VINE RESPONSE TO COMPOST ADDITION ON A SANDY-LOAM SOIL IN THE NORTH-EAST OF ITALY. EFFECTS ON ROOT SYSTEM, VEGETATIVE GROWTH, YIELD AND GRAPE QUALITY OF CABERNET SAUVIGNON CV

Federica Gaiotti[1], Patrick Marcuzzo[1], Nicola Belfiore[1], Lorenzo Lovat[1], Diego Tomasi [1]

[1] CREA – Centro di ricerca per la viticoltura, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, 31015 Conegliano, Italy
**Corresponding author: federica.gaiotti@crea.gov.it*

Abstract
In this study two different compost types and two application methods were studied over 5 years (2009-2013) on mature Cabernet Sauvignon vines grown in a commercial vineyard in the AOC Piave area, northeastern Italy. The treatments compared were: IM: inter-row application of compost from cattle manure, at a rate of 4 t/ha/y fresh weight (fw); IW: inter-row application of compost from vineyard pruning waste, at 4 t/ha/y (fw); UW: under-row application of compost from vineyard pruning waste, at 4 t/ha/y (fw); C: control with no amendment/fertilization. Effects on soil characteristics and on vine performances, including root density and distribution, were assessed. IW treatment showed the best overall performance, displaying well-balanced root/shoot growth, increased yield, and satisfactory grape quality. Inter-row addition of compost from cattle manure (IM) and localized addition of compost from pruning wastes (UW) stimulated ether high vegetative growth or high root development and in both cases, a reduction in fruit quality was observed, likely due to competition between vegetative organs (shoots or roots) and the fruit.

Key words: compost, organic amendments, root system, grapevine, soil management practices

1 INTRODUCTION

In the last decades, the use of compost in agriculture has been strongly promoted by Italian policy in order to establish complete cycling of agricultural-waste organic matter via compost back into food production in the field. Too limited use of cow manure or organic soil amendments in the vineyard, minimal introduction of cover crops, increase in heavy machinery traffic, and inappropriate soil management, have accelerated soil exploitation (Pinamonti and Siche 2001). As a consequence, a significant decrease of soil organic matter has been observed in many Italian wine areas.

In the vineyard, compost can be used to both increase organic matter in the soil and to replace chemical fertilizers in low-impact agricultural systems. Several studies have reported positive effects of compost on soil chemical, physical, and biological properties (Pinamonti 1998, Nendel and Reuter 2007, Morlat and Chaussod 2008). Experiments have been carried out to assess the effects of organic fertilizers on production and quality of different woody and herbaceous plants; however, grapevine response to compost addiction has scarcely been investigated in the past. Most of the studies focused on the effect of compost on vine vigour, yield, quality of the grape and on wine sensory properties (Pinamonti 1998, Korbouleulewsky et al. 2004, Mugnai et al. 2012). Studies which included root analysis in response to compost application in the vineyard are quite limited, thus there is still very little understanding of how this practice can influence vine below-ground development, and its impact on vine vegetative and reproductive growth.

The root system is the part of the plant that is most immediately impacted by soil properties. Application of compost can affect root growth by influencing nutrient availability in the soil. Whereas inorganic fertilizers are available immediately, compost decomposes only gradually, mineralizing nutrients over many years, depending on its origin, chemical composition, and climate conditions. Among nutrients, nitrogen, in particular, is known to exercise a major impact on root growth, with effects dependent on chemical form, spatial and temporal patterns of supply. Roots absorb and conduct water and nutrients to the aerial parts of the vine. Moreover, various plant hormones, synthesised in the roots, are required for adequate development of the shoots. Consequently, size and density of the vine root system is related to size (vigour) and performance of the canopy (Hunter and Volschenk 2001).

In this trial we evaluate the effects of application of two different types of compost (compost from vine pruning wastes and from cattle manure) and two distribution methods (inter-row and under-row) on a vineyard on a sendy-loam soil. By investigating for the first time the effects of compost addition on overall vine balance, including root growth, vegetative growth, and production, this study represents a step forward in improving sustainable nutrient management practices in the vineyard.

