Performance of sugarcane varieties, irrigation levels and nitrogen fertilization.

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INTRODUCTION

CHAPTER I.
❖ Performance of sugarcane (RB) varieties

CHAPTER II.
❖ Agroclimatic parameters of the sugarcane region of Alagoas, Brazil;
❖ Sugarcane yields as a function of irrigation levels and nitrogen fertilization;
❖ Irrigation levels and rates of nitrogen fertilization of maximum economic efficiency;
❖ Water Use Efficiency (WUE);
CHAPTER I.

PERFORMANCE OF SUGARCANE VARIETIES (RB)
OBJECTIVES OF THE SUGARCANE BREEDING

Productivity
- Phytomass
- Sugar
- Ethanol

Quality
- Sugar
- Alcohol
- Honey

Tolerance
- Diseases
- Pests
- Drought

Adaptability
- Climate
- Soil

Response
- Menuring
- Irrigation

Harvest
- Epoch
- Period of Industrial Use
- Mechanization

LATEST TENDENCIES
- Mechanized harvest
- Biomass production
- Irrigation response
GENETIC IMPROVEMENT METHODS OF THE SUGARCANE

BOTANICAL CROSSINGS

Bi-parental crossings

Multiple crossings
or melting pot
FACTORS THAT INFLUENCE THE FLOWERING OF THE SUGARCANE

✓ Climatic factors

✓ Genetic characteristics of the varieties

✓ Nutritional level of the plants
CLIMATIC FACTORS

Photoperiod (day length)

12,0 horas 12,5 horas

No flowering Flowering No flowering

Air temperature

18 °C 31 °C

No flowering Flowering No flowering

Humidity
Brazilian climatology

Climate map of Brazil with emphasis on dry season.

Dry season
SEP - MAR

Dry season
APR - AUG

CROSSING STATION OF THE SERRA DO OURO
Brazilian production

Crop Season 2010/2011

Harvested Area (ha) ~ 8.03 milliones

Yield sugarcane (ton) ~ 624.9 milliones

Yield sugar (ton) ~ 38.67 milliones

Yield ethanol (L) ~ 27,699.55 milliones

Source: CONAB, 2011.
Crop season 2010/2011
Harvested area (ha) ~ 440,000
Sugarcane yield (ton) ~ 29,000,000
CLIMATIC CHARACTERISTICS OF THE CROSSING STATION OF THE SERRA DO OURO, MURICI, AL. BRAZIL.

Localization: (09°13’S; 35°50’W; 515m)

Distance of the litoral: 35 km

Air relative humidity: 93.2%

Annual rainfall: 2,363 mm

Air minimum temperature: 18.9°C

Air maximum temperature: 27.1°C

Photoperiod or the amount of light hours per day

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct *</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.6</td>
<td>12.4</td>
<td>12.2</td>
<td>11.9</td>
<td>11.7</td>
<td>11.6</td>
<td>11.7</td>
<td>11.8</td>
<td>12.1</td>
<td>12.3</td>
<td>12.5</td>
<td>12.7</td>
</tr>
</tbody>
</table>

* Beginning of the induction period in the Brazilian Northeast
FLOWCHART OF THE GENETIC IMPROVEMENT OF SUGAR CANE SUGAR BY BOTANICAL CROSSING

Phase : 01
CROSSING: for seed

Phase : 02
SEEDING: for seedlings

Phase : 03
T1: individual seedlings planting

Phase : 04
T1: selection and multiplication of clones

Phase : 05
T2: tests for disease resistance, sucrose content...

Phase : 06
T2: continuation of the tests, diseases, drought, productivity

Phase : 07
T3: tests and selection in ratoons and plants

Phase : 08
T3: tests and selection in ratoons and plants

Year 01
Phase : 01
CROSSING: for seed

Year 02
Phase : 02
SEEDING: for seedlings

Year 03
Phase : 03
T1: individual seedlings planting

Year 04
Phase : 04
T1: selection and multiplication of clones

Year 05
Phase : 05
T2: tests for disease resistance, sucrose content...

