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STATUS OF NUTRIENTS IN VINEYARDS OF ĆEMOVSKO POLJE

SUMMARY

The results of investigation of nutrient status in vineyards of Ćemovsko polje are shown in this paper. In order to provide a more reliable basis for the definition of relationships between grapevine (nutrients in leaf petiole – P, K, Ca, Mg, Fe, Mn, Cu and Zn) and soil properties (pH, total carbonates, humus (organic matter), exchangeable Mg and available P, K, Fe, Mn, Zn and Cu), factor and correlation analyses were applied. In the top layer (0 – 30 cm), investigated highly calcareous and alkaline soil had high concentration of nutrients, exceptionally for iron which was on the limit between low and medium level, and for phosphorus on low level. In the underlying soil layer (30 – 60 cm), nutrient contents were low.

The content of Cu was very high in the both soil layer, due to its accumulation through agronomic practice, where Cu as a common ingredient of the plant protection products used especially in vineyards. In average, the level of P, K, Ca, Mg, Zn and Cu in leaf petioles indicated optimal supply of grapevine. However, the deficiency of Fe and Mn was detected. A common cause of chlorosis is a deficiency of these elements, which are of crucial importance for photosynthesis.Four factors determining soil chemical characteristics were identified by factor analysis. They accounted for about 78% of the total variance. The communalities of parameters, considering four factors, varied from about 59% for available K to 85% for humus and exchangeable Mg.

Two main factors represented the statuses of: 1) mutually complementary available fraction of Zn and Mn (positive pole) and pH and carbonate (negative pole), and 2) humus and available Fe. Directly proportionality was found between the content of Mn in petiole and the score of first factor ($p = 0.037$). It means that the status of Mn in grapevine depends directly on the available fraction of Mn in soil (DTPA-Mn), as well as indirectly on the pH value and CaCO3 content. The availability of Fe (DTPA-Fe) depends on the content of humus, since positive statistically significant ($p = 0.015$) correlation was found. The management practices which can influence on availability of Fe and Mn are the increase of organic matter (humus) and modification of the soil pH. The applications of fertilizers containing Fe and Mn through leaves or soil are recommended.

Keywords: soil, petiole, nutrient, deficiency, factor

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INTRODUCTION

Along with climatic conditions, soil characteristics and nutrient supply are important determinants of quantity and quality of yield of agricultural plants (Peuke, 2009). The chemical and physical properties of soil affect the availability of nutrient for plant uptake (Havlin et al., 2005), and in such a way nutrient concentration ranges in plants (Peuke, 2009). In the Mediterranean area, it is estimated that 20–50% of fruit crops are affected by Fe deficiency causing dramatic economic losses (Yunta et al. 2013). Many vineyards in mentioned area are on calcareous soil and therefore due to the deficiency of nutrients under risk of chlorosis. A common cause of chlorosis is a deficiency of Fe and Mn, essential elements, which are the building blocks used to create the thousands of organic compounds that make up plant tissue or drive growth processes. Iron is a component of certain enzymes and proteins that are used during photosynthesis and in respiration. Manganese is an enzyme activator during chlorophyll production and as a structural component of the chloroplasts where photosynthesis occurs (http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/iron-chlorosis/).

The typical symptom of Fe chlorosis is a lack of chlorophyll (yellowing) in the intervenial of youngest leaves during the active growth period and growth depression (Bavaresco et al., 1993; Gruber and Kosegarten, 2002).

The Mn deficiency has little practical effect on vine yields since it appears in late season on older leaves that contribute little to vine function. The symptoms begin on the basal leaves as a chlorosis between the veins (Hamman et al., 1998).

The use of foliar analysis for assessing the nutritional status of plants is an old practice. The aim of study was to reveal the cause of grapevine leaf yellowing and to compare the results of soil and petiole (sampled during full bloom) analyses. In order to avoid shortcomings in the interpretation of simple relationship between nutrients in leaf petiole and soil parameters, the principal component analysis was applied.

