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Impact of organic fertilization on soil properties, plant physiology and yield in two newly planted olive (*Olea europaea* L.) cultivars under Mediterranean conditions

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ABSTRACT

The aim of the present research was to investigate the effect of two commercial organic fertilizers (Activit and Agrobiosol) on two newly planted olive cultivars for two successive years. Two cultivars were used, 'Koroneiki' an olive oil cultivar and "Konservolia" a table olive one. The organic fertilizers were combined with inorganic fertilizers which when used alone served as control. Organic fertilizer application resulted in lower soil pH values (8.0–8.15 compared to 8.46 in control) and higher cation exchange capacity (up to 19.6 meq 100 g^{-1} compared to 17.1 meq 100 g^{-1} in control). Soil N, K, Mn and Zn concentration were higher under the combined application of Activit plus inorganic fertilizer. A significant increase of leaf area index was observed when organic fertilizers were used. Nutrient concentrations of the leaves were in all treatments within the adequacy range. Carbon assimilation rate also increased under organic fertilization in 'Koroneiki' in summer (17.4–18.7 $\mu mol\, m^{-2}\, s^{-1}$) compared to control (14.9 $\mu mol\, m^{-2}\, s^{-1}$). Yield of 'Koroneiki' trees during the second year (the only cultivar bearing fruits) was higher under both organic fertilizers application, reaching almost 55% increase compared to the use of only inorganic fertilizer.

1. Introduction

Organic and inorganic fertilizers use is primarily based on providing nutrients to plants, sustaining plant growth and development and increasing yield. Inorganic fertilizers are cheaper and thus more affordable, resulting in the use of more mineral and less organic fertilizers (OF), increasing thus incidents of unbalanced fertilization, soil physical structure deterioration and degradation, salt accumulation, secondary salinization etc (Hernández et al., 2014; Lu et al., 2011). Under Mediterranean climate conditions, the high summer temperatures along with the intensive land cultivation, enhance soil organic matter (SOM) decomposition, by increasing its annual mineralization rate, making thus the use of organic matter yearly necessary (Diacono and Montemurro, 2010; Gasparatos et al., 2011). This decline of SOM content is considered to be one of the major processes of soil degradation (Diacono and Montemurro, 2010).

The build-up of SOM is by far a slower and more complex process than its decomposition, making thus organic amendments a "must be" action if sustainable production is the primary goal (Diacono and Montemurro, 2010). Integrated nutrient management supports judicious use of combinations of organic and inorganic fertilizers, aiming at restoring organic matter in the soil, enhancing nutrient use availability and efficiency and maintaining or even improving soil physical, chemical and biological properties (Hernández et al., 2014). Traditional OF (residues of agricultural and food processes) have maintained soil productivity for thousands of years. In modern environmentally-friendly horticultural systems consistent OF are often used to improve soil biological and physical properties. The use of organic matter (OM) in plant fertilization has been found to improve chemical and microbial properties of soils. Organic matter increases the content of organic carbon, microbial biomass (Bravo et al., 2012) and cation exchange capacity. It also improves soil biological properties (microflora and microfauna) (Giusquiani

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et al., 1995), soil structural stability and lowers bulk density and surface crusting of the soil (Schjonning et al., 1994; Chang et al., 2010), improving thus moisture retention, water infiltration rate, hydraulic conductivity of soil (Bravo et al., 2012; Chang et al., 2010), leading to increased crop yield (Jha et al., 2011; Marzouk and Kassem, 2011). Furthermore, organic manure may be beneficial to crop and soil on the long term (Tirol-Padre et al., 2007), as OM mineralizes during the season, providing nutrients for plant uptake gradually and slower than mineral fertilizers, while its efficiency in enhancing crop growth and yield has also been reported, in the short term, by combining OM with mineral fertilizers (Aisueni et al., 2009). Within a limited range of SOM content, the crop yield for a given soil increases with the increase in SOM (Chang et al., 2010; Kwabiah et al., 2003). Baldi et al. (2010) observed that repeated applications of compost in a nectarine orchard increased root proliferation and lifespan compared to un-amended soil. Nevertheless, according to Amoah et al. (2012) and Bravo et al. (2012) the use of OF alone as substitutes of chemical fertilizers is not enough to maintain productivity of high-yielding crops, while Lu et al. (2011) found that partial substitution of inorganic fertilizers by OF met crop's nutrient demands and sustained macronutrient efficacy, suggesting that the combination of OF plus mineral fertilizers could be more efficient than either one alone.

The influence of organic fertilizations on fruit tree growth and productivity is poorly investigated (Bravo et al., 2012). Therefore, the aim of the present study was to test the hypothesis that the combination of chemical and organic fertilizers may increase soil nutrient availability and uptake, promoting growth and enhancing yield, evaluating at the same time the effects on CO_2 fixation and carbohydrate production of newly planted olive trees.