2 MATERIALS AND METHODS

Vineyard and treatments. The studied vineyard was located in the Piave area, in northeastern Italy (lat. 45°44'32' N; long. 12°30'34' E). The vineyard was planted in 2003 to the Cabernet Sauvignon variety grafted onto 3309 rootstock and trained to a simple Guyot system at a vine spacing of 2.2 m x 0.9 m. As typical of commercial practice in this area, herbicide was applied in the under-row while the inter-row was covered by spontaneous grass. No irrigation was applied during the experiment. For 5 years (2009-2013) the following treatments were compared in a randomized block design with three replicates of 6 vines: IM: inter-row supply of compost from cattle manure, at a rate of 4 t/ha fresh weight (fw) every year; IW: inter-row application of compost from vineyard pruning waste, at 4 t/ha fw /y; UW: under-row application of compost from vineyard pruning waste, at 4 t/ha fw /y; C: control with no amendment/fertilization.

Climate and soil. The area has a Mediterranean climate, with warm summers and cool winters. The average seasonal (March-September) mean air temperature and rainfall in the study period were 18.4° and 520 mm, respectively. The experimental site had a sandy-loam soil, with medium water reserve (120 to 150 mm in the first meter of soil). Soil physical and chemical composition were analysed at the beginning of the experiment, before application of compost. Chemical composition was assessed a second time at the end of the experiment, in March 2014, along with the microbial biomass content.

Agronomic traits and grape composition. Grape harvest was performed at technological maturity, defined as total soluble solids (TSS) ≥19 Brix and titratable acidity (TA) ≤9 g/L of tartaric acid. Yield per vine and average cluster weight were recorded on 18 vines for each treatment, using a hanging scale. Cluster weight was calculated by dividing fruit yield per vine by the number of clusters harvested. Winter pruning wood from the same vines was weighed, as an indicator of vine vigour. The Ravaz index was calculated by dividing the yield per vine by the dormant pruning weight. Fruit composition (soluble solids, pH, titratable acidity, anthocyanin content) at harvest was measured on a sample of 1 kg of grape collected randomly from all vines of each replicate.

Root analysis. At the end of the experiment (March 2014), the grapevine root system was studied by using the trench method, as described by Bhom (1979). Three vines for each treatment were selected and three 1m-deep and 1m-long trenches were dug at two different distances from the vine-row (45 cm and 90 cm), in order to assess both vertical and horizontal distribution of the root system.

Living roots were counted in five 20-cm-thick soil layers by positioning a grid (20 cm × 20 cm inner frame) against the profile with the vine in the center. The total number of roots was counted in each grid, and roots were categorized by diameter: <1 mm (fine roots), 1 to 2 mm (medium roots), and >2 mm (woody roots). The results were expressed as number of roots per square meter.

Statistical analysis. Statistical analysis was performed using STATISTICA version 8 (StatSoft Inc., Tulsa, OK). When analysis of variance showed statistical differences ($P \leq 0.05$), means were separated by the Newman-Keuls test for roots and all the other parameters. Dunnett's multiple comparison test was used for shoot length analysis.

3 RESULTS AND DISCUSSION

Compost showed a positive effect on soil chemical and biological characteristics, regardless of type or distribution method. Improvements in organic matter, total nitrogen, and microbial biomass in the soil were observed in all amended treatments, compared to the control (Tab.1). Improvements were smaller compared to those reported in other studies testing the use of amendments in vineyards (Morlat and Chaussod 2008, Mugnai et al. 2012) but data are not subject to easy comparison, due to differences in origin and chemical composition of the added organic matter. It must be also underlined that in this experiment, low amounts of organic material were applied, since it was observed at the beginning of the experiment that the soil in the study-site already enjoyed good background fertility.

A positive effect of amendment on root density was recorded only for compost from pruning wood wastes, while compost from cattle manure did not show a significant influence on the root system (Fig.1). Pruning-waste compost significantly increased total root density, compared to control. Differences were significant only for fine (<1 mm) and medium (1-2 mm) roots (data not shown). Under-row compost application stimulated larger vertical and horizontal root growth than the inter-row application. These data suggest that when compost was applied locally, close to the vine-row, nutrients were efficiently absorbed by the vine, promoting overall plant growth (roots and canopy). On the contrary, when it was applied to the entire inter-row, nutrient absorption was lower and did not significantly improve above-ground growth compared to the control.

