Turkish Journal of Agriculture and Forestry
http://journals.tubitak.gov.tr/agriculture/
Research Article

Turk J Agric For
(2016) 40: 194-202
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doi:10.3906/tar-1502-87

Impact of long term soil management practices on the fertility and weed flora of an almond orchard

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Received: 16.02.2015 • **Accepted/Published Online:** 21.08.2015 • **Final Version:** 05.02.2016

Abstract: Soil management techniques can definitely influence soil quality, and particularly soil organic matter content, biological complexity, structure, and water holding capacity. Tillage may also have a negative effect by increasing erosion and organic matter oxidation processes, which have unavoidable repercussions on fertility. The objective of the current research was to test the effects of five different management techniques applied for 35 years on a rain-fed almond grove (*Prunus amygdalus* Batsch) in a hot-dry environment on some physicochemical, hydrological, and biological parameters. The following soil management techniques were compared: no-till (NT), with weed control by preemergence herbicides; NT, with chemical weed control by foliar herbicides; NT, with weed control by mowing; tillage, with sowing and field bean green manuring; and conventional tillage. The current survey supplied interesting results, considering the typical soil and climate conditions of the tested area (southern Italy), characterized by high summer temperatures, low rainfall, clay loam soil, and an arable layer of 0.40 m. The most influenced values are those concerning the organic matter due to the supply of biomass resulting from weed mowing or field bean green manuring. The NT system with a single mowing in the spring seems to induce a higher water holding capacity (–15,000 hPa) as compared with the traditionally plowed soil. The biomass incorporation through field bean green manure resulted in a higher available water content (11.82%). All practices favoring an increase in organic matter induced a subsequent increase of microbial biomass content. The number of existing families and species of weed flora was largely influenced by different soil management techniques, as shown by the greater adaptation of grasses to the management practices involving weed control by foliar herbicide or mowing, and of several species associated with the technique involving the application of preemergence herbicides. In general, the almond orchard management involving minimum soil disturbance and the supply of biomass resulting from specially sown cover crops or weed development have shown substantial benefits to the physicochemical, hydrologic, and biologic soil properties.

Key words: No-till, conventional tillage, biomass incorporation, microbial biomass, hydrologic parameter

1. Introduction

Soil management techniques can definitely influence soil quality, acting especially on soil organic matter content, biological complexity, structure, and water holding capacity (Kladivko, 2001). In the rain-fed orchards of the semiarid Mediterranean agrosystems, where soil conservation is one of the major agronomic challenges (Ramos et al., 2011), soil management is limited by the particular climate conditions, characterized by water deficits in the spring–summer period.

Therefore, agricultural practices should be aimed at increasing water availability and reducing evapotranspiration losses. Tillage before the rainy period is a common practice to facilitate water supply in the soil profile, but may be more harmful for the biological component and organic matter dynamics than no-till or grass planting (Hernandez, 2005). The use of cover crops and reduced tillage may increase soil organic matter and water infiltration (Roberson et al., 1991). In particular, plant cover is a major soil quality factor not only for conservation and to increase organic matter (Vance, 2000), but also and especially as a source of microorganisms with C and energy through root exudates and plant residues (Ramos et al., 2011). On the other hand, all changes in the activity and composition of the soil microbial component, often induced by these agricultural practices, may in turn cause variations in soil fertility, thus increasing the supply of nutrients to plants (Crecchio et al., 2007).

The study of single specific soil microorganisms may be useful in some cases (rhizobia, mycorrhiza), but

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it does not supply any information on the functioning of the soil ecosystem. This is because the processes that take place in the soil depend on the interactions among different microorganisms. Consequently, it may be more useful to consider the soil microbial population as a single undifferentiated unit (Stockdale and Brookes, 2006). The soil microbial biomass accounts for about 1%–3% of the organic carbon potential (Martens, 1995); it acts as a small and labile reservoir of the main organic compounds and as a catalyst in nutrient transformations, thus playing a vital role in geochemical cycles and ecosystem functioning (Smith et al., 1995). Tillage contributes through aeration to organic matter oxidation, reducing not only organic carbon, but also all other soil minerals that are not bound to organic matter and that may be easily washed out by leaching. In soils subjected to mechanical disturbance the decline of organic matter unavoidably leads to a reduction in natural porosity and an increase of soil bulk density, which may decrease infiltration capacity and hydraulic conductivity. Especially in dry environments, a key factor of fertility is the amount of soil organic matter that depends both on crop residues and the root biomass left by crops in the soil. In short, the no-till or minimum tillage practices satisfy the needs of "conservative farming", in which the main objectives are soil protection and maintaining its functions (Pisante et al., 2012).

