VINASSE: A LIQUID FERTILISER

By
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KEYWORDS: Sugarcane, Vinasse, Liquid fertiliser, Nitrogen, Yield.

Abstract

The effects of vinasse sprinkling and vinasse plus nitrogen on sugarcane yield and soil chemical characteristics were evaluated over seven consecutive years. The trial was laid down on 08–11–1995 at Usina São José da Estiva, São Paulo state on Yellow-Red Latosol, allic, sandy texture (sandy loam allic, Typic Hapludox). The experiment was established in a second cut of RB72454 variety, and it was harvested for seven years up till 2002. The statistical design was a factorial 4 x 4 randomised blocks with four repetitions of vinasse doses (0, 100, 200 and 300 m³/ha) and nitrogen (0, 50, and 150 kg/ha). The experimental plots were seven sugarcane lines 10 m long. The five central sugarcane lines were harvested for sugarcane yield (t/ha). After each harvest, the same treatments were re-applied to the respective plots. The data analysis leads to the following conclusions: a) vinasse is a soil fertility improver that promotes deep root development; b) it promotes a nutrient lixiviation, specially, calcium to 75 cm deep, magnesium to 250 cm deep, sulfur and potassium in high concentrations to 350 cm deep; c) the sugarcane yield was significantly improved as vinasse doses increased; d) the interaction of vinasse and nitrogen doses proved to be more efficient than vinasse alone regarding sugarcane yield; e) nitrogen doses should be reduced as vinasse doses increase, and an economic evaluation is recommended to obtain the adequate nitrogen dose.

Introduction

The name vinasse is widely used for a residue that comes from a distillation of alcoholic solution named wine, which is a result of alcoholic fermentation (Elias Neto and Nakahodo, 1995). The wine is a product or a by-product from alcoholic fermentation of saccharose solution named must.

The must can be obtained from juice of several agricultural products like grapes, oranges, sugar beet, sugarcane and many others or directly from sugar, molasses or final molasses.

The vinasse of Brazilian alcohol production comes from fermentation of sugarcane juice, mixed with molasses, which are by-products of sugar production. Therefore, the classic definition of vinasse regarding the must components is vinasse from juice, molasses and a mixture of both.

This classification is generic, considering the actual status of alcohol production in Brazil. The truth is that, in the same season, an attached distillery could produce three types of vinasse since it is fermenting only juice, or molasses, or a mixture (juice plus molasses).

The vinasse is also known as stillage and slop. On average, to produce one litre of alcohol, 13 litres of vinasse is produced. This value ranges from 10 to 15 litres, depending on cane quality and the industrial process.

Vinasse has high organic matter content and potassium but medium to low values for nitrogen and calcium, and low contents of phosphorus and magnesium.

Several quotations could be found in the literature regarding chemical composition of vinasse. Its natural composition depends on its origin. Orlando Filho and Leme (1984) analysed the three types of vinasse and the data are presented in Table 1.
The main methods for vinasse application are: direct application by truck, trucks for transport and application through self-propelled sprinklers and/or canal transport, and application through sprinklers (Figure 1).

Ferreira (1980) reviewed the literature regarding the effects of vinasse on soil characteristics. The authors concluded that natural vinasse addition to soils is a rational option since vinasse is an excellent fertiliser, which brings several benefits to physical, chemical and biological soil properties.

Among these advantages are increases in soil pH, cation exchange capacity (CEC), some nutrients availability, better soil structure (more stable soil structure by addition of organic matter), and soil moisture (water retention potential). Natural vinasse addition also benefits soil micro fauna and flora.
Vinasse is a residue with a high pollutant potential (high BOD—biochemical oxygen demand) due to its high organic matter content, so it should be used correctly. Depending on its use, the organic matter decomposition is accelerated due to its lower C/N ratio (Tedesco et al., 1999).