No significant effect of compost addition was measured on the root system in IM treatment. This might be explained by competition between above-ground and below-ground organs for nutrients and assimilates, since IM treatment showed the highest vegetative growth of all treatments.

Concerning grapevine productive and qualitative response in the presence of compost in the soil, we observed a significant effect on above-ground growth over all 5 years of the experiment. Yield increased in all compost treatments by 15 to 20% (Tab. 2), with differences related to the higher number of bunches and higher bunch weight. Vegetative growth increased too, except for IW treatment. Ravaz index values recorded over the 5 years of the experiment was unaffected by compost addiction, indicating a balanced ratio of fruit to wood. Compost treatments did not improve overall grape quality; on the contrary, a small but significant reduction in total soluble solids, total anthocyanins, and flavonoids was reported in UW an IM treatments. These results could be explained by higher vegetative growth in IM treatment and better root development in UW treatment. Shoots and roots represent strong sinks that can compete with fruit for nutrients and carbohydrates, reducing sugar accumulation in the berries, and this occurs especially when nutrient supply is limited.

4 CONCLUSIONS

Results obtained in this study demonstrated that the application of compost in a vineyard can have beneficial effects on soil fertility, root growth, yield, and grape quality. However, attention must be paid to application rates, to origin and chemical composition of compost, and to the application method. We suggest that in sites characterized by soils in Mediterranean climates with a good background fertility, inter-row application of compost from vine pruning wastes at 4 t/ha fw/y or at a slightly higher rate can successfully replace mineral fertilization, ensuring balanced root/shoot growth, improving yield and maintaining grape quality. Moreover, the positive effects observed on soil fertility must encourage the adoption of compost amendments as a sustainable vineyard management practice.

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5 LITERATURE CITED

Hunter JJ and Volschenk CG. 2001. Effect of altered canopy: root volume ratio on grapevine growth compensation. S Afr J Enol Vitic 22(1):27-30.

Korboulewsky N, Robles C and Garzino S. 2004. Effects of sewage sludge compost on volatile organic compounds of wine from Vitis vinifera cv. red Grenache. Am J Enol Vitic 55: 412-416.

Morlat R. 2008. Long-Term Additions of Organic Amendments in a Loire Valley Vineyard on a Calcareous Sandy Soil. II. Effects on Root System, Growth, Grape Yield, and Foliar Nutrient Status of a Cabernet franc Vine. Am J Enol Vitic 59:364-374.

Morlat R and Chaussod R. 2008. Long-term Additions of Organic Amendments in a Loire Valley Vineyard. I. Effects on Properties of a Calcareous Sandy Soil. Am J Enol Vitic 59:353-363.

Mugnai S, Masi E, Azzarello E and Mancuso S. 2012. Influence of Long-Term Application of Green Waste Compost on Soil Characteristics and Growth, Yield and Quality of Grape (*Vitis vinifera* L.). Compost Sci Util 20(1):29-33.

Nendel C and Reuter S. 2007. Soil Biology and Nitrogen Dynamics Of Vineyard Soils As Affected by a Mature Biowaste Compost Application. Compost Sci Util 15(2):70-77.

Pinamonti F. 1998. Compost mulch effects on soil fertility, nutritional status and performance of grapevine. Nutr Cycl Agroecosys 51:239-248.

Pinamonti F and Siche L. 2001. Compost utilization in fruit production systems. *In* Compost utilization in horticultural cropping systems. Stoffella PJ and Kahn BA (eds.), pp. 177-200. Lewis Publishers, New York, USA.

