EFFECT OF MANAGEMENT ON TOPSOIL STRUCTURE

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Abstract

This paper aims to show the effectiveness of different soil management strategies for improving soil structure in degraded areas within two vine farms in Tuscany (Italy). The management practices adopted were: Composted organic amendment addition (COMP), Green Manure (GM), Dry mulching (DM) and Control (CONTR). Topsoil samples were taken at the beginning of the trial (2015) and two years later, and analyzed for bulk density (BD) and aggregate stability by wet sieving. The strategies adopted to restore the functionality of degraded vineyard soils diversely affected BD and aggregates stability. In both the farms COMP proved to be the best strategy to reduce BD, while GM and DM gave the best results in terms of aggregate stability increase.

Keywords: *aggregate stability, compost, cover crops, soil management, soil structure, viticulture*

Introduction

Soil management practices can deeply affect soil structure, with direct consequences on vine yield and environmental and landscape protection. The effects produced by soil management can be immediate or appreciable in the long term. The porosity increase determined by tillage operation is an immediate effect; however, depending on the pedoclimatic conditions and the type of tillage implement adopted, this increase can be more or less long-lasting (Zhai et al., 1990). The long term effects produced on soil structure are mainly mediated by the influence that management practices have on soil organic matter. A soil with a good supply of organic matter generally has a more stable structure and is able to better withstand compaction by agricultural machinery and rainfall beating action. Soil structure is recognized to control many soil processes (Rabot et al., 2018). It regulates water retention and infiltration, gaseous exchanges, soil erodibility, root penetration, and, in turn, soil organic matter and nutrient dynamics. Soil structure also affects the habitat of soil organisms, driving their diversity and activity.

Increasing the organic matter content is a strategy to improve soil structure. This goal can be achieved by adding organic matter, as pruning residues and manure (composted or not), or indirectly by the adoption of vegetation cover, both spontaneous grass or cover crops.

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One of the soil properties most used for assessing soil structural conditions is bulk density (BD). BD is considered particularly useful for evaluating the soil compaction status (Rabot et al., 2018). In fact, root mass, density and diameter decrease as the soil BD increases (Dal Ferro et al., 2012), as well as water infiltration, nutrient availability, gas exchange and soil microorganism activity. Another indicator of soil structure quality is aggregate stability, the ability of soil to retain its structure under the action of water and mechanical stress (Dexter, 1988). A low aggregate stability increases soil susceptibility to surface crusting, runoff and erosion (Nciizah and Wakindiki, 2015).
This paper aims to investigate the effectiveness of different soil management strategies for improving topsoil structure conditions in degraded areas within two vine farms in Tuscany (Italy).

Materials and methods

The experimental sites are located in two commercial farms in Tuscany (Italy): i) Fontodi, Panzano in Chianti (Firenze) and ii) San Disdagio, Roccastrada (Grosseto). Both sites show a Mediterranean suboceanic climate, with long term mean annual temperature around 13.5°C and total rainfall about 880 mm. The two farms have a different story: Fontodi is under organic farming regime since 2000, and from that date the soil was managed by compost addition and permanent grass cover; San Disdagio, instead, is organic since 2014 and the soil is managed by rotary tilling to 20 cm depth. In each farm, three blocks (250 m^2 each) with degraded soil, and three control plots on non-degraded soil (ND) were selected. In each block on degraded soil, four plots were delimited and the following different management strategies were adopted: addition of Composted organic amendment COMP), Green manure (GM) (Vicia Faba minor L. and Hordeum Vulgare L.), Dry mulching (DM) (Trifolium Squarrosum L.) and degraded Control (CONTR).
Topsoil sampling was carried out on April 2015 (T0), before the start of the trial, and two years later, on May 2017 (T2), to determine BD (0-10 and 10-30 cm depth) and aggregate stability (0-10 cm).
BD was determined on soil at field capacity by the core method (Blake and Hartge, 1986). Soil aggregate stability was determined by wet sieving (Kemper and Rosenau, 1986) and expressed by the mean weight diameter (MWD) index. Twenty grams of pre-sieved 4.75-10 mm dry aggregates were directly soaked for 5 minutes on the top of a nest of sieves with openings of 4.75, 2.0, 1.0, 0.25 and 0.05 mm immersed in water (fast wetting). We preferred this wetting procedure instead of capillary rise because it should effectively mimic the breakdown mechanisms that aggregates experience under high intensity (>30 mm h^{-1}) rainfalls events (Legout et al., 2005). The nest of sieves with its content was then vertically shaken in water by an electronic-controlled machine with a stroke of 40 mm per 10 minutes, at a rate of 30 complete oscillations per minute.
With the aim of taking into account the variability of soil properties (□x) between plots of the same block at T0, the % variation respect to T0 has been calculated as follow:

