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EFFECTS OF ORGANIC VERSUS CONVENTIONAL MANAGEMENT ON SOIL AND LEAF MICRONUTRIENTS IN GREEK APPLE ORCHARDS

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Abstract: Organic farming has expanded rapidly in Europe over the last decade due to environmental, economic and social concerns. A comparative study of organic and conventional apple orchard management systems was conducted in order to compares Fe, Mn, Cu and Zn availability in soil as well as to evaluate the concentration of micronutrients in the leaves of apple trees. The soil in both orchards was characterized as a clay loam – clay soil and was very uniform in morphological and physical properties suggesting that any differences in the measured soil parameters may be attributed to the management system and not to soil heterogeneity. The soil of the organically cultivated orchard exhibited significantly lower Cu and Zn concentrations than that of the conventional one. The application of various agrochemicals like pesticides and synthetic fertilizers in the conventionally managed soils seems to increase the content of these metals. In addition the results of this study indicated that the type as well as the application rate of inputs of organic matter in the organically management orchard are insufficient in order to increase the availability of metals in soil. All leaf nutrients were within the sufficiency range in both management systems. The orchard management system had a significant effect on the concentration of Cu and Zn in apple leaves while time of sampling had a significant effect on almost all measured nutrients, except from Mn. Copper concentration was significantly higher in leaves of the organically cultivated orchard, especially during the last two sampling events probably to the extent use of many copper-containing fungicides in organic orchards in Greece.
Key Words: Soil available metals, Agricultural management, Organic farming, Leaf micronutrients, Apple orchard

1. INTRODUCTION

Organic farming has expanded rapidly in Europe over the last decade due to environmental, economic and social concerns (Condron et al. 2000, Stockdale et al. 2001). As an alternative agriculture system, organic farming has been proposed as a solution to environmental problems arising from conventional management such as frequent pesticide applications, excess inputs of chemical fertilizers, soil degradation and the presence of pesticide residues in food. Organic production systems are increasing in the European Union, with annual growth rate of 26 % and hold an increasingly important position in current agriculture (Herencia et al., 2008a). The area of Greece dedicated to organic management increased from 1.188 ha in 1994 to 152.117 ha in 2007 (Hellenic Ministry of Rural Development and Food, http://www.minagric.gr/).

The transition from conventional to organic farming often causes significant changes of soil chemical properties and is thus likely to modify the processes that affect soil fertility. These changes affect metal availability to crops either directly by contributing to nutrient pools, or indirectly, by influencing the soil environment. Recent studies comparing conventional and organic farming have shown an increase in organic matter and nutrient content in organically managed soils (Herencia et al., 2008b). However comparisons of organic with conventional managed systems are complex and difficult because there is a great deal of overlap in management techniques.

The aim of this study was (i) to determine the effect of organic versus conventional management practices on Fe, Mn, Cu and Zn availability in a clay loam – clay soil using the chelating agent DTPA (diethelynetriaminepentaacetic acid) and (ii) to evaluate the concentration and seasonality of Fe, Mn, Cu and Zn on leaves of apple trees under the two agricultural practice methods.

2. MATERIAL AND METHODS

2.1. Orchard Site and Cultural Practices

The experiment took place on two adjacent commercial apple orchards approximately 1.0 ha each, in order to avoid any pedoclimatic impact on the possible differences detected. The distance between farms was approximately 500 m and both orchards had an orthogonal shape. The variety used was “Starking Delicious” grafted on MM106 rootstock. The orchards were typical of the region where they were located (cultivar, tree training system, planting distances etc) and were cultivated under conventional (C) and organic (O) agricultural practices (Figure 1). The two farms were located in Velina village, Korinthia County, Greece (Lat 37 ° 59' 0", Long 22 ° 34' 0") at an altitude of 950 m. The meteorological data during the last 15 years were collected by a nearby official meteorological station. Based on the data collected the climate of the region is characterized as a typical Mediterranean type climate, with the rainy season timed mainly during autumn and winter months and less in spring, while the summer is quite dry. The mean annual precipitation is 476 mm. The mean annual temperature in the region is 17.5 ^{o}C, the mean minimum temperature 11.2 ^{o}C and the mean maximum one 22.2 ^{o}C.

The two farmers employed different strategies on both weed, pest and disease management as well as on fertilizer application. The conventional orchard was treated with non-selective herbicide (glyphosate) on the rows and soil tillage between rows. Fertilization was applied by the use of 11-15-15 (N-P-K) fertilizer 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 fertilization was conducted as foliar treatments with soluble fertilizers (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) during the early (one application-fruit diameter up to 20 mm) and the last stages of fruit growth (one-two applications – fruit about 80-90% of final size). Any organic amendment to the soil of the conventional farm is attributed to the incorporation of weeds and of the fruits thinned. The farmer in the organic orchard applied sheep manure during the first year of conversion from conventional to organic orchard (six years before the main experiment took place) at a dose rate of 20 kg per tree.

