Use of Organic Amendment from Olive and Wine Industry in Agricultural Land: A Review

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Summary

Agricultural land is under severe treats as population grows, land degradation remains unabated and climate extremes increased. Globally, olive oil production and a wine industry represents important sector in the economy of Mediterranean countries. These two sectors play an important role on ecosystem stability due to considerable amount of resources used in production while organic wastes remain as threat in ecosystems. Orchards and vineyards land use are susceptible to degradation. The drivers for vineyard and orchards degradation are numerous and they are mostly triggered by human activities. Intensive management enhances soil organic matter loss, structural instability, compaction, surface crust, runoff and soil loss. Tillage and agrochemicals contribute to structural instability and act as drivers for soil erosion and degradation. Therefore, the environmentally friendly use and management of such endangered land are required, which often involves use of organic amendments into soil. The review focuses on the analyses of organic wastes use from olive and wine industry that could be a valuable source for soil improvement. Present paper shows positive aspect of organic waste on soil through increased content of soil organic carbon and nutrients concentrations, water-holding capacity and soil porosity. Olive and wine pomaces enhances soil aggregate stability and water infiltration, while decrease erosion. Olive mulch can be used as mulching material to exert good control over weeds. Overall, organic by-products increase soil quality and can be recommended for investigation at the regional level to assess its suitability for wider application in Mediterranean Croatia.

Key words

soil degradation, Mediterranean, olive waste, wine pomace, compost

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Introduction

Mediterranean is well known for wine and olive oil production. Around three quarters of the world olive oil production comes from the European Mediterranean countries (Azbar, 2004). In addition, wine industry represents another important sector in the economy of Mediterranean countries. Wine production has been traditionally regarded as an environmentally friendly process. However, it requires a considerable amount of resources such as water, fertilizers and organic amendments; and on the other hand, produces a large amount of wastewater and organic wastes (Ruggieri et al., 2009). This ecological problem within the proper soil management can act as potential source for soil protection. The increasing demand for food leads to higher anthropogenic pressure on land and water resources. This leads to the degradation of these resources, which is often followed with soil organic matter depletion. This phenomenon is consequence of changes in land use and agriculture intensification. Low organic matter content in Pronounced Mediterranean soil degradation that affects all countries in Mediterranean basin are widely reported (Annabi et al., 2007; Bastida et al., 2008; Novara et al., 2014, 2016; Bogunovic et al., 2017a). It is mostly triggered by inappropriate land use and management, which involves mining, forest fires, overgrazing, tillage, use of agrochemicals etc. However, measures to control soil degradation require significant costs. Therefore, cover crops and crop residue incorporation to soil usually help to control soil degradation and erosion (Novara et al., 2013b; Sadeghi et al., 2015; Rodrigo Comino et al., 2017). Finally, presence of annual vegetation and plant residues on the soil surface allows negligible soil loss. Olives can play a significant part in protecting Mediterranean region from further degradation and desertification (Geeson, 2002). In Mediterranean climate, organic matter provided by crop residues is not usually enough to quickly improve soil quality (Virto et al., 2007; Moreno et al., 2016). Therefore, sources such as urban wastes or compost from different origins represent promising alternative (Annabi et al., 2007; Bastida et al., 2008; Reeve et al., 2012). In addition, increased demand for olive oil and wine increases by-products and wastes quantity, which could be utilized as sources of organic matter. Just the olive oil industry in Mediterranean countries produces large amounts of waste with more than four million tons each year in Spain alone (Fernández-Hernández et al., 2014; Moreno et al., 2016) and thereby opens demand for adoption of innovative solutions. Therefore, it is necessary to investigate impacts of olive and wine organic by-products on soil. This paper describes the impact of organic residues from olive and wine industry on soil using available literature. First part of this study provides overview of degradation process that occurs in Mediterranean soils and role of key factor that control the severity of degradation - organic matter. Second part describes by-products from wine and olive oil industry, and their impact on soil properties.

