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Comparison of soil-to-root transfer and translocation coefficients of trace elements in vines of Chardonnay and Muscat white grown in the same vineyard

Vystavna Yuliya[a,b,*], Rätsep Reelika[a,c], Klymenko Nina[d], Drozd Olena[e], Pidlisnyuk Valentina[b], Klymenko Mykola[f]

[a] O.M Beketov National University of Urban Economy at Kharkiv, Department of Environmental Engineering and Management, vul. Revolutsii 12, Kharkiv 61002, Ukraine
[b] Matej Bel University, Department of the Environment, Tajovskeho 40, Banska Bystrica 97401, Slovakia
[c] Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Department of Horticulture, Kreutzwaldi 1, Tartu 51014, Estonia
[d] Institute of Agroecology and Environmental Management of National Academy of Agricultural Sciences of Ukraine, vul. Metrologichna 12, Kiev 03143, Ukraine
[e] National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O.N.Sokolovsky", Chaikovska, 4, Kharkiv 61024, Ukraine
[f] NSC "Nikitsky Botanical Garden", the Autonomous Republic of Crimea, Yalta, pos. Nikita, 98648, Ukraine

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ABSTRACT

The soil-to-root transfer and translocation coefficients of essential and non-essential elements in different parts of *Vitis vinifera* L. depend on environmental and anthropogenic factors and can be variety-specific. Knowledge about uptake and translocation of trace elements by different varieties is necessary for prediction contamination of grapes and wine products and understanding tolerance of cultivars to the environment. The study focused on determination of transfer and translocation patterns of so-called essential (Mn, Fe, Cu and Zn) and non-essential (Cd, Co, Cr, Ni and Pb) elements by vines of Chardonnay and Muscat white of the same age and grown at the similar environmental conditions in Inkerman vineyard, South Crimea in 2013. Samples of irrigation water, soil, fine and coarse roots, leaves and canes were taken in May and berries were harvested in August. The soil enrichment factor, soil-to-root transfer and translocation (roots, leaves and canes) coefficients were calculated based on the trace elements concentration gradients. The principle component analysis and the variables correlation were used for the data treatment. Results showed the contamination of vineyard soil by Pb, which was due to contaminated irrigation water. There was a little variation between Chardonnay and Muscat white in terms of essential trace elements transfer from soil to roots. Translocation patterns were significantly different for non-essential elements, cultivars and plant parts. Pb had the highest variability in transfer and translocation patterns between varieties. Bio-concentration factors varied between cultivars and the highest value was detected for Zn and Fe.

1. Introduction

Geography, climate, soil type and composition together with anthropogenic factors (pollution and viticulture management) influence physiological processes within grapevine varieties (Loreboullet et al., 2013; Protano and Rossi, 2014; Dinis et al., 2014), and affect the transfer of trace elements (TE) from soil to plant and TE translocation in aerial organs (Albulescu et al., 2009; Abreu et al., 2012 Vystavna et al., 2014). Water management, soil composition, light and temperature are critical factors for viticulture, that impact nutrient and TE uptake by grapevines (Scienza et al., 1986; Angelova et al., 1999; Sofo et al., 2013; Alkis et al., 2014). Therefore, elevated TE concentration in *Vitis vinifera* L. (*V. vinifera* L.) can cause grape juice and wine contamination which affect product quality (Provenzano et al., 2010 Vystavna et al., 2014).

At the similar environmental and anthropogenic conditions, differences in nutrient and TE uptake patterns are distinguished between grape varieties (Scienza et al., 1986; Albulescu et al., 2009) which are mainly controlled by anatomical, physiological and

* Corresponding author.
E-mail addresses: vystavna@yahoo.com (Y. Vystavna), reelika.ratsep@emu.ee (R. Rätsep), ninaklymenko@yandex.ru (N. Klymenko), elena_drozd@ukr.net (O. Drozd), valentina.pidlisnyuk@umb.sk (V. Pidlisnyuk), olga.gnbs@mail.ru (M. Klymenko).

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biochemical characters (Ocete et al., 2008; Dinis et al., 2014). Previous data indicated variety-specific uptake of elements by *V. vinifera* L.: (i) Scienza et al. (1986) and Cugnetto et al. (2014) reported that rootstock and variety had influence on the selective absorption of elements to vines; (ii) Chopin et al. (2008) and others (Scienza et al., 1986; Ko et al., 2007; Provenzano et al., 2010) reported that the uptake mechanism was defined by species; (iii) Ko et al., 2007; Provenzano et al., 2010 showed significant differences between TE translocation concerning red and white varieties of grapes. The distribution of certain TE in transfer and translocation in *V. vinifera* L. were investigated by several authors: (i) Ko et al. (2007) determined that concentration of Cr in grapes did not show variations between varieties and this element poorly translocated from roots to aerial plant parts, (ii) Chopin et al. (2008) found the alteration of TE uptake in coarse and fine roots, soil depths and aerial parts, (iii) Angelova et al. (1999) reported that Cd, Cu, Pb, and Zn in vines penetrated via the root system into the grapevine and accumulated in its aerial parts, (iv) Todic et al. (2006) found higher concentrations of Pb and Ni elements in roots and leaves than in berries.

In spite of obtained results (Angelova et al., 1999; Todic et al., 2006; Ko et al., 2007; Chopin et al., 2008; Provenzano et al., 2010) on TE uptake in *V. vinifera* L., there is still a lack of knowledge about TE soil-to-root transfer and translocation in the aerial parts regarding certain varieties e.g., Chardonnay and Muscat white which are used world-wide for the wine production. Our previous research (Vystavna et al., 2014) reported that TE composition in grape juice and in wine could be different for Chardonnay and Muscat white which were equal in age and grown at the same vineyard plot. Discrepancy in TE composition could be due to the variety-specific mechanisms of TE uptake in white cultivars.

