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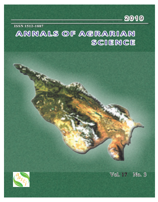

Micronutrient mobility in soil under different management practices in organic vineyards

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A B S T R A C T

The current study aimed to improve micronutrient mobility in soil using different soil management practices in organic vineyards, where a holistic approach to agricultural production sets a number of limits compared to conventional farming. Therefore, we applied several already well-known practices to monitor changes in micronutrient composition and their potential availability to plant, while assessing them as possible pollutants of the environment if an access amount is mobilised. The study was conducted in three different soil-climatic conditions under established organically managed vineyards, were micronutrients such as Mn, Fe, Cu, Mo, Ni, Zn were observed. The results have shown that cover cropping with grass mixture, mulching with wood chips, and application of organic fertilizer had a positive impact on the increase of mobility and bioavailability of Mn, Fe, and Mo. Although, in some cases reduction in nutrient mobility was observed, especially in the case of Fe and Zn.

Keywords: Micronutrient mobility, Soil fertility management, Organic agriculture, Organic vineyard, Microelements, Bioavailability.

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Introduction

Organic agriculture is one of the fast-growing sectors of agriculture. The global market for organic food and drink has increased from 2000 to 2017 nearly five times and exceeded 92 billion EUROs [1]. According to a recent survey (FiBL, 2019) in 2017 about 69.8 million hectares were managed organically worldwide and compared to 1999 this is a growth by 533 % [1]. Organic agriculture is spread in 181 countries of the world, and its share of agricultural land and farms expanding as the market for organic products is growing, not only in the major markets like Europe, North America, and Japan but also in developing countries [2].

An increasing trend observed in organic agriculture during the last decades indicates the necessity to improve agricultural production and maintain a quality of produce. Among many challenges in organic agriculture, one of the main is to enhance productivity and compete with a conventional agricultural system, as organic farming is often associated will low productivity [3]. Crops productivity directly linked to the maintenance of soil fertility, which mainly relays on organic input due to the restriction of synthetic fertilizers.

There are different soil management practices to ensure an adequate supply of agricultural crops with nutrients. The current study aimed to study micronutrient content and availability through understanding their mobility in soil under different management practices in organic vineyards.

Methods

There were three different sites selected under different soil-climatic conditions. Soil pits were dug on each vineyard plot of the study areas. At least one soil profile was made on each study site and 3 to 6 samples were taken. A detailed field description for each soil profile included site description and a profile description including soil colour (Munsell charts), mottles, coarse fragments, structure, consistence, effervescence (10% hydrochloric acid), roots, pores, cracks, biological and human activity, etc. were conducted. Soil samples from each pit were taken and analysed in laboratory conditions for basic physical and chemical properties. The soils in study areas, according to WRB (World Reference Base for Soil Resources) classification [4], belong to Kastanozems - Site 1; Cambisols – Site 2 and Site 3.

Treatments and experimental design

There were several treatments under which micronutrient mobility was observed during two years after the establishment of the selected agricultural practice.

Site 1 - Municipality of Sagarejo, Khashmi (latitude: 41.782626; longitude: 45.180690): a) control – cultivation between rows to supress weeds and to prevent crust formation; b) cover cropping with alfalfa; c) organic fertilizer containing microorganisms - lithobionts, actinomycetes and azotobacter, later referred as OF.

Site 2 - Municipality of Akhmeta, Maghrani (latitude: 42.090207; longitude: 45.344527): a) control - cultivation between rows to supress weeds and to prevent crust formation; b) cover cropping with grass mixture; c) OF.

Site 3 - Municipality of Khulo, Maniaketi (latitude: 41.632467; longitude: 42.384846): a) control - cultivation between rows to supress weeds and to prevent crust formation; b) organic mulching with wood chips.

In each vineyard, two rows with a length of 20-30 m were selected for individual treatment as described above.

Soil sampling and processing

Soil samples were collected in the vineyards within rows from 0–20, 20–40, 40-60 cm soil depths using spade before the start of the experiment, at the beginning of vegetation season (April, 2017), and after establishing management practices from 0-20 cm in order to monitor changes in micronutrient composition 2 times per year in May and August during 2017-2018. Two rows were dedicated to each soil management practice, therefore within each row, a composite sample from top 20 cm was prepared by taking samples from 3-5 locations, depending on a length of a row, so finally two composite samples were taken for laboratory analysis per treatment during each sampling period. The soil samples were oven-dried at 40°C, ground to pass through a 1-mm sieve, and stored in plastic containers for laboratory analysis of selected soil physical and chemical properties.

Measurement of soil parameters

Soil textural analysis was performed by following a pipette method. The textural class was determined according to soil textural classification proposed by Kachinsky [5], as the national soil classification system is based on it. Soil bulk density was measured by the core sampling method using 100 ml stainless steel cores by placing the core in the middle of each soil layer in three replications. Soil hygroscopic moisture was determined by a gravimetric method at 105°C using drying oven till constant weight.

Soil pH was studied in soil: water ratio of 1:2.5 by following standard methods as described by Talakhadze [6]. The organic carbon (OC) content of the soils was determined using wet oxidation method according to Walkley and Black [7], calcium carbonate with Scheibler calcimeter, cation exchange capacity and exchangeable bases in barium chloride extraction with final determination using flame atomic absorption spectrometer (AAS). Total nitrogen (N) concentration was estimated by modified Kjeldahl method (ISO 11261:1995) [8], available phosphorus (P) by molybdenum blue method followed after extraction as described by Olsen et al. (1954) [9], available potassium (K) by flame atomic absorption spectrophotometer (AAS) using neutral 1N ammonium nitrate extractant according to DEFRA (Department of the Environment, Fisheries and Rural Affairs, UK) method. Mobile and potentially plant-available micronutrients Fe, Mn, Zn, and Cu of the soil samples were estimated by using atomic absorption spectrophotometer (AAS) following the extraction by 1N ammonium acetate buffer (pH=4.8) solution and final measurements were done on Inductively coupled plasma mass spectrometry (ICP-MS). Ammonium acetate buffer was chosen to ensure comparability to the maximum permissible values established according to legislative norms [10] of Georgia.

