td>15.3 b</td>
<td>44.8 b</td>
<td>136.9 b</td>
</tr>
<tr>
<td>Irrigation-140 kg ha⁻¹ N</td>
<td>39.86 a</td>
<td>132.8 a</td>
<td>21.7 a</td>
<td>61.8 a</td>
<td>216.1 a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>14.01</td>
<td>14.9</td>
<td>10.48</td>
<td>15.07</td>
<td>12.57</td>
</tr>
</tbody>
</table>

Means followed by different letters differ significantly by Tukey test (p<0.05).

Gava, et. al. (2010)
Simulation: APSIM-Sugarcane ("Agricultural Production Systems Simulator").
Table 1. Yields and fertilizer nitrogen use efficiency by sugar cane (mean first and second ratoons) when drip-fertigated in a silty clay soil at Belle Vue, Mauritius

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (tonnes ha(^{-1}))</th>
<th>Fertilizer N use efficiency (%)</th>
<th>15N dilution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cane</td>
<td>Sugar</td>
<td>Difference method</td>
</tr>
<tr>
<td>1. Control (no N)</td>
<td>66.9</td>
<td>6.96</td>
<td>–</td>
</tr>
<tr>
<td>2. N buried 10 cm on one side of cane rows</td>
<td>128.2</td>
<td>14.56</td>
<td>32.6</td>
</tr>
<tr>
<td>3. N drip-fertigated daily during 5 weeks</td>
<td>138.0</td>
<td>14.20</td>
<td>54.0</td>
</tr>
<tr>
<td>4. N drip-fertigated daily during 10 weeks</td>
<td>142.6</td>
<td>15.14</td>
<td>62.0</td>
</tr>
<tr>
<td>5. N drip-fertigated daily during 20 weeks</td>
<td>130.0</td>
<td>13.46</td>
<td>52.5</td>
</tr>
<tr>
<td>6. 1/3 N drip-fertigated daily over 10 weeks +</td>
<td>123.8</td>
<td>13.16</td>
<td>51.8</td>
</tr>
<tr>
<td>2/3 N during next 10 weeks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD ((p = 0.10))</td>
<td>20.6</td>
<td>1.84</td>
<td>19.6</td>
</tr>
</tbody>
</table>

120 kg N per ha as urea applied to all treatments (except the control) as from September.
Water and nitrogen interaction

A. Cane Yield

- Plant crop: $Y = 97.0 + 0.74X$, $r^2 = 0.23$
- 1st ratoon: $Y = 92.6 + 0.62X$, $r^2 = 0.18$
- 2nd ratoon: $Y = 102.4 + 0.085X$, $r^2 = 0.24$
- 3rd ratoon: $Y = 76.2 + 1.92X$, $r^2 = 0.59$

B. Sugar Yield

- $Y = 12.5 + 0.13X$, $r^2 = 0.54$

Wiedenfeld & Ensiso (2008)
**Effect of nitrogen fertilization and drip irrigation (H₂O) in the yield of sugarcane and accumulation of N.**

<table>
<thead>
<tr>
<th>Irrigated treatments</th>
<th>Dry matter stalks (Mg ha⁻¹)</th>
<th>Yield stalks (Mg ha⁻¹)</th>
<th>Yield sugar (Kg ha⁻¹)</th>
<th>Dry matter shoot (Kg ha⁻¹)</th>
<th>Accumulation N (Kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 N kg ha⁻¹</td>
<td>24.1</td>
<td>83.6</td>
<td>14.4</td>
<td>41.4</td>
<td>97.5</td>
</tr>
<tr>
<td>70 N kg ha⁻¹</td>
<td>25.7</td>
<td>97.5</td>
<td>16.7</td>
<td>49.3</td>
<td>163.9</td>
</tr>
<tr>
<td>140 N kg ha⁻¹</td>
<td>39.9</td>
<td>132.8</td>
<td>22.3</td>
<td>61.8</td>
<td>216.1</td>
</tr>
<tr>
<td>210 N kg ha⁻¹</td>
<td>39.8</td>
<td>130.4</td>
<td>21.6</td>
<td>64.1</td>
<td>227.0</td>
</tr>
<tr>
<td>Average</td>
<td>32.4</td>
<td>111.1</td>
<td>18.8</td>
<td>54.2</td>
<td>176.2</td>
</tr>
<tr>
<td>CV (%)</td>
<td>11.5</td>
<td>15.4</td>
<td>5.2</td>
<td>12.6</td>
<td>18.3</td>
</tr>
<tr>
<td>F – reg. 1⁰ gr</td>
<td>37.92*</td>
<td>30.7*</td>
<td>25.5*</td>
<td>23.84*</td>
<td>37.44*</td>
</tr>
<tr>
<td>R²</td>
<td>0.73</td>
<td>0.69</td>
<td>0.65</td>
<td>0.63</td>
<td>0.92</td>
</tr>
<tr>
<td>F – reg. 2⁰ gr</td>
<td>1.3 *</td>
<td>16.4 *</td>
<td>14.26 *</td>
<td>12.00*</td>
<td>2.9 ns</td>
</tr>
<tr>
<td>R²</td>
<td>0.75</td>
<td>0.72</td>
<td>0.69</td>
<td>0.65</td>
<td>-</td>
</tr>
</tbody>
</table>

* Significant by F test at p<0.05, ns: not significant.

Gava, et. al. (2010)
Simulation: APSIM-Sugarcane ("Agricultural Production Systems Simulator").

Gava, et. al. (2010)
Concentration of N-NH$_4$ and N-NO$_3$ in profiles 0-20 cm and 20-40 cm in different doses of N-fertilizer.

Kölln et al. (2010).
Yield maximum theoretical to sugarcane

Conclusion

Last year?

This field?

Next year?

That field?
Thank's for your attention
Glauber Gava: ggava@apta.sp.gov.br