U.S. Borax

Final Report – Coffee Trial

“Study of Boron in Brazilian Agriculture”

Dr. Fabio Vale

Piracicaba, March / 2016
Coffee Trial
First harvest – 2014
Coffee Trial

- Place – Sítio São João
- City – Espírito Santo do Pinhal/SP
- Variety – Catuai Amarelo ICA 62 (Yellow Catuai)
- Age – 5 years
- Application treatments date: 11/11/2013
- Spacing between rows: 3.2 m
- Spacing between trees: 0.7 m
- Trees per hectare: 4465
- Plots – 3 rows x 8 trees
- 9 treatments and 4 replications = 36 parcels
- Blocks randomized
Details of the Plots

- Plots – 3 rows x 8 trees
- The six central plants of line 2 were harvested.

<p>| | | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>x</td>
<td>O</td>
<td>x</td>
</tr>
<tr>
<td>x</td>
<td>O</td>
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<tr>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Row 1 | Row 2 | Row 3

x = unharvested plants
O = harvested plants

USB - Study of Boron in Brazilian Agriculture
Coffee Trial
Coffee Trial
Coffee Trial
All parcels were fertilized with:

- 50 g/tree of single superphosphate in October/13
- 200 g/tree of the blend 20-00-15 in November/13 (same day of treatment application)
- 200 g/tree of the blend 20-00-15 in January/14
- 60 g/tree of urea in March/14

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Source</th>
<th>B rate (kg/ha)</th>
<th>Source rate (kg/ha)</th>
<th>Source rate (g/tree)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2</td>
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<td>3</td>
<td>Ulexite</td>
<td>3</td>
<td>30.0</td>
<td>6.7</td>
</tr>
<tr>
<td>4</td>
<td>Granubor®</td>
<td>1.5</td>
<td>10.7</td>
<td>2.4</td>
</tr>
<tr>
<td>5</td>
<td>Granubor</td>
<td>3</td>
<td>21.4</td>
<td>4.8</td>
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<tr>
<td>6</td>
<td>Boric acid</td>
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<td>7</td>
<td>Boric acid</td>
<td>3</td>
<td>17.6</td>
<td>4.0</td>
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<tr>
<td>8</td>
<td>Solubor®</td>
<td>1.5</td>
<td>7.5</td>
<td>1.7</td>
</tr>
<tr>
<td>9</td>
<td>Solubor</td>
<td>3</td>
<td>15.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Parcel</td>
<td>Treatment</td>
<td>Parcel</td>
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<td>Parcel</td>
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</tr>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>11</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>12</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>13</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>14</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>15</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>16</td>
<td>3</td>
<td>25</td>
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<tr>
<td>8</td>
<td>8</td>
<td>17</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>18</td>
<td>4</td>
<td>27</td>
</tr>
</tbody>
</table>
Soil Samples (0-20 cm depth), Before Fertilizers Application (in June/13)

<table>
<thead>
<tr>
<th>Depth</th>
<th>pH(\text{CaCl}_2)</th>
<th>OM</th>
<th>P(_{\text{resina}})</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Al</th>
<th>H+Al</th>
<th>S</th>
<th>B</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>g dm(^{-3})</td>
<td>mg dm(^{-3})</td>
<td>mmol(_c) dm(^{-3})</td>
<td>mmol(_c) dm(^{-3})</td>
<td>mmol(_c) dm(^{-3})</td>
<td>mmol(_c) dm(^{-3})</td>
<td>mmol(_c) dm(^{-3})</td>
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<td>mmol(_c) dm(^{-3})</td>
<td>mmol(_c) dm(^{-3})</td>
<td>mmol(_c) dm(^{-3})</td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>5,3</td>
<td>21</td>
<td>29</td>
<td>2,3</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>28</td>
<td>7</td>
<td>0,5</td>
<td>2,4</td>
<td>48</td>
<td>1,9</td>
<td>2,3</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Depth</th>
<th>SB</th>
<th>CEC</th>
<th>V</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>----</td>
<td>mmol(_c) dm(^{-3})</td>
<td>----</td>
<td>---</td>
</tr>
<tr>
<td>0-25</td>
<td>21,4</td>
<td>49,4</td>
<td>43</td>
<td>4,5</td>
</tr>
</tbody>
</table>

