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Litter dynamics of *Olea europaea* subsp. *Europaea* residues related to soil properties and microbial N-biomass in a Mediterranean agroecosystem

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ABSTRACT

Residues decomposition is an important process for plant nutritional demands. The present work was conducted in order to investigate the olive tree residues decomposition (leaves and shoots: buried in a horizontal and a sloping site of an organic olive grove) and its impact on soil properties and microbial N-biomass as affected by soil slope. Mean mass loss and C, N, K, and Mg release rates were higher in leaf than in shoots residues in both soil slopes. The incorporation of leaves and shoots in the soil of the olive grove contributed to its enrichment in certain nutrients such as N, K, Ca, and Mg. Soil organic carbon losses were compensated by the residue released soluble C compounds. The macroaggregates formed by fungal hyphae were not stable in water as Water Aggregate Stability tended to decline in the horizontal site and showed no change in the sloping site. The added amounts of N, P, and K by olive tree residues soil incorporation were 6.1, 0.4, and 7.2 kg ha^{-1} y^{-1} (sloping site) and 6.8, 0.3, and 8.8 kg ha^{-1} y^{-1} (horizontal site), respectively. These amounts are lower than the needed ones for olive trees (15–35 N, 8 P, ≤50 K kg ha^{-1} y^{-1}), so olive tree growers should use additional fertilization in order to have strong and productive olive trees.

1. Introduction

Soil incorporation of crop residues is essential for all farming systems, being more important for alternative farming systems, such as organic farming. It fills up soil organic matter pool. Organic matter is the main supplier of nutrients in soils and influences crop production through its high cation exchange and water holding capacities. It is very important to enrich soil organic matter using the soil incorporation of crop residues, especially in soils with low organic matter, as the soils in Greek agroecosystems [1]. Crop residues decomposition through nutrient release influences crop yield and minimizes fertilizer application [2,3], so it can help organic farmers who seek for different fertilization practices than inorganic fertilizers.

Crop residues decomposition rate and nutrient release are controlled by initial residue quality [4–6], environmental conditions [5,7–9] and the activities of soil organisms [10]. Farming systems management can also influence residue mass loss and nutrient release, since practices applied by organic growers increase microbial biomass C [11]. Soil microbial biomass is an ecological indicator of soil quality and it is responsible for the plant residues decomposition and the nutrient immobilization and mineralization [12]. This is a priority for organic farming since the plant production mainly depends on nutrient release through mineralization processes.

All over the world, there are approximately 10.2 million ha of olive groves [13]. Olive trees are well adapted to arid zones having low fruit production due to water scarcity, especially in areas with Mediterranean climate [14]. In the Mediterranean basin, olive tree (*Olea europaea* subsp. *Europaea*) is a native evergreen plant and an essential crop. Many olive groves are located either in moderate or in steep slope areas. In Greece, the olive grove fruit production is 2,080,815.4 Mg [13]. They cover 934,400 ha, 6% of which is under organic farming [15]. Organic growers are applying the regulations EC 834/2007, EC 889/2008, and EC 271/2010. Olive trees add considerable amounts of litter to the soils, 90% of which is leaves, being important in terms of fertilization [16].

The present work was conducted to investigate the decomposition of olive tree residues (leaves and shoots) and its impact on soil properties and microbial N-biomass in two sites, with different soil slope of an organic olive grove. The tested hypotheses were a) if the differences between the studied plant part residues (leaves and shoots) are related to their litter quality and origin, and b) if the soil properties and the

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Abbreviations

LH	Leaves in Horizontal site
LS	Leaves in Sloping site
Pp	Plant parts
SDa	Sampling Dates
SH	Shoots in Horizontal site
SOC	Soil Organic Carbon
SS	Shoots in Sloping site
WAS	Water Aggregate Stability
MWDD	Mean Weight-Diameter of Air-Dry Aggregates

microbial N-biomass are correlated with litter dynamics. At a secondary level, since several olive groves are located in slopping areas, differences between the two soil slopes, regarding the residue quality and decomposition, were explored. One practical implication of the results obtained would be the partial replacement of fertilizers with olive grove residues.

2. Materials and methods

2.1. Study area

The study area was an organic olive grove of 1 ha, located at Northern Greece (40°29′N, 22°55′E). The olive grove was characterized by a slope gradient ranging from 0 to 10%. The tree density was 200 individuals ha^{-1} in 7 m × 7 m quadratic spacing. The experiment was conducted from September 2010 to September 2011, at two sites of the olive grove with different sloping: on the hillslope of 8% (S) and to the no sloping (horizontal) field (H). Soil texture of the horizontal and the sloping site was clay loam (CL) and silty clay loam (SiCL), respectively. The soil physicochemical characteristics of both sites are presented in Table S1. Temperatures and rainfall data of the study area, according to the records of the Greek National Meteorological Service, are presented in Fig. S1.

The olive grove was planted with the variety "Chondrolia Chalkidikis" in 1988. The previous crop was wheat. The olive grove was managed organically since 1998. Farming practices were according to the European regulations of organic farming (EC 834/2007, EC 889/2008, and EC 271/2010). Sheep manure (250 kg ha^{-1}) was applied every 2–3 years.