Table 1: Soil properties after five consequent years of compost application, in comparison to the no amended control (data are average of three replicates ± standard deviation)

	Treatment			
Soil characteristics	**IW**	**IM**	**UW**	**C**
pH	7.9 ± 0.0	7.9 ± 0.1	7.8 ± 0.0	7.9 ± 0.0
Organic matter (g/kg)	25.9 ± 0.0	28.7 ± 0.1	27.9 ± 1.0	22.8 ± 1.1
Total N (g/kg)	1.6 ± 0.1	1.8 ± 0.1	1.6 ± 0.1	1.2 ± 0.0
Inorganic N (% of tot N)	0.5 ± 0.0	0.6 ± 0.0	0.7 ± 0.1	0.7 ± 0.1
C/N	7.9 ± 0.3	9.5 ± 0.6	9.9 ± 0.1	8.9 ± 0.2
Microbial biomass (μg dsDNA/g dry soil)	19.1 ± 3.2	18.1 ± 3.7	16.8 ± 2.5	15.5 ± 1.7

Table 2: Pruning weight, yield and fruit composition of Cabernet sauvignon vines in response to different organic amendments. Data are means of five years (2009–2013)

Treatment	Pruning weight (kg/vine)	Yield (kg/vine)	Ravaz index (kg/vine)	°Brix	Titratable acidity (g/L)	Total anthocyanins (mg/kg)	Total flavonoids (mg/kg)
IM	1,1 a	2,4 a	2,5	21,0 b	7,4	1048 b	2263 b
IW	0,8 bc	2,3 a	2,9	21,4 ab	7,3	1277 a	2816 a
UW	0,9 b	2,5 a	2,9	21,7 b	7,3	1183 b	2479 b
C	0,7 c	1,8 b	2,7	21,8 a	7,1	1312 a	2782 a
Signf	***	***	*ns*	**	*ns*	**	*
Treatment x year	*ns*	*ns*	*ns*	**	*ns*	*ns*	*ns*

*Means separated within columns by Student–Newman–Keuls test; *, **, ***and ns indicate significance at p ≤ 0.05, 0.01, 0,001 and not significant, respectively.*

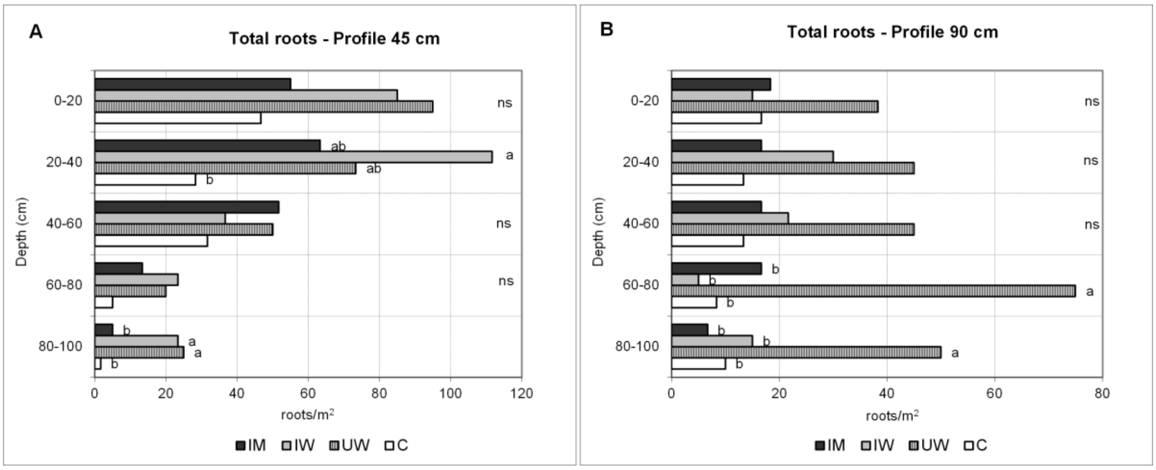

Figure 1: Mean total number of roots grown under different compost treatments and in a no amended control. Roots were counted in profiles at two distances (45 cm and 90 cm) from the vine row, and into five different soil layers up to a depth of 1.0 m. Results are expressed as number of roots/m². Within each profile, and within each of the soil layers, means followed by different letters differ significantly at p≤0.05 by Newman-Keuls test; ns=not significant.