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Short-term effects of de-oiled olive pomace mulching application on a young super high-density olive orchard

Salvatore Camposeo*, Gaetano Alessandro Vivaldi

Dipartimento di Scienze Agro-ambientali e Territoriali, Università degli Studi di Bari Aldo Moro, Via Amendola 165/A, 70126 Bari, Italy

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ABSTRACT

A two-year field experiment was performed in order to evaluate the suitability of de-oiled olive pomace for soil management in a young super high-density olive orchard. In the literature there are not works on this topic.

The research was conducted on three cultivars (Arbequina, Arbosana and Koroneiki) on which this very innovative oliveculture system has been calibrated up to now. Row mulching with de-oiled olive pomace face to plastic mulching materials (polypropylene tissue, polyethylene film), chemical and mechanical weeding was compared.

During the test de-oiled olive pomace mulching remained as solid layer and increased significantly the available K soil content, that doubled with respect to control and to other mulching materials and soil management methods. In the second year after application, where mulching material remained sound, soil mulching significantly improved stomatal conductance, net assimilation and water use efficiency with respect to both chemical and mechanical weeding. Nonetheless, olive tree growth in the mulched treatments was equivalent to that in weeded treatments. Yield parameters, both fruit per plant and oil content, behaved as morphological parameters as well.

The de-oiled olive pomace could be considered an alternative mulching material for a greater environmental sustainability of super high-density olive culture.

1. Introduction

Olive mill waste disposal is an issue of extreme importance in the Mediterranean area. In Italy, following the increase of olive oil production, the 2009 olive pomace production was 530,000 t and the total de-oiled olive pomace amounted to 267,000 t, +27% and +45% compared to the previous year, respectively (ASSITOL, 2010). The Italian olive pomace comes almost exclusively from three-phases systems; the de-oiled olive pomace is mostly used as fuel by the same extractors, causing air pollution problems so that it is essential to rethink a re-use more compatible with the environment. Recently, researches have stepped up on agronomic utilization of mill residue as soil amendment material, 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). It is 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; Antolín et al., 2005). 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 waste disposal in the Mediterranean areas (Roig et al., 2006). The topic is so important as to employ this olive oil by-product in animal nutrition as well (Molina Alcaide and Nefzaoui, 1996).

Traditional oliveculture soil management has long been considered a minor technical issue and, until the late seventies, only soil tillage has been used, especially under dry-farming conditions (Godini, 2002). After the introduction of significant changes in planting systems, soil management has aroused interest in research, as it represents one of the aspects to be considered for obtaining specific goals not only quantitative and qualitative but also for environmental protection. When it comes to soil manage-

Abbreviations: DOP, de-oiled olive pomace; TNT, nonwoven tissue; PEN, polyethylene film; CHI, chemical weeding; MEC, mechanical weeding; EC, electrical conductivity; TOC, total organic carbon; ψ_l, leaf water potential; g_s, stomatal conductance; *E*, transpiration; *A*, net assimilation; WUE, normalized water use efficiency.

* Corresponding author. Tel.: +39 080 5442982; fax: +39 080 5442508.
E-mail addresses: camposeo@agr.uniba.it (S. Camposeo), gaetano.vivaldi@uniba.it (G.A. Vivaldi).

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ment techniques, it is essential to consider the different existing systems, as traditional, intensive and super high-intensive, these having different technical solutions (Camposeo and Godini, 2010). In fact, a unique technique does not exist, and a good idea is to integrate different management techniques, each with specific advantages and disadvantages (Haynes, 1980). The most used soil management technique still today in intensive orchards (300–600 plants ha^{-1}) is tilled bare soil (Godini, 2006). However the introduction of grass covering technique replacing conventional tillage in fruit tree plantings is increasing, as it allows the preservation and improvement of physical (Gómez et al., 1999; Wheaton et al., 2008), chemical (Corleto and Cazzato, 2006; Granatstein and Mullinix, 2008) and biological of no-tilled soil fertility (Benitez et al., 2006; Hernández et al., 2005; Moreno et al., 2009; Sirrine et al., 2008).