2.2. Plant Material – Experimental Design

All trees chosen were of uniform size without any visible symptoms of either disease or pest infestation by the time of trial initiation, in the mid-spring. In both orchards, trees were planted in 1990, were open-vase trained and planted at 5m x 5m distances. A total of nine trees per orchard were randomly chosen, comprising three groups of three trees (three replicates of the same treatment). The trial followed the split-plot design. The management system comprised the main plot, the replicate the sub-plot and the trees the experimental units. For the data on leaf analysis the time of sampling comprised the sub-plot and the replicate of the three trees the experimental unit.

2.3. Soil and Leaf Sampling

Soil sampling took place in July from three different places per plot in a "W" pattern (nine soil cores per orchard) by the use of a 5 cm diameter auger to a 30 cm depth after removal of the aboveground biomass. Three leaf samplings took place, the first one at the beginning of flowering (approximately 5 days before full bloom – DBFB), the second one when fruit diameter was almost 40mm (65 DAFB) and the third one at fruit maturity (150 DAFB). Nearly 40 healthy leaves were collected around the canopy of each sampled tree, at a height of approximately 1-2 m above ground, from non bearing shoots. One sample of leaves per plot was collected. Leaves were placed into paper bags and transferred to the laboratory, where they were carefully washed with running tap water and three times with de-ionized one, before drying them in an oven at 70 ^{o}C till constant weight and ground then into fine powder.

2.4. Soil and Leaf Analysis

Soil morphological description was obtained following standard procedures (Soil Survey Staff, 1998). Soil samples were air-dried and ground to 2 mm prior to analysis. Particle size analyses were made using the hydrometer method, with a 2-h reading for clay concentration (Gee and Bauder, 1986). Available metal contents were extracted from the soils by shaking 10 g samples for 2 h with 20 ml 0.005 DTPA (diethylene-triamine-pentaacetic acid) adjusted to pH = 7.3), prepared as described by Lindsay and Norvell (1978). Several studies have showed that the DTPA is the most suitable extractant for the determination of metals availability in soils (Herencia et al., 2008a, Herencia et al., 2008b). Plant material was dried at 70 ^{o}C for 48 hours, weighted and ground. 0.5g of the plant sample was dry-ashed in an oven at 500 ^{o}C for 4h and the ash was subjected to wet digestion in concentrated nitric acid (Westerman, 1990). Fe, Mn, Cu, Zn concentrations were determined by using a Varian SpectrAA-300 atomic absorption spectrometer. Quality control was assured by duplicate samples and procedural blanks.

(a) (b)

Figure 1. The studied apple orchards under a. conventional and b. organic agricultural management

2.5. Statistical Analysis

Data derived from this experiment were analyzed according to the split plot design. When ANOVA presented significant effects of management system, differences on soil analyses were determined by the Student's t-test. Data of the effect of time on leaf micronutrients were analyzed by orthogonal comparison test and any significant interaction between management system and time was determined by the use of Tukey HSD. Each sample of either soil or leaves was analyzed twice. Statistical analysis was performed using JMP 7.0 statistical software (SAS Institute).

3. RESULTS AND DISCUSSION

The soil in both orchards was characterized as a clay loam – clay soil with no significant differences in sand, silt and clay content (Figure 2). In addition the soil was very uniform in morphological and physical characteristics like color, structure and hydromophology (Soil Survey Staff, 1998), implying that the differences in soil and plant micronutrients's concentrations may be attributed mainly to the management system and not to soil heterogeneity. Since comparisons of organic with conventional management systems are difficult because of the variation of many potential factors (soil type, climate conditions, crops etc.), soil homogeneity is essential in order for these comparisons to be experimentally valid (Gosling and Shepherd, 2005).

Table 1 shows the concentrations of soil available Fe, Mn, Cu and Zn concentrations extracted by the DTPA method. The soil of the organically cultivated orchard exhibited significantly lower Cu and Zn concentrations than that of the conventional one. The application of various agrochemicals like pesticides and synthetic fertilizers in the conventionally managed soils seems to increase the content of these metals. Nevertheless, the organic orchard has shown higher values of Mn than the conventional although there were no statistically significant differences. Much scientific literature shows that the organic – managed soils have significantly higher soil micronutrient content due the ability of organic matter to increase the solubility of the metals (Stockdale et al., 2001, Herencia et al., 2008a, Herencia et al., 2008b).
However the results of this study indicated that the type as well as the application rate of organic matter inputs in the organically management orchard are insufficient in order to increase the availability of metals in soil. In the case of Mn, the microbial decomposition of added organic compounds created probably reducing conditions which increased its solubility.

