Journal of Cleaner Production 107 (2015) 498–508

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental sustainability of different soil management techniques in a high-density olive orchard

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ARTICLE INFO

Article history:
Received 9 October 2013
Received in revised form
19 June 2014
Accepted 21 June 2014
Available online 4 July 2014

Keywords:
De-oiled olive pomace
No tillage
nonwoven tissue
Polyethylene film
LCA
Sustainable olive cropping system

ABSTRACT

Recent olive cultivation in Mediterranean Countries is characterised by the strong diffusion of high-density cropping systems and by the most environmentally conscious management regarding all the agronomic practices and the waste disposal as well. This research has investigated the possibility of the use of De-Oiled Pomace (DOP) as an eco-friendly tool for weed control in a high-density olive orchard providing an environmental comparison with other soil management techniques. Five methods of weed control have been compared in a two-year experimental orchard at the Bari University (Southern Italy): mulching with de-oiled olive pomace (DOP), nonwoven tissue (TNT) and polyethylene film (PEN), chemical (CHI) and mechanical (MEC) weeding, on the three most adapted to high-density orchards olive cultivars (Arbequina, Arbosana and Koroneiki). The data collected during the experimental test are submitted to an LCA (Life Cycle Assessment) analysis and five scenarios have been drafted based on DOP use and destinations.

The results showed that the chemical wedding produced the greatest environmental burdens, and the higher environmental performances of DOP mulching scenarios for all environmental indexes, with burdens reductions and/or environmental credits. The presence in the following years of some bio-markers sensitive to macro and micro pollutants and heavy metals, in experimental plots mulched with DOP, confirmed the high environmental sustainability of this technique, excluding any kind of soil pollution in the medium-term period in the high-density olive orchard.

1. Introduction

In recent years oil olive orchard undergone deep changes regarding agronomic practices. In fact olive tree cultivation tends quickly to move from traditional low-density (<200 trees per hectare) to modern medium-density cropping systems (300–400 trees per hectare) and overall to new high-density cropping systems (>1200 trees per hectare), that represent a very interesting proposal for olive orchard profitability (Camposeo et al., 2008). The high-density cropping systems are characterized by strong reduction of production costs thanks to total mechanization, from planting to harvesting (Godini et al., 2011). This cost reduction must necessarily be accompanied by sustainable production policies as now required from Europe and from the market (Roselli et al., 2009; De Gennaro et al., 2012). The high-density cropping systems are based on early bearing (3^{rd} year from planting), yield stabilization starting from 5^{th}–6^{th} year from planting (8–10 t per hectare per year) with very negligible alternate bearing and continuous harvesting (Camposeo et al., 2008; Camposeo and Godini, 2010). These cultivation systems are born in Spain in the Nineties and had a rapid spread all over the world. There are three cultivars on which, up to now, this system has been calibrated: two Spanish, 'Arbequina' and 'Arbosana', and one Greek, 'Koroneiki' (Camposeo and Godini, 2010; Godini et al., 2011). Several physiological and agronomic aspects are already started to studying for high-density olive orchards in Mediterranean environments: canopy growth (Strippoli et al., 2013), irrigation (Gomez-del-Campo, 2013; Vivaldi et al., 2013), harvesting time (Camposeo et al., 2013). Soil management assessment is showing its crucial relevance especially in hilly areas, where the high-density olive orchards allow a good soil protection thanks to the temporary inter-

Abbreviation: VOP, Virgin Olive Pomace; DP, Dry Pomace; OPO, Olive Pomace Oil; DOP, De-oiled Olive Pomace; TNT, Nonwoven Tissue; PEN, Polyethylene film; CHI, Chemical weeding; MEC, Mechanical weeding; LCA, Life Cycle Assessment; ADP, Abiotic Depletion Potential; AP, Acidification Potential; EP, Eutrophication Potential; GWP, Global Warming Potential; ODP, Ozone layer Depletion Potential; POPC, Photochemical Ozone Creation Potential; PED, Primary Energy Demand.

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http://dx.doi.org/10.1016/j.jclepro.2014.06.064
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row grass covering (Metzidakis et al., 2008) and to an higher soil covering (over 60%; Camposeo et al., 2013 unpublished data). Soil management in high-density plantings can be conducted by means of mechanical or chemical weed control on the row (Camposeo et al., 2008; Camposeo and Godini, 2010). Nevertheless, mulching made with different plastic and organic materials could represent a row management technique alternative. This technique was successfully tested and applied in vineyards and other fruit tree species (Ferrara et al., 2012; Mellouli et al., 2000; Jacometti et al., 2007; Mage, 1982).

The olive oil production chain causes by-products such as olive waste water (OWW), olive virgin pomace (OVP) and the Olive Pomace Oil (OPO), in order to avoid damage to the environment this waste must be properly disposed or processed. Therefore, in recent years many authors have accurately evaluated the environmental burdens associated with the production of olive oil taking into account field, mill extraction, by-products disposal and packaging (Salomone et al., 2002, 2010, 2012; De Gennaro et al., 2012; Notarnicola et al., 2003, 2004; 2013; Nicoletti et al., 2001). By-products disposal and/or reuse of, are the stages of the process that creates considerable diversity of environmental impact; moreover their chemical and physical characteristics are related to the extraction of olive oil method. For this reason, the qualitative and quantitative characteristics of these by-products are closely related to the facilities used for oil extraction (ARPAL, 2006; Ferri et al., 2001).