Year 06
Phase : 06
T2: continuation of the tests, diseases, drought, productivity

Year 07
Phase : 07
T3: tests and selection in ratoons and plants

Year 08
Phase : 08
T3: tests and selection in ratoons and plants

Year 09
Phase : 09
F_E: experiments in the producing units

Year 10
Phase : 10
F_E: experiments and validation by producers (commercial launch)

Year 11
Phase : 10
F_E: experiments and validation by producers (commercial launch)
Gava, et al (2009) in the Jau-SP region, produced 141 and 115 with the RB867515, in irrigated and rainfed crop, respectively.
RESULTS

Isoquant of sugar yield (ton per hectare) in rainfed crop (plant cycle)
Isoquant of sugar yield (ton per hectare) in rainfed crop (1st ratoon cycle)
Isoquant of sugar yield (ton per hectare) in Irrigated crop (plant cycle)
RESULTS

Isoquant of sugar yield (ton per hectare) in Irrigated crop (1\textsuperscript{st} ratoon cycle)
**RESULTS**

Effective rainfall (Sep/05 to Nov/06) = 958
Effective rainfall (Nov/06 to Nov/07) = 955
Effective rainfall (Nov/07 to Nov/08) = 971

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Plant t ha⁻¹</th>
<th>WUE mm/t</th>
<th>1ʳᵃ ratoon t ha⁻¹</th>
<th>WUE mm/t</th>
<th>2ʳᵃ ratoon t ha⁻¹</th>
<th>WUE mm/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB863129</td>
<td>97</td>
<td>9,8</td>
<td>79</td>
<td>12,1</td>
<td>85</td>
<td>11,5</td>
</tr>
<tr>
<td>RB931003</td>
<td>93</td>
<td>10,3</td>
<td>82</td>
<td>11,7</td>
<td>107</td>
<td>9,1</td>
</tr>
<tr>
<td>RB867515</td>
<td>93</td>
<td>10,3</td>
<td>66</td>
<td>14,5</td>
<td>99</td>
<td>9,8</td>
</tr>
<tr>
<td>RB93509</td>
<td>99</td>
<td>9,7</td>
<td>96</td>
<td>10,0</td>
<td>100</td>
<td>9,7</td>
</tr>
<tr>
<td>RB971755</td>
<td>78</td>
<td>12,2</td>
<td>60</td>
<td>15,9</td>
<td>74</td>
<td>13,2</td>
</tr>
<tr>
<td>RB951541</td>
<td>78</td>
<td>12,3</td>
<td>72</td>
<td>13,3</td>
<td>82</td>
<td>11,9</td>
</tr>
<tr>
<td>RB92579</td>
<td>101</td>
<td>9,4</td>
<td>76</td>
<td>12,5</td>
<td>95</td>
<td>10,2</td>
</tr>
<tr>
<td>RB72454</td>
<td>74</td>
<td>12,9</td>
<td>71</td>
<td>13,4</td>
<td>62</td>
<td>15,6</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>89</strong></td>
<td><strong>10,7</strong></td>
<td><strong>75</strong></td>
<td><strong>12,7</strong></td>
<td><strong>88</strong></td>
<td><strong>11,0</strong></td>
</tr>
</tbody>
</table>

Water use efficiency (consumption form) of sugarcane cultivars in rainfed crop (three cycle).

Gava, et al (2009), in the Jaú-SP region, found a WUE of 12.8 with the RB867515.
### RESULTS

Plant: Effective rainfall plus irrigation = 1.915

1ª ratoon: Effective rainfall plus irrigation = 1.727

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Plant (t ha⁻¹)</th>
<th>WUE</th>
<th>1ª ratoon (t ha⁻¹)</th>
<th>WUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB92579</td>
<td>183</td>
<td>10.4</td>
<td>155</td>
<td>11.2</td>
</tr>
<tr>
<td>RB93509</td>
<td>176</td>
<td>10.9</td>
<td>133</td>
<td>13.0</td>
</tr>
<tr>
<td>RB931003</td>
<td>166</td>
<td>11.6</td>
<td>135</td>
<td>12.8</td>
</tr>
<tr>
<td>RB867515</td>
<td>155</td>
<td>12.4</td>
<td>125</td>
<td>13.8</td>
</tr>
<tr>
<td>RB951541</td>
<td>151</td>
<td>12.7</td>
<td>115</td>
<td>15.0</td>
</tr>
<tr>
<td>RB98710</td>
<td>141</td>
<td>13.6</td>
<td>140</td>
<td>12.4</td>
</tr>
<tr>
<td>RB863129</td>
<td>132</td>
<td>14.5</td>
<td>110</td>
<td>15.7</td>
</tr>
<tr>
<td>RB971755</td>
<td>131</td>
<td>14.6</td>
<td>121</td>
<td>14.3</td>
</tr>
<tr>
<td>RB72454</td>
<td>131</td>
<td>14.6</td>
<td>117</td>
<td>14.8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>152</strong></td>
<td><strong>12.8</strong></td>
<td><strong>128</strong></td>
<td><strong>13.7</strong></td>
</tr>
</tbody>
</table>

Water use efficiency (consumption form) of sugarcane cultivars in irrigated crop (two cycle).