In southern Italy, where the climate is characterized by high summer temperatures and low rainfall, almond growing is quite widespread in marginal areas, where irrigation water is not available and good soil management is essential for increasing crop yields.

To provide further insights into this area, this work aimed to test the effects of five different management techniques applied for 35 years on a rain-fed almond grove in a hot-dry environment on some physicochemical, hydrological, and biological parameters.

2. Materials and methods

2.1. Experimental details

The current research was conducted within a long-term study initiated in October 1976 on an almond (*Prunus amygdalus* Batsch) variety collection plot of the experimental farm "La Piantata", sited in Bari (close to Bitetto) in southern Italy, at an altitude of 126 m a.s.l. with the following GPS coordinates: 41°2′30″N and 4°18′20″E. Plant spacing was 7 × 7 m and the plants were rain-fed. The soil was clay-textured (Lithic Ruptic–Inceptic Heploxeralf, USDA classification; Soil Survey Staff, 2010) and 0.40 m deep. The climate is classified as "accentuated thermo-Mediterranean" according to the classification of UNESCO–FAO Maps, and characterized by hot and dry summers and moderately rainy winters. At the beginning of the trial soil samples were taken from the soil (about 0.40 m deep) in each elementary plot and were tested. The measured soil parameters were homogeneous across the whole test area; Table 1 shows the mean values of the main physical, chemical, and hydrologic characteristics.

Table 1. Physicochemical soil properties at the start of the trial (1976).

Parameters		Units	Values
Particle-size analysis			
Total sand	2 > ø > 0.02 mm	(g kg^{-1})	312
Silt	0.02 > ø > 0.002 mm	(g kg^{-1})	301
Clay	ø < 0.002 mm	(g kg^{-1})	387
Chemical properties:			
Total nitrogen (Kjeldahl method)		(g kg^{-1})	1.7
Available phosphorus (Olsen method)		(mg kg^{-1})	41.0
Exchangeable potassium ($BaCl_2$ method)		(mg kg^{-1})	348.0
Organic matter (Walkley–Black method)		(g kg^{-1})	23.7
Total limestone (Dietrich–Fruhling method)		(g kg^{-1})	2.4
Active limestone		(g kg^{-1})	0.7
ECe (saturation extract electrical conductivity)		(dS m^{-1})	0.31
pH			7.8
Cation exchange capacity ($BaCl_2$ method)		(meq 100 g^{-1})	30.10
Hydrologic properties			
Field capacity		(g kg^{-1} d.w.)	367
Wilting point (–1.5 MPa)		(g kg^{-1} d.w.)	185
Bulk density		(t m^{-3})	1.2

The following soil management techniques were compared over a 35-year period:

A. No-till (NT), with weed control by preemergence herbicides;

B. NT, with chemical weed control by foliar herbicides;

C. NT, with weed control by mowing and green mulching effect;

D. Tillage with sowing and field bean (*Vicia faba* L. var. *minor* Beck) green manuring;

E. Conventional tillage.

A randomized block experimental design with 5 replicates was adopted in the field, with 147 m^2 elementary plots of 3 almond plants (cultivar Filippo Ceo) of the same age (with 7 × 7 m spacing).

In technique A, preemergence herbicide was applied every year in November using different active substances according to the availability of commercial formulates, in order to both prevent their soil buildup and the natural selection of weeds resistant to the applied chemicals. After 1991, due to the market withdrawal of some preemergence herbicides, oxadiazon + glyphosate was used. In technique B, the application of foliar herbicide or mowing was carried out in May, and the dry mass of plants was left on the ground and used as mulch. The active substances used for techniques A and B in different years are shown in Table 2. In technique C, the cover was ensured in winter by wild flora, whereas in late spring weeds were controlled mechanically and the plant mass was left on the same plots and used as mulch. In technique D, tillage was done in October, field bean sowing in November, and green manuring in April. Lastly, in technique E, four tillage works per year were performed in October, February, April, and July. The annual fertilizer application rates were 80, 60, and 70 kg ha^{-1} respectively, for N, P_2O_5, and K_2O.

