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Comparative effects of organic and conventional apple orchard management on soil chemical properties and plant mineral content under Mediterranean climate conditions

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Abstract

The effects of conventional and organic management systems on soil chemical properties and leaf nutrients under Mediterranean conditions were studied over a 2-year period on adjacent commercial apple orchards in Southern Greece. The soil in both orchards was characterised as a clay loam–clay and was uniform in morphological and physical properties. The results indicated no significant differences in soil chemical properties between the different management systems, including soil organic matter (SOM), pH, cation exchange capacity (CEC) and C/N ratio. However, soil samples from the conventional orchard exhibited significantly higher values ($p < 0.01$) of electrical conductivity (EC) and higher concentrations of K, Ca, Na, Cu and Zn, which were likely the result of chemical fertiliser application. Despite the fact that organic systems promote the accumulation of soil organic matter and fertility over time through the use of organic sources, in our study, the SOM values declined, suggesting that the type and the rate of organic matter input in the organic orchard were insufficient. The leaf nutrients, with the exception of P and Ca, were within the sufficiency range in both management systems. The present findings did not provide evidence of major differences in the leaf macronutrient content between conventionally and organically grown apple trees. Nevertheless, our leaf analysis revealed higher concentrations of Zn in the conventionally grown trees and opposite results for Cu, probably due to the extensive use of copper-containing fungicides in organic orchards in Greece.

Keywords: soil organic matter, organic farming, leaf nutrients, apple orchard

1. Introduction

Organic farming has gained ground worldwide and has expanded in the last decade due to environmental, economic and social concerns (Araujo *et al.,* 2008). Organic farming has been proposed as an alternative agricultural system to help solve the environmental problems arising from conventional management, such as frequent pesticide applications, excessive inputs of chemical fertilisers, soil degradation and the presence of pesticide residues in food (Stockdale *et al.,* 2001). In the European Union, organic production systems have been increasing with an annual growth rate of 26% and currently play an increasingly important role in agriculture (Herencia *et al.,* 2008a).

The transition from conventional to organic farming often results in significant changes in the soil chemical properties and is thus likely to modify the processes that affect soil fertility. These changes also affect the mineral availability to crops either directly by contributing to nutrient pools or indirectly by influencing the soil environment. Studies comparing conventional and organic farming systems have shown an increase in soil organic matter (SOM) and mineral contents in organically managed soils (Herencia *et al.,* 2008b). Nevertheless, there is still inconsistent data on the effect of different management systems on soil properties. According to Gosling and Shepherd (2005), the comparison of organically and conventionally managed systems is rather complicated and difficult due to the great overlap in management techniques.

As suggested by Marinari *et al.* (2006) and Vakali *et al.* (2011), management systems react differently under different climatic regimes; thus, it is important to evaluate the effect of organic management on the soil properties and plant mineral nutrition under a wide range of climatic regimes. According to Canali *et al.* (2009), there is insufficient data on the simultaneous comparison between the two farming systems under Mediterranean conditions.

Previous findings have shown that the marketable defect-free apple fruits produced from organically and conventionally grown trees of the study area exhibited similar quality characteristics (Roussos and Gasparatos, 2009). Because the published data on the soil chemical properties and plant mineral content show no consistent trends that may be attributed to different management systems, further studies are necessary to obtain more information on this topic. Therefore, the aim of this study was to evaluate the effects of organic management practices on the soil chemical properties of the 0- to 30-cm soil depth and on the apple orchard mineral content through a comparison with a conventional system under the Mediterranean climate of Southern Greece.

2. Materials and methods

2.1. Orchard site and cultivation practices

As apple (*Malus domestica* Borkh.) is the fourth most important tree crop in Greece, following olive, citrus and peach (Vasilakakis, 2010), the present study was focused on commercial apple orchards. The experiment took place in adjacent commercial, irrigated apple orchards, one organic and one conventional, each approximately 1.0 ha in size, to avoid any pedoclimatic impact on the possible differences detected. The variety used was “Starking Delicious” grafted onto MM. 106 rootstock. The orchards were typical of the region in which they were located (e.g., cultivar, tree training system, planting distances) and were cultivated under conventional (C) and organic (O) agricultural practices. The two farms were located in the village of Velina, Korinthia County, Greece (Lat 37 ° 59’ 0’’, Long 22 ° 34’ 0’’) at an altitude of 950 m. The meteorological data for the last 15 years were collected by a nearby official meteorological station. Based on these data, the region is characterised as a typical Mediterranean climate, with the rainy season occurring mainly during the autumn and winter months, whereas the summer is quite dry. The mean annual precipitation is 476 mm. The mean annual temperature in the region is 17.5 ^{o}C, with a mean minimum temperature of 11.2 ^{o}C and a mean maximum temperature of 22.2 ^{o}C.