The OVP consisting of olive pulp, fragments of kernels and water, are generally processed for drying and extraction of residual fats from OPO by chemical solvents (n-hexane). The solid residue of this process is the de-oiled olive pomace (DOP) with a 90–92% of dry matter (Tufarelli et al., 2013) and characterized by: a calorific value of about 20.63 MJ kg^{-1}_{DOP}, good levels of nutrients and polyphenols, low heavy metal content and the absence of pathogenic organisms (Balice et al., 1990). The production cycle of the exhausted pomace is shown in Fig. 1.

The DOP is considered a bio-fuel of vegetable origin by European Community on energy-environment standards (EC, 2009), but considering the waste European legislation, it is necessary to verify the possibility of using it as fertilizer/amendant in agriculture without risk for agro-ecosystems. In fact, European standards on waste requires compliance with the hierarchy that encourages recycling over energy recovery if it ensures the best overall results with regard to the health, environmental, social and economic impacts (EC, 2008).

Recently, researches have stepped up on agronomic utilization of solid mill residues as soil amendment materials, as it is or after composting, in order to maintain soils aggregate stability (Alburquerque et al., 2006; Brunetti et al., 2005; Chandra and Sathiavelu, 2009; López-Piñeiro et al., 2008, 2010; Saviozzi et al., 2001; Mekki et al., 2006). It's worthwhile in large areas of the Mediterranean region subjected to soil degradation processes, due to losses of organic matter by intensive agricultural practices (Albarrán et al., 2004). Indeed, this technique seems to bring benefits to soil, increasing total organic carbon and humic substances (Altieri and Esposito, 2008; López-Piñeiro et al., 2008), creating physical conditions more favourable (Al-Widyan et al., 2010; El-Asswad et al., 1993; Kavdir and Killi, 2007; Mellouli et al., 1998), showing a positive effect on nitrogen, phosphorus and potassium in term of fertilizing values (Cucci et al., 2008; López-Piñeiro et al., 2008; Montemurro et al., 2004; Uygur and Karabatak, 2009). Moreover, this agronomic utilization could alleviate the problem of olive mill wastes disposal in the Mediterranean areas (Roig et al., 2006).

More recently a work has been made in order to studying the effects of de-oiled olive pomace as soil mulching in a high-density olive orchard compared to other management techniques, in order to re-cycle this olive mill waste and enhance the environmental sustainability of this, very innovative, oliveculture system (Camposeo and Vivaldi, 2011). Mulching effects, both on soil and plant, were evident from the second year of experimental tests. DOP mulching remained as solid layer during this period. On the contrary, the plastic film mulching used as weed control techniques, already started to deteriorate at the end of the first year after application, so reducing the vegetative and productive performance of olive trees. DOP did not show any toxicity effect on plant performances, both vegetative and productive, irrespective of the cultivated genotype. The most important DOP effect was to enhance the potassium soil availability. Considering the great importance of soil potassium content for olive-culture, because olive tree features high potassium requirements (Restrepo-Diaz et al., 2008), DOP mulching could reduce the amount of K fertilizer. Very similar results were observed in a vineyard with the same soil managements (Ferrara et al., 2012). Therefore, DOP could be considered a suitable mulching material for greater agronomic sustainability of high-density oliveculture, and suitable for intensive plantings (Camposeo and Vivaldi, 2011). The use of this mulching material should be also considered as a tool for an environmental sustainability use of waste materials in high-density fruit tree systems.

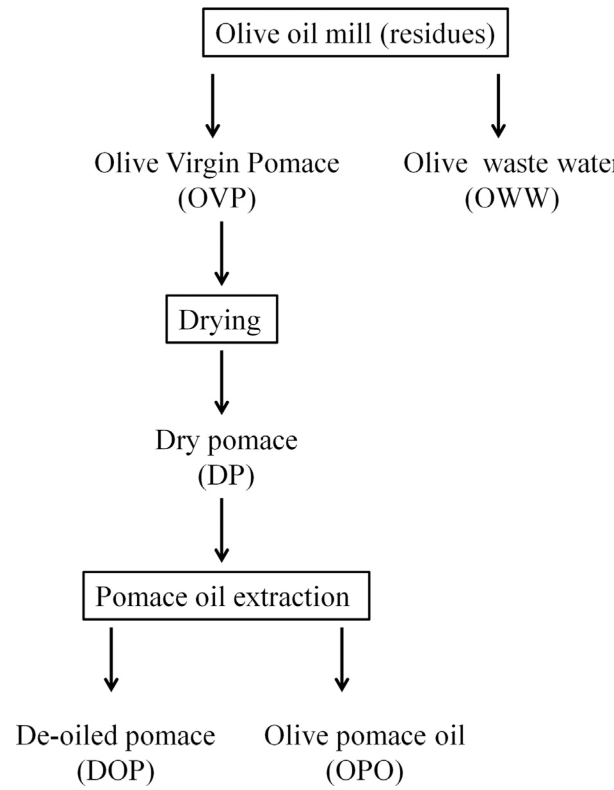

Fig. 1. Production cycle of the DOP.

In the cultivation process, potential impacts on environmental matrices caused by DOP mulching use, are related to migration in groundwater and in the atmosphere of the chemical compounds present and their persistence in the superficial and deeper soil layers (Barbera et al., 2013). In particular polyphenols, which are responsible for the herbicide effect, do not reach the groundwater because their concentration is rapidly reduced in the upper layers of the soil (0–25 cm) (Mekki et al., 2007). On the contrary heavy metals and nitrates are subject leaching by rainwater and