Gava, et al (2009), in the Jaú-SP region, found a WUE of 13.4 with the RB867515.
Water use efficiency of sugarcane varieties in two cycles.

Kingston (1994) cited by Inman-Bamber (2005) found a range from 5.0 to 11.95 mm t\(^{-1}\).
In this experiment, the cultivars RB92579, RB93509 and the RB931003 were the most productive in the two crop system (irrigated and rainfed);

The cultivar RB92579 was the most efficient in the use of the irrigation water, with the consumption ranging from 9.4 to 12.5 mm t⁻¹ (in rainfed crop) and 10.4 to 11.2 mm t⁻¹ (in irrigated crop);

The water use efficiency decreases from one cycle to another;
CHAPTER II.

IRRIGATION LEVELS AND NITROGEN FERTILIZATION
MATERIALS AND METHODS

- The field study was conducted at the Federal University of Alagoas, Rio Largo, AL, Brazil;
- **Planting = Jan/2009**
- First harvest = Feb/2010;
- Second harvest = Feb/2011;
- The RB92579 cultivar was the one used.

**TREATMENTS APPLIED TO SUGARCANE**

<table>
<thead>
<tr>
<th>Irrigation levels (%ETo*)</th>
<th>N Fertilization (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,0 ETo</td>
<td>0</td>
</tr>
<tr>
<td>0,25 ETo</td>
<td>50</td>
</tr>
<tr>
<td>0,50 ETo</td>
<td>100</td>
</tr>
<tr>
<td>0,75 ETo</td>
<td>150</td>
</tr>
<tr>
<td>1,00 ETo</td>
<td>200</td>
</tr>
<tr>
<td>1,25 ETo</td>
<td></td>
</tr>
<tr>
<td>1,50 ETo</td>
<td></td>
</tr>
</tbody>
</table>

* ETo = Reference evapotranspiration
**MATERIALS AND METHODS**

**CANE PRICE (R$ per ton)**

<table>
<thead>
<tr>
<th>CRS *</th>
<th>CRS PRICE (R$ KG⁻¹)</th>
<th>Cane price (R$ t⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle</td>
<td>Min.</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>0,471</td>
</tr>
</tbody>
</table>

Source: SINADÇUCAR - AL

* CRS = Commercially recoverable sucrose content

**Water applied price (R$ per mm)**

<table>
<thead>
<tr>
<th>FIXED COST</th>
<th>APLICATION COST</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life time</td>
<td>level</td>
<td></td>
</tr>
<tr>
<td>R$ ha⁻¹</td>
<td>(Year)</td>
<td>(mm)</td>
</tr>
<tr>
<td>7.200,00</td>
<td>10</td>
<td>600</td>
</tr>
</tbody>
</table>

# MATERIALS AND METHODS

## NITROGEN PRICE

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>R$ per ton*</th>
<th>R$ per kg of N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium sulfate</td>
<td>450.00</td>
<td>2.50</td>
</tr>
<tr>
<td>Urea</td>
<td>723.00</td>
<td>1.61</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>2.05</strong></td>
</tr>
</tbody>
</table>

* Source: Usifértil (telephone consultation)
MATERIALS AND METHODS

Agrometeorological station
MATERIALS AND METHODS

Water reservoir

Pump house
MATERIALS AND METHODS

Planting the stalk pieces

Drip irrigation system
Rainfall (P) and reference evapotranspiration (ETo), from Jan 2009 to Feb 2011, in the region of Rio Largo, AL. Brazil.
RESULTS

## RESULTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant</th>
<th>First ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 ETo</td>
<td>0 mm</td>
<td>0 mm</td>
</tr>
<tr>
<td>0.25 ETo</td>
<td>157 mm</td>
<td>127 mm</td>
</tr>
<tr>
<td>0.50 ETo</td>
<td>312 mm</td>
<td>240 mm</td>
</tr>
<tr>
<td>0.75 ETo</td>
<td>447 mm</td>
<td>346 mm</td>
</tr>
<tr>
<td>1.00 ETo</td>
<td>585 mm</td>
<td>473 mm</td>
</tr>
<tr>
<td>1.25 ETo</td>
<td>741 mm</td>
<td>587 mm</td>
</tr>
<tr>
<td>1.50 ETo</td>
<td>873 mm</td>
<td>734 mm</td>
</tr>
</tbody>
</table>
RESULTS

Cane yield curve fertilized with different nitrogen rates in function of irrigation levels (Plant - a and 1st ratoon - b).
The irrigation average level in order physical maximum productivity and economic maximum efficiency in Plant (a) and 1st ratoon cycle (b).
Agricultural productivity and water use efficiency (expressed in the form of consumption - mm.t⁻¹)

Average of 9.1 and 11.6 mm t⁻¹, in the plant and in the 1st ratoon, respectively.
DALRI (2006) concluded that in the most situations, the relationship between water consumption and productivity ranged 8 and 12 mm.t\(^{-1}\).

Gava, et al (2008), in the Jau-SP region, observed a WUE from 13.4 with the cultivar RB867515.

Wiedenfeld and Enciso (2008) found a consumption from 12.5 to 16.6 mm per ton (in plant crop) and from 10.6 to 12.9 (in 1\(^{st}\) ratoon crop).
RESULTS

Cane yield (t ha⁻¹) and growth rate (t month⁻¹) of the sugarcane
# POTENTIAL OF CANE PRODUCTION IN THE IRRIGATED WORLD

<table>
<thead>
<tr>
<th>Region</th>
<th>Ton of cane month&lt;sup&gt;-1&lt;/sup&gt;</th>
<th>Ton of cane ha&lt;sup&gt;-1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Central</td>
<td>12.5 - 15</td>
<td>150 – 180</td>
</tr>
<tr>
<td>Peru</td>
<td>15 - 16</td>
<td>180 – 200</td>
</tr>
<tr>
<td>Australia</td>
<td>14</td>
<td>165</td>
</tr>
<tr>
<td>South Africa</td>
<td>12 - 14</td>
<td>140 – 160</td>
</tr>
<tr>
<td>Brazil (SE)*</td>
<td>7 – 8</td>
<td></td>
</tr>
<tr>
<td>Brazil (NE)*</td>
<td>4.5 - 6</td>
<td></td>
</tr>
</tbody>
</table>

* Rainfed

Source: Flávio Luiz de Aguiar, 2007 (NETAFIM / STAB Lecture)
Law of the Minimum of Liebig
Law of the Minimum of Liebig
RESULTS

Cane yield curves irrigated with different water levels in function of the nitrogen fertilization rates.
RESULTS

The nitrogen average level in order physical maximum productivity and economic maximum efficiency in plant crop (a) and the first ratoon (b).
RESULTS

Cane yield (t ha⁻¹) and increase rate per kg of N applied.

In this study, the average found was 90 and 59 kg of cane per Kg of N applied, in plant and 1st ratoon cycle, respectively.

Wiedenfeld and Enciso (2008) found from 65 to 85 kg of cane per kg of N applied in the plant through second ratoon crops. In the third ratoon crop, the slope increased to 191 Kg of cane per Kg. of N applied.
Isoquant of the agricultural productivity of sugarcane in function of irrigation and nitrogen fertilization levels.
Replacement rate of nitrogen by irrigation water
RESULTS

Region of rational production
CONCLUSIONS

✓ The physical maximum productivity could be obtained with irrigation level of 185% and 170% of the ETo in sugarcane plant and 1st ratoon, respectively;

✓ The physical maximum productivity, in relation the nitrogen fertilization, were achieved with 167 and 157 kg of nitrogen per hectare in plant and 1st ratoon, respectively;

✓ The yields of maximum economic efficiency is highly dependent of the price of the CRS;

✓ The rate of replacement of water by nitrogen is inversely proportional to the increase of irrigation level, and the equivalence point is in 400 mm of water and 125 kg of nitrogen.
REFERENCES


✓ Usifértil – Seller Company of fertilizers, Maceio, AL. Brazil.

ACKNOWLEDGMENTS

NETAFIM

PMGCA

Sugar factory associated