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NUTRIENT UPTAKE EFFICIENCY OF FIVE PISTACHIO (*PISTACIA VERA* L.) VARIETIES*

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Abstract

Pistacia vera L., whose edible fruit is the pistachio, is an economically important crop. It is cultivated worldwide and over 50 different varieties have been described attending to morphological and phenological characteristics. The selection of a suitable cultivar may affect the profitability of the orchards, and thus requires careful consideration for any given region. The type and concentration of nutrients taken up by the plant affect its development and eventually the quality and quantity of the fruits. It is a matter of discussion whether all varieties have the same capacity to absorb nutrients. In order to clarify this aspect, in this study the efficiency of nutrient uptake has been assessed for five pistachio varieties: three males (M38, G1, and Mateur), and two females (Batoury, and Joley), by measuring the concentration of 30 chemical elements in leaves by Inductively Coupled Plasma (ICP) and *C/N* micro-elemental analyses. Data were subjected to a non-parametric Friedman test, using a series of Wilcoxon Rank Sum test with a Bonferroni correction as *post hocs*. Our findings demonstrate that all these varieties have an equal uptake capacity for Al, Cr, Cu, K, Li, Mn, Ni, Pb, S, Sr, Ti, Tl, Zn, N, B, Fe, Mg, Na, and V. No differences related to the gender of the plants were detected. Only Mateur exhibited significantly higher levels of Ca and lower levels of C. Stock plants from an experimental plot were used as material. These plants are not used for productive purposes, and flowering and fruiting are partially restricted by removing potential nutrient-demanding structures. These findings support the contention that the presence/absence of such organs has more influence on the nutrient uptake than does the variety itself.

Keywords: pistachio, nutrient uptake, nutrition, nutrient content.

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INTRODUCTION

Although native to the Mediterranean basin, *Pistacia vera* L. is grown worldwide because of its edible fruit, the pistachio. Pistachio is much appreciated as a finger food and is also used as the main ingredient of some sauces, cold cuts and cheeses, sweets, and pastries. With Iran and the USA as the main producers, the crop is the fifth in global nut production (Amirteimoori, Chizari 2008). Human domestication has given rise to over 50 cultivated varieties, with only few morphological and physiological differences between them: seed size, flowering time and production rate (Kashaninejad et al. 2005, Razavi et al. 2007a, b, c, Chahed et al. 2008).

The quality and quantity of fruits and the profitability of the crop depend largely on the ability of the tree to take up nutrients. The influence of a variety/rootstock species on the nutrient-uptake capacity has been suggested (Crane, Iwakiri 1986, Rahemi, Tavallali 2007, Brown et al. 1994). To clarify this issue, in the present study we estimated the uptake of 30 different elements by five pistachio cultivars for which scanty data were available. Three of these cultivars were males: Mateur (cultivated in Morocco and very common in Tunisia), M38 (cultivated in Syria), and G1 (obtained at Centro Agrario el Chaparrillo, Castilla-La Mancha, Spain, from open pollination of var. Kerman), while the other two were females: Batoury – cultivated in Turkey and Syria, and Joley – cultivated in the USA (López et al. 2005).

MATERIALS AND METHODS

Plant material and experimental design

The study was conducted in a field of source plants at the Centro Agrario el Chaparrillo, Castilla-La Mancha (Spain), in November 2012. These plants are maintained as a collection of different varieties and do not serve for productive purposes, so that the number of individuals belonging to each variety is usually low. A total of four plants per variety (Batoury, Joley, Mateur, M38, and G1, all grafted onto *P. atlantica* Desf.) were sampled. All plants were grafted in 1993 except for M38 (1994) and G1 (2003). According to the FAO classification, the soil is a luvic calcisol, and the pH is over 8 due to a high content on $CaCO_3$. The cation-exchange capacity (CEC) is base saturated, and the organic matter content is low. All plants were maintained with minimal management under a controlled deficit irrigation strategy. Vermicompost was used as fertilizer (3,000 kg ha^{-1} every two years). No foliar feeding was applied except for two copper fungicidal treatments.