The super high-density oliveculture system, developed in Spain in the nineties and spread on over 100,000 ha in the world, is based on a plant density of 1600–1800 plants ha^{-1} and it is characterised by a high reduction of the cultural costs thanks to a whole mechanization, from planting to harvesting (Godini, 2006). The benefit of this new system mainly depends on the availability of cultivars with compact habit, slow canopy growth and early bearing, up to now owned by Arbequina, Arbosana and Koroneiki cultivars (Camposeo and Godini, 2010). Soil management criteria in super high-density olive plantings represent a technique still to be investigated. Researches carried out in Apulia showed that the middle strip can be managed with grass covering from October to March followed by chemical weed control, then soil tillage in late spring and in summer; mechanical or chemical weed control can be used on the row (Camposeo et al., 2008; Godini, 2006). A more recent study showed that the temporary grass between rows and the chemical weeding along the rows could be one of the strategies useful for super high-density plantings, considering that the young plants should be protected with 20 cm high special polypropylene shelters during the first 3 years (Camposeo and Godini, 2010). The spacing used in this new oliveculture system (4.0 × 1.5 m apart) also allows to fully mechanize soil management by mean of an intra-row weeder, on one side or both sides, already used in row crops (Melander, 1997).

Nevertheless, mulching made with different plastic and organic materials could represent a row management technique alternative to mechanical and/or chemical weed control, to be applied also after the first year planting. This technique, successfully tested and applied in vineyards and other tree species, creates physical (Mellouli et al., 2000) chemical (Fang et al., 2007; Pinamonti, 1998) and biological (Jacometti et al., 2007; Saviozzi et al., 2001) conditions more favourable to roots development, with positive effects on plant growth, early bearing and yield (Mage, 1982; Tilander and Bonzi, 1997). Our idea is to use the de-oiled olive pomace as organic material for soil mulching in super high-density olive orchards. No works have evaluated its reclamation as mulching material. So, this work will serve as suitable opportunity for studying the effects of de-oiled olive pomace as soil mulching in a young super 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.

2. Materials and methods

2.1. Experimental design

A two years study (2007–2008) was carried out in the olive grove located at the Department experimental farm at Valenzano-Southern Italy (41° 01′ N; 16° 45′ E; 110 m a.s.l.), on a sandy clay soil (sand, 630 g kg^{-1}; silt, 160 g kg^{-1}; clay, 210 g kg^{-1}) classified as a Typic Haploxeralf (USDA) or Chromi-Cutanic Luvisol (FAO). The site is characterised by a typical Mediterranean climate with a long- term average annual rainfall of 560 mm, two third concentrated from autumn to winter, and a long term average annual temperature of 15.6 °C. The olive grove has been planted in 2006; the trees were trained according to the central leader system and spaced 4.0 m × 1.5 m (1667 plants ha^{-1}) with a North–South rows orientation, according to the Spanish super high-density training system. Props, drip irrigation and routine cultural practices (nutrition, pruning, disease control) were set up as already described (Camposeo et al., 2008; Camposeo and Godini, 2010; Godini, 2006). The study was performed on 3 cultivars: Arbequina, Arbosana and Koroneiki. Three different row soil management methods were compared for each cultivar (Fig. 1):

Fig. 1. Row mulching in the super high density olive experimental field in spring 2007.

1. mulching with de-oiled olive pomace (DOP), nonwoven tissue (TNT) and polyethylene (PEN);
2. chemical weeding (CHI);
3. mechanical weeding (MEC).

A split-plot design with 3 replications was adopted, arranging the 3 cultivars in the main plots and the 5 (3 + 1 + 1) soil managements in the sub-plots Each sub-plot, 10.5 m long, consisted of 7 plants. The 3 mulching materials were lying under the trees along the row, 1.05 m width. The DOP was applied with 3 cm thick by distributing 165 kg per plot, equivalent to 0.33 m^3 of waste (bulk density, 500 kg m^{-3}; basis weight, 15 kg m^{-2}); the DOP used was collected from an oil extraction plant located in Bari, which employed organic solvent for oil separation. The TNT was a polypropylene film in green colour (basis weight, 90 g m^{-2}). The PEN was in black colour with the same basis weight of TNT (90 g m^{-2}). The mulching materials were applied in middle March 2007 shortly before the vegetative growth, after row weeds removal by mowing. The CHI plots were chemically treated in March, July and October of both years, using a systemic post-emergence herbicide (glyphosate, N-(phosphonometil)glycine, $C_3H_8NO_5P$) at 2.5 L ha^{-1} of commercial product. The MEC plots were naturally grass covered from October to March of both years, providing for the periodic mowing from April to September. Main climatic data were collected at the agro meteorological station of the Mediterranean Agronomic Institute (IAM-B) in Valenzano (Bari), about 3 km far from the experimental field.

2.2. Soil and DOP characteristics

The main soil physical and chemical characteristics were determined just before the application of the different soil management