2.2. Soil physicochemical properties

In the autumn of 2011, before herbicide application and tillage, 6 soil samples were randomly taken from each plot at 0–0.40 m depth and tested for their physical, chemical, and biological properties.

The analyses carried out on soil samples concerned the following: electrical conductivity (ECe) and pH of the saturation extract; total nitrogen (N), determined using the Kjeldahl method as described by Duchaufour (1970); available phosphorous (P), determined using the method of Watanabe and Olsen (1965) extracting P with 0.5 M solution of $NaCO_3H$ (Olsen and Dean, 1965) and photocolorimetric (absorbance at 650 nm) determination of ammonium phosphomolybdate; exchangeable potassium (K), determined using a solution of barium chloride and triethanolamine (TEA) and adjusting pH to 8.2 (100 g of $BaCl_2$ $2H_2O$ with 22.5 mL of TEA adjusted to pH 8.2 using HCl 1 M) to estimate K^+ concentration by atomic absorption spectrophotometer; organic matter, measured using the modified Walkley–Black method (Jackson, 1973); total organic carbon (TOC), obtained by oxidation at 170 °C, with potassium dichromate in the presence of sulfuric acid (the excess potassium dichromate was measured by Mohr's salt titration) (Yeomans and Bremner, 1988); total extracted carbon and humified carbon (HA + FA = humic and fulvic acids) according to Sequi et al. (1986) and Gucci et al. (2012); and cation exchange capacity, obtained with the $BaCl_2$ method (Pratt and Holowaychuk, 1954).

Table 2. Active substance of herbicides in the soil management A (preemergence herbicides) and B (foliar herbicides) for each year of the trial.

Soil management A		Soil management B	
Years	Herbicides	Years	Herbicides
1976–1987	Diuron + Bromacile	1976–1987	Diquat
1988	Bromacile	1988–2000	Paraquat
1989	Propyzamide + Simazine	1989	Glifosate
1990	Diclhorenil + Tiobezamide	1990	Paraquat
1991	Chlorprofam + Diuron	1991	Paraquat
1992–1999	Glifosate + Simazine	1992–1999	Paraquat
2000–2003	Oxadiazon + Glifosate	2000–2003	Glifosate
2004–2008	Oxifluorfen	2004–2008	Glufosinate amm.
2009–2011	Oxadiazon + Glifosate	2009–2011	Glifosate

2.3. Hydrological properties

In order to determine the soil water retention curve, six undisturbed soil cores were collected from each plot by gently hand-hammering stainless steel cylinders (with a height of 5 cm and a diameter of 8 cm) into the surface horizon of the soil after the first few centimeters (<3 cm) had been removed. For the points ranging from saturation (0 hPa) to field capacity (–333 hPa) and the wilting point (–15,000 hPa), pressure membranes (in polyamide with pores Ø of 0.45 µm) and Richards' plates were used.

2.4. Analysis of microbial components

To assess the possible variations induced on microbial components, in April 2012 the microbial biomass carbon was calculated for three replicates for each treatment. The measure was carried out by the fumigation-extraction method (Vance et al., 1987) slightly modified, namely by a 50% reduction in sample size (25 g of dry weight) and in the volume of K_2SO_4. The microbial biomass carbon was calculated by the following equation:

C biomass = Ec × 2.64 (Vance et al., 1987),

where Ec is the additional flux of organic carbon (µg C g^{-1} of soil) extracted by fumigation.

The significance of differences in terms of biomass between different treatments was assessed by ANOVA and Duncan's test. The simple linear correlation coefficient (r) between the microbial biomass and chemical parameters was also calculated.

2.5. Analysis surveys of weed flora

Between 2010 and 2012 field surveys were carried out in October and May, with a view of assigning percentage of ground cover to each weed species based on visual estimates. The data obtained from the field surveys were used to calculate the number of existing families and species as well as the Shannon diversity index (Shannon and Weaver, 1949), and to check the degree of diversity between the species found for each soil management technique. The Shannon diversity index value was calculated in accordance with Armengot et al. (2013). Those data were then submitted for ANOVA; the means were compared using Duncan's test.