Land degradation diffusion and processes

Land degradation processes, which involve a reduction of the potential productivity of the land, (e.g. soil degradation and accelerated erosion, reduction of the quantity and diversity of natural vegetation) are widely spread in the Mediterranean basin (Hill et al., 1995; Novara et al., 2012; Bogunovic et al., 2015; Comino et al., 2016). Considering vegetation as the functional, tangible equivalent of terrestrial ecosystems (Graetz, 1990), it follows that changes in vegetation structure and structural dynamics provide important indications for land degradation processes (Novara et al., 2013; Keesstra, et al., 2016; Prosdocimi et al., 2016a; Kisic et al., 2017). Their precise characterization, together with the identification of soil condition, constitutes core elements for monitoring the dynamic behavior of Mediterranean ecosystems. During the 20th century, the increase in population has drastically accentuated the risks and extent of soil degradation (Richards, 1991; Geeson et al., 2002; Prodoscimi et al., 2016b). The adoption of the strategy for environmental-friendly soil management represents primary concern. Soil degradation represents the loss of actual or potential soil productivity and utility as a result of natural or anthropogenic factors (Lal, 1993), but nowadays the natural processes are accelerated by human activity. Soil degradation processes include organic matter decline, compaction, erosion, salinization, landslides, contamination, sealing and biodiversity decline (Montanarella, 2007). Although used to alleviate soil related constraints in achieving potential productivity, tillage can make a wide range of degradative processes (e.g. deterioration in soil structure, accelerated erosion, depletion of soil organic matter and fertility) (Birkas et al., 2015). Improperly used tillage is main fault for depletion of organic matter in soils in addition to conservation tillage systems (Birkas et al., 2008; Kisic et al., 2002; Bogunovic et al., 2017b) and their loss trough CO_2 emissions (Bilandžija et al., 2016; Bogunovic et al., 2017c). Such soils are susceptible to settling and surface crusting (Birkas et al., 2006a; Farkas et al., 2009), compaction (Sajko et al., 2009; Bogunovic and Kisic, 2017) and erosion (Basic et al, 2004; Kisic et al, 2017a, b; Bogunovic et al., 2018).

Furthermore, soil salinization and alkalization are regarded as major causes of desertification and represent a serious form of soil degradation in the Mediterranean region. This type of degradation is pronounced with human-induced salinization triggered with poor quality of irrigation water, especially along the coasts where seawater intrusion into the fresh water aquifers is common (Zdruli, 2012).

Land degradation and desertification are a consequence of man's impact on the earth's ecosystems. Indeed, they can in many cases be prevented and/or responded to by using strategies and methods to restore land and soil qualities (Runolfsson and Andress, 2004). These strategies include a proper management that involves preservation and increase of concentration of soil organic matter.

Role of soil organic matter in soil and consequences of its loss in soil system

The amount of organic matter (OM) in a mineral soil is an extremely important factor in determination of its characteristics and suitability for use in agriculture (Craswell and Lefroy, 2001; Lal, 2004; Bronick and Lal, 2005). Soil organic matter positively influences hydraulic, physical and chemical soil properties. For instance, OM constantly releases nutrients through cation exchange reactions, through decomposition, and as chelated elements (Allison, 1973). In addition to that, soil OM is also used as a source of energy and sustenance for soil biota (Lal, 1991); it helps to improve soil structure (Bronick and Lal, 2005; Dexter and Birkás, 2004; Birkas et al., 2006b), which affects better permeability and water conservation (Funderburg, 2001), while the surface runoff and erosion are decreased (Basic et al., 2002; García-Díaz et al., 2016; Novara et al., 2016). Addition of OM helps to decrease bulk density and penetration resistance, while increases porosity and water holding capacity (Horn et al., 1994; Abdollahi at al., 2014; Yazdanpanah et al., 2016). Soils rich in OM are also resilient to mechanical pressures by vehicular traffic (Slowinska-Jurkiewicz and Domzal, 1988, 1991a; Hamza and Anderson, 2005; Nawaz, 2013) and structural distortion marked as unstable aggregates (Bissonnais, 1996; Legout, 2005).

Loss of organic matter is often identified as one of the main factors contributing to declining soil productivity, but it is misleading to equate a loss in soil organic matter with a loss in soil productivity (Penny, 2001). Mediterranean soils generally possess low organic matter content, making them particularly vulnerable to weathering and degradation (Kosmas et al., 1997; Zalidis et al., 2002). Supplementing degraded Mediterranean soils with organic mulches and composts has great potential in terms of the remediation of these soils and enhancement of soil productivity (Zalidis et al., 2002; Altieri and Esposito, 2008; Kavdir and Killi, 2008; Tang et al., 2013).

