# Residual effects of sugar beet vinasse on plant growth

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**Abstract**

Residual effect of a concentrated and depotassified beet vinasse on growth and mineral composition of tall fescue (*Festuca arundinacea*) was studied. Results were compared with those obtained for a mineral fertilizer treatment and a control. Vinasse and inorganic fertilizer had been previously applied to two different soils at two rates for five years. High doses of vinasse produced the highest yield and the highest concentrations of P and K in tissue plant, while decreasing Na, Mn, and Zn assimilability.

## Introduction

Beet vinasses are effluents from the alcoholic fermentation of sugar beet molasses and their later ethanol destillation. Vinasse causes considerable pollution problems in rivers and lands near alcohol factories because of its high organic matter and total salt contents (Algur and Kadioglu, 1992; Cabrera *et al.*, 1987).

Land application of wastewater is recognized as an important alternative disposal method, both in recycling nutrients essential for plant growth, and in increasing soil fertility (Ward, 1990).

Agronomical use of vinasses is being studied at present for several authors (Algur and Kadioglu, 1992; López *et al.*, 1990, 1992; Murillo *et al.*, 1993). In all cases it was evaluated the possible consequences, on different aspects of the soil-plant system, after a direct application of vinasse. Information on the residual effect of vinasse over a long period of time is lacking, and we iniciated these studies to obtain this information.

## Methods

From 1989 to 1993, a concentrated and depotassified beet vinasse (density 1.3; pH 5; dry matter 54%; total organic matter 40%; N 3.3%; P 0.02%; K 3.5%) was applied to greenhouse containers (ca. 0.42 $m^2$, 50 cm depth) filled with two topsoils (Table 1): a Xerorthent (loam-clay-sandy soil, S1) and a Xeropsamment (sandy soil, S2).

During this period, five fertilization treatments in a completely randomized design with five replicates per treatment, were assayed: two rates of beet vinasse (V1 and V2); two rates of a mineral fertilizer (MF1 and MF2 supplying the same amounts of N and P as the vinasse treatments); and a control (C), without fertilization. A summary of fertilization during the period 1989–1993 is described elsewhere (López *et al.*, 1990). Ryegrass (*Lolium multiflorum*) was cropped annually and the yield and nutrient contents of tissue plants determined.

In 1994, (study reported here), the residual effect was evaluated and, thus, no organic or mineral fertilizer was applied. Tall fescue (*Festuca arundinacea* cv. Manade) was grown in the same containers.

At 76, 129 and 172 days after sowing, tall fescue was clipped to 3 cm height, weighed and analysed. Plant samples were washed with tap and deionized water, oven dried at 70 °C for 48 h, and ground to pass through a 40 mesh screen. Nitrogen was determined by Kjeldahl digestion. Mineral elements were determined according to Jones *et al.* (1991).

From dried weight and nutritional mineral content in tissue plants, nutrient extraction at each clipping and the total nutrient extraction were determined.

The data were subjected to analysis of variance and the mean separation performed by the Tuckey test. A

*Table 1.* Soils Characteristics

| Soil | Treat. | N | P | K | O.M. | pH | E.C. |
|---|---|---|---|---|---|---|---|
| | | (mg kg$^{-1}$) | | | (%) | | (1:5) |
| | | Initial conditions | | | | | |
| S1 | – | 536 | 2.5 | 170 | 0.53 | 7.90 | – |
| S2 | – | 347 | 3 | 47 | 0.14 | 8.45 | – |
| | | After five years of treatment | | | | | |
| | C | 689 | 3 | 91 | 1.29 | 7.29 | 0.80 |
| | V1 | 772 | 8 | 91 | 2.07 | 7.69 | 0.48 |
| S1 | V2 | 746 | 20 | 125 | 1.24 | 7.49 | 0.59 |
| | MF1 | 674 | 9 | 108 | 1.52 | 7.68 | 0.64 |
| | MF2 | 746 | 14 | 91 | 1.47 | 7.78 | 0.43 |
| | C | 646 | 5 | 75 | 0.81 | 8.04 | 0.14 |
| | V1 | 524 | 8 | 50 | 0.62 | 7.93 | 0.24 |
| S2 | V2 | 786 | 33 | 66 | 0.93 | 7.96 | 0.20 |
| | MF1 | 495 | 7 | 50 | 0.53 | 8.07 | 0.20 |
| | MF2 | 480 | 11 | 42 | 0.84 | 7.91 | 0.23 |

