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Effects of distillery vinasses on vineyard yield and quality in the D.O.C “*Oltrepò Pavese Pinot Nero*” – Lombardy, Italy

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Abstract In a fifteen year old vineyard of Pinot Noir at a density of 5000 vines per hectares, located in the DOC zone Oltrepò Pavese, the influence of growing doses of distillery vinasses on vegetative growth, leaf mineral levels, grape yield and quality was tested in a four year period. Doses of vinasses were computed to apply 0 (test), 50, 100, 150 kg N ha^{-1}. Vinasses doses were factorially combined with three levels of urea (0, 50 and 100 kg N ha^{-1}). In plots without vinasses supply, ureic nitrogen reduced the number of blind buds and increased the potential and actual bud fertility. The application of vinasses nitrogen had a similar result, even if ureic and vinasses nitrogen had no additive effects. The most profitable grape yield was obtained by application of 50 kg ha^{-1} of nitrogen either in urea or in vinasses form. Highest vinasses supply improved the ripening levels of grapes increasing sugars and reducing acidity of juice. Results clearly show the possibility to use vinasses for proper vineyard fertilisation.

Keywords Fertilisation; grapevines; vinasses

Introduction

Total Italian viticultural acreage is around 875.000 hectares, out of which 92% is devoted to wine grapes (ISTAT, 2003). A vineyard with a grape yield of 13 t ha^{-1} generates on average 3.7 t ha^{-1} of solid residues and 8.6 t ha^{-1} of wastewater. Solid residues consist of 2.3 t ha^{-1} of vinasses, 0.7 t ha^{-1} of lees, 0.4 t ha^{-1} of grape stalks and 0.3 t ha^{-1} of filtration and clarification sediments (Sangiorgi *et al*., 1996). Vinasses are generally used to extract alcohol, tartrate and oil from seeds. Exhausted vinasses may be used as forage, combustible material or fertiliser. This latter employment is an ancient use, nowadays still applied, which consists in the soil incorporation of cultural residues like leaves, pruning wood and other winery by-products.

Effects of vinasses incorporation on soil nutrient and humic balance and fertility and on crop yield not have much been studied. Bottini (1967) on the basis of the chemical composition and supposing a slow mineralisation rate, suggested blending vinasses with manure or to use it to prepare compost with ash, limewater and ammonium sulphate. Garoglio (1973) suggested using vinasses as fertiliser in calcareous soils jointly with Thomas phosphates or phosphorite; moreover the mixture of exhausted vinasses with alkaline fertiliser was suggested to neutralise the tannic acidity to prevent possible negative effect on soil microbiological activity. More recently, Fregoni (1999) considered that vinasses, stalks and other cultural residues were sufficient to counteract the annual mineralisation of soil organic matter; moreover he highlighted the boron richness and the acidic power of vinasses. Polyphenol levels in winery sludge seem to have had a negative effect on the number and activity of soil microorganism with consequences more evident in laboratory on *Lepidium sativum* growth than in the field on corn yield (Vescovi and Tano, 1997). Even other scientists (Vallini *et al*., 1984; Filippi *et al*., 1992; De Bertoli, 1995; Golueke and Diaz, 1997) suggested the use of by-products for agro-industry, if they derive from processes free of special reactants, both alone or mixed with other products.

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High Italian vinasses yield, that can be estimated around 1.800.000 t y^{-1} and shortage of scientific data on their use as viticultural fertiliser (see Proc. 2nd Int. Spec. Conf. on Winery Wastewaters, 1998), suggested to develop an experimental trial to evaluate in a vineyard the influence of growing doses of distillery vinasses on vegetative growth, leaf mineral levels, grape yield and quality.

Methods

The trial was conducted in the four year period 1997–2000, in a fifteen year old vineyard of Pinot Noir, "Casarsa" trained (downwards growing cordon) at a density of 5000 vines per hectares, located in the DOC zone Oltrepò pavese, in the Lombardy region (Northern Italy).

The doses of vinasses were computed to apply 0 (test), 50, 100, 150 kg N ha^{-1}. Total nitrogen content of vinasses ranged from 16.6 to 19.0 g/kg dw in the different years. Organic carbon content of vinasses ranged around 50% (47–51%); therefore the annual supply of organic dry matter was ranging from 2.6–2.9, 5.2–5.9 and 7.9–8.8 t ha^{-1} respectively. Vinasses doses were factorially combined with three doses of urea (0, 50 and 100 kg N ha^{-1}). The experimental design was repeated in three randomised blocks.