The organic farmer due to the low availability of any type of manure in Greece and its subsequent high cost, used to incorporate weed and pruning residues and non-marketable or dropped fruits and fresh residues of vegetable crops as organic amendments (i.e plant compost), trying to compensate any nutrient losses and to strengthen nutrient cycling (Condron et al., 2000). The mean plant residues' mass of this type was estimated to be approximately 20-30 kg per year per tree, distributed through a period of nine months (February to November), with the major organic additions being in February, July and October. 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 on 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 in order to compensate metal nutrient losses for the particular organic apple orchard.

All leaf nutrients were within the sufficiency range in both management systems (Sanchez et al., 2007). The orchard management system had a significant effect on the concentration of Cu and Zn in apple leaves while time of sampling had a significant effect on almost all measured nutrients, except from Mn (Table 2).

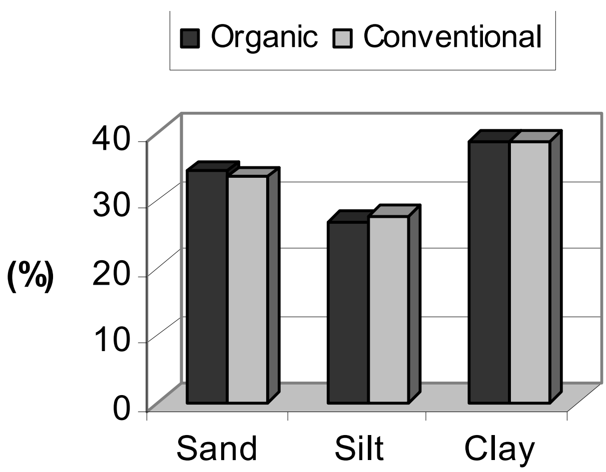

Figure 2. Particle size distribution under organic and conventional soil management

Table 1. Influence of orchard management system on soil available metals concentration

	Available Metals (mg kg $^{-1}$)			
Management System	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 means of the same column, according to Student's T-test, at 5% significance level. ns, not significant - *, p<0.05.

Table 2. Effects of orchard management system (OM), time and their interaction on micronutrient concentration in apple leaves

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

5DBFB (5 days before full bloom) - 65DAFB (65 days after full bloom) - 150DAFB (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 orthogonal comparison test (effect of time) and Tukey HSD (OM * Time interaction) at α=0.05

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 (Nachtigall and Dechen, 2006). Significant interaction between orchard management and time was detected only concerning Zn and Cu concentration. Copper concentration was significantly higher in leaves of the organically cultivated orchard, especially during the last two sampling events. Many copper-containing fungicides, such as Bordeaux mixture, copper oxychloride, copper octanoate and copper hydroxide are registered for use in organic orchard in Greece, according to the Council Regulations (EU) 2092/91, Annex II and No 404/2008. Although copper concentrations determined in the leaves of organically managed orchard were quite high, were below the toxicity limits adopted (Kaplan, 1999). These high Cu leaf concentrations determined in the organic orchard, reflect the application of copper containing formulations during the last stages of fruit development.

Zinc concentration exhibited a steady decrease throughout the growing season, with its concentration being significantly higher in leaves of conventionally grown trees. The higher Zn concentration in the leaves of conventionally managed orchard could be attributed to the application of Zn containing foliar fertilizer, while the same has been also reported by Peck et al. (2006), who observed the specific zinc deficiency symptoms on apple leaves.

4. REFERENCES

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 Zeal. J. Agric. Res., 43: 443-466.

Gee, G.W., Bauder, J.W., 1986. Particle - size analysis. In: Klute A. (Eds.), Methods of soil analysis. Part 1: Physical and Mineralogical Methods, ASA, SSSA, Madison, WI, 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. Agric. Ecosyst. Environ., 105: 425–432.

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

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

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

Lindsay, W.L., Norvell, W.A., 1978. Development of DTPA soil test for zinc, iron,manganese and copper. Soil Sci. Soc. Am. J., 42: 421–428.

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

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.

Sanchez, E.E., Giayetto, A.A., Cichon, L., Fernadez, 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.

Soil Survey Staff, 1998. Key to soil taxonomy, 8th edn. USDA, Natural Resources Conservation Service, Washington DC.

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. Adv. Agron., 70: 261-327.

Westerman, R.L., (Ed.) 1990. Soil testing and plant analysis, 3rd edition, SSSA, Madison W1.