*Table 2.* Effects of different treatments and soil type on elemental composition of tall fescue at selected clipping

| Clip | Treat. | N | P | K | Na | Mn | Zn |
|---|---|---|---|---|---|---|---|
| | | % | | | | mg kg$^{-1}$ | |
| | | Soil S1 | | | | | |
| | C | 3.63 a | 0.15 a | 1.83 ab | 1.27 a | 97 a | 74 a |
| | V1 | 3.67 a | 0.26 b | 1.80 a | 1.38 a | 69 a | 56 a |
| 1 | V2 | 2.75 a | 0.27 b | 2.30 b | 1.11 a | 70 a | 48 a |
| | MF1 | 3.23 a | 0.24 b | 1.44 a | 1.47 a | 88 a | 64a |
| | MF2 | 3.56 a | 0.25 b | 1.48a | 1.40 a | 99 a | 48 a |
| | | Soil S2 | | | | | |
| | C | 3.30 b | 0.11 a | 2.06 a | 0.37 a | 112 b | 61 b |
| | V1 | 2.22 a | 0.18 b | 1.81 a | 0.51 ab | 67 a | 30 a |
| 2 | V2 | 2.14 a | 0.25 c | 1.98 a | 0.43 a | 61 a | 30a |
| | MF1 | 2.35 a | 0.16 ab | 1.79 a | 0.58 b | 83 a | 39 a |
| | MF2 | 2.28 a | 0.17 ab | 1.73 a | 0.48 ab | 77 a | 30 a |

significance level of $p < 0.05$ was considered throughout the study.

Multivariant Discriminant Analysis of total nutrient extraction data was carried out by the Statgraphics computer program (Statgraphics, 1989).

## Results and discussion

### *Yields*

Yield of tall fescue was higher in soil S1 (loam-clay-sandy soil) than in soil S2: mean grass weight averaged over all treatments and clippings was 1427 kg ha$^{-1}$ for

*Table 3.* Standardized discriminant coefficients.

| | Soil S1 | | Soil S2 | |
|---|---|---|---|---|
| Variables | F1 | F2 | F1 | F2 |
| N | 1.17674 | 0.19223 | −1.87844 | 0.74230 |
| P | 2.31942 | 0.28398 | 2.69114 | 0.89905 |
| K | −0.71408 | −1.59387 | 1.80433 | −0.37005 |
| Na | 1.90686 | 0.53361 | 0.01545 | −0.54487 |
| Ca | −1.03744 | 0.96591 | −3.93211 | 0.03535 |
| Mg | −0.67652 | −0.19034 | −0.14766 | 0.41729 |
| Fe | −0.54362 | −1.10567 | −0.44199 | −0.85139 |
| Cu | −0.88883 | −0.01157 | 0.54742 | −0.18079 |
| Mn | 0.53283 | 0.67540 | 0.08617 | 0.25144 |
| Zn | −0.96473 | 0.09336 | 1.05669 | 0.38216 |
| Variance (%) | 88.48 | 10.03 | 48.69 | 42.91 |

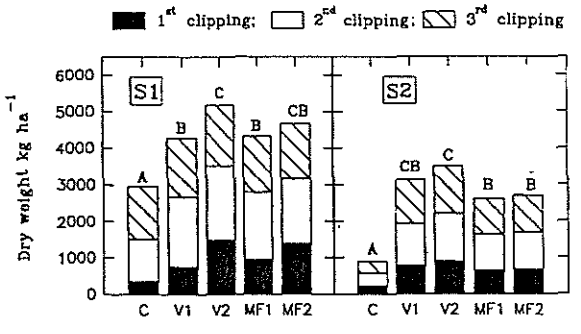


*Fig. 1.* Dry weight of tall fescue biomass for each treatment in soil S1 and S2.