Mineral uptake by the different varieties

Mineral uptake capability of the selected varieties was determined by evaluating the concentration of 30 chemical elements (Al, As, B, Be, Bi, C, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, N, Na, Ni, P, Pb, S, Sb, Se, Sr, Ti, Tl, V, Zn) in fresh leaves randomly taken from the trees sampled. These elements are considered essential for plant nutrition. The samples consisted of 100 g of leaf tissue, dried at 60ºC for 24h, and finely powdered. A Flash EA 1112 Series-LECO TRUSPEC device was used to analyze the total C and N, while the other 28 elements were analyzed by HNO_3/H_2O_2 (4:1) digestion in an UltraClave Microwave Milestone, and ICP-OES using an ICAP 6500 DUO device. The limit of detection for Be, Bi, Co, Li, Mo, Sb, Se, Sr, Ti, Tl and V is <0.5 mg kg^{-1}, <0.1 mg kg^{-1} for As, Cd, Cr, Cu, Mn, Ni, Pb, Zn and B, <2.0 mg kg^{-1} for Al, Fe, S and P, and <100.0 mg kg^{-1} for K, Na, Mg and Ca. The wavelengths and the measurement degree of uncertainty are shown in the Table 1. The analyses were made at the Ionomic Laboratory of CEBAS--CSIC (Murcia, Spain), following the reporting standard UNE-EN ISO 11885.

Statistical analyses

To test mineral concentration differences in leaves, data were subjected to a non-parametric Friedman test (Friedman 1937) using the SPSS software package (SPSS 20 for Windows, 2007). As *post hoc* analyses, a series of Wilcoxon Rank Sum test with a Bonferroni correction were used ($p < 0.025$). The existence of outliers was ruled out using the Grubbs test.

RESULTS AND DISCUSSION

The analysis of nutrient accumulation in leaves showed that the uptake of nine elements As, Be, Bi, Cd, Co, Mo, P, Sb, and Se was below the detection range (<0.5 mg kg^{-1} for Be, Bi, Co, Mo, Sb and Se, <0.1 mg kg^{-1} for As and Cd, and <2 mg kg^{-1} for P) and thus were excluded from further analysis. The concentration mean values and the standard deviation of all elements are shown in Table 1.

All the varieties exhibit the same nutrient-uptake efficiency for 19 of the elements analyzed (see Table 1). However, Mateur showed significant accumulation of Ca ($\chi^2 = 10.886$, $p = 0.028$) and loss of C ($\chi^2 = 11.800$, $p = 0.019$) at a significance level of 0.05 (Table 2).

In terrestrial plants, the water and solutes move from the soil through the roots into the xylem vessels, from where they are delivered to different organs and used in a wide variety of processes throughout the plant. The uptake rate may vary due to a number of factors such as the plant age, the seasonal variations, grafting, mycorrhizae interactions, or differential crop load (Tavallali, Rahemi 2007, Martínez-Ballesta et al. 2010, Aznarte-Mellado et al. 2014).

Table 1

Accumulation of chemical elements by variety (means and deviations) with the Friedman test data