Vinasse is a source of water and nutrients and also a deep soil fertility improver. Kofler (1986) said that, in some countries, the sugarcane root system reaches 160 cm deep while, in Brazil, the average depth is 60 cm. This smaller depth for the sugarcane root system is due to deep soil low fertility. The mechanism of vinasse soil fertility improvement can be explained by its specific anions like sulfate and non-specific ions like Cl, which are translocated through the soil carrying Ca++, Mg++, and K+ to deep soil (Camargo et al., 1983; Orlando Filho et al., 1994, 1996; Penatti and Forti, 1997).

Common practice widely adopted in the Brazilian sugar industry is ferti-irrigation with vinasse. There is ample literature describing data obtained in several trials that prove the benefit of vinasse for sugarcane yield improvement associated or not with savings of mineral fertiliser (Robaina, 1983; Penatti et al., 1988, 1997).

Penatti and Forti (1997) laid down a trial in a low activity clay soil to study the consequences of sprinkling 300 m³/ha of vinasse for three consecutive years. An increase of 39 t/ha of sugarcane was observed in the whole cycle (Figure 2), besides a potassium translocation to deep soil (Figure 3).

![Figure 2](image_url)

**Figure 2**—Observed sugarcane yield (t/ha) in three consecutive harvest seasons for vinasse doses compared to mineral fertiliser (100–00–150 kg/ha of N-P₂O₅-K₂O).

![Figure 3](image_url)

**Figure 3**—Amounts of potassium (mmol/dm³) in four soil depths for vinasse doses in samples taken six months after first vinasse sprinkling (May, 1996) and after four vinasse sprinklings (October, 1999).

It can be seen (Figure 3) that the potassium amount was raised in the superficial layer (0–25 cm) from 3.5 mmol/dm³ in 1995–1996, with the maximum vinasse dose of 300 m³/ha, to 5.0 mmol/dm³ in the year of 1999, reaching 5% of the original value (1.2 mmol/dm³) of CEC (cation exchange capacity). In the second soil layer (25–50 cm), the potassium increment, with the maximum dose (300 m³/ha), was almost the same as for the first layer (0.7 mmol/dm³ to 2.4 mmol/dm³). The potassium enrichment of the third (50–75 cm) and fourth (75–100 cm) soil layers occurred but in lower concentrations than in the upper
layers. These data have confirmed previous observations of the potassium dynamics in soils. When the upper soil layers become saturated, the element is lixiviated to subsequent soil layers improving chemical characteristics, facilitating sugarcane root development. The vinasse doses of 200 and 300 m³/ha promoted potassium and sulfur lixiviation in the soil profile until 100 cm depth.

Orlando Filho et al. (1995), working in sandy soils, laid down a trial using mineral nitrogen (60 kg/ha) and vinasse doses of 150, 200 and 300 m³/ha to observe the nitrogen lixiviation and a possible water table contamination. Soil samples were taken four times at 5th, 15th, 20th and 25th weeks after vinasse sprinkled on total area. The vinasse chemical composition was: pH = 4.2; %C = 0.6; N = 0.46 kg/m³; P₂O₅ = 0.17 kg/m³; and K₂O = 4.22 kg/m³. The observed data have shown no NO₃⁻ or NH₄⁺ lixiviation among other nitrogen composts that were determined by total N through the soil profile, and there was no pollution from the mineral or vinasse N, mostly due to N microbiological immobilisation in the soil. The sugarcane yield increased with vinasse doses. These results are similar to those obtained by Penatti and Forti (1997).

Dynia (2000), working with vinasse and water table contamination, has found that nitrate (NO₃⁻) has not caused water contamination. This study was carried out in three soil types, two Oxisols (clay) and one Entisol (sand) cultivated with sugarcane over the Botucatu aquifers for more than 10 years.

**Material and methods**

The trial was laid down in a soil type Red-Yellow Latosol, allic, sandy texture (LV) (EMBRAPA, 1999) (sandy loam allic, Typic Hapludox, Soil Survey Staff, 1998) (Table 2) in a second cut of RB72454. The second cut was in October 13, 1995, and the experiment installation was on November 08, 1995. After each harvest, the vinasse doses were sprinkled in the same areas in seven consecutive seasons, from 1996 to 2002.