3. Results

After 35 years of different soil management practices, the results showed marked differences in terms of physicochemical, hydrologic, and biologic properties.

3.1. ECe, pH, organic matter, total nitrogen, available phosphorus, and exchangeable potassium

Table 3 shows that under different soil management conditions, no significant differences were observed between the electrical conductivity and the pH of the saturation extract (equal to 0.29 dS m^{-1} and 7.8, respectively), maybe due to the high buffering capacity of soils, in accordance with Cucci et al. (2008). The organic matter contents and total nitrogen were highest in the C and D plots, intermediate in the B plot, and minimum in the A and E plots; these were obviously influenced by the organic matter applied by field bean green manure or the biomass of wild flora. Moreover, the soils under treatments C and D showed higher contents of humic and fulvic acids, with values of 5.1 and 4.6 g kg^{-1}, thus proving that the soil application of organic matter also induces an increase in more stable humus. In different soil management practices, the cation exchange capacity values showed the same dynamics as the organic matter. The variations in available phosphorus and exchangeable potassium were negligible and not statistically different between the various treatments (Table 3). Further analyses to check for phosphorus and potassium availability were not carried out because the soil was well supplied with both nutrients.

3.2. Hydrological constants and water holding capacity

Results showed that under moisture conditions above field capacity (Ψ > –316 hPa) the treatment with mowing (C), relative to a matric potential of –10 hPa (Table 4), induced an increase of water holding capacity as compared with

Table 3. Influence of different soil management practices on the physicochemical soil properties.[1]

Soil management	EC_e	pH	OM	N	TEC	HA+FA	CEC	P	K
	(dS m^{-1})		(g kg^{-1})				(meq 100 g^{-1})	(mg kg^{-1})	
NT preem. herb.	0.28 a	7.8 a	26.8 C	1.7 C	8.8 c	3.1 b	29.98 c	57.0 a	371.0 a
NT foliar herb.	0.29 a	7.8 a	32.0 B	2.0 B	10.1 b	3.6 b	31.12 b	53.0 a	351.0 a
NT mowing	0.28 a	7.9 a	39.7 A	2.5 A	10.2 b	5.1 a	31.88 a	56.0 a	366.0 a
Till. green man.	0.30 a	7.7 a	36.4 A	2.4 A	13.8 a	4.6 a	31.61 a	59.0 a	372.0 a
Conv. till.	0.29 a	7.9 a	27.1 C	1.7 C	12.2 ab	2.7 b	30.21 c	54.0 a	345.0 a

NT: no-till; ECe: electrical conductivity of the saturation extract; OM: organic matter; N: total nitrogen; TEC: total extracted carbon; HA+FA: humified carbon; P: available phosphorus; K: exchangeable potassium; CEC: cation exchange capacity.

[1] The values without any letter in common are significantly different at P < 0.01 (capital letter) or at P < 0.05 (lower case letter) (with Duncan's test).

Table 4. Influence of different management techniques on water content (% dry soil) as related to the soil matric potential.[1]

Soil	Matric potential (hPA)				
management	0	–10	–60	–316	–15,000
NT preemer. herb.	38.01 D	34.30 C	31.40 D	27.92 D	19.80 B
NT foliar herb.	38.06 D	34.72 B	32.33 C	29.25 C	19.38 C
NT mowing	41.84 B	39.93 A	34.41 A	29.83 B	20.09 A
Till. green man.	43.17 A	34.00 D	33.51 B	30.35 A	18.53 D
Conv. till.	39.43 C	34.78 B	31.38 D	28.25 D	18.11 E

NT: no-till. [1]The values without any letter in common are significantly different at $P < 0.01$ (with Duncan's test).

the other treatments. Unger et al. (1991) also found that conservation farming methods can result in higher water holding capacity, higher organic matter content, and higher infiltration rate. At field capacity, the highest soil moisture content (30.35% dry soil) was found on the soil with field bean green manure (treatment D), due maybe to the presence of the crop that had improved the distribution of soil macro- and microporosity. The percentage of available water on a dry weight basis (Figure 1) was highest with field bean green manuring (treatment D), but statistically different only from the data obtained for no-tilled and chemically weeded plots by preemergence herbicides (treatment A). These results show more or less the same pattern as the organic matter content (Table 3); in particular, in treatment A, the organic matter content was lowest.