Lack of organic matter in soils results in: decreased input of slow-release fertilizer, insufficient water holding capacity, high runoff and compaction with deteriorated structure. Such soils are poorly aerated, therefore, less suitable for beneficial soil organisms, so natural inputs of nutrients via mineralization are eventually slow. In addition, poorly aerated soils are not as good for plants, worsening the efficiency of their roots at taking up nutrients (Muir, 2011). Therefore, low organic matter content is one of the common features of Mediterranean soils. According to the European Environment Agency (1995) there is the loss of nutrients and organic matter on as much as 3.2 million hectares of land in Europe. The decline of organic matter is of particular importance in the southern parts of Europe, where 74% of the land has less than 3.4% organic matter. Intensive farming enhances the processes of organic matter mineralization, which emphasizes the need for additional inputs of organic matter in soil. Therefore, organic waste reuse through soil system for different land purposes seems to be the best way to improve soil organic matter content. When organic wastes are composted then, these practices contribute to elimination of non polluted organic wastes with public health safety and environmental advantages (Felipo, 1996).

Results and discussion

The influence of olive waste on soil properties

A 97% of total olive production in the world belongs to Mediterranean area, which has important facilities for olive oil industry that produces 95% of the world's olive oil (Aragón and Palancar, 2001). Almost 75% of the olive harvest is waste, produced in significantly large quantities during short periods of time (FAIR, 2000; Omer and Mohamed, 2012). Table 1 shows basic chemical properties of olive waste presented through different research. Different available literature sources report high variation of chemical concentrations of olive waste. This can be explained by different ages of maturity of olive waste in different experiments, different varieties of olives, treatments of olive waste after process in oil mills and numerous other factors that have implications on olive waste chemical properties.

Despite the mentioned variability of properties, among the organic waste materials produced by agricultural and industrial activities, olive mill wastes derived from the olive oil extraction process may represent a suitable soil amendment, because contains a large amount of organic matter. Apart from that, it can: increase soil organic carbon, major nutrients concentrations (e.g. N, K), water-holding capacity and porosity, soil aggregate stability (Kavvadias et al., 2011; Mahmoud et al., 2012; Brunetti et al., 2005); and decrease pesticide mobility (Cox et al., 1997) and problems associated with erosion (Pleguezuelo et al., 2009). In this context, Abu-Rumman (2016) investigated changes in soil physical properties on clay soil. Results show that water holding capacity, root depth and accumulated infiltration increased as organic waste application rates increased. In López-Piñeiro et al. (2008) research, application of olive mill pomace increased soil stable aggregates from 64% to73 % after five years. Gómez-Muñoz et al. (2011) described the major properties of 7 out of the 11 composted olive mill pomaces currently produced in Andalusia, and found that olive compost was very rich in organic matter. Garcia-Ruiz et al. (2012) compared soil after long-term application of olive mill pomace with control treatment, and concluded that the addition of composted olive mill pomace improved soil quality. Ferrara et al. (2014) evaluated the effects of three different soil management systems in a vineyard that use olive pomace and concluded that exhausted olive pomace can be used as mulching material to exert good control over weeds as part of more sustainable management of the vineyard. Alburquerque et al. (2006) reported that the application of a composted wet solid material obtained from continuous two-phase centrifugation of olive to soil increased concentrations of phosphorus and potassium and decreased the contents of calcium and magnesium. Xua et al. (2005) reported that soil pH changed with applications of different rates of plant residues. pH of solid olive waste residue is around 6, therefore its application rate is important to regulate soil pH. Moreno et al. (2016) examined the impact of olive husk compost on intensively managed greenhouse soil. Composted olive husk increased soil organic matter content, which is consistent with the low degradation rate of the compost in soil and confirms its usefulness as a source of organic carbon for soil. Increased soil organic matter content resulted in decreased bulk density and also in increased porosity and available water in the soil. The amendment was also an effective source of nutrients, particularly N, P, K and Ca, the last of which contributed to decrease of exchangeable Na levels in the soil surface layer.

Table 1. Descriptive characteristics of pH, electrical conductivity (EC), organic matter (OM), phosphorus (P) and potassium (K) of olive waste

pH	EC (dS/m)	OM (%)	P (%)	K (%)	Source
8.40	1.40	72.7	4.70	19.00	Moreno et al. (2016)
4.69	1.19	–	–	2.10	Pisante and Stagnari (2005)
4.90	0.91	18.5	0.05	0.08	Gougoulias et al. (2013)
5.38	4.64	90.8	0.08	1.04	Tortosa et al. (2012)
5.60	3.80	32.6	–	–	Madejon et al. (1998)