- Soil with medium organic matter content
- Medium P concentration; medium K concentration; medium Ca concentration and low Mg concentration
- Low B concentration
Area Before Fertilization
Blend Granubor® + NPK
Solubor®
Solubor® Application
Rainfall

Daily rainfall - July 2013 to June 2014
Rainfall

Monthly rainfall - July 2013 to June 2014

mm

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>jul/13</td>
<td>68.5</td>
</tr>
<tr>
<td>ago/13</td>
<td>14.0</td>
</tr>
<tr>
<td>set/13</td>
<td>73.5</td>
</tr>
<tr>
<td>out/13</td>
<td>190.5</td>
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<tr>
<td>nov/13</td>
<td>159.0</td>
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<tr>
<td>dez/13</td>
<td>119.3</td>
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<tr>
<td>jan/14</td>
<td>74.5</td>
</tr>
<tr>
<td>fev/14</td>
<td>55.5</td>
</tr>
<tr>
<td>mar/14</td>
<td>116.5</td>
</tr>
<tr>
<td>abr/14</td>
<td>32.0</td>
</tr>
<tr>
<td>mai/14</td>
<td>27.0</td>
</tr>
<tr>
<td>jun/14</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Rainfall

Precipitation - July 2013 to June 2014

mm

July 2013 to June 2014
Rainfall

Total rainfall during the experiment was 930 mm, which is lower than normal years.

Amount below normal between January and April, the period of greatest development of culture.

There was a decline in yield in the major production areas in coffee region.

Problem in fruits with malformed seeds.
Evaluations to Be Made

лиз Leaf analysis – in the beginning of February (2014 and 2015)
лиз Yield in June 2014
лиз Coffee quality in July 2014
лиз Soil tests per plot to evaluate B content in October 2014
Taking Leaves Samples (02/05/14)
Methodology

1° PAR
2° PAR
3° PAR
4° PAR

1. 3rd and 4th pairs of leaves
2. Two side of the plants
Tissue Test

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability

No significative differences in B in leaves in function of sources and rates of B

Average = 66,20 mg/kg   VC = 12,64%

≈ Values are the average of 4 replicates
≈ Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
≈ No significative differences in B in leaves in function of sources and rates of B
Harvest

June, 6th
Plants Before Harvest
Plants Before Harvest
Harvested Six Plants per Plot
Removal of Impurities
Coffee Fruits from Six Plants
Steps After Harvest

- Measuring the amount of liters of coffee fruits generated per plot.
- Selection of a sample per plot by separating a liter of coffee fruits harvested.
- Sample placed in a container with water.
- Selection of floating fruits, that were to surface water.
  - Fruits with malformed seeds
- No floating fruits were separated in green and mature.
Measuring the amount of liters of coffee fruits generated
Fruits per Plants (L/plant)

Average = 4.58 L/ha  VC = 19.67%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Fruits per Plants (L/plant)

- Granubor® in rate 1.5 kg/ha was the best treatment
- Granubor > Ulexite
- Lower rate > Bigger rate, probably because of toxicity of B
- Granulated sources > Soluble sources = Control
Selection of a sample per plot by separating a liter of coffee fruits harvested
Sample in a Container

Floating fruits

Green and mature fruits
Drying Samples in the Sun
Selection of Fruits

- % Floating
- % Mature
- % Green

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Floating</th>
<th>Mature</th>
<th>Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>33%</td>
<td>23%</td>
<td>44%</td>
</tr>
<tr>
<td>Ulexite (1.5 kg/ha)</td>
<td>35%</td>
<td>30%</td>
<td>36%</td>
</tr>
<tr>
<td>Ulexite (3 kg/ha)</td>
<td>35%</td>
<td>30%</td>
<td>36%</td>
</tr>
<tr>
<td>Granubor (1.5 kg/ha)</td>
<td>18%</td>
<td>33%</td>
<td>48%</td>
</tr>
<tr>
<td>Granubor (3 kg/ha)</td>
<td>23%</td>
<td>30%</td>
<td>45%</td>
</tr>
<tr>
<td>Boric acid (1.5 kg/ha)</td>
<td>35%</td>
<td>35%</td>
<td>35%</td>
</tr>
<tr>
<td>Boric acid (3 kg/ha)</td>
<td>30%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Solubor (1.5 kg/ha)</td>
<td>22%</td>
<td>28%</td>
<td>53%</td>
</tr>
<tr>
<td>Solubor (3 kg/ha)</td>
<td>24%</td>
<td>24%</td>
<td>43%</td>
</tr>
</tbody>
</table>
Selection of Fruits

- High variability among treatments
- Floating fruits – worst characteristic
  - Ulexite and Solubor® had more floating fruits
  - Granubor® had less floating fruits
- Mature fruits – Best characteristic
  - Granubor® and Control had best results
Steps After Drying

The grains were mixed (float, ripe and green) and then weighed.

