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REGULAR ARTICLE

Migration of nutrients from soil to plant in olive orchards

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Abstract

Olive growing is gaining much interest in Slovenia. In thgis work we report the results of the 5 year experiments, on 9 locations, with the cultivar "istrska belica". The results of soil and plant analyzes of the olive orchard on carstic soil indicated some unexpected facts about macro-nutrient mobility: although the phosphorus in soil is very low, its values in plants are almost optimal. A similar pattern also occurs with magnesium. On the other hand, we would expect low foliar potassium values, as reported in literature for rainfed orchards on calcareous soils, yet they are not. Also calcium levels are not as expected for orchards on carstic soil (higher values), and thus indicate calcium deficiency. It would definitely be interesting to study it in more details. We found that the results show a negative correlation between phosphorus and potassium plant mobility and soil organic matter.

Key words: Foliar, Nutrients, Olive, Soil

Introduction

Olive oil production is gaining a lot of interest in Slovenia. First, because the wine market is already filled with wine, so selling olive oil seems much easier at the moment. But also the quality of Slovenian olive oil is very high. Producers are mainly smaller, our relatively north position also influences higher levels of polyphenols and, consequently, higher bitterness and spiciness. But to produce maximum oil quality, good fertilization practices are needed.

Especially in smaller orchards, typical for Slovenian agriculture, traditional fertilization may lead to excessive rates of some fertilizers, mainly relatively to N (Fernández-Escobar et al., 2009), but also a lack of other nutrients. Unbalanced orchard fertilization can cause environmental degradation (Fernandes and Rossiello, 1995), negatively affect olive oil quality as well as flower quality (Fernandez-Escobar et al., 2008).

Most scientific papers on the fertilization of olive orchards, are based on Spanish or Portuguese experiences (Connor and Fereres, 2004; Fernández-Escobar et al., 2009; Rodrigues et al., 2012; Ferreira et al., 2013), which emphasis foliar nutrition. Optimum tree nutrition could be achieved by combining this information with soil and environmental factors that affect tree growth, and symptoms of nutrient deficiency or excess.

Surprisingly, although we all realize that organic matter is one of the most important components of soil, practically no study to authors knowledge reports this parameter. Application of organic materials in crop production has been strongly encouraged in many places, as a replacement for part or all of the mineral fertilizer used, but often without due consideration to their quality and profitability. Where the main purpose of a recommendation to use organic materials was to decrease the required rate of mineral fertilizer, this raises questions about the optimal proportions of organic and inorganic fertilizers for yield and profit (Pinitpaitoon et al., 2011). On the other hand, the ecological (organic) plant production is gaining interest, resulting in more intensive organic fertilization. Increase in organic matter improves aggregation, water holding capacity, hydraulic conductivity, total porosity, resistance to water and wind erosion, and lowers bulk density and the degree of compaction (Celik et al., 2010). But organic matter in soil also influences soil nutrient mobility. There are many studies on biochar impact

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on nutrient leaching (Laird et al., 2010; Yao et al., 2012), showing that biochar application might decrease nitrogen leaching by 11% and phosphorous by 69%.

With the present experiment we wanted to monitor nutrient mobility in Slovene olive orchard, we wanted to compare tree nutritional status with the literature data, but also try to check if any correlation between nutrients mobility and soil organic matter could be found.

Materials and Methods

To study the nutritional status of Slovenian olive orchards, foliar and soil analyzes have been conducted in 5 consecutive years, on 9 locations, planted with "istrska belica" variety, rainfeed, 10 – 20 years old.

Soil analyses were conducted at the beginning of the experiment (2007), according to Slovenian guidelines: phosphorus and potassium were analyzed after amon-lactate extraction (Leskošek, 1993). Phosphorus has been determined spectrophotometrically after the development of blue color with amonmolybdate (as P_2O_5), while potassium with atomic absorption at 769,9 nm (as K_2O). Magnesium in soil has been analyzed with atomic absorption after extraction in 0.01 M $CaCl_2$. Calcium in soil has not been analyzed, since it is not a problem in calcorous soils and we don't have efficient guidelines for analysis interpretation. pH was determined after extraction in 0.1 M KCl, while organic matter considered ISO 14235:1999, after degradation of organic matter with sulphochromic acid.