MATERIAL AND METHODS

The soil samples (from 0-30 cm and 30-60 cm depth) and leaf petioles of grapevine (from opposite flower cluster, near the middle of the shoot) were taken in 11 localities of Ćemovsko polje. The basic soil parameters were determined by methods widely used in Former Republics of Yugoslavia (Džamić *et al.*, 1996). The content of available Fe, Mn, Zn and Cu (extraction with 0.005 M DTPA) as well as of exchangeable Mg (extraction with 1 M NH_4CH_3COO) in soil were determined by flame atomic absorption spectrophotometry (FAAS).

In acid digest (HNO_3 and $HClO_4$) of dried leaf petioles, P was determined spectrophotometrically, K and Ca flame photometrically, and the other elements by FAAS. The results were processed by means of the SPSS 10.0 Program. The statistical analyses included descriptive (mean and standard deviation), correlation and factor analysis. By factor analysis the original set of 10-correlated soil parameters (pH, humus, total carbonates, exchangeable Mg, available P, K, Fe, Mn. Zn and Cu), were transformed into a new set of mutually uncorrelated factors according to Topalović *et al.* (2006; 2010).

RESULTS AND DISCUSSION

The descriptive statistics (minimal, maximal and mean values with standard deviation) of soil parameters are given in Tables 1 and 2. In the top layer (0 – 30 cm), investigated highly calcareous and alkaline soil had high concentration of nutrients exceptionally for iron which was on the limit between low and medium level, and for phosphorus on low level.

Table 1. Descriptive statistics for the top soil layer

Soil Layer (0 – 30 cm)	Minimum	Maximum	Mean	Std. Deviation
pH (H_2O)	7.68	7.88	7.77	0.05
Humus (%)	3.52	5.53	4.48	0.66
Total carbonates (%$CaCO_3$)	14.5	45.8	28.2	9.9
P_2O_5 (mg/100 g)	0.9	24.7	6.8	7.1
K_2O (mg/100 g)	12.4	37.5	19.2	6.0
Mg (mg/100 g)	15.7	32.4	23.8	4.8
Fe (ppm)	7.3	22.3	10.7	4.3
Mn (ppm)	3.6	29.1	13.3	7.9
Cu (ppm)	2.3	37.3	11.3	9.9
Zn (ppm)	1.1	8.0	3.7	2.0

In the underlying soil layer (30 – 60 cm), nutrient contents were low. The content of Cu was very high in the both soil layer, due to its accumulation through agronomic practice, where Cu as a common ingredient of the plant protection products used especially in vineyards. Considering organic matter i.e. humus, the top soil layer is on optimal level, since the underlying one has low content.

As shown in Table 3, the average content of P, K, Ca, Mg, Zn and Cu in leaf petioles indicated optimal supply of grapevine. However, the deficiency of Fe and Mn was detected.

Four factors determining soil chemical characteristics were identified by factor analysis (Table 4). They accounted for about 78% of the total variance. The communalities of parameters, considering four factors, varied from about 59% for available K to 85% for humus and exchangeable Mg.

Table 2. Descriptive statistics for the underlying soil layer

Soil Layer (30 – 60 cm)	Minimum	Maximum	Mean	Std. Deviation
pH (H_2O)	7.36	8.32	8.04	0.20
Humus (%)	1.04	3.02	1.85	0.57
Total carbonates (%$CaCO_3$)	57.3	88.6	68.5	7.2
P_2O_5 (mg/100 g)	2.5	12.4	6.4	3.0
K_2O (mg/100 g)	3.5	17.5	7.1	3.6
Mg (mg/100 g)	13.2	22.2	16.8	2.5
Fe (ppm)	3.1	7.8	5.6	1.4
Mn (ppm)	1.9	13.6	6.7	3.6
Cu (ppm)	0.5	14.5	2.6	3.4
Zn (ppm)	0.3	2.7	0.8	0.7

Table 3. Descriptive statistics for the leaf petiole of grapevine sampled in bloom.