The conventional orchard was treated with a non-selective herbicide (glyphosate) within the rows and the soil tillage between the rows. Soil tillage was implemented with a rotary tiller only when fertilisers were incorporated into the soil at a depth of approximately 20-30 cm. Fertilisation was applied using 11-15-15 (N-P-K) fertiliser at a dose rate of 4-5 kg per tree biannually during the middle of winter and with calcium ammonium nitrate (at a dose rate of 1-2 kg per tree) twice every spring. Additional fertilisation was applied in the form of foliar treatments of soluble fertilisers (21-21-21, N-P-K plus 0.025% Mn, 0.0215% Fe, 0.016% Mg, 0.015% Cu, 0.011% Zn, 0.019% B, 0.007% Mo and 0.002% Vitamin B1, all expressed as w/w) during the early (one application when fruit diameter was up to 20 mm) and last stages of fruit growth (one-two applications when fruit diameter was approximately 80-90% of the final size).

In the organic orchard, sheep manure was applied during the first year of conversion from conventional to organic cultivation (six years before the main experiment took place) at a dose rate of 20 kg per tree. One pass with a rotary tiller at a depth of approximately 20-30 cm was performed at least three times per year (February, July and October) to control the weed population and incorporate the plant residue into the soil. Weeds, pruning residue and non-marketable or dropped fruits and the fresh residue of organically grown vegetable crops were incorporated into the soil and served as organic amendments (i.e., green manure). The mean mass of this type of plant residue was estimated to be approximately 20-30 kg per year per tree and was distributed over a period of nine months (February to November), with the major organic additions being in February, July and October.

The plant protection program included the use of herbicides (glyphosate- applied once in March and once in August), insecticides (chlorpyrifos-methyl and cypermethrin from late spring to early summer), miticide (fenpyroximate in early summer) and fungicides (fenbuconazole and copper oxychloride in spring and summer) in the conventional orchard. In contrast, the farmer of the organic orchard used fungicides (copper hydroxide in late spring and early autumn), insect traps (for monitoring) and biological pest control products (Carpocapsa and *Adoxophyes orana* granulosis viruses and *Bacillus thuringiensis* during the summer). A detailed description of the crop protection program of the two management systems is reported by Roussos and Gasparatos (2009).

2.2. Plant material

The experiment was conducted during 2005 and 2006 and the cultural practices of the farmers had been monitored for 4 years prior to the onset of the experiment. All of the sampled trees were of uniform size and without any visible symptoms of either disease or pest infestation at the time of the initiation of the trial. For both orchards, the trees were planted in 1990, open-vase trained and planted at distances of 5 x 5 m. Three groups of three trees per orchard were randomly chosen as the sample trees in the middle of each orchard, avoiding the orchards’ borders, which served as buffer zones.

2.3. Soil and leaf sampling

Representative soil samples were collected at a 30-cm depth according to a sampling procedure –zigzag or "W" pattern (Pennock *et al.,* 2008) - adapted to the size and shape of each orchard using a 5 cm diameter auger after the removal of the aboveground biomass in early September. Three soil samples were collected per orchard each year (2005 and 2006). Three leaf samplings were performed, the first at the beginning of flowering (approximately 5 days before full bloom – DBFB), the second when the fruit diameter was nearly 40 mm (65 DAFB) and the third at fruit maturity (150 DAFB). Approximately 40 healthy leaves were collected around the canopy of each sampled tree, at a height of approximately 1-2 m above the ground, from non-bearing shoots. One sample of leaves per plot was collected. The leaves were placed in paper bags and transferred to the laboratory. The leaves were then carefully washed with running tap water and three times with de-ionised water. After drying in an oven at 70 °C until they reached a constant weight, the leaves were ground into a fine powder.

