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ASSESSMENT OF SOIL FERTILITY AND LEAF NUTRIENTS IN OLIVE ORCHARDS

SUMMARY

The status and relationship between soil characteristics and nutrient contents in olive leaves of autochthonous Montenegrin cultivar 'Žutica' and Italian 'Leccino' were investigated. The sampling was done in the municipality of Tivat.

The content of nutrient elements in olive leaves depend on cultivars, physiological phases of sampling, edaphoclimatic, pedological characteristics and agronomic techniques.

Regarding the results of soil and leaf analysis, it is generally recommended to decrease fertilization with K, but in some orchards to increase with N. Since the content of Fe, and in the most cases of Mg, was below optimal, the foliar fertilizers should be applied. In saline and calcareous soils, the application of organic fertilizers could improve nutrient uptake, transport and availability to the plant.

The correlation between Ca and N in olive leaves was significantly negative ($p=0.005$). The negative relationships (very close to significance level 0.05) of soil clay component with leaf Cu, and between silt component and P, but positive relationship of humus component with leaf Zn were found.

Keywords: Žutica, Leccino, olive leaves, soil, nutrients, fertilizer

INTRODUCTION

The olives (*Olea europaea* L.) are cultivated worldwide on nearly 11 million ha, with more than 90% of that area in the Mediterranean Basin, characterized by cold and wet winters, but hot and dry summers (Zipori *et al*., 2020). The factors which effect on quality and quantity of olive yield are season climatic conditions, irrigation, soil characteristics and agronomic practices (Knežević *et al*., 2017; Markoč, 2019; Mhanna *et al*., 2021).

About 70% of the olive orchards are traditional and marginal with a medium to very low productivity due to the lack of appropriate orchard

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management (in a significant degree). In these rainfed orchards, water is very often the limiting factor for nutrient availability and uptake. Insufficient rainfall may lead to significant decrease of yield, because of lack of nutrients in the root zone. Excessive rainfall has the same effect on yield due to significant losses of nitrogen from the rhizosphere, thus autumn fertilization is not recommended. About 30% of the olive orchards are usually drip-irrigated, fertirrigated and planted with quick-growing young olive plantings, which have suitable productivity but usually associated with higher environmental impacts (Gargouri *et al.*, 2006; Gencer *et al*., 2019; Zipori *et al*., 2020). The farmers often manage their orchards regardless the soil fertility. Unnecessary applications of fertilizers i.e. over- or under-application cause also economic losses, environmental pollution and unsatisfactory yields. It may be prevented by taking into account the analysis of soil and plant (Miranović, 2006).

Although olives prefer deep loam texture soil, they can grow well on almost any well-drained and aerated soil with moderately fine texture (ranging from sandy to silty clay, loamy soils). The most suitable soil is 6.5–8.5 (from the neutral, slightly alkaline values to alkaline ones). It is known that olive trees are tolerant to mild saline conditions (Gargouri *et al*., 2006; Toscano *et al*., 2015).

The olive trees are very tolerant towards soil carbonates. Namely, excellent yield and vegetative growth were observed, in both soils with low content of carbonates and where this parameter being 50%, with a limit of 76% (Gargouri *et al*., 2006).

Organic matter enhances the olive tree productivity through positive effects on soil structure, water retention capacity and availability of some nutrients (limiting erosion, nitrogen leaching, phosphorus precipitation and iron inactivation). Soyergin *et al*. (2002) considered that the content of soil organic matter more than 1% being suitably for well growth. Thus, preserving soil richness in organic matter is very important in the sustainability of olive farming.

The available fraction of P depends on adsorption by various minerals, mostly by carbonates and may be influenced by several factors like pH and soil organic matter (Topalović *et al*., 2006).

Potassium as a relatively mobile nutrient can be rapidly leached in sandy ones. The available K content in the soil is correlated to clay content. The olive trees can compensate, partially, the lack of soil P and K due to uptake of these nutrients from huge soil volume (Gargouri *et al*., 2006). Tubeileh *et al*. (2014) found that available soil K and soil depth explained together 77% of the yield variability, which increased to 83% by incorporating leaf B and Fe concentrations.