2. Materials and methods

2.1. Experimental design – plant material

The study was conducted at the experimental orchard of Agricultural University of Athens for two successive years. One year old uniform olive plants of the cultivars 'Konservolia' and 'Koroneiki', were used as experimental material and planted in rows at 4×2.5 m distances in soil non-cultivated for at least four years. Chemical and OF were applied as top dress at planting, based on soil analysis and manufacturers' recommendations as follows: a) 300 g per plant of a granular chemical fertilizer (11–15-15, N-P_2O_5-K_2O), which comprised the control treatment (C), b) the chemical fertilizer plus 300 kg ha^{-1} of the organic fertilizer Agrobiosol (7-1-1.5, N-P-K, 0.24% calcium (Ca), 0.09% magnesium (Mg), 0.02% chloride (Cl), 1.31% sodium (Na), 41.1 mg kg^{-1} iron (Fe), 49.6 mg kg^{-1} zinc (Zn), 9.9 mg kg^{-1} copper (Cu), 8.76 mg kg^{-1} molybdenum (Mo), pH 3.2 with 90% OM and a carbon to nitrogen ratio 6:1) (Ag) comprised by fungal biomass of *Penicillium chrysogenum* formulated in flakes of less than 0.5 cm diameter and thickness and finally c) the chemical fertilizer plus 20 kg 100 m^{-2} of the organic fertilizer Activit (4-3-2, N-P_2O_5-K_2O, 1.5% MgO, 9.6% CaO, 0.76% Cl, 0.42% Na_2O, 1300 mg kg^{-1} Fe, 450 mg kg^{-1} Mn, 300 mg kg^{-1} Zn, 90 mg kg^{-1} Cu, 45 mg kg^{-1} boron (B), 10 Fe, 450 mg kg^{-1} Mn, 300 mg kg^{-1} Zn, 90 mg kg^{-1} Cu, 45 mg kg^{-1} boron (B), 10 mg kg^{-1} Mo, 2 mg kg^{-1} cobalt (Co), pH 6.4 and with 62% OM comprised by chicken manure, formulated into pellets of approximate length 2 cm, with a carbon to nitrogen ratio of 9:1) (Ac). The total amount of N, P_2O_5 and K_2O applied per hectare per treatment for the first year was: a) 33 kg N, 45 kg P_2O_5 and 45 kg K_2O in control treatment, b) 54 kg N, 51.87 kg P_2O_5 and 50.4 kg K_2O plus 270 kg organic matter in Agrobiosol treatment and c) 113 kg N, 105 kg P_2O_5 and 85 kg K_2O plus 1240 kg of organic matter in Activit treatment. In order to ensure reproducibility of the treatments, the same batch of OF were used during the next year too. During the first year the two OF were also analyzed (N, P, K, organic matter, pH and Na) in order to test their synthesis, which within the 5% limit was in accordance with their labels. During the second year, in late March, the water soluble fertilizer Fertifil (21-21-21, N-P-K plus Mn 0.025%, Fe 0.0215%, Mg 0.016%, Cu 0.015%, Zn 0.011%, B 0.019%, Mo 0.007% and vitamin B1 0.002%, all expressed as w/w) was used as control chemical fertilizer at the dose rate of 50 g per plant, while the OF were applied at the same dose rate as the previous year along with Fertifil. The total amount of N, P_2O_5 and K_2O applied per hectare per treatment for the second year was: a) 10.5 kg N, 10.5 kg P_2O_5 and 10.5 kg K_2O in control treatment, b) 31.5 kg N, 17.37 kg P_2O_5 and 15.9 kg K_2O plus 270 kg organic matter in Agrobiosol treatment and c) 90.5 kg N, 70.5 kg P_2O_5 and 50.5 kg K_2O plus 1240 kg of organic matter in Activit treatment. Six trees per cultivar were used at each treatment and each tree served as a replication.

At planting the trunk diameter and plant height were recorded and re-measured at the end of the second year of experimentation in order to assess cumulative growth. During the flowering period of the second year the flowering intensity was estimated using a four-grade scale (0–3), indicative of flower absence (0) or of high number of flowers per tree-the majority of the canopy bearing flowers (3). At the end of the second year the leaf area index (LAI) was also measured by the use of a leaf area meter (Li-2000, Li-Cor, Lincoln, USA), based on equal initial canopy volume per cultivar (estimated as spherical canopy). All trees were left unpruned during the years of experimentation in order to assess their growth.

2.2. Samplings and analyses

All samplings were performed during the second year. Soil sampling took place during the middle of July. Soil samples were air-dried and ground to pass a 2 mm prior to analysis. Particle size analyses were made using the hydrometer method, with a 2-h reading for clay content (Gee and Bauder, 1986). Electrical conductivity (EC) and soil pH was measured in a 1: 1 soil: distilled water (w-v) suspension (McLean 1982). Organic matter was determined using the Walkley-Black wet digestion method (Nelson and Sommers, 1982) and total N titrimetrically after distillation of NH_3 by Kjeldahl digestion (Bremner and Mulvaney, 1982). Exchangeable cations and Cation Exchange Capacity (CEC) were determined using an ammonium acetate extraction method. Extractable Zn, Fe, Mn and Cu were determined with diethylene-triamine-pentaacetic acid (DTPA) (Lindsay and Norvell, 1978). Plant available P was determined according to Olsen et al. (1954).

Fully expanded leaves were sampled immediately before fertilizer application in March of the second year. The second sampling event took place in June, the third one in September and the last one in late October, a few days before harvest. Leaves were washed with running tap water, then thrice with deionized one, before being dried in an oven at 70 °C till constant dry weight. Leaf N was analyzed by the Kjeldahl method while P colorimetrically using the H_2SO_4/H_2O_2 digestion method (Gasparatos and Haidouti, 2001). Dried leaf tissues were ashed in a muffle furnace for 6 h at 500 °C. The ash was subjected to wet digestion in concentrated nitric acid. Sodium and K were analyzed with flame emission photometry, while Ca, Mg, Zn, Mn, Fe and Cu with atomic absorption spectrometry (Varian SpectrAA300) (Roussos et al., 2007). The contents of macronutrients [N, P, K, Ca, Mg and Na] were expressed as percentage of dry weight, and for micronutrients (Fe, Mn, Cu and Zn) as mg kg^{-1} of dry weight.

Olive fruits were harvested manually separately per tree in early November and transferred to the laboratory, where the yield per tree and the weight of fruit were measured. Only 'Koroneiki' bear fruits during the second year.