Soils was clay-loam, sub-alkaline (pH 7.4), moderately calcareous (total carbonate 16%), poor in organic matter (*ca*. 1%), rich in available phosphorus (*ca*. 58 ppm Olsen P), sufficient in exchangeable potassium (K % CEC 3.9).

Vinasses were supplied every January and after few days they were incorporated into the soil by a mechanical tillage at the depth of 10–15 cm; while ureic nitrogen was supplied just before bud break (early April). Pruning intensity was normalized around 20–30 buds per vine according to their vigour. Every year the following data were collected: shoot number and fertility, leaf nutritional levels, by sampling mature leaves (3rd–4th leaf above distal clusters), grape yield, technological (soluble sugars, pH, total acidity, malic and tartaric acids) and phenolic maturity (anthocyanins and polyphenols levels).

Total soluble solids (Brix) were determined by a table, temperature-compensated refractometer; titratable acidity was determined on 7.5 mL of juice diluted in 10 mL of distilled water by titration with 0.1 N of NaOH to pH 8.2 end-point and expressed as g/L of tartaric acid; the pH of undiluted juice was determined using a pH meter; malic and tartaric acids were determined at 210 nm using a Shimadzu HPLC LC-10 AD (Shimadzu Co., Tokyo, Japan) connected to a Shimadzu UV-VIS detector SPD-10 A. Anthocyanin and total polyphenol analyses were run using 20 frozen berries, which were weighed and had their skins removed by hand, rinsed in distilled water, blotted dry by paper towel and weighed. The skins were then soaked in 50 mL ethanol 95%: water: hydro-chloric acid, (70 : 29 : 1 v/v/v) for at least 24 hours. The total extract was filtered to remove plant debris and adequately diluted (from 10 to 100 times). Total anthocyanins and polyphenols were spectrophotometrically estimated after Di Stefano and Cravero (1991) and expressed in mg/kg fresh berry mass of malvidin 3 glucoside and (+)catechin, respectively. Leaf analysis was carried out by elemental analyser (N) and atomic absorption spectrometry (others) after wet mineralisation. Data were statistically processed by usual methods: normality tests followed by analysis of variance with SPSS statistical software (v. 11.0, SPSS Inc. Chicago, Illinois).

Results and discussion

General data recorded in the three-year period of the trial (Table 1) showed a yielding level on average in comparisons to the local conditions (*ca*. 15 t ha^{-1}) with a ripening profile in agreement with the enological destination of the grapes (white sparkling wine). The nutritional status of the vines showed a moderate levels for all the nutrients in contrast with optimal range.

Table 1 General means and standard deviations of the vegetative, yield, qualitative and nutritional variables recorded in the three-year trials

Variables	Average	St. dev.
blind buds (%)	12.5	10.2
clusters per shoot	1.13	0.41
yield (kg/vine)	3.55	2.3
cluster number	28.5	10.5
cluster mass (g)	118	46
Brix	21.0	1.6
Titratable acidity (g/L tartaric acid)	9.6	2.6
pH	3.35	0.12
Malate (g/L)	2.33	0.94
Tartrate (g/L)	4.00	0.88
Total polyphenols (mg/kg (+) catechin)	2,609	785
Anthocyanins (mg/kg malvidin 3 glucoside)	410	160
Leaf N (% dw)	1.68	0.29
Leaf P (% dw)	0.18	0.04
Leaf K (% dw)	1.53	0.19
Leaf Ca (% dw)	3.11	0.34
Leaf Mg (% dw)	0.18	0.03
Leaf Fe (ppm dw)	87	27

The statistical data processing was able to show a significant effect of fertilisation on blind buds, bud fertility and grape yield.

In plots without vinasses supply, ureic nitrogen reduced the number of blind buds and increased the potential and actual bud fertility; the vine response to urea application was related to nitrogen amount (Figures 1 and 2). The effect of vinasses supply on blind bud percent and fertility was valuable, even if it was not related to nitrogen quantity. A response was detected only to the first rate of vinasses application (50 kg N ha^{-1}) without any further reaction to supplementary doses (100 and 150 kg N ha^{-1}). The effect of vinasses supply had no additive effects with ureic nitrogen application. From the statistical point of view, the effect of vinasses application (50, 100 or 150 kg N ha^{-1}) with or without ureic nitrogen was equivalent to 50 kg ha^{-1} of ureic nitrogen application.