2.4. Soil and leaf analysis

The soil samples were air-dried and ground to 2 mm prior to analysis. The particle size analyses were conducted using the hydrometer method, with a 2-h reading for the clay concentration (Gee and Bauder, 1986). Electrical conductivity (EC) and soil pH were 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 was titrimetrically measured after the distillation of NH_3 using the Kjeldahl digestion (Bremner and Mulvaney, 1982). Exchangeable cations and the cation exchange capacity (CEC) were determined using an ammonium acetate extraction method (Thomas, 1982). Plant available P was determined according to Olsen et al. (1954). The available metals were extracted from the soils by shaking 10 g of sample for 2 h with 20 ml 0.005 diethylenetriamine-pentaacetic acid (DTPA) adjusted to pH = 7.3, prepared as described by Lindsay and Norvell (1978). Several studies have shown that DTPA is the most suitable extractant for the determination of metal availability in soils (Herencia *et al.,* 2008a; 2008b).

For the mineral analysis, the leaf samples were treated using standard procedures (Jones and Case, 1990). Nitrogen was analysed using the Kjeldahl method, whereas P was evaluated colorimetrically using the H_2SO_4/H_2O_2 digestion method (Gasparatos and Haidouti, 2001). Potassium and Na were measured using flame emission spectroscopy and Ca, Mg, Fe, Mn, Cu and Zn were measured using atomic absorption spectrophotometry (Varian SpectrAA 300). The contents of the plant macronutrients and mesonutrients (N, P, K, Ca, Mg and Na) are expressed as the percentage of dry weight; the contents of the plant micronutrients (Fe, Mn, Cu and Zn) are expressed as mg kg $^{-1}$ of dry weight.

2.5. Statistical analysis

The trial was a pseudo-replicated trial (the management system was single replicated per year, whereas the three plots within each orchard served as replications for the statistical analysis) following the split-plot design (Roussos and Gasparatos, 2009). Due to the small number of organically managed apple orchards in Greece, this kind of replication was used for strengthening the reliability of the statistical analysis without any effect on the actual conclusions, based on the recorded raw data. Nevertheless, the data derived through the limited number of orchards used could possibly represent the specific agricultural practices employed. The management system comprised the main plot, the subplot comprised the replicate and the trees constituted the experimental units. Concerning the soil properties, significant differences between the management systems were determined using Student's *t*-test. Data on the effect of time on the leaf nutrient concentrations were analysed by an orthogonal comparison test and any significant interaction between management system and time was determined using Tukey's HSD. Each sample of either soil or leaves was analysed twice. The statistical analyses were performed using JMP 7.0 statistical software (SAS Institute).

3. Results and Discussion

3.1. Effect of the orchard management system on the soil chemical properties

The soil in both orchards was a clay loam–clay soil with no significant differences in the sand, silt and clay contents (Figure 1).

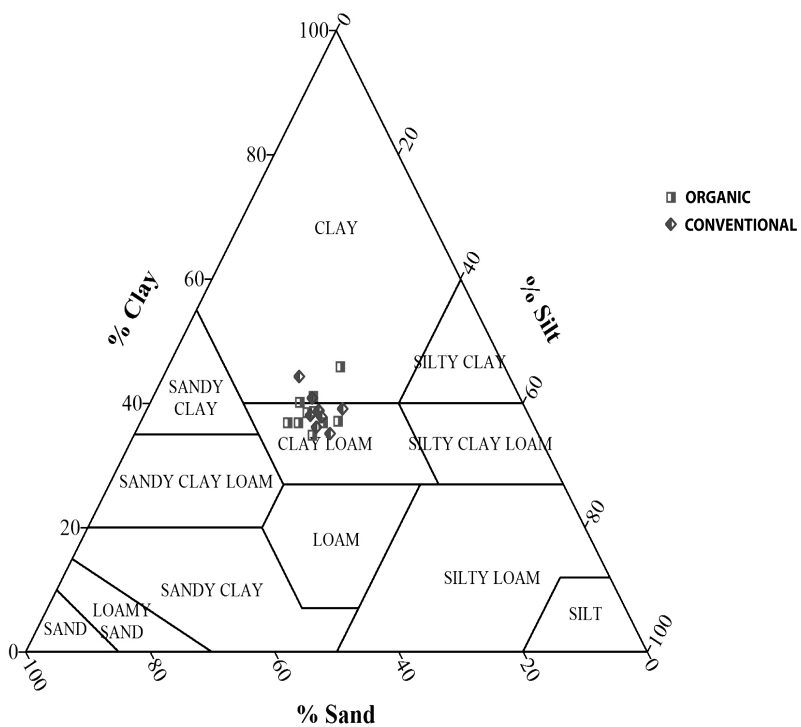

Figure 1. Particle size classes of the conventionally and organically managed soil samples.