Microelements such as Fe, Zn, Mn, and Cu are required in small or very small amounts. Due to fact that most olive orchards are grown on calcareous soils, their availability may be limited.

Besides the functions of nutrients in plant metabolism (Pasković *et al.*, 2020), the plant tolerance or resistance to biotic or abiotic stresses can be affected by their status (Fernández-Escobar, 2019).

This research was carried out to determine status and relationship between soil characteristics and nutrient levels in olive leaves of autochthonous Montenegrin cultivar 'Žutica' and Italian 'Leccino' (as the most common and widespread allochthonous olive cultivar).

MATERIAL AND METHODS

The soil samples were taken from 0–30 cm and 30–60 cm depth from olive orchards in Tivat Municipality (Grbalj, Gornji Grbalj, Pelinovo, Dumidran, Radovići). The soil sampling was done on 12th March, and olive leaves on 1st July from the middle of current season non-fruit-bearing shoots.

The soil parameters were determined by methods described by Džamić *et al*. (1996, cited by Lekić, 2016). The concentrations are expressed on air-dried basis.

Plant material was dried at 65ºC and ground in laboratory mill. After acid digestion with HNO_3 and $HClO_4$ (2:1), the total elemental concentrations – Ca, Mg, Fe, Mn, Zn and Cu were determined by FAAS (Shimadzu, AA – 6800). Total nitrogen was determined by Kjeldahl method. The concentrations are expressed on dry matter.

Due to fact there are no meteorological data for Tivat, the average values of temperature and precipitation were given for three coastal towns in Montenegro (Herceg Novi, Bar and Ulcinj) in period 1981–2010 (http://www.meteo.co.me/).

The data statistical analysis was performed by SPSS 23.0. The descriptive statistics, bivariate correlation analysis and Principal component analysis (PCA) with Varimax rotation were done.

RESULTS AND DISCUSSION

The optimal conditions for olive growth, development and fruit yield are average annual temperatures between 15°C and 25°C. It can withstand maximum temperatures of up to 50 °C, but minimal temperature -7 °C (no longer than 8–10 days). The annual precipitation demand lies between 700–850 mm (Ozturk *et al*., 2021).

The average annual temperature for three coastal towns was around 16°C, and annual sum of precipitation in the range 1189–1771 mm. The changes of parameters per months are given in Fig. 1.

The results of the soil analysis (Table 1 and 2) show great variability in soil properties. These soils belong to the category of fertile ones, with weakly acidic to alkaline reaction, from carbonate-free to calcareous conditions, and from optimal to very high humus content.

The available concentrations of nutrients ranged from optimal, through high to very high in the samples of topsoil layer, and in the most soil samples of the underlying layer. These results indicate the high effect of fertilization on soil properties.

In the upper layer, the soils mainly belong to the textural class of clay loam, and in the underlying layer to light clay. Only at one location, there is a sandy loam soil.