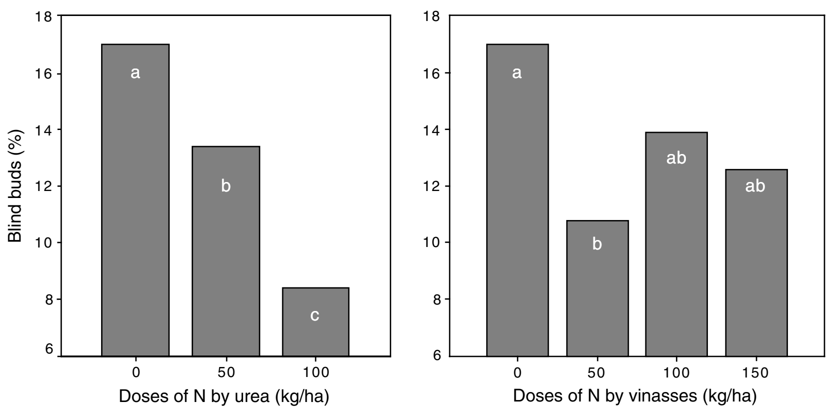

Figure 1 Left – Effect of ureic nitrogen doses in plots without vinasses fertilisation on blind buds. Right – Effect of vinasses nitrogen doses on blind buds: no fertilised plots versus vinasses fertilised plots (average data from three levels of urea supply). Means specified by the same letter are not statistically different per P = 5%

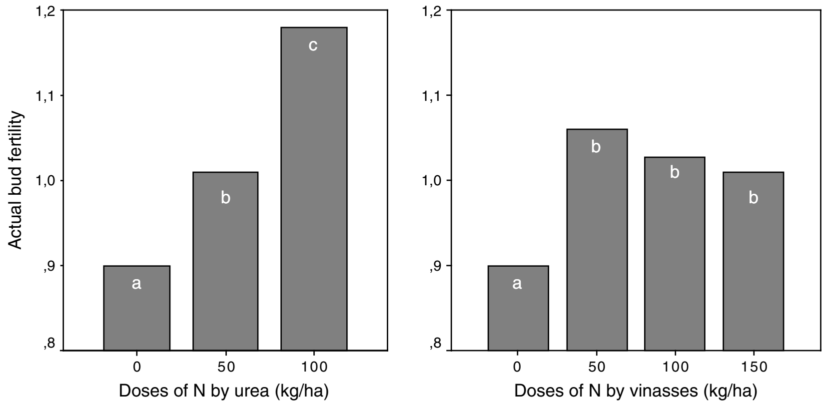

Figure 2 Left – Effect of ureic nitrogen doses in plots without vinasses fertilisation on bud fertility. Right – Effect of vinasses nitrogen doses on bud fertility: no fertilised plots versus vinasses fertilised plots (average data from three levels of urea supply). Means specified by the same letter are not statistically different per P = 5%

The effect of the experimental plan was similar for what concerned grape yield that was modified according to the reduction of blind buds, i.e. with the increase of the number of fertile shoots, and the increase of bud fertility. Without urea fertilisation the grape yield increased with the intermediate doses of vinasses (50 and 100 kg N ha^{-1}), whereas the highest dose of vinasses tended to be no different in yield in comparisons to the unfertilised plots. The most profitable grape yield was obtained by application of 50 kg ha^{-1} of nitrogen either in urea or in vinasses form (Figure 3).

Leaf mineral nutrition was not modified by the treatments for what concerned N, Fe, Ca, and Mg; while both ureic and vinasses nitrogen reduced the P levels (Figure 4). Ureic nitrogen also reduced the K leaf levels.

Must composition was significantly influenced by the experimental treatments: vinasses supply improved the ripening levels of grapes increasing sugars and reducing acidity of juice; tartaric acid levels were reduced by the highest application of vinasses (Figure 5). Anthocyanins and total polyphenols were not affected.