As noted previously by Roussos and Gasparatos (2009), the soil was very uniform in morphological and physical characteristics, including colour, structure and drainage capability, implying that any differences in the soil properties and plant nutrient concentrations could be attributed mainly to the management system and not to soil heterogeneity. The comparable CEC values also confirm the similar pedological origin of the soils under the two management systems (Table 1).

Table 1. Effect of orchard management system on soil chemical properties.

Treatment	**Soil chemical properties**				
	CEC	**pH**	**C/N ratio**	**SOM**	**EC**
	$cmol_c\ kg^{-1}$			**%**	**$dS\ m^{-1}$**
Organic	19.23	7.17	5.94	1.84	0.91
Conventional	20.28	7.43	6.52	1.97	1.22
Significance	ns	ns	ns	ns	**

Significance denotes any statistically significant difference between the means of the same column according to Student's *t*-test at 5% significance level. ns, not significant; $^{**}p < 0.01$.

Because comparisons of organic with conventional management systems are difficult due to the variation of many potential factors (e.g., soil type, climate conditions, crops), soil homogeneity is essential for these comparisons to be experimentally valid (Gosling and Shepherd, 2005; Canali *et al.* 2009).

The SOM is usually considered to be one of the most important properties of soils due to its significant impact on other biological and physicochemical soil properties. Thus, it is noteworthy that there was no significant difference in the levels of SOM between the two management systems (Table 1), which is in accordance with the data reported by Gossling and Shepherd (2005). Inputs of organic matter (animal and green manures, crop residues and composts) are generally considered to be higher in organic systems; nevertheless, as was found in the present study the application rates of these inputs (mainly as plant residues) were probably insufficient to increase the amounts of soil organic matter. Similar data have been previously reported by Sanchez *et al.* (2007), who found low SOM levels (< 2%) in the topsoil under an organic fruit production system. These results indicate that the continuous addition of higher quantities of manure under an organic management system is important to maintain a sufficient level of SOM, which is easily oxidised, especially under the Mediterranean climatic conditions of the present study.

With the exception of the EC values and concentrations of Na, K, Ca, Cu and Zn, the variables evaluated did not present significant differences under the two management systems (Table 2). As EC is strongly influenced by management practices, it can be used as an indicator of the extended use of fertilisers in soil. An increase in the EC in conventionally managed soils could be due to the higher input of salts (in the forms of chemical fertilisers and/or pesticides) (Table 1), which was further supported by the higher Na concentration in the conventionally managed soil (Table 2).

Table 2. Effect of orchard management system on soil nutrients.

Treatment	Soil nutrients					
	N	P	K	Ca	Mg	Na
	%	mg kg^{-1}	cmol$_c$ kg^{-1}			
Organic	0.14	23.5	1.01	3.50	2.24	0.21
Conventional	0.15	21.2	1.27	4.81	2.34	0.23
Significance	ns	ns	***	**	ns	*

Significance denotes any statistically significant difference between the means of the same column according to Student's *t*-test at 5% significance level. ns, not significant; *p< 0.05; **p< 0.01; ***p< 0.001.

However, under both agricultural systems, EC and Na were low and did not influence plant growth. The available K and Ca values in the conventionally managed soils were higher than those in the organically managed soil due to the application of mineral fertilisation (Table 2). Numerous studies have shown a K deficiency in organic farms due to the lower input of nutrients (Stockdale *et al.,* 2001; Berry *et al.,* 2003; Gossling and Shepherd, 2005). In contrast, the biannual application of a fertiliser containing 15% w/w K_2O in high quantities in the conventional orchard preserved adequate soil K levels. The higher Ca concentration observed in the conventional orchard could be explained by the use of calcium ammonium nitrate, which reduces soil acidity and supplies the soil with Ca.