3.3. Microbial biomass

ANOVA showed a significant difference between all treatments ($P < 0.05$) (Figure 2), pointing out that different treatments influence the availability of nutritional substrates to microorganisms, and therefore the C content of the microbial biomass. The highest value of microbial biomass was found in the plots supplemented with organic matter, while the lowest value was observed in the plot treated with preemergence residual herbicides (Figure 2). More specifically, by comparing the two treatments supplied with plant material, it emerged that in the treatment in which organic matter was supplied to the soil by mowing (C), the microbial biomass value was higher than in the treatment where the plant material was incorporated into the soil by green manure (D).

Statistical analysis showed a positive correlation between the microbial biomass and the content of organic matter, TOC, and total N (Table 5).

3.4. Autumn and spring weed surveys

In the autumn surveys, the total ground cover was highest in NT, foliar herbicides (56.8%), followed by NT, mowing (52.3%), and tillage, green manuring (54.4%); the lowest

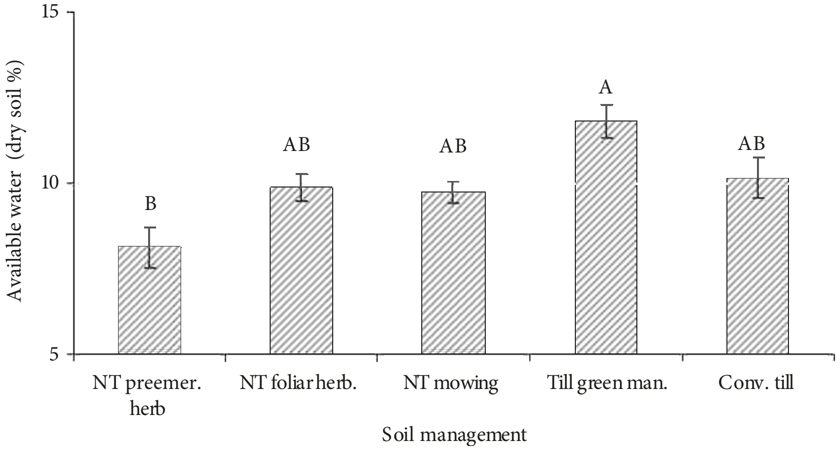

Figure 1. Influence of different soil management techniques on the soil available water. NT: no-till. The values without any letter in common are significantly different at $P < 0.01$ (with Duncan's test).

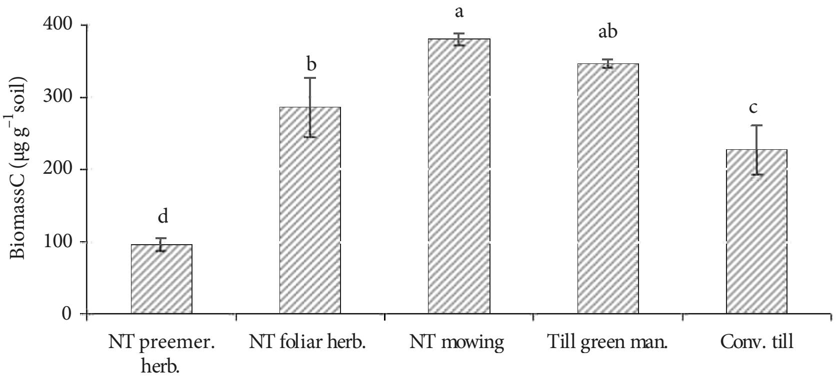

Figure 2. Influence of different soil management techniques on microbial biomass carbon content. NT: no-till. The values without any letter in common are significantly different at $P < 0.05$ (with Duncan's test).

Table 5. Pearson product-moment correlation coefficient between the microbial biomass and the soil properties.