The statistical design was randomised blocks with four repetitions of a 4 x 4 factorial design with vinasse doses and amounts of mineral nitrogen. The treatments were 0, 100, 200 and 300 m³/ha of vinasse and 0, 50, 100 and 150 kg/ha of mineral nitrogen applied through urea. The experimental plots were seven sugarcane lines, 10 m long, and only five central lines were harvested for sugarcane yield (t/ha).

In the treatments where vinasse was not sprinkled, the nitrogen doses were 0, 50, 100 and 150 kg/ha plus 50 kg of P₂O₅/ha plus 150 kg of K₂O/ha. The urea was applied by hand, buried near and by the side of sugarcane ratoon lines.

**Table 2—Soil chemical analyses before trial installation.**

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>pH</th>
<th>O.M.</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>H⁺Al</th>
<th>S</th>
<th>CEC</th>
<th>V</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–25</td>
<td>4.7</td>
<td>11</td>
<td>6</td>
<td>2.2</td>
<td>7.8</td>
<td>4.1</td>
<td>19</td>
<td>14</td>
<td>33</td>
<td>43</td>
<td>10</td>
</tr>
<tr>
<td>25–50</td>
<td>4.9</td>
<td>8</td>
<td>4</td>
<td>1.4</td>
<td>8.7</td>
<td>6.3</td>
<td>17</td>
<td>16</td>
<td>33</td>
<td>49</td>
<td>6</td>
</tr>
</tbody>
</table>

The vinasse was transported from the industrial area to the trial in a tank truck and sprinkled using a fire-hose (Figure 4). The flow was controlled by a hydrometer to guarantee the exact dose to each treatment (plot). From each tank truck, vinasse samples were taken when the tank was full, half and almost empty. These vinasse samples (Table 3) were analysed by Copersucar Technology Center Laboratory.

![Fig. 4—Trial vinasse sprinkling.](image)
Table 3—Vinasse analyses (kg/m³) from average samples taken in tank truck.

<table>
<thead>
<tr>
<th>Sample (year)</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>CaO</th>
<th>MgO</th>
<th>O.M.</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg/m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>0.6</td>
<td>0.07</td>
<td>3.2</td>
<td>1.8</td>
<td>0.4</td>
<td>18.6</td>
<td>3.75</td>
</tr>
<tr>
<td>1996</td>
<td>0.6</td>
<td>0.06</td>
<td>4.0</td>
<td>1.2</td>
<td>0.4</td>
<td>17.0</td>
<td>4.30</td>
</tr>
<tr>
<td>1998</td>
<td>0.6</td>
<td>0.12</td>
<td>3.7</td>
<td>0.8</td>
<td>0.4</td>
<td>12.2</td>
<td>4.47</td>
</tr>
</tbody>
</table>

Note: total amounts of P₂O₅ and K₂O during the trial, the soil chemical disturbance was evaluated as a function of vinasse application, taking soil samples at four depths (0–25 cm; 25–50 cm; 50–75 cm and 75–100 cm).

The samples were taken at initial condition (control—not applied) and just after each sugarcane harvest (treated); after the sugarcane sixth cut, soil samples were taken until 250 cm and until 500 cm after the seventh cut.

The soil samples were collected using an auger until 100 cm depth and trenches for 200 cm and 500 cm. The yield was obtained by weighing the five central sugarcane lines of each plot.

**Results and discussion**

**Soil chemical characteristics**

Enrichment of soil chemical properties in the first four years of the trial could be detected from the soil analyses to 100 cm depth.

These changes are mostly due to nutrients that come from vinasse such as sulfur and potassium (Figure 5).