The concentrations of the soil available Fe, Mn, Cu and Zn extracted by the DTPA method are presented in Table 3. The soil of the organically cultivated orchard exhibited significantly lower Cu and Zn concentrations than that of the conventional orchard. The application of various agrochemicals, such as pesticides (copper containing fungicides) and synthetic fertilisers (containing both Cu and Zn), in the conventional orchard could account for the increased soil content of these metals through foliar run off.

Table 3. Effect of orchard management system on soil micronutrients.

	Soil micronutrient (mg kg^{-1})			
Treatment	Fe	Mn	Cu	Zn
Organic	11.3	34.8	3.40	0.67
Conventional	11.3	31.1	5.96	1.23
Significance	ns	ns	*	*

Significance denotes any statistically significant difference between the means of the same column according to Student's *t*-test at 5% significance level. ns, not significant; *p< 0.05.

Nevertheless, the organic orchard showed higher values of Mn than the conventional orchard, although there were no statistically significant differences. Many studies have shown that organically managed soils with adequate levels of organic inputs have significantly higher soil micronutrient contents due to the ability of the organic matter to increase the solubility of metals (Stockdale *et al.,* 2001; Herencia *et al.,* 2008a; 2008b). However, the results of this study indicated that the type and the application rate of the organic matter input in the organically management orchard were not sufficient to increase the availability of the metals in the soil. Microbial decomposition of organic compounds creates reducing conditions that increase the solubility of some micronutrients, especially that of Mn (Herencia *et al.,* 2008a), accounting for its higher concentration in the organic orchard compared to the conventional one.

Due to the low availability of any type of manure in Greece and its subsequent high cost, the organic farmer incorporated weeds, pruning residues, non-marketable or dropped fruits and fresh residues of vegetable crops as organic amendments (i.e., plant compost) to compensate for any nutrient losses and to strengthen nutrient cycling (Condron *et al.,* 2000). However, the decomposition and mineralisation of organic materials require significant time and can potentially decrease the nutrient availability in the soil. In accordance with our results, Herencia *et al.* (2008b) have shown that the use of plant compost in organic farming had no significant effect on the availability of Fe, Mn and Cu over five different crop cycles. These results indicated that the organic orchardist must consider how to use, in terms of quantity and composition, the permitted organic inputs to compensate for mineral nutrient losses in the particular organic apple orchard.

3.2. Effect of orchard the management system and time on leaf mineral concentrations

Except for the Cu and Zn contents, the type of management system did not exhibit any significant influence on the concentrations of most of the nutrients evaluated and all of the leaf nutrients were within the sufficiency range under both management systems, with the exception of P and Ca (Table 4) (Sanchez *et al.,* 2007).

Table 4. Effects of orchard management system (OM), time and their interaction on macronutrients and mesonutrients concentration in apple leaves.

Treatment	Nutrient (%)					
	N	P	K	Ca	Mg	Na
OM						
Organic	2.38 a	0.15 a	1.99 a	0.41 a	0.34 a	0.16 a
Conventional	2.87 a	0.16 a	1.43 a	0.45 a	0.39 a	0.14 a
Time						
5 DBFB	3.44 a	0.22 a	2.24 a	0.45 a	0.25 a	0.17 a
65 DAFB	2.54 b	0.12 b	1.75 b	0.68 b	0.51 b	0.14 b
150 DAFB	1.89 c	0.11 c	1.15 c	0.16 c	0.33 a	0.13 b
OM * Time						
O-5 DBFB	3.14 a	0.21 a	2.47 a	0.45 a	0.25 a	0.18 a

continued...

Treatment	Nutrient (%)					
	N	P	K	Ca	Mg	Na
O-65 DAFB	2.28 a	0.12 a	1.99 a	0.64 a	0.45 a	0.15 a
O-150 DAFB	1.72 a	0.11 a	1.51 a	0.14 a	0.33 a	0.14 a
C-5 DBFB	3.75 a	0.23 a	2.01 a	0.45 a	0.25 a	0.17 a
C-65 DAFB	2.80 a	0.13 a	1.50 a	0.73 a	0.58 a	0.14 a
C-150 DAFB	2.07 a	0.11 a	0.79 a	0.17 a	0.34 a	0.12 a

5 DBFB (5 days before full bloom); 65 DAFB (65 days after full bloom); 150 DAFB (150 days after full bloom); OM, orchard management system; C, conventionally cultivated orchard; O, organically cultivated orchard; *denotes interaction. Means within the same column followed by different letters are significantly different according to an orthogonal comparison test (effect of time) and Tukey's HSD (OM * Time interaction) at α=0.05.