S1 and 854 kg ha$^{-1}$ for S2. Earlier laboratory incubation studies showed a much higher N release from the mineralization of the residual organic N in soil S1 than in soil S2 after three years of treatment with V, MF and C (Martín-Olmedo *et al.*, 1995). Furthermore, increases in tall fescue growth as the soil clay content increased were also observed by other authors (Devitt *et al.*, 1990; Tester *et al.*, 1982).

The mineralization process, slower in soil S1 than in soil S2 due to a higher protection of the organic matter and soil biomass (Martín-Olmedo *et al.*, 1995), might be responsible for greater differences in soil S2 between organic (V1 and V2) and mineral (MF1 and MF2) fertilizer treatments.

Maximum yields at each harvest clipping (Fig. 1) corresponded, in both soils, to the high vinasse rate (V2), in agreement with previous studies (Martín-Olmedo *et al.*, 1995) in which potentially mineralizable nitrogen, total-N and organic matter were higher in soils treated with vinasse than in those treated with mineral fertilizer or control. V1 and MF1 produced almost equal yields, being both statistically higher than the control.

No phytotoxicity was observed after long-term vinasse application, ratifying anterior experiments (López *et al.*, 1992).

### *Nutritional stage*

The intrinsic soil fertility, greater in S1 than in S2, is responsible for greater levels of macro and micronutrients in plants grown in soil S1 (Table 2).

A decrease of the Fescue Nitrogen Content (FNC) was observed along the growth period. In the first clipping FNC values for all the treatments were within the proposed critical range (2.8–3.4%) (Martin & Matocha, 1973), while in further clippings, FNC values, excepting for the control, were below that range. In general, an inverse relationship between dry matter weight and FNC was observed: lowest FNC was registered for V2 treatment as a dilution effect (Jarrel & Beverly, 1981). Similar results were reported by Eck *et al.* (1981) in fescue and by Lund & Doss (1980) in rye. These low values at the end of the experiment were most likely due to reduced N release from residual N of soils with time, and to the possible presence of dead and senescent tissues in the final harvest (Devitt *et al.*, 1990).

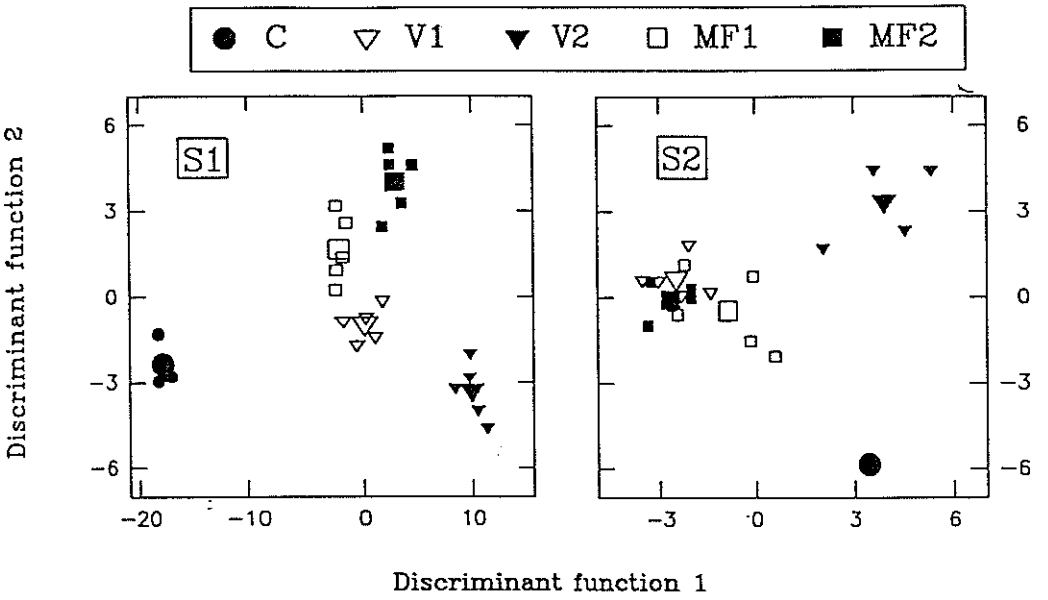


*Fig.* 2. Discriminant analysis of total nutrient extraction data. (Big symbols correspond to group centroids).