Table 2. Descriptive characteristics of pH, electrical conductivity (EC), organic matter (OM), phosphorus (P) and potassium (K) in wine pomace

pH	EC (dS/cm)	OM (%)	P (%)	K (%)	Source
9.58	1.36	–	0.1	4.2	Bertran et al. (2004)
6.5–8.5	1.57–4.1	84.15–89.1	0.18–0.52	–	Arvanitoyannis (2006)
3.8–6.8	1.62–6.15	66.9–92.0	0.094–1.09	1.19–7.28	Bustamante et al. (2007)
7.3	8.10	–	1.61	1.41	Mbarki et al. (2017)
6.5–6.8	0.49–2.01	–	0.61	2.48	Chen et al. (1988)

The role of wine pomace on soil properties

The wine industry is an important sector in economy of Mediterranean countries e.g. Spain that has one of the largest vineyards in the world (Bettini, 2015; Ruggieri et al., 2009). As we noted, wine production produces a large amount of wastewater and organic wastes, where some of these wastes are being used as by-products (grape pomace and lees) whereas the remaining organic wastes (stalk and wastewater sludge) has been traditionally incinerated or disposed in landfill (Bordiga, 2016; Ruggieri et al., 2009). Table 2 shows basic chemical properties of wine pomace presented through different research. Presented variability of general wine pomace chemical characteristics can be explained similarly as it was explained for olive waste, e.g. different wine varieties and different treatments of wine pomace after pressing.

Nevertheless, as it is reported in Zacharof (2016), winery waste can be divided on solid waste (it is generated during the collection of grapes) and liquid waste (generated during the wine making process). Wine pomace can be useful for soil, but it can't be incorporate direct to the soil because of long time of decomposition (Dobrei et al., 2005), which can cause serious problems since degradation products can inhibit root growth (Nerantzis and Tataridis, 2006). Grape pomace can be potentially used as soil conditioner or for fertilizer production (Ioannis et al., 2006; Ferrer al., 2001) where compost as fertilizer leads to higher yields and quality grapes for special wines (Nistor et al., 2014); promotes soil health due to the microorganism population (Matteson and Jenkins, 2007); represents an alternative source for obtaining natural antioxidants (Ioannis et al., 2006) and improves the percentages of organic matter and the soils' physical properties (aeration, water holding capacity, etc.) (Ribereau - Gayon and Peybaud, 1982). In this context, Bertran et al. (2004) studied two residues (sludge and grape stalks), mixed in two proportions and examined the effects of grinding the grape stalks. Results showed that compost had a high agronomic value and is particularly suitable for the soils of the vineyards that have very low organic matter content. Diaz et al. (2002) also reported that the grape pomace could be recycled as a soil conditioner in view of its organic and nutrient contents. Bustamante et al. (2010) investigated effects of soil amendment with winery and distillery waste composts on organic carbon mineralization in two arable soils (sandy-loam and clay-loam). The results showed that the addition of exogenous organic matter stimulated microbial growth, enhanced soil respiration and increased water-extractable carbon contents in both soils. Masowa et al. (2015) investigated the effect of winery solid waste compost on maize growth and biomass production on sandy soil. Maize growth attributes and dry matter yield were significantly increased following compost application relative to the unfertilized control. This study also showed that winery solid waste composts could serve as good sources of K and Zn. Paradelo et al. (2009) study showed that compost amendment significantly increased the consistency, water holding capacity, and aggregate size and stability of the slate processing fines. Same researchers reported that water holding capacity and consistency were positively correlated to total organic carbon. In spite of its advantages, the application of agricultural wastes in soil can lead to problems pertaining to their heavy metal content. Pinamonti et al. (1997) reported that the heavy metal content is a crucial factor leading to restricted agricultural use of compost.

Conclusion

This review clearly indicated the problems of decreasing soil productivity in intensive managed agricultural soil. As a consequence, soil organic matter content decreased in arable soils, and available results presented in this paper showed a large potential of organic waste from olive and wine pomace. Literature review reveals that organic by-products from olive and wine industry represent valuable substrate with beneficial effects on soil quality and can act positively on sustainability of agricultural land. In addition to contributing to the maintenance of soil properties, the composting of olive and wine pomace could increase its quality and reduce environmental problems of waste disposal. Numerous experiments with different soils and Mediterranean-type climates showed positive effect of organic waste compost from olive and wine industry on physical, chemical and microbiological soil properties. These positive results on soil quality can serve as a recommendation for sustainable agricultural production, but further investigation will be necessary at the regional level to assess its suitability for wider application in Mediterranean Croatia. Future testing in numerous vineyards and orchards will reveal the level of suitability in order to enhance soil conservation in them.

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