Leaf samples have been taken each year after flowering. Leaf analysis has been performed after incineration of leaf sample at 550°C. Ashes have been diluted in 0.3 M hydrochloric acid (ISO 6869). For phosphorus analysis, samples were treated with molibdovanadate, according ISO 6491, while potassium, magnesium and calcium have been determined with atomic absorption according to ISO 6869. Leaf nitrogen has been analyzed according to the Kjeldahl method.

The results of soil analysis indicate that, in 7 of the 9 locations, the organic matter remained within the optimum range, except for locations VA and VB, where organic matter showed a high value. The same two locations have elevated levels of potassium. Even higher values of potassium are in location JA. On the other hand, only locations VB and JA have optimal values of phosphorus, while all the others have low values (being 3 extremely low). All except one (GC) have low magnesium levels.

After soil analysis, foliar analyzes have been performed each year after flowering (July). Variations among the years are similar to the report of Fernández-Escobar et al. (2009) and do not exceed 25% relative standard deviations (across years).

The most surprising facts are that although soil phosphorus values are low (MB, HN, VA, GC) or very low (MA, JB, HB), leaf values are optimal in all the samples. This is in agreement with (Fernández-Escobar et al., 2009; Boulal et al., 2013), who also report no problem in achieving foliar P levels in olive leaves. On the other hand, lack of phosphorus is one of the biggest agricultural problems in the near future, since modern agricultural systems are dependent on continual inputs of phosphorus fertilizers processed from phosphate rock, which is a non-renewable resource that takes 10-15 million years to cycle naturally (Cordell, 2010). Accordingly, optimum phosphorus levels in olive orchards, although soil levels are extremely low, are worth of studying in detail (Rennenberg and Herschbach, 2013).

On the other hand, Restrepo-Diaz et al. (2008) reported that foliar K levels in rainfed orchards of calcareous soil are low, even when they are established on soils with high K content, yet this it doesn't seem to be the case in our experiment, since only in two locations (GC in GP) K values are below optimum.

Table 1. Soil analysis of 9 Slovenian olive orchards.

location	Optimum values	MA	MB	JA	JB	HN	HB	VA	VB	GC
pH		7.1	7.0	7.1	7.1	7.1	7.0	7.0	7.0	6.8
Organic matter (%)	2 - 4	3.3	2.6	2.6	2.5	2.5	3.0	4.2	4.7	3.0
P_2O_5 (mg/100g)	13 - 25	4	6	17	5	11	5	11	17	6
K_2O (mg/100g)	20 - 30	19	19	43	27	21	23	31	39	24
MgO (mg/100g)		4	5	5	4	5	5	6	5	11

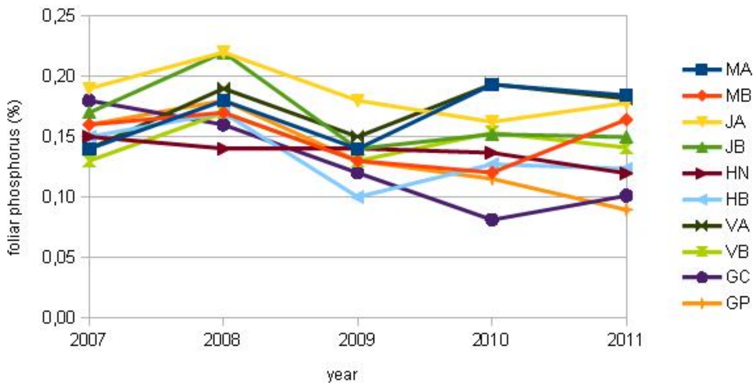

Figure 1. Annual variation in foliar phosphorus levels.