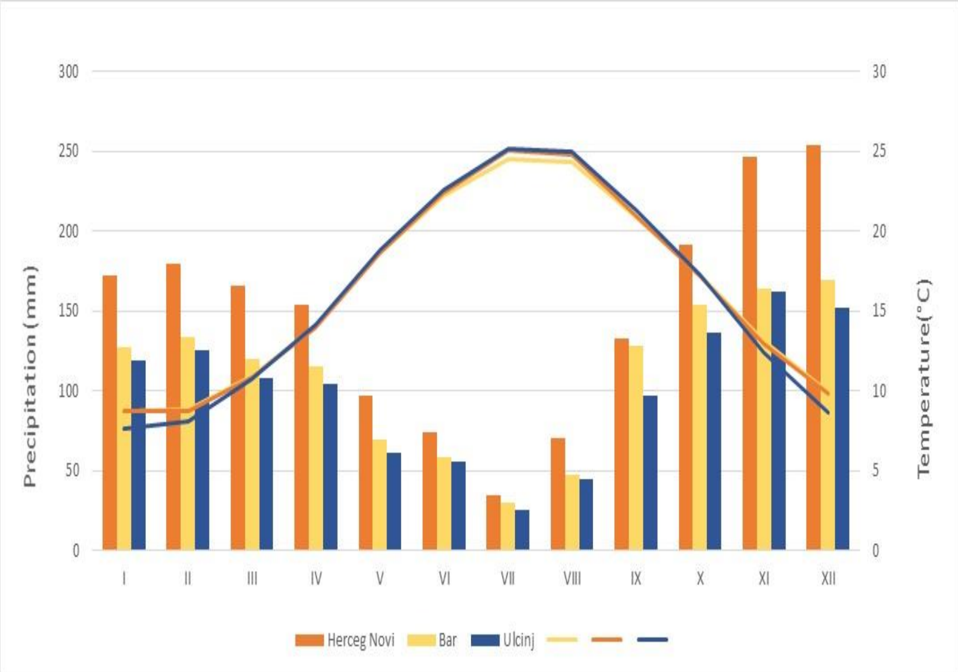

Figure 1. Climatic parameters in three coastal towns in Montenegro

The nutrient contents in leaves of Žutica' and 'Leccino' are presented in Fig. 2 and 3. In some orchards of both cultivars the N deficiency was recorded. The Fe content was below optimal in both cultivars, while Mg content was mainly below or at the lower limit of optimal. Also, Ca in 'Žutica' leaves was at the lower limit of optimal content, in average. The potassium content was above the optimal value in both cultivars, as well as Cu in 'Leccino'. The supply of olives with other nutrients was generally optimal (Connell & Vossen, 2007).

In the leaves of five olive cultivars (two Croatian – 'Istarska bjelica' and 'Lastovka', two Italian – 'Pendolino', 'Leccino', and one Spanish cultivar – 'Hojiblanca') sampled as in our study, Pasković *et al*. (2013) found lower concentrations for P (0.08−0.12%) and K (0.77−1.24%), mainly similar or higher for Mg (0.08−0.15%) and Ca (1.14−2.04%), respectively.

The concentration of microelements in our samples were close to maximum for Fe (38−54.5 ppm), close to minimum for Zn (17.8−30.17 ppm) and Mn (23.8−33.4 ppm), but higher for Cu (5.8−7.17 ppm) than ones found in the mentioned 5 cultivars grown in Croatia (Pasković *et al*., 2013).

Table 1. Descriptive statistics for soil parameters (topsoil samples from olive orchards in the municipality of Tivat)

Soil layer (0-30 cm) in olive orchard	Leccino			Žutica		
	Min	Max	Mean±sd	Min	Max	Mean±sd
pH(H_2O)	6.27	7.60	6.92 ± 0.67	6.39	7.58	7.02 ± 0.60
pH(KCl)	5.69	7.13	6.38 ± 0.72	5.76	7.00	6.41 ± 0.62
Total carbonates (%$CaCO_3$)	0.00	53.70	17.90 ± 31.00	0.00	25.20	9.83 ± 13.48
Humus (%)	5.67	6.61	6.11 ± 0.47	5.39	7.46	6.28 ± 1.07
Available P (mg P_2O_5/100 g)	7.10	57.70	40.00 ± 28.52	8.40	18.00	14.23 ± 5.12
Available K (mg K_2O/100 g)	17.20	115.70	56.10 ± 52.41	20.50	111.00	60.37 ± 46.20
Electrical conductivity (microS/cm)	86.70	154.80	114.10 ± 35.95	86.50	161.90	116.53 ± 39.97
Exchangable Ca (mg/100 g)	238.00	2212.00	905.00 ± 1131.98	292.00	2104.00	923.00 ± 1023.58
Exchangable Mg (mg/100 g)	9.60	27.60	18.23 ± 9.02	18.50	33.60	24.67 ± 7.92
Available Fe (mg/kg)	10.90	33.30	25.57 ± 12.71	15.40	22.40	19.83 ± 3.86
Available Mn (mg/kg)	13.20	103.30	54.53 ± 45.51	17.00	93.10	48.47 ± 39.72
Available Cu (mg/kg)	12.69	31.00	19.62 ± 9.93	4.61	27.72	12.80 ± 12.94
Available Zn (mg/kg)	2.01	8.55	5.60 ± 3.32	1.85	10.62	4.87 ± 4.98
Coarse sand (%)	2.62	24.10	14.28 ± 10.86	1.33	20.21	7.84 ± 10.72
Fine sand (%)	36.87	45.61	41.84 ± 4.49	23.72	46.92	37.37 ± 12.13
Silt (%)	22.15	31.00	27.01 ± 4.49	24.23	39.72	32.89 ± 7.91
Clay (%)	10.70	23.90	16.88 ± 6.64	16.83	27.52	21.90 ± 5.37
Total sand (%)	48.22	67.15	56.12 ± 9.85	43.45	48.25	45.21 ± 2.64
Total clay (%)	32.85	51.78	43.88 ± 9.85	51.75	56.55	54.79 ± 2.64