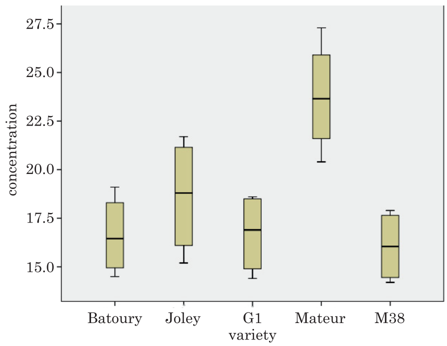
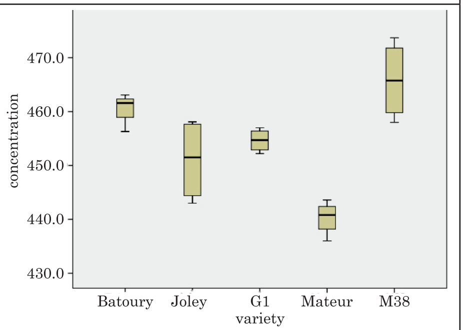
Element	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	$\chi^2(2)$	*P* value	Wave-length (nm)	Degree of uncer-tainty (%)
	Batoury		Joley		Mateur		M38		G1		Friedman Test		ICP-OES	
Al ($mg\ kg^{-1}$)	54.29	13.53	84.15	20.51	87.30	11.94	94.15	36.16	82.25	24.03	4.400	0.355	167.079 396.152	5.38
B ($mg\ kg^{-1}$)	168.9	34.40	158.8	23.35	160.90	21.06	161.1	19.52	215.6	26.33	8.200	0.085	208.959	3.54
C* ($g\ kg^{1}$)	460.6	0.29	451.0	0.774	440.3	0.317	465.8	0.725	454.6	0.216	11.80	0.019*	--	--
Ca* ($g\ kg^{-1}$)	16.62	0.207	18.62	0.304	23.75	0.290	16.05	0.187	16.70	0.212	10.88	0.028*	184.006 315.887	4.34
Cr ($mg\ kg^{-1}$)	0.257	0.253	0.057	0.067	0.057	0.066	0.087	0.063	0.100	0.125	4.000	0.406	205.552	4.3
Cu ($mg\ kg^{-1}$)	46.67	25.68	44.09	28.04	78.58	42.45	56.28	39.45	66.81	61.10	1.400	0.844	324.754 224.700	4.12
Fe ($mg\ kg^{-1}$)	43.09	5.162	71.51	8.715	62.48	7.99	65.62	19.96	58.39	12.18	2.603	0.626	259.940 238.204	3.92
K ($g\ kg^{-1}$)	7.65	0.073	19.77	0.172	17.30	0.301	15.30	0.43	17.40	0.248	9.400	0.052	766.490	4.56
Li ($mg\ kg^{-1}$)	2.435	0.785	1.730	0.261	1.787	0.254	1.505	0.157	2.150	0.509	7.949	0.093	670.784	6.78
Mg ($g\ kg^{-1}$)	4.92	0.118	5.95	0.149	5.47	0.062	3.72	0.038	5.55	0.079	8.759	0.067	202.582 279.079	4.7
Mn ($mg\ kg^{-1}$)	44.06	9.292	55.14	8.395	47.86	1.922	41.94	5.201	49.19	7.256	4.000	0.406	259.373	6.15
N ($g\ kg^{-1}$)	14.22	0.110	16.37	0.217	13.35	0.163	13.67	0.159	14.37	0.120	3.800	0.434	--	--
Na ($g\ kg^{-1}$)	0.03	0.002	0.04	0.001	0.06	0.002	0.08	0.003	0.04	0.002	5.527	0.237	589.592	5.23
Ni ($mg\ kg^{-1}$)	54.29	13.53	84.15	20.52	87.30	11.94	94.15	36.16	82.25	24.03	2.987	0.560	231.604	4.83
Pb ($mg\ kg^{-1}$)	0.282	0.169	0.230	0.092	0.342	0.096	0.305	0.145	0.340	0.067	2.600	0.627	220.353	6.14
S ($g\ kg^{-1}$)	1.00	0.014	1.17	0.017	1.07	0.005	0.95	0.010	1.07	0.009	3.884	0.422	180.731 182.034	4.25
Sr ($mg\ kg^{-1}$)	367.8	67.80	442.1	109.8	474.3	63.28	326.9	38.92	344.6	61.67	7.400	0.116	421.552	7.04
Ti ($mg\ kg^{-1}$)	3.247	0.640	5.000	1.283	5.202	0.728	6.040	2.305	4.867	1.667	6.200	0.185	336.121 334.941	8.12
Tl ($g\ kg^{-1}$)	127.1	3.216	170.3	5.182	147.3	2.429	74.17	0.612	146.9	3.524	8.800	0.066	190.856	7.05
V ($mg\ kg^{-1}$)	3.335	0.916	4.012	0.998	3.707	0.411	2.515	0.215	3.715	0.524	8.800	0.066	268.796 292.402	6.78
Zn ($mg\ kg^{-1}$)	9.165	2.646	11.05	1.916	13.64	4.466	13.09	1.336	12.43	3.097	7.646	0.150	206.200	5.02

* C and Ca showed significant variations at a signification value $\alpha < 0.05$. Wavelength and ICP measurement's degrees of uncertainty are shown.

Our data suggest that Batoury, Joley, Mateur, M38 and G1 have an equal uptake (regardless of the variety gender), given that no significant differences were found in the accumulation of 19 elements. Only Mateur showed a biased accumulation of Ca and a significantly low concentration of C. Our data might be the reflection of phenological differences. In fact, Mateur is the earliest variety and thus should be the first to show signs of ageing (Guerrero Villase-

Table 2

Graphic representation of the mean values in C and Ca concentration by variety, and Wilcoxon Rank Sum test analysis showing significant differences for the variety Mateur (bold).

Chemical element	**Concentration in leaves**				**Graphics**
	variety	concen-tration (g kg^{-1})	$\chi^2(2)$	*p* value	
Calcium	Batoury Joley G1 **Mateur** M38	16.62 18.62 16.70 **23.75** 16.05	10.88	0.028	
Carbon	Batoury Joley G1 **Mateur** M38	460.6 451.0 454.6 **440.3** 465.8	11.80	0.019	

ÑOR et al. 2010). Both Ca and C are related to vegetative propagation. At the time of our sampling (early November), the leaf production ceases, plants stop growing and senescence begins. That would explain the low levels of C, strongly correlated with leaf production (JONASSON et al. 1997), and high levels of Ca, differentially accumulated in senescent tissues (PICCHIONI et al. 1997).