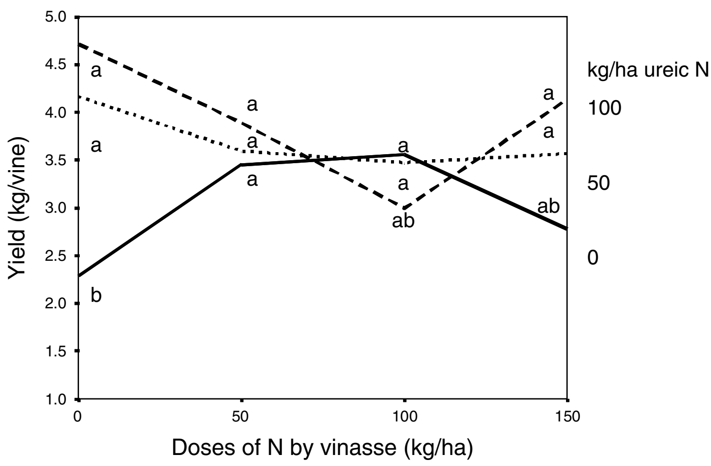

Figure 3 Effect of ureic and vinasses nitrogen doses on yield (three-year means). Means specified by the same letter are not statistically different per P = 5%

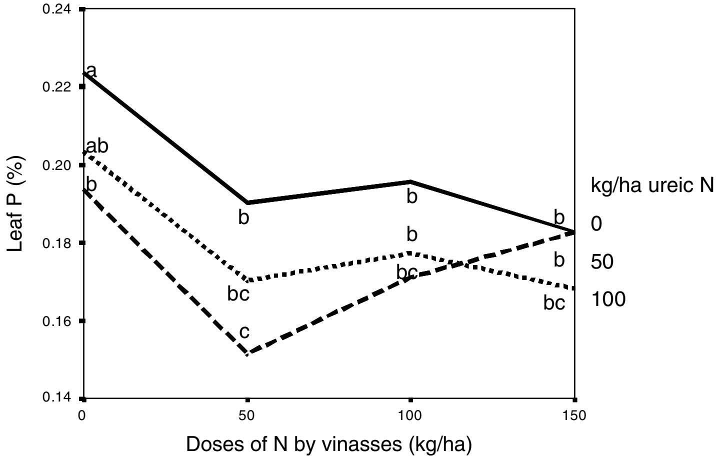

Figure 4 Effect of ureic and vinasses nitrogen doses on P leaf levels (three-year means). Means specified by the same letter are not statistically different per P = 5%

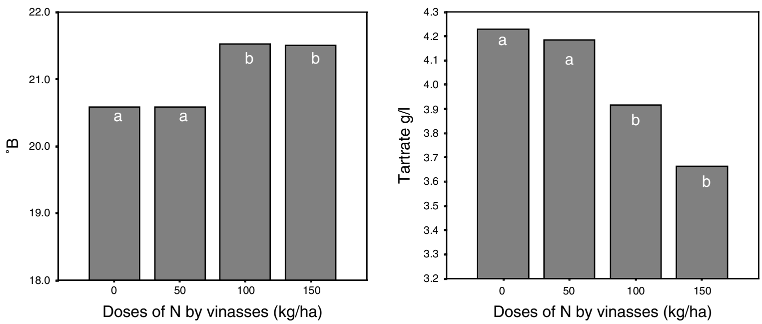

Figure 5 Effect of vinasses nitrogen doses on juice sugar and tartrate levels (three-year means). Means specified by the same letter are not statistically different per P = 5%

Conclusions

The results clearly show the possibility to use vinasses for a proper vineyard fertilisation. Vinasses supply was able to substitute the effect of ureic nitrogen on vineyard yield, even if the absence of an additive effect of vinasses and ureic nitrogen would suggest that high doses should be avoided to limit the possible nitrogen microbiological immobilisation and the consequent competition for nitrogen among soil bacterial populations and vines. Moreover possible negative effects of vinasses polyphenols on soil microbiological activity cannot be excluded. For these reasons an integration among intermediate doses of mineral fertiliser and vinasses seems the correct solution. In addition, the supply of vinasses modified the grape ripening profiling. The highest vinasses doses improved sugar levels even if they reduced the levels of tartrate. This effect could be related to an improvement of the vine physiological status, in term of leaf photosynthetic efficiency and root activity during grape maturation, connected to the summer nitrogen mineralisation from vinasses, which improved the sugar accumulation but also the berry growth during ripening and the consequent reduction in tartaric acid concentration.

According to our three-year trial and pedo-climatic conditions, the annual supply of 50 kg ha^{-1} of nitrogen by vinasses, corresponding to 2.5–3.0 t ha^{-1} of organic matter, with a possible addition of mineral nitrogen according to the annual vineyard crop load and vegetative status, for a Pinot Noir vineyard devoted to the production of sparkling wines, resulted in sustainable fertilisation plan.

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