In olive leaves cv. Picual, Cornicabra and Manzanilla sampled in harvest (November) and usual pruning (March) in the southwest region of Spain, the concentration of nutrients were P: 0.09−0.15%, K: 0.66−0.98%, Mg: 0.07−0.18%, Ca: 1.73−2.70%, Fe: 76−117 ppm, Mn: 36−64 ppm, Zn: 14−19 ppm and Cu: 24−111 ppm (Martínez-Navarro *et al.*, 2021). The content of Mg, Zn, P and K was similar to higher, but lower for Fe, Mn and Cu in tested samples of 'Žutica' and 'Leccino’ in Montenegro.

In the study of 21 olive cultivars (17 Turkish), the concentration of nutrients in leaves taken at the beginning of December were N: 1.89−2.03%, P: 0.12−0.2%, K: 0.84−1.02%, Ca: 1.72−2.12%, Mg: 0.15−0.27%, Fe: 53.6−78.8 ppm, Mn: 23.1−32.92 ppm, Zn: 15.1−26.8 ppm and Cu: 11−25 ppm (Toplu *et al.*, 2009). Nevertheless the different cultivars, physiological phases of sampling, edaphoclimatic and pedological characteristics as well as the agronomic techniques, our results are higher for K, lower for Ca and Mg, but similar for Fe, Zn and Cu in comparison to ones monitored in cultivars grown in Türkiye. Besides, Toplu *et al*. (2009) also found significantly negative correlation between Ca and N in leaves, and positive between Zn and Mn. These correlation coefficents are -0.940 (p=0.005) and 0.772 (p=0.072) for altogether leaf samples of 'Žutica' and 'Leccino'.

Table 2. Descriptive statistics for soil parameters (samples of underlying soil layer from olive orchards in the municipality of Tivat)

Soil layer (30-60 cm) in olive orchard	Leccino			Žutica		
	Min	Max	Mean±sd	Min	Max	Mean±sd
pH(H_2O)	7.04	7.85	7.41 ± 0.41	6.28	7.71	7.03 ± 0.72
pH(KCl)	6.40	7.31	6.81 ± 0.46	5.67	7.13	6.47 ± 0.74
Total carbonates (%$CaCO_3$)	0.00	59.90	22.03 ± 32.94	3.80	26.60	11.40 ± 13.16
Humus (%)	3.01	4.60	3.91 ± 0.81	3.99	6.94	5.11 ± 1.60
Available P (mg P_2O_5/100 g)	5.50	14.70	9.33 ± 4.79	0.20	17.30	6.40 ± 9.47
Available K (mg K_2O/100 g)	8.00	42.50	23.13 ± 17.64	18.90	25.30	21.27 ± 3.51
Electrical conductivity (microS/cm)	79.80	206.10	137.77 ± 63.78	62.10	163.50	106.63 ± 51.81
Exchangable Ca (mg/100 g)	238.00	2185.00	968.00 ± 1060.93	157.00	2077.00	869.00 ± 1051.72
Exchangable Mg (mg/100 g)	6.00	29.90	17.37 ± 11.99	16.20	37.00	24.70 ± 10.91
Available Fe (mg/kg)	7.30	24.10	15.57 ± 8.40	10.20	20.40	16.80 ± 5.72
Available Mn (mg/kg)	7.20	42.50	29.93 ± 19.72	18.30	37.30	29.53 ± 9.96
Available Cu (mg/kg)	2.97	29.35	12.85 ± 14.38	2.40	9.63	6.31 ± 3.65
Available Zn (mg/kg)	0.32	2.98	1.99 ± 1.45	1.05	3.13	2.30 ± 1.10
Coarse sand (%)	7.61	24.19	18.62 ± 9.54	0.97	19.13	7.14 ± 10.39
Fine sand (%)	30.99	40.89	35.41 ± 5.03	22.77	51.28	34.45 ± 14.94
Silt (%)	20.70	26.13	24.03 ± 2.92	21.50	36.90	30.71 ± 8.13
Clay (%)	14.22	35.27	21.93 ± 11.60	21.20	36.00	27.70 ± 7.56
Total sand (%)	38.60	65.08	54.04 ± 13.78	30.28	52.60	41.59 ± 11.16
Total clay (%)	34.92	61.40	45.96 ± 13.78	47.40	69.73	58.41 ± 11.17