The inactivity of pistachio trees at this stage is illustrated in Figure 1, which compares our data to the range of 10 chemical elements found in the literature. Although six elements were within the range of sufficiency (four micronutrients, i.e. B, Fe, Mn and Zn; and two macronutrients, i.e. Ca and K), Mg, N, and S showed a basic concentration, implying a decreasing trend (Figure 1). Only Cu was over the normal range in the plants studied probably due to fungicidal treatments (Figure 1).

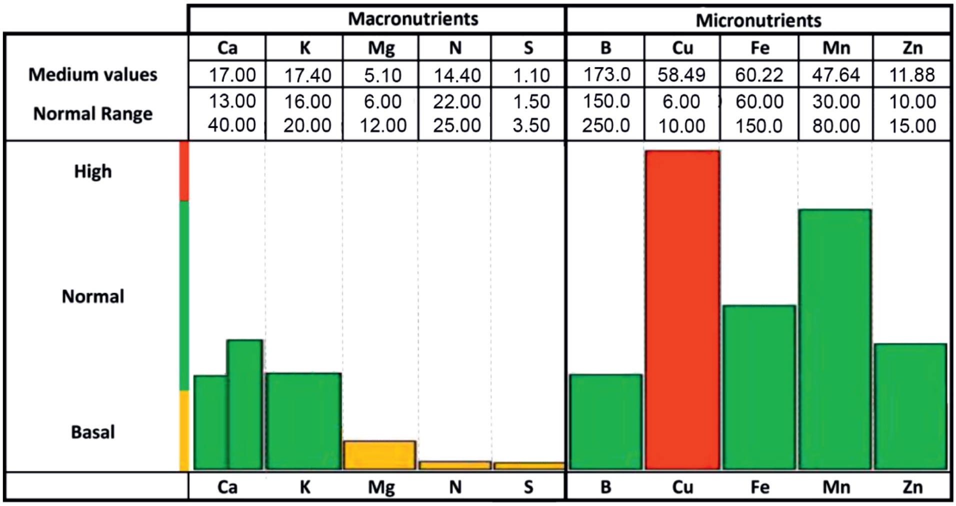


Figure 1. Graphic representation of the relative mean values of concentrations of macro- and micronutrients in leaves of the five pistachio varieties analyzed in this paper. The nutritional state of the plants is estimated according to the sufficiency ranges (sufficiency ranges in mg kg^{-1} for micronutrients and in g kg^{-1} for macronutrients taken from Picchioni et al. (1997) and Harmankaya et al. (2014) as measured in early August, corresponding to stage III, beginning of fruiting. Our data were collected in November)

There are two innovative aspects of our analysis. Firstly, a higher number of elements was analyzed. Secondly, the plants of pistachio used to obtain material belong to a plant collection. These types of plants do not serve for production purposes but for experimental observations, and consequently are subject to frequent pruning. This would partially restrict flowering and fruiting, by removing potential nutrient-demanding structures. In this sense, Vemmos (1999) demonstrated that while fruiting trees exhibit a variable uptake of minerals, mainly Mg, Ca, Mn, K, Zn, and N, non-fruiting pistachio trees maintain a constant concentration of those nutrients. Also, a reduction of P and N is observed in mature fruit trees after a heavy fruiting year (Rosencrance et al. 1996).

All these data suggest that the physiological state of the plant and the demand of nutrients from different structures (e.g. buds, flowers, fruits, leaves) are more influential factors in the distribution of nutrients throughout the plant than is the variety itself.

CONCLUSIONS

1. The five pistachio varieties analyzed here (males M38, G1, Mateur, and females Batoury and Joley) exhibited a comparable capacity of nutrient

uptake for 19 out of 30 chemical elements measured, regardless of the variety gender.

2. Mateur showed a significant accumulation of Ca and a significant low concentration of C, direct consequences of tissue senescence. Mateur is the earliest variety and thus, these should be the first signs of ageing.

3. We studied non-producing pistachio trees used for experimental observations, and consequently subject to frequent pruning. This partially restricts flowering and fruiting, by removing potential nutrient-demanding structures. Our data support the contention that the presence of such organs is more influential in nutrient uptake than the variety itself.

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