Our results are comparable to those reported by Nachtigall and Dechen (2006) and Holb *et al.* (2009), studies in which leaf N, P and K concentrations were reported to decrease during the apple tree vegetative cycle. The nitrogen concentration gradually decreased over time, reaching values below 1.8% in the organic orchard by the end of our experimental period (Table 4). This value is lower than the mean value (2%) determined by Nagy and Holb (2006) in leaves sampled in September from seven different apple cultivars. Our result clearly shows a tendency for nitrogen deficiency by the end of the cultural period in organically cultivated trees. Nevertheless, as previously reported by Holb et al. (2009), the dynamics of N uptake were similar under both management systems. However, the low nitrogen and concentrations of other nutrients (i.e., P, Ca, Mg, Fe, Mn and Zn) in the apple leaves could be attributed to a dilution caused by the larger shoot mass (length) under organic management (Roussos and Gasparatos, 2009), as the mean shoot length in the organic orchard was estimated to be approximately 24 cm, whereas that in the conventional orchard was 17 cm. Whereas the potassium content was slightly but not significantly higher in the leaves of the organic apple trees, the opposite (lower K concentration in organic orchard) was determined in the soil samples. This discrepancy could be attributed to the increased yield of the conventional orchard and the translocation of K to the fruits, where it was found in great abundance and was the major element found in the fruits (Roussos and Gasparatos, 2009).

The orchard management system had a significant effect on the concentration of both Cu and Zn in the apple leaves and the time of sampling had a significant effect on almost all of the measured nutrients except for Mn (Table 5). In addition, the iron concentration presented a significant increase during the third sampling. The seasonal fluctuation of leaf mineral elements corresponds to the plant nutrient demand at each sampling event (Holb *et al.,* 2009; Holb and Nagy 2009).

Table 5. Effects of orchard management system (OM), time and their interaction on micronutrients concentration in apple leaves.

Treatment	Micronutrients (mg kg $^{-1}$)			
	Fe	**Mn**	**Cu**	**Zn**
OM				
Organic	76.7 a	88.6 a	205.1 b	21.9 b
Conventional	82.6 a	116.3 a	117.2 a	30.0 a
Time				
5 DBFB	71.5 a	96.8 a	111.2 a	30.3 a
65 DAFB	69.8 a	97.4 a	217.5 b	25.1 ab
150 DAFB	97.8 b	113.3 a	154.8 ab	22.6 b
OM * Time				
O-5 DBFB	69.2 a	71.8 a	105.0 a	24.2 bc
O-65 DAFB	65.6 a	85.8 a	297.8 b	20.9 c
O-150 DAFB	95.5 a	108.4 a	212.6 ab	20.7 c
C-5 DBFB	73.8 a	121.7 a	117.4 a	36.4 a
C-65 DAFB	74.0 a	108.9 a	137.2 a	29.1 b
C-150 DAFB	100.2 a	118.3 a	97.1 a	24.7 bc

5 DBFB (5 days before full bloom); 65 DAFB (65 days after full bloom); 150 DAFB (150 days after full bloom); OM, orchard management system; C, conventionally cultivated orchard; O, organically cultivated orchard; *denotes interaction. Means within the same column followed by different letters are significantly different according to an orthogonal comparison test (effect of time) and Tukey's HSD (OM * Time interaction) at α=0.05.

Significant interactions between orchard management and time were detected only with regard to the Zn and Cu concentrations (Table 5). The copper concentration was significantly higher in the leaves of the organically cultivated orchard, especially during the last two sampling events. According to the Council Regulations (EU) 2092/91, Annex II and No. 404/2008, many copper-containing fungicides, such as Bordeaux mixture, copper oxychloride, copper octanoate and copper hydroxide, are registered for use in organic farming in Greece. Although the copper concentrations in the leaves of the organically managed trees were quite high, they were below the toxicity limits (Kaplan, 1999). These high leaf Cu concentrations determined in the organic orchard reflect the application of copper-containing fungicides during the last stages of fruit development (in September), whereas no copper-containing fungicide was applied during that time in the conventional orchard.