Petiole	Minimum	Maximum	Mean	Std. Deviation
P (%)	0.2	0.5	0.4	0.1
K (%)	1.2	3.0	2.0	0.5
Ca (%)	1.7	2.7	2.2	0.3
Mg (%)	0.2	0.7	0.5	0.1
Fe (ppm)	19.3	25.8	22.9	2.3
Mn (ppm)	10.1	35.2	21.4	8.6
Cu (ppm)	7.2	21.1	10.2	3.4
Zn (ppm)	17.8	52.5	34.7	8.9

Table 4. Factor analysis for soil: Eigenvalues, cummulative of the total variance, factor loading of the 4 factors, and communality estimates of the 10 soil parameters

	Factor 1	Factor 2	Factor 3	Factor 4	Commun.
Eigenvalue	2.60	2.28	1.52	1.40	
Cumulative (%)	26.0	48.8	64.0	78.0	
pH (H_2O)	-0.817	-0.171	-0.114	-0.307	0.803
Total carbonates	-0.812	0.108	0.109	0.319	0.784
Zn	0.772	0.311	0.348	0.127	0.829
Mn	0.611	-0.504	0.004	0.363	0.759
Humus	0.099	0.886	0.134	-0.187	0.847
Fe	0.062	0.801	0.149	0.232	0.721
P_2O_5	-0.093	0.370	0.824	0.116	0.838
Cu	0.513	-0.116	0.712	0.025	0.785
K_2O	0.121	-0.082	0.190	0.730	0.590
Mg	-0.070	0.551	-0.339	0.651	0.847

Factor 1 is composed from two complementary groups of parameters. Group I: DTPA-Zn and DTPA-Mn reperesenting available fraction of these elements and group II: soil pH and total carbonates. This is expected, due to fact that the availability of mentioned elements decreases at pH > 6.

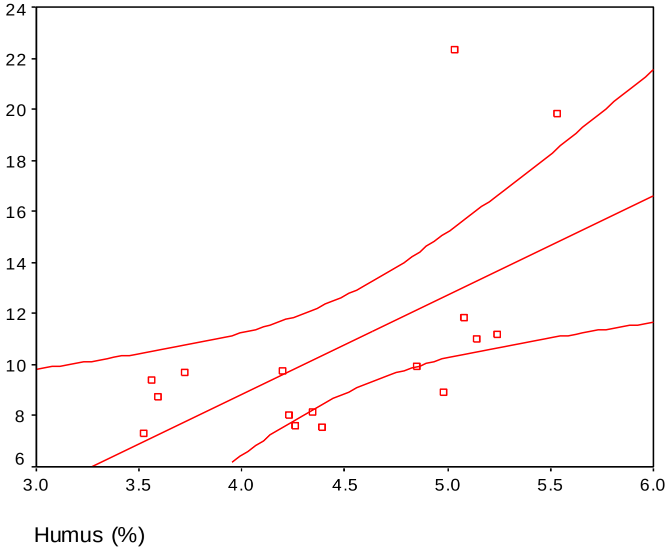

Figure 1. Available Fe vs. humus in top soil layer (R = 0.594, p = 0.015)

Factor 2 is consisting from humus and DTPA-Fe due to associations of Fe with humic substances. Naimely, the availability of Fe (DTPA-Fe) depends on the content of humus, since positive significant correlation was found.

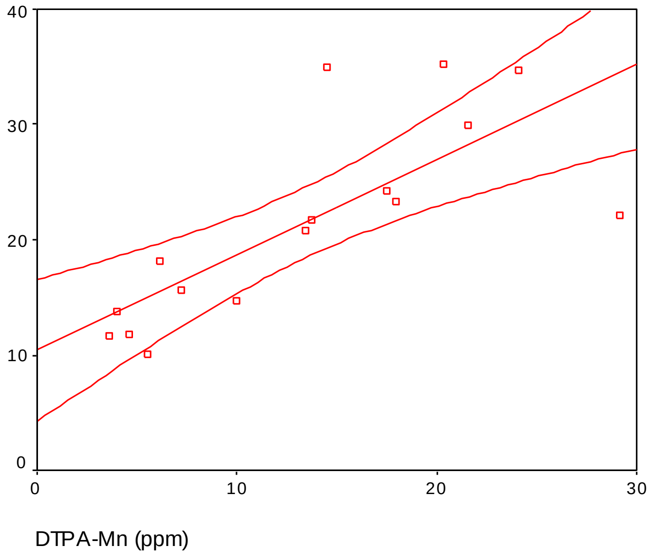

Figure 2. Total manganese in petiole vs. available Mn in top soil layer (R = 0.764, p = 0.001)

