PHOSPHORUS DYNAMICS IN GRAPEVINE ON ACID AND CALCAREOUS SOILS

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Abstract: Influence of soil reaction on phosphorus content and dynamics in grapevine (V*itis vinifera c*.) was investigated on the variety Sauvignon blanc in the Plešivica wine-growing region (North-western Croatia) in 2007. The trial was set up on three vitisol subtypes: dystric cambisol (pH $_{KCl}$ 3.75), pseudogley (pH $_{KCl}$ 4.68) and rendzina on marl (pH $_{KCl}$ 7.25). Equal fertilization and vine protection were applied in all three vineyards. To determine the level and dynamics of phosphorus in plant material, leaf samples were taken three times in the course of the growing period: at the flowering and veraison stages and at the end of the growing period. Statistical methods used in the present study included correlation and regression/analysis of variance. Regression analysis revealed that vine leaf phosphorus content increases with increasing the soil reaction pH; it starts with 0.02% for each pH unit at the flowering stage and reaches the value of 0.11% at harvest. At all samplings, higher leaf phosphorus contents were found in calcareous soil compared to acid soil. Phosphorus concentrations at the veraison stage were 2 times and at the end of the growing period even 3 times higher in leaves of plants grown on rendzina compared to plants grown on dystric cambisol. These differences may be attributed to better solubility of calcium phosphates in calcareous soils compared to aluminium and iron phosphates in acid soils. Differences in sugar and acid concentrations in must indicate a positive correlation between concentrations of leaf phosphorus and must sugar (R=0.90) and negative correlation between the leaf concentration of phosphorus and must content of acids (R= - 0.89).

Keywords: grapevine, phosphorus, soil reaction, leaf, must

Introduction

Though there are abundant data on the quantitative relation between phosphorus sorption and soil properties, influence of soil properties and phosphorus forms on the kinetics of phosphorus sorption and desorption has been little investigated (Horta and Torrent, 2007). In comparison to other plant nutrients, the mobility of phosphorus in soil is low because of the generally low solubility of phosphate compounds and the strong P–binding capacity of soil components (Kadar, 2007). The main factor determining phosphorus solubility and availability to plants is the soil reaction (pH), that is base saturation of the cation exchange complex. In the conditions of neutral and alkaline pH reaction, different forms of Ca-phosphates prevail in soil, which are more soluble that aluminium and iron phosphates in acid soils (Füleky, 2006). Chemical binding and transformations of soil phosphorus are correlated with soil moisture and temperature (Sárdi et al., 2006). In highly acid soils, secondary clay minerals decompose and free aluminium, iron and manganese ions are formed, which deposit phosphate ions (Jemo et al., 2007) and/or are toxic to vine plants (Smart et al., 1991). Phosphorus inactivation may occur also in calcareous vineyard soil due to high concentration of Ca- ions and high soil reaction pH (Shehata et al., 1996). Although little is known about the influence of phosphorus on vine growth and development, the research results to date point to positive correlation between phosphorus fertilization and phosphorus concentration in vine leaves. Also, the phosphorus content in vine leaves has a significant effect on plant vegetative growth, number of clusters per vinestock and sugar content (Skinner and William, 1988). Assessment of the level of vine phosphorus sufficiency is one of the major problems in vine nutrition with this element. For this reason, the research goal was to determine the impact of soil reaction on phosphorus content and dynamics in grapevine leaves. Use was made of the European criteria for assessment of the level of vine phosphorus sufficiency, which are based on whole leaf analysis in contrast to American criteria according to which only leaf petiole is analyzed (Bravdo, 2007).

Materials and methods

Investigations were conducted in the Plešivica wine-growing region (North-western Croatia) in 2007. Influence of soil reaction on phosphorus dynamics in vine plants was studied on the variety Sauvignon Blanc (planted on SO4 rootstock), on three vitisol subtypes: dystric cambisol, pseudogley and rendzina on marl. Soil chemical properties were determined in layers at 0-30 and 30-60 cm depths before the trial was set up (after harvest) in 2006, (Table 1). Identical agricultural management practices were applied in all three vineyards. Basic fertilization with 500 kg ha^{-1} of Hydrocomplex NPK12:11:18 was applied on 28/02/2007.

Table 1. Chemical properties of studied soils

Soil	Depth	pH	%		mg kg^{-1}		mg kg^{-1}	%
type	cm	KCl	humus	Total N	P_2O_5	K_2O	Al^{3+}	CaO
Dystric cambisol	0-30	3.73	1.34	0.11	168.90	322.60	304.00	-
	30-60	3.76	0.92	0.08	24.50	164.60	229.50	-
Pseudogley	0-30	4.67	1.31	0.13	162.00	333.30	5.60	-
	30-60	4.69	0.86	0.09	19.50	141.30	5.30	-
Rendzina on marl	0-30	7.24	2.01	0.17	74.70	316.60	-	21.50
	30-60	7.27	1.26	0.13	37.40	146.60	-	20.50