The zinc concentration exhibited a steady decrease throughout the growing season, with its concentration being significantly higher in the leaves of the conventionally grown trees (Table 6). This higher Zn concentration could be attributed to the application of the Zn-containing foliar fertiliser twice or thrice within the growing season; similar results have been reported by Peck *et al.* (2006) who observed specific zinc-deficiency symptoms in the leaves of an organic apple orchard.

Of note is the fact that, although the yield per tree in the organic orchard was much lower than that of the conventional one (35 kg vs. 80 kg, respectively), the mineral concentrations determined in the leaf samples from both orchards do not justify this difference. This is partly due to the heavy fruit fall during the summer in the organic orchard (which otherwise would have had a high production) caused by codling moth infestation along with the greater dilution of the mineral nutrient concentrations in the shoots of the organic apple trees, which exhibited greater growth than those in the conventional orchard.

4. Conclusions

Based on the homogeneity of the inherent soil characteristics and under the same tillage operations (rotary tiller), our study did not provide evidence of statistically significant differences in the SOM between conventionally and organically grown apples. The comparison of the two management systems has emphasised that, in soils under organic farming, the continuous addition of high quantities of manure is important to maintain an adequate level of SOM, which is easily oxidised under the Mediterranean climatic conditions. In addition, the farm management system did not exhibit any significant influence on the mineral contents of the trees.

Nevertheless, from an economic and environmental perspective, the fertilisation program applied in the conventional orchard could be considered more complex, expensive and with an increased carbon footprint in comparison to the organic orchard, which was essentially not fertilised (in terms of commercially available organic fertilisers). This, along with the lack of significant differences in the soil chemical properties between the two management systems, does not fully justify such a high investment of chemical fertilisers. Therefore, these economical and environmental advantages and the possible higher value of the organic apple fruit might partly compensate for the lower yields and the increased labour hours of organic management.

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References

Araujo, A.S.F., Santos, V.B., Monteiro, R.T.R. 2008. Responses of soil microbial biomass and activity for practices of organic and conventional farming systems in Piaui state, Brazil. European Journal of Soil Biology 44, 225-230.

Berry, P.M., Stockdale, E.A., Sylvester—Bradley R., Phillips, L., Smith, K.A., Lord, E.I., Watson, C.A., Fortune, S. 2003. N, P and K budgets for crop rotations on nine organic farms in the UK. Soil Use and Management 19, 112-118.

Bremner, J.M., Mulvaney, C.S. 1982. Total nitrogen. In: A.L. Page, R.H. Miller, D.R. Keeney (eds). Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. ASA, SSSA, Madison, WI, USA, pp: 595-615.

Canali, S., Di Bartolomeo, E., Trinchera, A., Nisini, L., Tittareli, F., Intrigliolo, F., Roccuzzo, G., Calabretta, L. 2009. Effect of different management strategies on soil quality of citrus orchards in Southern Italy. Soil Use and Management 25, 34-42.

Gasparatos, D., Haidouti, C. 2001. A comparison of wet oxidation methods for determination of total phosphorus in soils. Journal of Plant Nutrition and Soil Science 164, 435–439.

Condron, L.M., Cameron, K.C., Di, H.J., Clough, T.J., Forbes, E.A., McLaren, R.G., Silva, R.G. 2000. A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand. New Zealand Journal of Agricultural Research 43, 443-466.

Gee, G.W., Bauder, J.W. 1986. Particle - size analysis. In: A. Klute (ed). Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. ASA, SSSA, Madison, WI, USA, pp: 383-411.

Gosling, P., Shepherd, M. 2005. Long – term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. Agriculture, Ecosystems and Environment 105, 425–432.

Herencia, J.F., Ruiz, J.C., Morillo, E., Melero, S., Villaverde, J., Maqueda, C. 2008a. The effect of organic and mineral fertilization on micronutrient availability in soil. Soil Science 173, 69-80.

Herencia, J.F., Ruiz, J.C., Melero, S., Garcia-Galavis, P.A., Maqueda, C. 2008b. A short- term comparison of organic v. conventional agriculture in a silty loam soil using two organic amendments. Journal of Agricultural Science 146, 677 – 687.