This result is similar to those obtained by Penatti and Forti (1997) for clay soil but more intense. In the present trial, the potassium lixiviation has changed significantly to 100 cm deep, according to the vinasse doses, from the beginning of potassium concentration of 1.1 to 4.9 mmol/dm³ in four years for the maximum vinasse dose (Figure 5).

![Fig. 5—Potassium concentration in four soil depths after six months (left) and four years (right) for four doses of vinasse sprinkling.](image)

These results allowed understanding of the maximum depth for vinasse nutrients lixiviation. For that, soil samples were taken to 250 cm deep after the sixth cut and before vinasse sprinkling (Figures 6 and 7) and to 500 cm deep after the seventh cut (Figures 8 and 9).

The vinasse doses had changed the soil profile chemical characteristics, increasing pH and organic matter mostly in the first and second soil layers (Figure 6).

However, the most important change occurred in sulfur and potassium concentration until the 200–250 cm soil layer (Figure 7) proving that vinasse is a deep soil fertility improver.
Once it was verified that sulfur and potassium reached the soil depth of 250 cm, another sequence of soil samples was taken to 500 cm deep. The objective was to determine the limits for lixiviation of the chemical elements. It was observed that sulfur and potassium were lixiviated to the depth of 350 cm according to the vinasse doses (Figure 8).

Other important nutrients for sugarcane had also increased their concentration in the soil profile. However, the phosphorus stayed in the 0–25 cm layer, calcium was lixiviated to 75 cm deep, magnesium to 250 cm deep, and soil basis saturation increased to 250 cm deep, according to vinasse doses.

**Sugarcane yield (t/ha)**

The vinasse increased sugarcane yields by improving soil fertility and also by supplying water to the plant as verified in the trial results and literature review. Vinasse doses up to 300 m³/ha applied in six consecutives seasons (1996 to 2001) produced 96 t/ha more than the minimum vinasse dose (Figure 9). This increase in sugarcane yield was due to the role of vinasse as a nutrient supplier but also due to its water content. The obtained yield by the treatment mineral fertilisation (57–28–115 kg/ha of N-P₂O₅-K₂O) was 73 t/ha lower than that obtained in the maximum vinasse dose for the six years trial (Figure 9 and Table 3).
Fig. 9—Comparative sugarcane yield (t/ha) obtained with vinasse doses and mineral fertilisation (57–28–115 kg/ha of N-P₂O₅-K₂O) in six consecutive harvest seasons.

The accumulated average data obtained in the six harvested seasons indicated significant response for nitrogen doses without vinasse and for the interaction of vinasse plus nitrogen (Table 4 and Figure 10). It was observed that, as the vinasse dose increased, the mineral nitrogen responses decreased. So, for that reason, it is recommended that the mineral nitrogen dose be decreased as the vinasse dose is increased (Table 4 and Figure 10).

In this case, for the vinasse dose of 100 m³/ha, it would be necessary to add mineral nitrogen at 100 kg/ha.

Table 4—Sugarcane average yield and accumulated yield (t/ha) for vinasse doses, mineral nitrogen and interaction (vinasse + nitrogen) for six consecutive seasons.