Factor 3 includes available P and Cu, and factor 4 is represented by available K and exchangable Mg.

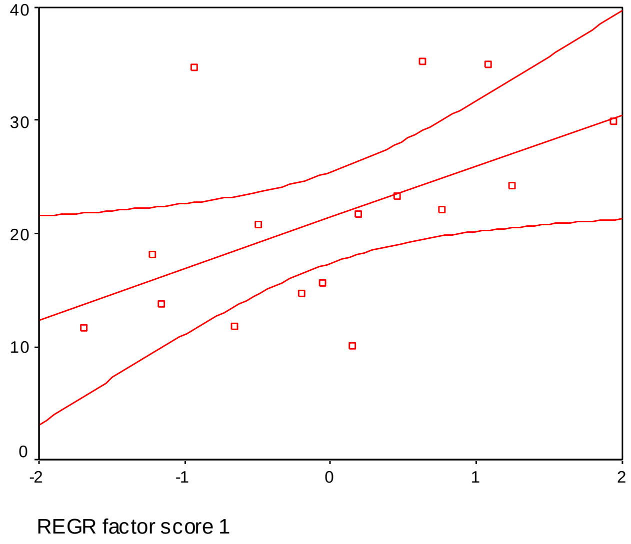

Figure 3. Total manganese in petiole vs. regression factor score 1 for top soil layer (R = 0.532, p = 0.034)

The nutrient uptake by plants can be affected by these factors determining soil chemism. Because of that, the correlations of nutrient contents in leaf petiole of grapevine with the scores of above-mentioned factors were examined. Direct proportionality was found between the content of Mn in petiole and the score of first factor (p = 0.037). It means that the status of Mn in grapevine depends directly on the available fraction of Mn in soil (DTPA-Mn), as well as indirectly on the pH value and $CaCO_3$ content.

The management practices which can influence on availability of Fe and Mn are the increase of organic matter (humus) and modification of the soil pH. The use of Fe and Mn fertilizers is recommended.

Manganese sulfate as a foliar spray at the loose cluster stage has corrected the deficiency in some California vineyards (Hamman et al., 1998). Manganese chelate products have been used as foliar sprays with some success (Fageria et al., 2009). Foliar spray treatments of Fe chelates or of ferrous sulfate result in a temporary correction, at best. If chlorosis is severe and persists, repeated applications at 10 to 20-day intervals may be necessary (Hamman et al., 1998).

Fe chelates (iron(3+) ethylenediamine-N,N'-bis(hydroxyphenylacetic acid i.e. FeEDDHA) and ferrous sulfate are the most commonly used to prevent Fe-chlorosis. The former is substantially more effective than the latter but more expensive and easily leached from the soil (Hamman et al., 1998). The study of Diaz et al. (2010) recommended the use of $Fe_3(PO_4)2{\cdot}8H_2O$ (vivianite) because of its effectiveness (<30% Fe) and long-term fertilizing effect over the other Fe salts applied to the soil due to the presence of phosphate, which favors its transformation to poorly crystalline lepidocrocite, from which Fe is readily available to plants. Moreover, it is not easily leached from the soil, inexpensive, environmentally safe.

CONCLUSIONS

The results of soil and petiole analysis indicated relatively poor supplying of grapevine with Fe and Mn. The Fe and Mn availability in soil could be controlled by management practices that increase the content of organic matter (humus) and modify the pH value of soil. The applications of fertilizers containing Fe and Mn through leaves or soil are recommended.

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