Further knowledge on TE uptake and translocation by *V. vinifera* L. would give more knowledge for understanding the influence of vineyard geochemistry on grape, juice and wine composition, exploring the tolerance of cultivars to the changing environment and defining the role of natural barriers in formation of wine quality.

The study focused on the soil-to-root transfer and translocation of TE, namely: Fe, Mn, Cd, Cu, Co, Cr, Ni, Pb and Zn in Chardonnay and Muscat white varieties with similar rootstocks. Both experimental vines were the same age, grew in one vineyard plot under equal environmental, irrigation and treatment conditions. The objectives were as follows: (i) to identify the patterns of soil-to-root transfer of selected TE in Chardonnay and Muscat white and (ii) to describe TE partitioning in aerial parts (canes, leaves and berries) for two varieties using the translocation coefficient.

2. Materials and methods

2.1. Study site

The studied vine-growing site was located in South Crimea, Ukraine (44°33′13.82″N 33°39′18.22″E) (Fig. 1). Geologically the area belongs to the southwestern edge of the Crimean Mountains which is an element of the Mediterranean fold belt. The bedrock consists of Triassic layers of conglomerate, sandstone, siltstone and argillite. The vineyard was located in the valley of the Chorna River. Water from the river was used for vine irrigation (Vystavna et al., 2014). The irrigation condition relied on the weather and comprised of c.a. 250–300 m^3 of directly supplied riverine water per ha of the vineyard. The region has a temperate continental climate with elements of the subtropical Mediterranean, an average annual temperature is +12 °C and annual precipitation is 360 mm (Vystavna et al., 2014).

Vine cultivars Chardonnay and Muscat white (both are with rootstocks 41B – *V. vinifera* cv. 'Chasselas' × *Vitis berlandieri* Planch.)

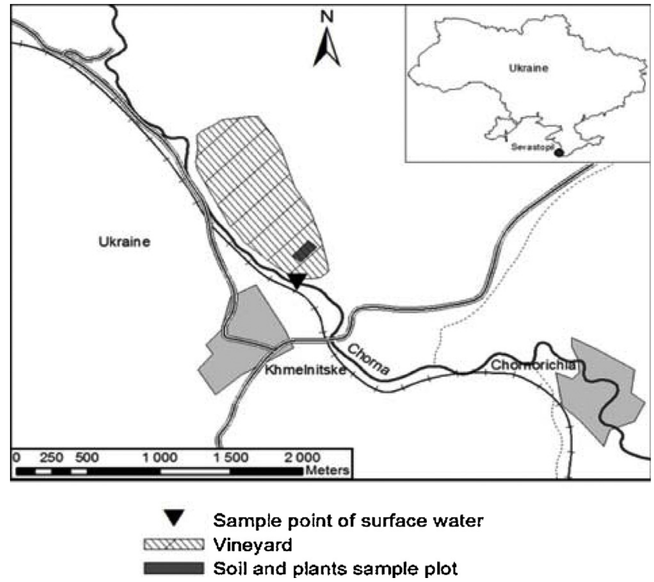

Fig. 1. Sampling site location.

were cultivated at the Inkerman vineyard since 2007 on the surface of 72 ha. Sampled cultivars were 6 years old. The annual yield of Muscat white berries is c.a. 7.0 t per ha and Chardonnay is c.a. 5.0–6.0 t per ha. For each grapevine variety the juice outcome is c.a. 70%.

The local soil is a Calcic Fluvisol (Clay Loamic). Soil has alkaline pH (8.1 ± 0.2), high content of $CaCO_3$ (30 ± 5%) with active carbonates of 11–16%, mobile nutrients (average value is at the layer 0–60 cm), nitrate nitrogen is 6–11 mg kg^{-1} and content of K_2O is 220–280 mg kg^{-1} (Vystavna et al., 2014). The organic component forms about 14% at the top layer (Atlas, 1979). The deep ploughing (60 cm) and rotation of the soil layer were done before the vineyard establishment in 2007. During the plantation of the vineyard a significant amount of phosphorus-based and metal-based fertilizer Kristalon® was applied. Herbicide-Uragan forte®, fungicides-mancozeb, penconazole and propiconazole were used for the crop protection after the sampling of soil, roots, leaves and canes of the research.

2.2. Reagents and solutions

Standard solutions were prepared by the dilution of the analytical standards (1000 mgL^{-1}) supplied by State Standard Solutions of Ukraine. Grade metal solutions (BDH, Poole, Dorset, UK) were used for atomic adsorption spectroscopy with a flame atomizer (FA AAS). All metal solutions were of the highest purity to ensure minimal errors (Giokas et al., 2004). Merck Suprapur® HNO_3 (65%) was used for the stabilization of the standard solutions and natural samples. NaOH (30%, Merck Suprapur®) and HCl (32%, Reidel) were used for the pH adjustment of the solutions.

2.3. Sampling and samples preparation

The sampling of soil, roots, leaves and canes was carried out once during the vegetation period in May 2013; grapes were sampled one week before harvesting in August 2013. The study included the sampling of the soil at the depth of 0–20 cm and 20–40 cm at the vineyard (number of sampling points, N = 8). In addition, roots (diameters, d < 2 mm and d > 2 mm), canes (N = 8), grapes (N = 8) and leaves (N = 8) of Muscat white and Chardonnay were collected. All samples were taken in triplicates from the defined experimental plot of which had a size of 2.16 ha (Fig. 1).