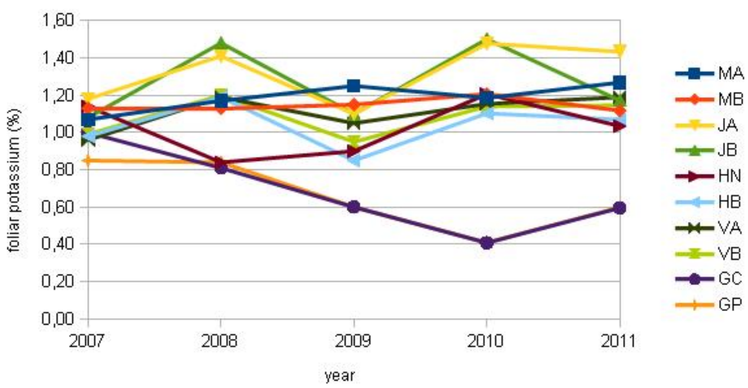

Figure 2. Annual variation in foliar potassium levels.

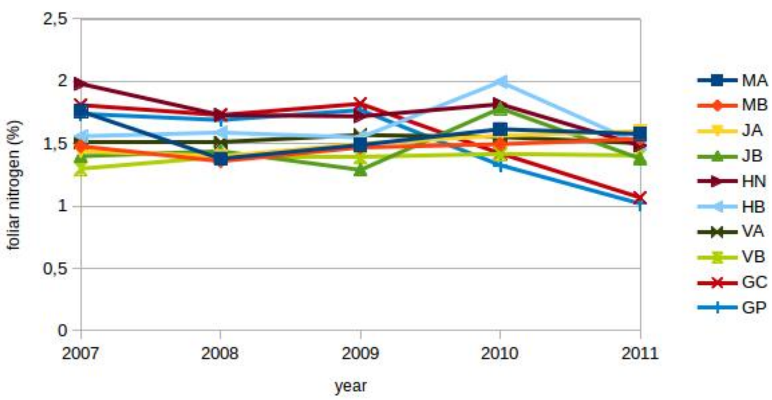

Figure 3. Annual variation in foliar nitrogen levels.

Nitrogen levels seem pretty constant, except for the locations GC and GP, where values have decrease from optimal to low. The same trend is observable also for phosphorus and potassium, while the opposite for magnesium and calcium. Regarding very low soil magnesium values, the obtained results showed that all magnesium leaf concentrations are below optimal range, except for locations GP and GC, where leaf magnesium status has improved and reached optimal range and even exceeded it. One possible explanation is that although soils have high magnesium levels, it does not surpass leaf values. Even more, because we can notice similar change also for other parameters, as already mentioned.

Also very surprising are calcium foliar levels, which should not be a problem on calcareous soils, but are below optimal in 8 cases (MA, MB, JA, JB, HN, HB, VA, VB).

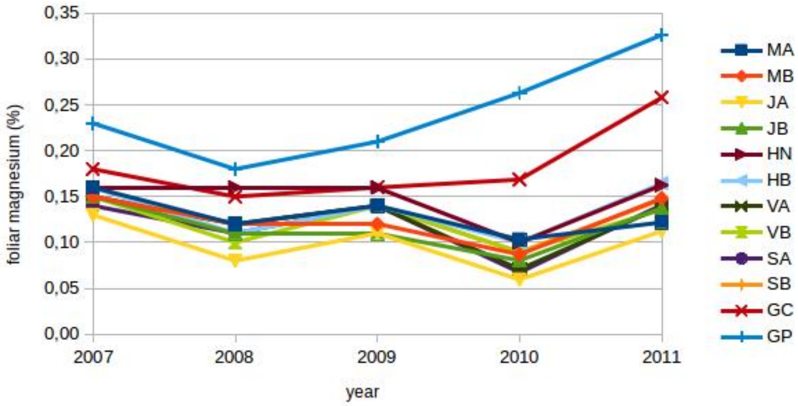

Figure 4. Annual variation in foliar magnesium levels.