$\Delta x = (T2x\text{-}T0x)/T0x*100$ (1)

Data were analyzed statistically by one-way (Management = M) and two-way (Management = M and soil depth = D) ANOVA, using the StatSoft Statistica 10.0 software package (StatSoft, Tulsa, USA). Post-hoc mean separation was performed by Duncan's multiple range test.

Results and discussion

Although the pedological survey showed evidences of soil physical degradation phenomena, namely compaction and erosion, in both the farms, the analyses carried out on the 2015 topsoil samples did not highlight significant differences between degraded and not degraded plots. Despite this, we monitored the effect of different management strategies on BD and aggregates stability, soil properties notoriously affected by management practices.

In Fontodi, although no significant differences between the treatments were evidenced, COMP highlighted the greatest reduction of BD values (Table 1). In San Disdagio, BD displayed significant decrease respect to CONTR in the surface layer (0-10 cm) of COMP and GM soils, the only treatments in which organic material was incorporated into the soil by tillage.

Treatments	Depth (cm)	Fontodi	San Disdagio
COMP	0-10	-7.24 b	-18.19 b
	10-20	17.98 ab	7.65 a
GM	0-10	16.15 ab	-17.29 b
	10-20	13.40 ab	0.06 a
DM	0-10	3.67 ab	3.78 a
	10-20	21.41 ab	1.17 a
CONTR	0-10	0.64 ab	0.25 a
	10-20	21.98 ab	4.00 a
ND	0-10	4.21 ab	1.42 a
	10-20	32.36 a	-5.43 ab

Table 1
Percent variation of BD (Δ_{BD}) at the end of the trial (2017) respect to 2015.

In both farms, COMP appears the best strategy to decrease soil BD, even though the effects were limited to the surface layer only. Nevertheless, in Fontodi the effect was less evident respect to San Disdagio. This result is probably due to the fact that in Fontodi, in the years before the beginning of the trial, compost addition had already been made. In San Disdagio, where the management adopted until 2014 can not be considered conservative, GM, which similarly to COMP involves the burial of organic matter, showed a positive effect on soil BD.

With regard to the aggregate stability, in Fontodi, although all the treatments showed an improvement respect to CONTR, a significant MWD increase was observed only in ND, where permanent spontaneous grass cover was present (Table 2).

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In San Disdagio, MWD values increased in all treatments; however, even in this case, the soil under cover crops (GM and DM) showed higher MWD values respect to COMP. GM, in particular, showed a significant improvement of aggregate stability compared to CONTR.

Treatments	Fontodi	San Disdagio
COMP	-5.8 ab	56.56 ab
GM	16.76 ab	162. 788 a
DM	34.12 ab	111.68 ab
CONTR	-37.84 b	29.79 b
ND	64.24 a	65.68 ab

Table 2
Percent variation of aggregate stability index (Δ_{MWD}) at the end of the trial (2017) respect to 2015.

The management strategies adopted to improve structural conditions of degraded vineyard soils had different effects on BD and aggregate stability.
Relatively to BD, COMP proved to be the best strategy for its reduction in both the soil types. With regard to the increase of topsoil aggregate stability, the adoption of cover crops (GM and DM) has proved to be the best soil management strategy. Our results agree with those of other studies about the capability of such crops to increase the resistance of surface aggregates to the splashing impact of raindrops (Mati, 1994; Bronick and Lal, 2005). Such positive effect of cover crops on soil aggregate stability is not due to the increase of total organic matter content, which on the contrary decreased, but more probably to the enmeshing effect of fine roots, to the release of root exudates, and to the boost of beneficial fungi and other microorganisms populations that promote the formation and stabilization of soil aggregates (Sarrantonio, 2007; Schutter and Dick, 2002).
In organically managed vineyards, the use of cover crops and organic amendments has proven to be an effective approach for improving topsoil structural features. However, further research is needed, particularly in Mediterranean growing areas, to evaluate the long-term effects of such management systems both on soil hydrology, and qualitative and productive response of vineyards under different pedoclimatic conditions.

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