	OM (g kg^{-1})	N (g kg^{-1})	TOC (g kg^{-1})	MB
OM (g kg^{-1})	1			
N (g kg^{-1})	0.99	1		
TOC (g kg^{-1})	0.98	0.96	1	
MB	0.93	0.92	0.93	1

OM: organic matter; N: total nitrogen; TOC: total organic carbon; MB: microbial biomass.

ground cover was found in NT, preemergence herbicides. In the same survey, the mean number of botanical families and species observed was statistically lower in the chemical weed control treatments. The highest Shannon index (1.9) was calculated in the treatment with conventional tillage that was, however, statistically different only from the value observed in treatment NT, preemergence herbicides (1.3) (Table 6).

Table 6. Effects of different soil management techniques on weeds ground cover, number of families, species botanical and Shannon index.[1]

Soil management	Autumn survey				Spring survey			
	Ground cover (%)	Families (n m^{-2})	Species (n m^{-2})	Shannon index	Ground cover (%)	Families (n m^{-2})	Species (n m^{-2})	Shannon index
NT preem. herb.	2.7 c	4.2 c	4.8 c	1.3 b	19.0 d	4.5 c	6.2 c	0.6 d
NT foliar herb.	56.8 a	9.2 b	9.2 b	1.5 ab	89.0 a	9.02 ab	15.5 a	1.7 bc
NT mowing	52.3 a	11.0 ab	13.2 a	1.6 ab	90.0 a	7.0 b	11.2 b	1.5 c
Till green man.	54.4 a	12.2 a	14.8 a	1.6 ab	41.0 c	8.7 ab	12.2 ab	2.1 ab
Conv. till	30.9 b	11.2 ab	13.0 a	1.9 a	72.0 b	9.05 ab	14.5 ab	2.02 ab

[1] The values without any letter in common are significantly different at $P < 0.05$ (with Duncan's test).

In the spring surveys the statistically highest mean total cover was observed in the treatments of weed control by NT foliar herbicides (89.0%) and by mowing (90.0%), while the lowest was found in the treatment NT, preemergence herbicides (19.0%). The highest mean number of botanical species was found in the plots submitted to treatment B (15.5 m^{-2}), which was statistically different only from what was found for treatments NT mowing (11.2 m^{-2}) and NT, preemergence herbicides (6.2 m^{-2}). The statistically lowest mean number of botanical families (4.5) and Shannon index values (0.6) were estimated for the treatment NT, preemergence herbicides.

4. Discussion

The survey supplied interesting results, considering the typical soil and climate conditions of the tested area, characterized by high summer temperatures, low rainfall, clay loam soil (38.7% of dry soil), and an arable layer of 0.40 m.

The most influenced values were those concerning the organic matter and humified carbon (humic and fulvic acids) contents, due to the supply of biomass resulting from the mowing of weeds or the field bean green manuring; this is in accordance with what is reported in other studies (Galantini and Rosell, 2006). The different weed management techniques have induced marked differences in terms of weed ground cover, both in autumn and springtime. In particular, the systems based on postemergence chemical weed control or chopping resulted in a significant ground cover and a subsequent conspicuous biomass. It was interesting to find that when weeds or the cover crop were allowed to grow in the periods in which they were less competitive, and when they were removed after they had developed a conspicuous biomass, the soil had a much higher humified carbon content (humic and fulvic acids) as compared with the traditionally plowed treatment. This does confirm that the organic fertilization with fresh biomass incorporated into the soil not only supplements the soil with organic matter, but also modifies the rates of its humification and/or decay by increasing the most stable humus; this effect improves soil physical properties, water control, and the habitat of microflora and microfauna; it favors enzyme activity and improves the nutritional state (Sequi et al., 1986). The use of residual herbicide did not cause any damage to the soil; however, it did not produce significant beneficial effects on the physicochemical soil properties, maybe because of inadequate biomass development.