Holb, I.J., Nagy, T.P. 2009. Availability of calcium, magnesium, sulphur, copper, zinc and manganese in plant-soil system of integrated and organic apple orchards. Communications in Soil Science and Plant Analysis 40, 682 – 693.

Holb, I.J., Gonda, I., Vago, I., Nagy, T.P. 2009. Seasonal dynamics of nitrogen, phosphorus and potassium contents of leaf and soil in environmental friendly apple orchards. Communications in Soil Science and Plant Analysis 40, 694 – 705.

Holb, I.J., Heijne, B., Withagen, J.C.M., Gall, J.M., Jeger, M.J. 2005. Analysis of summer epidemic progress of apple scab in different apple production systems in the Netherlands and Hungary. Phytopathology 95, 1001 – 1020.

Jones Jr, J.B., Case, V.W. 1990. Sampling, handling and analyzing plant tissue samples. In: R.L. Westerman (ed). Soil Testing and Plant Analysis. SSSA, Inc.: Madison, Wisconsin, USA, pp: 389–427.

Kaplan, M. 1999. Accumulation of copper in soils and leaves of tomato plants in greenhouses in Turkey. Journal of Plant Nutrition 22, 237-244.

Lindsay, W.L., Norvell, W.A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. Soil Science Society America Journal 42, 421–428.

Marinari, S., Mancinelli, R., Campiglia, E., Grego, S. 2006. Chemical and biological indicators of soil quality in organic and conventional farming systems in Central Italy. Ecological Indicators 6, 701-711.

McLean, E.O. 1982. Soil pH and lime requirement. In: A.L. Page, R.H. Miller, D.R. Keeney (eds). Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. ASA, SSSA, Madison, WI, USA, pp: 199-224.

Nachtigall, G.R., Dechen, A.R. 2006. Seasonality of nutrients in leaves and fruits of apple trees. Scientia Agricola (Piracicaba, Braz.) 63, 493-501.

Nagy, P.T., Holb, I.J. 2006. Study on the macronutrient content of apple leaves in an organic apple orchard. Journal of Central European Agriculture 2, 329-336.

Nelson, D.W., Sommers, L.E. 1982. Total carbon, organic carbon and organic matter. In: A.L. Page, R.H. Miller, D.R. Keeney (eds). Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. ASA, SSSA, Madison, WI, USA, pp: 539-547.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A. 1954. Estimation of available phosphorus in soils by extracting with sodium bicarbonate. USDA Circ. 939. U.S. Gov. Print. Office, Washington D.C.

Peck, G.M., Andrews, P.K., Reganold, J.P., Fellman, J.K. 2006. Apple orchard productivity and fruit quality under organic, conventional and integrated management. HortScience 41, 99-107.

Pennock, D., Yates, T., Braidek, J. 2008. Soil sampling designs. In: M.R. Carter and E.G. Gregorich (eds.). Soil Sampling and Methods of Analysis. 2nd edition, Canadian Society of Soil Science. CRC Press of Taylor & Francis Group, Boca Raton, Florida pp: 1-14.

Roussos, P., Gasparatos, D. 2009. Apple tree growth and overall fruit quality under organic and conventional orchard management. Scientia Horticulturae 123, 247-252.

Sanchez, E.E., Giayetto, A.A., Cichon, L., Fernandez, D., Aruani, M.C., Curetti, M. 2007. Cover crops influence soil properties and tree performance in an organic apple (Malus domestica Borkh) orchard in northern Patagonia. Plant Soil 292, 193-203.

Stockdale, E.A., Lampkin, N.H., Hovi, M., Keatinge, R., Lennartsson, E.K.M., Macdonald, D.W., Padel, S., Tattersall, F.H., Wolfe, M.S., Watson, C.A. 2001. Agronomic and environmental implications of organic farming systems. Advances in Agronomy 70, 261-327.

Thomas, G.W. 1982. Exchangeable cations. In: A.L. Page, R.H. Miller, D.R. Keeney (eds). Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. ASA, SSSA, Madison, WI, USA, p: 159-166.

Vakali, C., Zaller, J.G., Köpke, U., 2011. Reduced tillage effects on soil properties and growth of cereals and associated weeds under organic farming. Soil and Tillage Research 111, 133-141.

Vasilakakis, M. 2010. General and specialized pomology. Gartaganis Publications: Thessaloniki, Greece, 894 p.