<table>
<thead>
<tr>
<th>Vinasse (m³/ha) + Nitrogen (kg/ha)</th>
<th>1°C 96–97</th>
<th>2°C 97–98</th>
<th>3°C 98–99</th>
<th>4°C 99–00</th>
<th>5°C 00–01</th>
<th>6°C 01–02</th>
<th>Media</th>
<th>Total production</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+0</td>
<td>119</td>
<td>111</td>
<td>96</td>
<td>86</td>
<td>68</td>
<td>89</td>
<td>95</td>
<td>569</td>
</tr>
<tr>
<td>0+50</td>
<td>124</td>
<td>131</td>
<td>113</td>
<td>109</td>
<td>80</td>
<td>111</td>
<td>111</td>
<td>668</td>
</tr>
<tr>
<td>0+100</td>
<td>131</td>
<td>138</td>
<td>121</td>
<td>122</td>
<td>90</td>
<td>118</td>
<td>120</td>
<td>720</td>
</tr>
<tr>
<td>0+150</td>
<td>135</td>
<td>144</td>
<td>125</td>
<td>119</td>
<td>88</td>
<td>120</td>
<td>122</td>
<td>731</td>
</tr>
<tr>
<td>100+0</td>
<td>123</td>
<td>133</td>
<td>113</td>
<td>117</td>
<td>80</td>
<td>91</td>
<td>110</td>
<td>657</td>
</tr>
<tr>
<td>100+50</td>
<td>125</td>
<td>137</td>
<td>118</td>
<td>121</td>
<td>87</td>
<td>116</td>
<td>117</td>
<td>704</td>
</tr>
<tr>
<td>100+100</td>
<td>130</td>
<td>143</td>
<td>124</td>
<td>121</td>
<td>89</td>
<td>120</td>
<td>121</td>
<td>727</td>
</tr>
<tr>
<td>100+150</td>
<td>134</td>
<td>151</td>
<td>123</td>
<td>116</td>
<td>91</td>
<td>113</td>
<td>121</td>
<td>728</td>
</tr>
<tr>
<td>200+0</td>
<td>128</td>
<td>148</td>
<td>127</td>
<td>113</td>
<td>81</td>
<td>118</td>
<td>119</td>
<td>715</td>
</tr>
<tr>
<td>200+50</td>
<td>131</td>
<td>151</td>
<td>130</td>
<td>120</td>
<td>91</td>
<td>122</td>
<td>124</td>
<td>745</td>
</tr>
<tr>
<td>200+100</td>
<td>136</td>
<td>152</td>
<td>129</td>
<td>121</td>
<td>92</td>
<td>130</td>
<td>127</td>
<td>760</td>
</tr>
<tr>
<td>200+150</td>
<td>133</td>
<td>153</td>
<td>123</td>
<td>122</td>
<td>100</td>
<td>130</td>
<td>127</td>
<td>761</td>
</tr>
<tr>
<td>300+0</td>
<td>127</td>
<td>157</td>
<td>129</td>
<td>117</td>
<td>97</td>
<td>126</td>
<td>126</td>
<td>753</td>
</tr>
<tr>
<td>300+50</td>
<td>129</td>
<td>159</td>
<td>132</td>
<td>121</td>
<td>197</td>
<td>133</td>
<td>130</td>
<td>781</td>
</tr>
<tr>
<td>300+100</td>
<td>132</td>
<td>157</td>
<td>133</td>
<td>120</td>
<td>100</td>
<td>128</td>
<td>128</td>
<td>770</td>
</tr>
<tr>
<td>300+150</td>
<td>130</td>
<td>155</td>
<td>129</td>
<td>123</td>
<td>102</td>
<td>125</td>
<td>127</td>
<td>764</td>
</tr>
<tr>
<td>57-28-115</td>
<td>126</td>
<td>138</td>
<td>115</td>
<td>116</td>
<td>85</td>
<td>100</td>
<td>113</td>
<td>680</td>
</tr>
</tbody>
</table>
Fig. 10—Polynomial regression for nitrogen doses and interaction of vinasse plus nitrogen for accumulated yield in six harvest seasons.

Conclusions

Based on the observed data the following conclusions could be obtained:

- Vinasse should be considered a by-product of alcohol production. Vinasse applied in soils improves their fertility and promotes the sugarcane root system growth.
- Vinasse carries elements to deep soil, that are important for sugarcane nutrition like calcium (75 cm), magnesium (250 cm), sulfur and potassium (350 cm).
- Sugarcane yield is significantly increased according to vinasse doses.
- The interaction of vinasse plus mineral nitrogen produced more cane (tonnes cane per hectare) than vinasse alone, so mineral complementation is needed; however, mineral nitrogen doses can be reduced as vinasse doses are increased. An economic analysis is recommended.