The no-tillage system with a single mowing (treatment C) in the spring seems to induce a higher water holding capacity (–15,000 hPa) as compared with the traditionally plowed soil. The biomass incorporation through field bean green manure resulted in higher available water content (11.82%). The investigated management practices also induced a differentiation in the microbial biomass content. Tillage was not shown to be a discriminant factor on the microbial biomass since there was no univocal response of treatments to its presence or absence. On the contrary, it is reported in the literature that the C content of the microbial biomass is sensitive to the variations induced by the type of tillage. In particular, Angers et al. (1993) found that no-tillage leads to a significant increase of microbial C content in the soil top layer, whereas Entry et al. (1996) reported lower biomass values in no-tilled soils that they justified by different climate conditions and texture as compared with the previous study. However, treatments A, B, and C did not differ from treatments D and E only in tillage, but also in other aspects that might have partly concealed the effect of tillage on the microbial biomass. All practices favoring an increase in organic matter induced a subsequent increase in the microbial biomass content, as reported by Singh et al. (2007) and Banu et al. (2004). The lack of tillage in treatment C as compared with D might have caused, in the top layers, more favorable conditions for a natural evolution of the organic matter content and humification. This resulted in greater structural stability and increased microbial biomass as well. These data are in accordance with what was reported in a study by Balota and Auler (2011), who drew attention to the influence of different methods of soil cover management on the microbial biomass. Similar to our work, these authors showed that with the same intake of plant material supply, the reduction of soil disturbance may improve microbial activity. They also highlighted the role of the roots and the existing root exudates in the mowing practice. Singh et al. (2007) stressed the importance of the chemical composition and the rates of decay of the inputs applied to the soil on the microbial biomass. Patel et al. (2010) also showed a significant correlation with other chemical and physical soil properties, such as soil moisture, clay content, and pH.

Moreover, the specific composition of weeds was largely influenced by different soil management techniques, as shown by a greater adaptation of grasses to the forms of management involving weed control by the foliar herbicide or mowing, and of the several species associated with the technique involving the application of preemergence herbicides. The first effect is important because the species belonging to the grasses are able to produce a conspicuous biomass and possess fasciculate rooting systems that can improve soil porosity. However, they have a strong competitive ability against cultivated species. The calculated level of flora diversity was lower in the preemergence herbicide treatment, which resulted in the selection of fewer species, with some prevailing over the others; this phenomenon was more accentuated during the spring surveys. In general, the almond orchard management involving the minimum soil disturbance and the supply of biomass derived from the green manure of field bean sown in November or from weed development showed substantial benefits to the physicochemical, hydrologic, and biologic soil properties. Moreover, they ensured a good floral balance in terms of species assortment. Although the confirmation needs data relating to the historical evolution of various wild species that are not provided in this experiment, it may be assumed that the community of spontaneous crops established in the almond orchard and the physicochemical soil properties influence each other, turning towards an optimal situation that constitutes a potential advantage if the function of weeds for agroecosystem stability is considered. The no-till of grass-covered soil with a single mowing in the springtime induced a higher water holding capacity as compared with the traditionally plowed soil with the biomass left on the ground for mulching. Incorporating the biomass through field bean manuring resulted in higher available moisture.

It should be emphasized, however, that, especially in arid countries, weeds may strongly compete for water resources with the cultivated plant; therefore, they should be properly managed. Integration among the compared techniques, in particular field bean green manure, mowing, or postemergence chemical control, may be suggested as a solution that could both satisfy agroenvironmental needs and protect crop revenue.

References

Angers DA, Bissonnette N, Legere A, Samson N (1993). Microbial and biochemical changes induced by rotation and till in a soil under barley production. Can J Soil Sci 73: 39–50.

Armengot L, José-María L, Blanco-Moreno JM, Bassa M, Chamorro L, Sans FX (2013). Weed harrowing in organically grown cereal crops avoids yield losses without reducing weed diversity. Agron Sustain Dev 33: 405–411.

Balota EL, Auler PAM (2011). Soil microbial biomass under different management and tillage systems of permanent intercropped cover species in an orange orchard. R Bras Ci Solo 35: 1873–1883.

Banu NA, Singh B, Copeland L (2004). Microbial biomass and microbial biodiversity in some soils from New South Wales, Australia. Soil Res 42: 777–782.

Crecchio C, Curci M, Pellegrino A, Ricciuti P, Tursi N, Ruggiero P (2007). Soil microbial dynamics and genetic diversity in soil under monoculture wheat grown in different long–term management systems. Soil Biol Biochem 39: 1391–1400.

Cucci G, Lacolla G, Caranfa L (2008). Improvement of soil properties by application of olive oil waste. Agron Sustain Dev 28: 521–526.

Duchaufour P (1970). Precis de Pedologie. Paris, France: Masson et Cie (in French).

Entry JA, Reeves DW, Backman CB, Raper RL (1996). Influence of wheel traffic and tillage on microbial biomass, residue decomposition and extractable nutrients in a Coastal Plain Soil. Plant Soil 180: 129–137.