Samples of vine leaves were taken three times during the growing period: at the flowering and veraison stages and at the end of the growing period (harvest). Average leaf samples were formed from 240 healthy, fully developed and undamaged leaves, taken opposite to clusters from 120 vinestocks (3 replicates x 40 vinestocks), on each soil. Soil phosphorus and potassium were determined according to Egner–Riehm-Domingo (Egner et al., 1960). Total soil nitrogen was determined by the Kjeldahl method (AOAC, 1995). Exchangeable aluminium in acid soils was determined by the Sokolova method, and the active lime content in calcareous soil was assessed by the Galet method (JDPZ, 1966). Leaf phosphorus was determined upon digestion with concentrated HNO_3 (MILESTONE 1200 Mega Microwave Digester) spectrophotometrically (AOAC, 1995). Must sugar content was determined using a digital Refractrometer PR-101, Atago, and the values were expressed as brix percentages. Total acids (TA) in must were determined by the titration method (EEC, 1990).

Statistical methods used in this study included correlation and regression/analysis of variance. Prior to their use as regressors, and in order to construct the most informative model, correlation was estimated between all soil variables. P content in leaves was then modelled using the selected soil variable, adding the effect of physiological phase (to respect the differences in P content between phases), as well as their interaction (allowing for the differential response to the soil variable in different phases). Finally, the relationship between harvest P content and must P, sugar, and TA content was examined by correlating them. All statistical analyses were performed using SAS (SAS Institute Inc., 2007) procedures CORR and GLM.

Results and discussion

As seen from the selected statistical model (Graph 1), phosphorus content and dynamics in vine leaves depended significantly on the soil pH as well as on the phenophases of vine plant development.

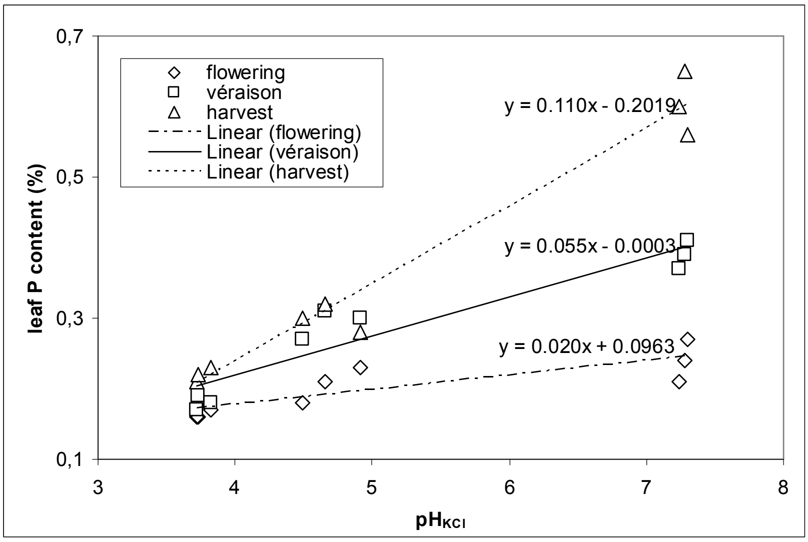

Figure1. Effect of soil reaction on phosphorus content and dynamics in vine leaves.

In all three phenophases (flowering[1], veraison[2] and harvest[3]), higher phosphorus contents were determined in vine leaves on calcareous soil compared to acid soils. Highest leaf phosphorus contents were determined at harvest, and the lowest at the flowering stage in all three soil types. Regression analysis indicated that leaf phosphorus content increases with a rise in soil reaction pH, starting with 0.02% for each pH unit at the flowering stage to reach 0.11% at harvest. These differences may be explained by better phosphorus solubility and availability from calcium phosphates in calcareous soil compared to aluminium and iron phosphates in highly acid soils (Marschner, 1995; Füleky, 2006). Significantly highest phosphorus content in vine leaves (0.60% P/DM) was recorded in calcareous soil at harvest, and the lowest (0.16% P/DM) at the flowering stage in highly acid soil. Phosphorus values determined in vine leaves on dystric cambisol (0.16[1], 0.18[2] and 0.22[3] % P/DM) and pseudogley (0.21[1], 0.29[2] and 0.30[3] % P/DM) are below optimal values (0.25-0.45 % P/DM) reported by Bergmann (1992). According to the same author, the level of vine phosphorus sufficiency on rendzina (0.24[1],0.39[2] and 0.60[3] % P/DM) can be allotted to the category of optimal to rich supply. Besides, investigations have revealed a relationship also between leaf phosphorus content and levels of phosphorus, sugar and total acids (TA) in must (Skinner and William, 1988). Stronger correlation was detected when it was compared with must sugar (R=0.90) and TA(R= - 0.89), while the relationship between leaf and must P was substantially weaker (R=0.64). Must sugar content on dystric cambisol and pseudogley amounted to 23.1% brix, and on rendzina to 26.3% brix. Must content of total acids (TA) ranged from 5.73 g l^{-1} on rendzina to 7.01 g l^{-1} on dystric cambisol.

Conclusions

The presented investigations have shown that soil reaction has a significant effect on phosphorus content and dynamics in vine leaves, and that likewise leaf phosphorus content influences the contents of phosphorus, sugar and total acids in must.

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