According to the highest loadings of topsoil parameters (with the greatest olive root densities) after Varimax rotation, component 1 could be assigned as carbonate component, component 2 as clay, component 3 as silt (negative) and component 4 as humus component (Fig. 4).

The bivariate correlation analysis between the scores of soil parameters and the content of leaf elements shows negative relationships of clay component with Cu (p=0.055), and between silt component and P (p=0.053); but positive relationship of humus component with Zn (p=0.055). The clay particles could decrease the plant uptake of some nutrients, because of their adsorption affinity for Cu and P. On the other hand, humus has beneficial effects on nutrient uptake, transport and availability to the plant in saline and calcareous soil conditions.

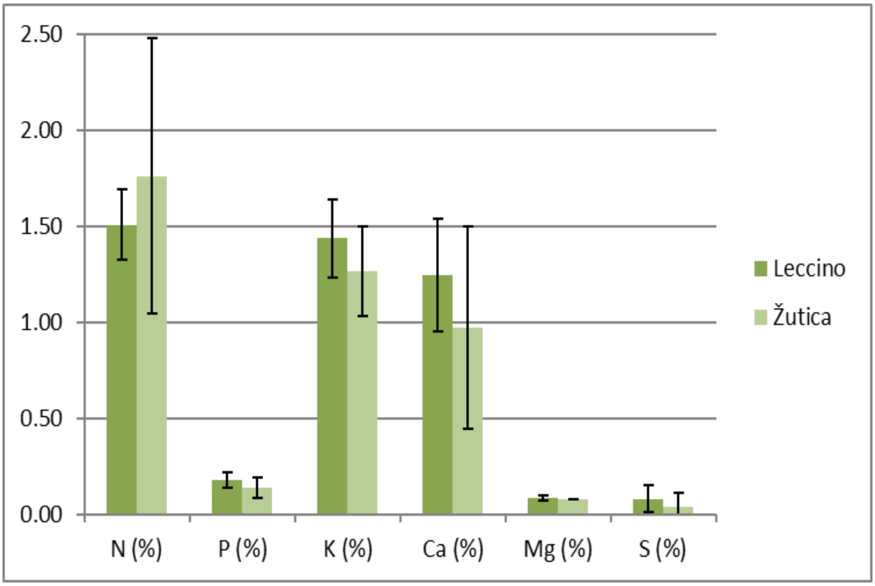

Figure 2. Macro- and mesoelements in olive leaves

In our study, there were no concrete data on fertilization. Farmers applied fertilizers according to their usual practice without insight into soil fertility and olive nutritional status.