- Weight of coffee beans

Grains were benefited, took up the bark. Then weighed

- Weight of coffee grains

Calculated the relationship between weight of grains and weight of beans = “Renda”
Yield Coffee Grains (t/ha)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.52 b</td>
</tr>
<tr>
<td>Ulexite (1.5 kg/ha)</td>
<td>2.58 a</td>
</tr>
<tr>
<td>Ulexite (3 kg/ha)</td>
<td>2.02 b</td>
</tr>
<tr>
<td>Granubor (1.5 kg/ha)</td>
<td>3.42 a</td>
</tr>
<tr>
<td>Granubor (3 kg/ha)</td>
<td>1.95 b</td>
</tr>
<tr>
<td>Boric acid (1.5 kg/ha)</td>
<td>1.72 b</td>
</tr>
<tr>
<td>Boric acid (3 kg/ha)</td>
<td>1.26 b</td>
</tr>
<tr>
<td>Solubor (1.5 kg/ha)</td>
<td>1.78 b</td>
</tr>
<tr>
<td>Solubor (3 kg/ha)</td>
<td>1.67 b</td>
</tr>
</tbody>
</table>

Average = 1.99 t/ha  VC = 32.89%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Yield

- Significant responses to the application of granular sources Ulexite and 
  *Granubor®* compared to Control and Soluble Sources (Boric Acid and 
  *Solubor®*)

- The explanation may be due to gradual solubility relative to the more soluble 
  sources, which may have higher losses caused by leaching of B.

- Even without significant differences, the source *Granubor* showed superior 
  results

- The rate of 1.5 kg/ha of B was sufficient to increase yield, and the rate of 3 
  kg/ha may be caused depreciation by possible toxicity

- The boric acid source in the highest rate caused a reduction in yield

- There was no effect on “Renda”
Soil Sampling
Soil Sampling, 0-20- e 20 40 cm depth
Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability

Only even comparisons of the same depth
Even one year after the implementation of the sources, the B continues in higher concentration in the surface layer, except for boric acid.

Significantly greater amount of residual B 0-20 cm in depth when using Ulexite and Solubor®, regardless of the dose applied.

B from boric acid source was leached in greater amount than when applied Solubor.

Granubor® treatments had lower amount of residual B in the soil than the source Ulexite. However, the yield was higher for the use of Granubor. This may indicate that the source Granubor had a solubility of more adjusted to the needs of the culture.
Conclusions for First Year

〜 Despite the adverse weather conditions, coffee plants were influenced by the application of boron in the soil

〜 Application of granular sources Ulexite and Granubor® showed significant results when compared to Control and Soluble Sources (Boric Acid and Solubor®)

〜 Even without significant differences, the source Granubor showed superior results

〜 The second crop which starts from now it will be important to the final conclusion of this experiment.
Second Year

Treatments application – November, 15th, 2014
Evaluations

- Leaf analysis – in the beginning of February 2015)

- Yield in June 2015

- Coffee quality in July 2015

- Soil tests per plot to evaluate B content in October 2015
Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability

No significative differences in B in leaves in function of sources and rates of B
Harvest

June, 26th, 2015
Harvest
Fruits per Plants (L/plant) – Sources and Rates

Average = 7,43 L/ha  VC = 15,39%

VALUES ARE THE AVERAGE OF 4 REPLICATES

MEANS FOLLOWED BY THE SAME LETTER DO NOT DIFFER STATISTICALLY BY THE SCOTT-KNOTT TEST AT 5% PROBABILITY
Fruits per Plants (L/plant) – Sources

Average = 7,43 L/ha  VC = 15,39%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Fruits per Plants (L/plant) – Rates

Average = 7,43 L/ha  VC = 15,39%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Granubor® in rate 1.5 kg/ha was the best treatment

Granubor = Ulexite = Solubor® > Boric acid

There was effects of boron application, rates have same results
Selection of Fruits – Sources and Rates