The laboratory studies were carried out in the Laboratory of the Soil Research Service of Scientific-Research Centre of Agriculture.

The results obtained were treated statistically to determine the significance of differences before and after treatment compared to control. Student's t-test was used, which is quite robust and can be valid even with smaller sample sizes.

Results and Discussion

General properties of soils under experiments on each site are given in Table 1, showing the main parameters influencing nutrient mobility and potential availability to plants. The results of concentrations of mobile forms of micronutrients such as Mn, Fe, Cu, Mo, Ni, Zn after one year from the start of the field trials are shown in Tables 2, 3, and 4. Sampling was done twice per year in May and August.

Table 1. *General soil fertility parameters for top 0-20 cm layer, at the start of field trials, April 2017*

Parameter	Sagarejo, Khashmi	Akhmeta, Maghraani	Khulo, Maniaketi
pH	8.29±0.29	6.67±0.22	6.42±0.15
Organic matter, %	3.72±0.54	3.69±0.28	6.07±0.35
Total nitrogen, %	0.32±0.02	0.35±0.03	0.56±0.07
Phosphorus (Olsen-P), mg/kg	10.00±5.30	31.90±4.80	144.90±17.80
Available potassium, mg/kg	379.25±34.65	187.75±38.25	326.6±17.70
Exchangeable Ca mg.eqv/100 g soil	43.56±3.19	46.31±6.2	27.46±0.49
Exchangeable Mg mg.eqv/100 g soil	2.22±0.18	4.5±0.48	3.33±0.17
Texture class	Light clay	Light clay	Medium loam

Table 2. *Mobile forms of micronutrients in vineyard soil of Sagarejo, Khashmi, (mg/kg), May-August 2018*

Treatment	Mn	Fe	Ni	Cu	Zn	Mo
Control	3.55±0.26	0.37±0.18	0.12±0.08	0.40±0.01	BDL*	BDL**
Cover cropping, alfalfa	3.46±0.10	0.58±0.27	0.14±0.10	0.36±0.02	BDL	BDL
Application of OF	3.05±0.24	0.51±0.16	0.11+0.08	0.33±0.02	BDL	BDL

*Below detection limit – 0.09 mg/kg

**Below detection limit – 0.9 mg/kg

Table 3. *Mobile forms of micronutrients in vineyard soil of Akhmeta, Maghraani, (mg/kg), May-August 2018*

Treatment	Mn	Fe	Ni	Cu	Zn	Mo
Control	36.20±3.33	2.24±0.26	0.36±0.06	0.09±0.01	0.32±0.01	BDL*
Cover cropping, grass mixture	44.69±3.61	2.05±0.08	0.50±0.06	0.26±0.02	0.76±0.02	BDL
Application of OF	38.41±3.38	0.42±0.14	0.37±0.05	0.10±0.03	0.17±0.02	3.24±0.47

* Below detection limit – 0.9 mg/kg

Table 4. *Mobile forms of micronutrients in vineyard soil of Khulo, Maniaketi, (mg/kg), May-August 2018*

Treatment	Mn	Fe	Ni	Cu	Zn	Mo
Control	40.34±3.18	0.54±0.13	0.13±0.05	0.13±0.02	0.50±0.02	1.57±0.51
Mulching, wood chips	51.05±1.54	0.70±0.10	0.14±0.04	0.16±0.01	0.56±0.03	3.31±0.44

Based on statistical analysis, in the case of Site 1 - Sagarejo, Khashmi, the only concentration of Cu in control and treatment with OF was statistically significant, showing that reduction in Cu mobile fraction was influenced by the application of OF. It seems that organic compounds containing in OF created stable bounds with copper, which has a high affinity to them [11, 12].

On Site 2 - Akhmeta, Maghraani, statistically significant changes were observed in the case of Mn and Zn, plant available pool of these elements was increased probably due to greater vigour of grass mixture to extract them from soil and enhance their mobility after mineralization as a result of incorporation into soil after ploughing. Similar pattern was observed in various studies, where cover cropping enhanced bioavailability of plant nutrients [13]. The mobility of Fe was significantly reduced after OF application, which might be related to the fixation capacities of the fertilizer constituents. On the other hand, OF fertilizer has a noticeable positive impact on the mobility of Mo, which was below the detection limit in control and grass mixture treatment. It can be associated with the activity of various microbial communities introduced into soil [14] via fertilization, although due to the complex composition of OF fertilizer and insufficient data about its performance under different soil-climatic conditions this phenomenon is subject to further studies, as organic matter highly impact metal mobility [15].

On site 3 - Khulo, Maniaketi mobility of Mn, Fe, and Mo was improved by the application of wood chips, which mainly improved water and temperature balance at the soil surface, which is the most active part both for macro- and microorganisms responsible for many biochemical processes taking place in soil [16].

In addition to observation of changes in micronutrients mobility caused enhancements in translocation abilities of some elements, which might be toxic to the environment in high concentrations, were compared to existing legislative norms, where maximum permissible limits for a number of elements including those being subject to our study are set. The comparison shows that none of the micronutrients assessed are in the access amount in the studied soils. All micronutrients at all sites and under each treatment are far below the limits set in Georgia [10].

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