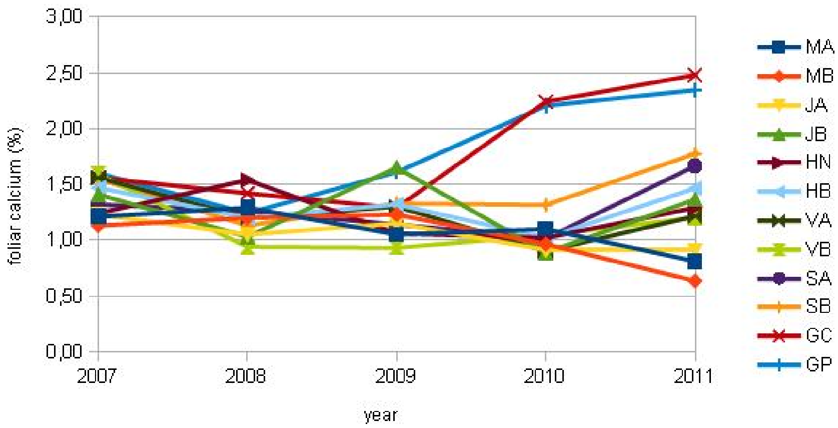

Figure 5. Annual variation in foliar calcium levels.

Table 2. Foliar macronutrient content, calculated as an average value across 5 years.

	Optimum values	MA	MB	JA	JB	HN	HB	VA	VB	GC	GP
N %	1.5 - 2.5	1.57	1.47	1.50	1.46	1.75	1.66	1.53	1.38	1.57	1.51
P %	0.1 - 0.22	0.17	0.15	0.19	0.17	0.14	0.14	0.17	0.14	0.13	0.13
K %	0.9 - 1.2	1.19	1.15	1.32	1.27	1.02	1.06	1.11	1.09	0.68	0.66
Mg %	0.16 - 0.3	0.13	0.13	0.10	0.12	0.15	0.13	0.12	0.12	0.18	0.24
Ca %	1.37 - 2.2	1.09	1.03	1.05	1.27	1.23	1.24	1.24	1.14	1.80	1.80

Table 3. Soil and leaf macronutrient content as expressed in fertility classes (A: very low. B: low. C: optimal. D: high. E: very high).

		MA	MB	JA	JB	HN	HB	VA	VB	GC	GP
P_2O_5 (mg/100g)	soil	A	B	C	A	B	A	B	C	B	B
P %	leaf	C	C	C	C	C	C	C	C	C	C
K_2O (mg/100g)	soil	B	B	E	C	C	C	D	D	C	C
K %	leaf	C	C	D	D	C	C	C	C	B	B
P_2O_5 (mg/100g)		MA	MB	JA	JB	HN	HB	VA	VB	GC	GP

There are several possible factors affecting the mobility of the nutrients. It is well known that potassium mobility is strongly influenced by soil pH, but in our soil samples pH range is very narrow. Antagonism is another possible explanation, yet except in one sample (JA, potassium), there are no extreme values in soil (E), so it is also not a probable explanation.

Additional attention should be paid on elevated levels of soil organic matter (SOM). We have found a negative correlation between SOM and phosphorus and potassium mobility (plant accumulation factor), although correlations are not significant (R2 = 0.1). Nevertheless, the span of the SOM values was not very wide, which definitely calls for additional research in a larger scale.

Conclusions

The results of soil and plant analyzes of the olive orchard on carstic soil indicated some unexpected fact about macro-nutrient mobility: although the phosphorus in soil is very low, its values in plants are almost optimal. A similar trend was also found for magnesium. On the other hand, we would expect low foliar potassium values, as reported in literature for rainfed orchards on calcareous soils, yet this pattern was not detected. Also calcium levels are not as expected for orchards on carstic soil, being found a calcium deficiency. It would definitely be interesting to study the nutritional interactions in detail. At the moment we can only indicate that the results show a negative correlation between phosphorus and potassium plant mobility and soil organic matter. Nevertheless, this is a very interesting starting point for future research.

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Author contributions

V. V. was involved in experimental setup and sampling, while T. J. was involved chemical analysis. Both authors contributed to data interpretation.

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