Galantini JA, Rosell RA (2006). Long-term fertilization effects on soil organic matter quality and dynamics under different production systems in semiarid Pampean soils. Soil Till Res 87: 72–79.

Gucci R, Caruso G, Bertolla C, Urbani S, Taticchi A, Esposto S, Servili M, Sifola M, Pellegrini S, Pagliai M et al. (2012). Changes of soil properties and tree performance induced by soil management in a high-density olive orchard. Eur J Agron 41: 18–27.

Hernandez AJ, Lacasta C, Pastor J (2005). Effects of different management practices on soil conservation and soil water in a rainfed olive orchard. Agric Water Manage 77: 232–248.

Jackson ML (1973). Soil Chemical Analysis. Englewood Cliffs, NJ, USA: Prentice Hall.

Kladivko EJ (2001). Tillage systems and soil ecology. Soil Till Res 61: 61–76.

Martens R (1995). Current methods for measuring microbial biomass C in soil: potential and limitations. Biol Fertil Soils 19: 87–99.

Olsen SR, Dean LA (1965). Phosphorus. In: Black, CA, editor. Methods of Soil Analysis. Part 2. Madison, WI, USA: American Society of Agronomy, pp. 1044–1045.

Patel K, Nirmal Kumar JI, Kumar RN, Kumar Bhoi R (2010). Seasonal and temporal variation in soil microbial biomass C, N and P in different types land uses of dry deciduous forest ecosystem of Udaipur, Rajasthan, western India. Appl Ecol Env Res 8: 377–390.

Pisante M, Stagnari F, Grant CA (2012). Agricultural innovations for sustainable crop production intensification. Italian Journal of Agronomy 7: 300–311.

Pratt PF, Holowaychuk N (1954). A comparison of NH_4OAc, $Ba(OAc)_2$, and buffered $BaCl_2$ method of determining cation exchange capacity. Soil Sci Soc Am Pro 18: 365–368.

Ramos ME, Robles AB, Sánchez-Navarro A, González-Rebollar JL (2011). Soil responses to different management practices in rainfed orchards in semiarid environments. Soil Till Res 112: 85–91.

Roberson EB, Sagir S, Firestone MK (1991). Cover crop management of polysaccharide-mediated aggregation in an orchard soil. Soil Sci 55: 734–739.

Sequi P, De Nobili M, Leita L, Cercignani G (1986). A new index of humification. Agrichimica 30: 175–179.

Shannon CE, Weaver W (1949) The Mathematical Theory of Communication. Urbana, IL, USA: University of Illinois Press.

Singh S, Ghoshal N, Singh KP (2007). Variations in soil microbial biomass and crop roots due to differing resource quality inputs in a tropical dryland agroecosystem. Soil Biol Biochem 39: 76–86.

Smith J, Halvorson JJ, Bolton H (1995). Determination and use of a corrected control factor in the chloroform fumigation method of estimating soil microbial biomass. Biol Fertil Soils 19: 287–291.

Soil Survey Staff (2010). Keys to Soil Taxonomy. 11th ed. Washington, DC, USA: USDA NRCS.

Stockdale EA, Brookes PC (2006). Detection and quantification of the soil microbial biomass–impacts on the management of agricultural soils. J Agr Sci 144: 285–302.

Unger PW, Stewart BA, Parr JF, Singh RP (1991). Crop residue management and tillage methods for conserving soil and water in semi-arid regions. Soil Till Res 20: 219–240.

Vance ED (2000). Agricultural site productivity: principles derived from long-term experiments and their implications for intensively managed forests. Forest Ecol Manag 138: 369–396.

Vance ED, Brookes PC, Jenkinson DS (1987). An extraction method for measuring soil microbial biomass C. Soil Biol Biochem 19: 703–707.

Walkley A, Black IJ (1934). An examination of the Degtjareff method for determining organic carbon in soils: effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci 63: 251–263.

Watanabe FS, Olsen SR (1965). Test of ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Sci 29: 677–678.

Yeomans JC, Bremner M (1988). A rapid and precise method for routine determination of organic carbon in soil. Commun Soil Sci Plan 19: 1467–1476.