Vinasse treatments showed the highest P and K concentration in fescue. High values of P could be related to the acidic pH of vinasse, while high values of K are related to the high K content of vinasse. Both sets of values were lower than the established critical ranges: 0.26–0.32% P and 2.5–2.8% K (Martin and Matocha, 1973).

Mn and Zn contents were lower for vinasse treatments. This fact could be attributed to the presence of complexing agents in the residual organic matter (Atkinson *et al.*, 1958).

*Extraction*

Multivariant discriminant analysis shows that function F1 and F2 explain the 98.5% and 91.6% of the variance in soil S1 and soil S2 respectively (Table 3).

Plot F1 vs F2 display a visual separation of the population data of the different treatments (Fig. 2). Analysing the standardized discriminant coefficients for all variables defining function 1 and 2 (Table 3), allows the discernment of the most determinant variables in the separation of the treatments. V2 treatment, which has extracted significantly the greatest amount of N, P, and K, is obviously the best differentiated from the rest of treatments in both soils.

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## References

Algur OF and Kadioglu A (1992) The effects of vinasse on the growth, biomass, and primary productivity in pea (*Pisum sativum*) and sunflower (*Helianthus annuus*). Agr Ecosyst Environ 39: 139–144.

Atkinson HJ, Giles GR and Desjardins JO (1958) Effect of farmyard manure on the trace elements content of soil and plants grown there-on. Plant Soil 10: 32–36.

Cabrera F, Moreno F, Nacci S and De Arambarri P (1987) Utilization of wastes from olive and sugar beet processing industries in fertirrigation. Proc 4th International CIEC Symposium, Braunschweig, pp 475–483.

Devitt DA, Morris RLI and Bouwman DC (1990) Response of tall fescue to composted sewage sludge used as a soil amended. J Plant Nut 13: 1115–1139.

Eck HV, Martínez T and Wilson GC (1981) Effect of fertilization and harvest frecuency on yield and quality of tall fescue and smooth bromegrass. Commun Soil Sci Plant Anal 12: 537–555.

Jarrel WM and Beverly RB (1981) The dilution effect in plant nutrition studies. Adv Agron 34: 198–224.

Jones Jr JB, Wolf B and Mills HA (1991) Plant Analysis Handbook. G.A. Micro-Macro Publishing, Athens, Georgia, USA.

López R, Cabrera F, Moreno S, Esenarro G and Llorente MM (1992) Efecto de la fertilización con vinaza concentrada sobre la produc-

ción y estado nutricional de ryegrass. Proc Cong Nacional Ciencia del Suelo, Pamplona 220–225.

López R, Cabrera F, Murillo JM and Machuca MJ (1990) Utilización como abono de vinaza concentrada. I Intern. Cong de Química de la ANQUE, Tenerife, vol II pp 223–232.

Lund ZF and Doss BD (1980) Residual Effect of Dairy Cattle Manure on Plant Growth and Soil Properties. Agron J 72: 123–130.

Martin WE and Matocha JE (1973) Plant Analysis as an Aid in the Fertilization of Forage Crops. In Soil Testing and Plant Analysis Walsh LM (ed.), Soil Sci Soc Am, Madison, pp 393–425.

Martín-Olmedo P, López R, Cabrera F and Murillo JM (1995) Nitrogen mineralization in soils amended with organic by–products of olive oil and sugar beet processing industries. Fresenius Environ Bull 4: 59–64.

Murillo JM, Cabrera F and López R (1993) Effect of beet vinasse on Germination and seedling performance of ryegrass (*Lolium multiflorum*). J Sci Food Agric 61: 155–160.

Statistical Graphics Corporation (1986) Statgraphics 2.1 User's guide, U.S.A.

Tester CF, Sikora LJ, Taylor JM and Parr JF (1982) Nitrogen utilization by tall fescue from sewage sludge compost amended soils. Agron J 74: 1013–1018.

Ward R (1990) Use of wastes in agriculture. Book of Proceedings 10th World Fertilizer Congress of CIEC, Nicosia 477–489.