REFERENCES


LA VINASSE–UN ENGRAIS LIQUIDE

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MOTS CLÉS: Canne a Sucre, Vinasse, Engrais Liquide, Azote, Rendement.

Resume

Les effets de l’épandage de la vinasse et d’un mélange de vinasse et d’azote sur le rendement de la canne à sucre et sur les caractéristiques chimiques du sol ont été évalués sur une période de sept ans. L’essai a été mis en place le 8 novembre 1995 à Usina Sao Jose da Estiva, dans l’état de Sao Paulo, sur un Yellow-Red Latosol, alllic, de texture sablonneuse (sandy loam alllic, Type Hapludox). L’expérience a été établie sur une deuxième coupe de la variété RB72454 et a été récoltée pendant sept ans jusqu’à 2002. Le modèle statistique comprenait des blocs randomisés avec un factoriel 4x4 et quatre répétitions de différentes doses de vinasse (0, 100, 200, et 300 m³/ha) et d’azote (0, 50 et 150 kg/ha). Les parcelles expérimentales étaient de sept lignes de cannes de 10m de long. Les cinq lignes centrales étaient récoltées pour le rendement (tonnes canne/ha). Les traitements étaient répétés après chaque récolte. L’analyse des résultats mène aux conclusions suivantes: La vinasse est un engrais qui améliore la fertilité du sol et favorise le développement des racines en profondeur. Elle augmente l’extraction des nutriments, en particulier le calcium jusqu’à 75 cm de profondeur, le magnésium jusqu’à 250 cm de profondeur, le soufre et le potassium en grandes concentrations jusqu’à 350 cm de profondeur. Le rendement de la canne est sensiblement amélioré avec une augmentation des doses de vinasse. L’interaction de la vinasse et de l’azote s’est avérée plus efficace que la vinasse appliquée seule. Les doses d’azote doivent être réduites quant celles de la vinasse sont augmentées; une évaluation économique est recommandée afin d’obtenir la dose adéquate d’azote.

VINAZUL: UN FERTILIZANTE LIQUIDO

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PALABRAS CLAVES: Caña de Azúcar, Vinazas, Fertilizante Líquido, Nitrógeno y Rendimiento.

Resumen

Se evaluaron el efecto del rociado de vinazas y de vinazas más nitrógeno en el rendimiento de caña de azúcar y las características químicas del suelo a lo largo de siete años consecutivos. El experimento de se inició el 08–11–1995 en la fábrica San José de Estiva, en el Estado de Sao Paulo en latosuelo amarillo-rojo, alio, textura arenosa. El experimento se estableció en un segundo corte de la variedad RB 72454, y se cosechó por siete años hasta el 2002. El diseño estadístico fue un factorial 4 x 4 en bloques al azar, con cuatro repeticiones de dosis de vinazas (0, 100, 200 y 300 m³/ha) y nitrógeno (0.50 y 150 kg/ha). El lote experimental fueron siete surcos de caña de 10m de longitud. Los cinco surcos centrales de caña se cosecharon para rendimiento (t caña/ha). Después de cada cosecha el mismo tratamiento se aplicó a cada lote. El análisis de los datos condujo a las siguientes conclusiones: a) las vinazas son un mejorador de la fertilidad del suelo que promueve un desarrollo profundo de la raíz; b) promueve una lixiviación de nutrientes, especialmente calcio hasta una profundidad de 250 cm, azufre y potasio en altas concentraciones hasta una profundidad de 350 cm; c) se incrementó significativamente el rendimiento de caña de azúcar en la medida en que se elevó la dosis de vinazas; d) la interacción de las dosis de vinazas y nitrógeno mostraron ser más eficientes que las vinazas solamente con respecto al rendimiento de caña de azúcar; e) las dosis de nitrógeno deben reducirse en la medida en que se incrementan las dosis de vinazas y se recomienda una evaluación económica para obtener las dosis adecuadas de nitrógeno.