% Mature | % Green
---|---
68,1% | 31,9%
72,9% | 27,1%
69,4% | 30,6%
70,6% | 29,4%
64,8% | 35,3%
73,8% | 26,3%
67,5% | 32,5%
68,4% | 31,6%
70,3% | 29,8%
Selection of Fruits – Sources

- **Control**
- **Ulexite**
- **Granubor**
- **Boric acid**
- **Solubor**

<table>
<thead>
<tr>
<th>Source</th>
<th>% Mature</th>
<th>% Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>68.1%</td>
<td>31.9%</td>
</tr>
<tr>
<td>Ulexite</td>
<td>71.1%</td>
<td>28.9%</td>
</tr>
<tr>
<td>Granubor</td>
<td>67.7%</td>
<td>32.3%</td>
</tr>
<tr>
<td>Boric acid</td>
<td>70.6%</td>
<td>29.4%</td>
</tr>
<tr>
<td>Solubor</td>
<td>69.3%</td>
<td>30.7%</td>
</tr>
</tbody>
</table>
Selection of Fruits – Rates

- **Control**: 68.1% Mature, 31.9% Green
- **1,5 kg/ha B**: 71.4% Mature, 28.6% Green
- **3,0 kg/ha B**: 68.0% Mature, 32.0% Green
Selection of Fruits

No effects between sources and rates of Boron in the maturation of coffee grains
Yield Coffee Grains (t/ha) – Sources and Rates

Average = 3,30 t/ha    VC = 14,27%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Yield Coffee Grains (t/ha) – Sources

Average = 3,30 t/ha   VC = 14,27%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Average = 3,30 t/ha   VC = 14,27%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Significative effects between sources and rates of Boron in the yield of coffee grains

Granubor® > Ulexite = Solubor® = Boric Acid = Control

Granubor in the lower rate is the best treatment

Trends to rate 3 kg/ha B better than 1.5 kg/ha, except to Granubor
Revenue (%) - Sources and Rates

Average = 46.3%
VC = 7.78%

Values are the average of 4 replicates
Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Revenue (%) - Sources

Average = 46,3%  VC = 7,78%

Values are the average of 4 replicates
Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Revenue (%) - Rates

Average = 46,3%  
VC = 7,78%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
There was no significant effect in sources and rates of boron on revenue of grains coffee.
Soil Sampling
B in Soil, 0-20 cm depth – Sources and Rates

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
B in Soil, 0-20 cm depth – Sources

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability

0-20 cm: Average = 1,18 mg/dm³   VC = 24,33%
B in Soil, 0-20 cm depth – Rates

0-20 cm: Average = 1,18 mg/dm³  VC = 24,33%

Values are the average of 4 replicates
Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
There was significant effects of rates of boron in the increment of boron in soil.

Despite the no significant effects, is possible to consider the effects of sources and granulated sources increase more amount of B in soil.
Conclusions for First Year

Coffee plants were influenced by the application of boron in the soil

Granubor® showed superior results
Two Years Average Yield
Very important consider two years average because this is how farmers consider yield.

Coffee has an important characteristic of one year with low yield and other with higher. It is a physiologic characteristic of the crop.
Fruits per Plants (L/plant) – Sources and Rates

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Fruits per Plants (L/plant) – Sources

Average = 6.01 t/ha       VC = 12.71%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Fruits per Plants (L/plant) – Rates

Average = 6,01 t/ha  VC = 12,71%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Yield Coffee Grains (t/ha) – Sources and Rates

Average = 2,65 t/ha
VC = 16,69%

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Yield Coffee Grains (t/ha) – Sources

Average = 2.65 t/ha  VC = 16.69%

Values are the average of 4 replicates
Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability
Yield Coffee Grains (t/ha) – Rates

Values are the average of 4 replicates

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability

Average = 2,65 t/ha   VC = 16,69%

Control 1,5 kg/ha B 3,0 kg/ha B

Coffee grains Yield (t/ha)
Conclusions and Recommendation

- Boron showed as an important micronutrient to coffee production
- Application is soil has a good response, and the suggestion is the rate 1.5 kg/ha per year, in the beginning of fertilization time (September to October)
- Granulated sources was more effective than soluble
- Granubor® was the best source, because it have a good solubility, more adjusted to the needs of the crop.
- Boron application wasn’t involved in quality characteristics in this trial (influence in maturation and revenue).
- More trials are important to consolidate the results