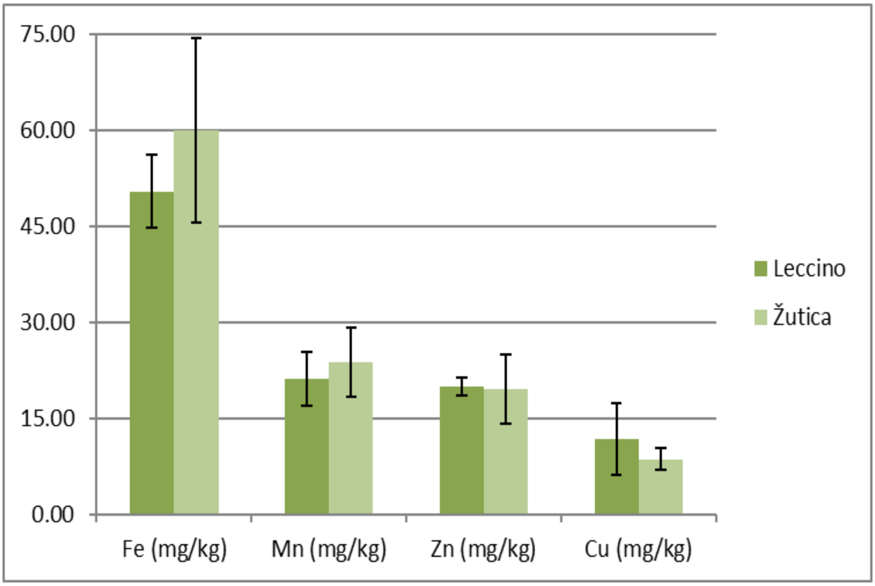

Figure 3. Microelements in olive leaves

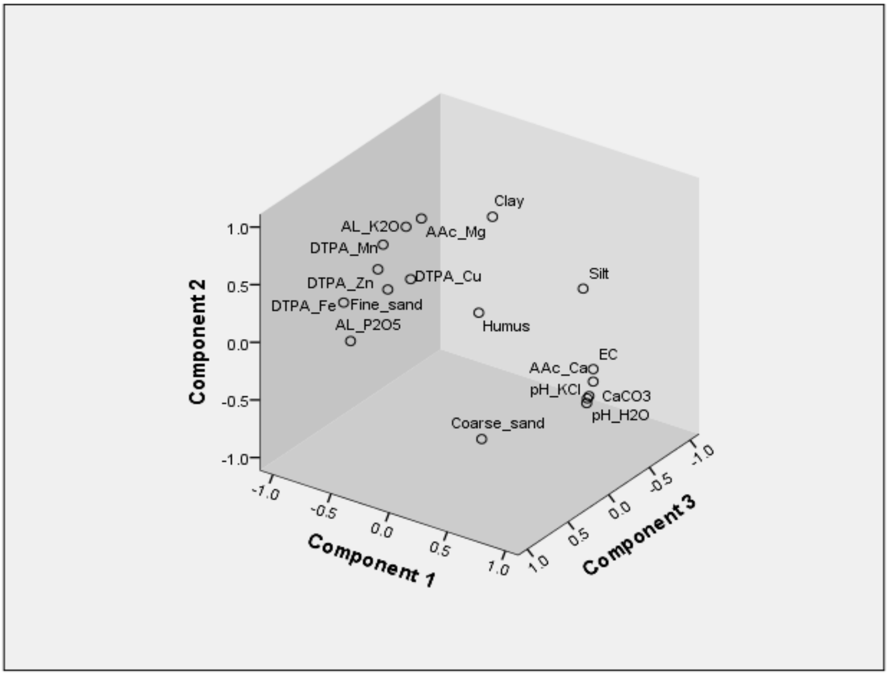

Figure 4. Component Plot in rotated space (PCA with Varimax rotation)

For drip-irrigated olive orchard, Cayuela *et al*. (2004) recommended that the doses for N, P_2O_5 and K_2O – 150, 30, and 250 kg/ha, respectively, could be achieved by combined application of compost (dose 40 kg per tree i.e. 14.3 t/ha) and mineral fertilizers.

The results of the olive tree fertilization trials in Marocco showed that the annual dose for N and K_2O of 0.5 kg per tree allowed a good yield, while phosphorus did not have a significant impact on the olive tree (Bouhafa, 2022). In Spain, Garcia (2009) proposed a balanced formula between N:P_2O_5:K_2O of 20:8:14 for the fertilization of olive trees.

CONCLUSIONS

Olive trees mostly uptake N, K and Ca as macro- and mesoelements, as well as Fe as microelement from soils. Amount of the required P is less than N and K. Fertilizers mostly used in olive production are the ones with N, K, and P. Fertilization program for the olive trees established without soil and/or leaf analysis results is at the head of these problems.

From aspect of soil fertility and olive supply with nutrients, it is generally recommended to decrease fertilization with K, but in some orchards to increase with N. Since the content of Fe and mostly Mg was below optimal, these elements should be applied through foliar fertilizers.

In saline and calcareous soils, the application of organic fertilizers is preferable.

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