The soil of both sites was not cultivated during the experimental period. Thereby weeds, such as *Abutilon theophrasti* Medicus, *Amaranthus blitoides* S. Watson, *Avena sterilis* L., *Circium arvense* (L.) scop, *Cynodon dactylon* (L.) Pers., *Papaver rhoeas* L. *Portulaca oleracea* L., *Sinapis avensis* L., and *Solanum eleagnifolium* L., grew profusely.

2.2. Description of the experimental set up

An area of 200 m^2 (10 m × 20 m) was selected in the centre of each site (horizontal, slopping). The distance between the experimental sites was 70 m. Plant parts (Pp) of four olive trees of each experimental site were collected in September 2010, dried and stored at 25 °C. The Pp derived from one year old shoots after the tree pruning. They were separated in leaves (L) and shoots (S). The mean dry weight of leaves per olive tree was 0.83 ± 0.07 kg and 0.69 ± 0.08 kg in the horizontal and in the sloping site, respectively, while the mean dry weight of annual shoots per olive tree was 3.23 ± 0.40 kg and 2.80 ± 0.33 kg in the horizontal and in the sloping site, respectively. Forty grams of Pp were placed in bags (30 cm × 18 cm) made of plastic net with 4.0-mm diameter holes. The annual shoots were cut to pieces with length 10–15 cm. Four litter treatments were used: leaves (LH) and shoots (SH) collected from the horizontal site and leaves (LS) and shoots (SS) from the sloping site. On 16 September 2010, litterbags with Pp were buried at a depth of 5 cm in four blocks (four replications) at each experimental site. Sixty-four litterbags [two Pp (L/S from the respective soil slope) x eight sampling dates x four replications] were used for each site. Litterbags of each treatment were carefully retrieved in October, November 2010, and in January, March, April, May, July, and September 2011. They were cleaned from any soil material adhering to the exterior of the bags. Caution was taken to avoid any physical losses of the litter inside the bag. Also, visible macro-fauna (e.g. earthworms, mature insects and larvae insects) and soil aggregates were removed from the discernible plant residues. At all sampling dates, a soil sample was also collected from a depth of 0–10 cm below each litterbag.

2.3. Litter physicochemical analysis

Samples of the raw material and leaf and shoot litter remaining in the bags at each sampling date were oven-dried at 65 °C for 72 h and then weighed. The dry material was ground in an electric mill to pass a

Table 1
Initial Cellulose + Lignin, C, N, P, K, Ca, Mg, Mn, Fe, and B concentrations and C/N, C/P, and N/P ratios in olive tree plant parts (means ± standard error in parentheses, n = 4) of the different Plant Parts.

Plant parts	Cellulose + Lignin	C	N	P	K	Ca	Mg	Mn	Fe	B	C/N	C/P	N/P
	(mg g^{-1})									(μg g^{-1})			
Sloping site													
Leaves	543.2^{a}	520	15.0^{a}	0.8^{a*}	8.3^{b}	10.7^{a}	1.1^{a}	0.05^{a*}	0.17^{b*}	22.97^{a}	34.6^{b}	654.5^{b}	18.9^{a}
	(5.3)	(3.3)	(0.2)	(0.0)	(0.3)	(0.4)	(0.1)	(0.0)	(0.0)	(0.7)	(0.6)	(14.5)	(0.2)
Shoots	660.8^{b}	519	7.3^{b}	0.5^{b*}	11.0^{a}	2.5^{b}	0.7^{b}	0.02^{b}	0.24^{a*}	16.12^{b}	70.8^{a}	1122.7^{a}	15.9^{b}
	(14.9)	(3.7)	(0.1)	(0.0)	(0.3)	(0.0)	(0.0)	(0.0)	(0.0)	(0.2)	(0.7)	(52.1)	(0.8)
Horizontal site													
Leaves	544.8^{a}	525	14.6^{a}	0.7^{a}	8.2^{b}	11.1^{a}	1.0^{a}	0.04^{a}	0.14^{a}	22.38^{a}	36.1^{b}	809.5^{b*}	22.5*
	(6.4)	(6.1)	(0.2)	(0.0)	(0.1)	(0.3)	(0.0)	(0.0)	(0.0)	(0.5)	(0.6)	(26.3)	(1.0)
Shoots	662.9^{b}	526	6.9^{b}	0.3^{b}	11.6^{a}	2.4^{b}	0.7^{b}	0.02^{b}	0.10^{b}	15.84^{b}	76.8^{a*}	1564.3^{a*}	20.4*
	(16.3)	(1.0)	(0.1)	(0.0)	(0.2)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.8)	(50.3)	(0.6)

For each soil slope, in each column, mean values followed by different exponential letters indicate statistical significant difference between plant parts according to the LSD criterion (leaves - shoots in each soil slope; P = 0.05).
*Indicates statistical significant difference between soil slopes according to the LSD criterion (leaves or shoots between soil slopes; $P \leq 0.05$).