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Resorption, mobilization and accumulation of metals in different parts of *Vitis vinifera* L.

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Summary

This study aimed to determine the variation in metal resorption, mobilization and accumulation in various parts of *Vitis vinifera* L. In contrast to N and P, the metal resorption is undesirable for plants. Root, stem, tendril, leaf and fruit samples were collected in green and senescence periods. Metal concentrations were determined by ICP-OES. Resorption efficiency and proficiency values of metals were calculated. Results showed Cr toxicity in organs of *Vitis vinifera*. All the metals mobilized among organs. Except Mn and Pb, resorption occurred for metals in various organs. Results indicated that metals were resorbed from various organs and accumulated in other plant tissues, especially in roots and leaves. Mn and Pb weren't reabsorbed from any organ and tended to accumulate especially in leaves. Due to leaf abscission, high metal content in senescent leaves is good for growth of *V. vinifera* and harmful for sustainability of soil and ecosystems.

K e y w o r d s : metal; mobilization; accumulation; resorption; *Vitis vinifera*.

Introduction

It is known that fertilizers and pesticides are used in agricultural fields and cause metal contaminations in crops. Because metals lead to various damages in metabolism, metal pollution is a vital problem for organisms. So, this necessitates the testing food materials and determining the metal contents.

Element contents in plants are regulated by several mechanisms such as photosynthesis, nutrient uptake and resorption. While photosynthesis and nutrient uptake enable plants to get new nutrients, nutrients in plants tissues are conserved by resorption. Mobilization of elements from senescent organs to durable organs in plants is called resorption. The resorption mechanism is important for nutrient conservation and plant growth. There are two measures of resorption, resorption efficiency (RE) and proficiency (RP). RE is the difference in nutrient contents between green and senescent organs (Aerts 1990). RP is the remaining nutrient concentration in senescent organs (Killingbeck 1996). There are many studies on resorption (Aerts 1990, Fife *et al.* 2008, He *et al.* 2020, Zheng *et al.* 2020). Because of their importance for plant growth, previous studies mostly focused on leaf N and P resorption (Kutbay *et al.* 2003, Kumar and Singh 2005, Nongbri and Barik 2020). But, little is known about resorption of metals in different plant organs, which is important for metal accumulation.

Metals are important elements in ecosystems because some of them are essential nutrients for organisms in low concentrations (Cu, Fe, Mn, Zn, Ni, Mo, Co); they become toxic above certain concentrations and the others are toxic even at very low concentrations (Rengel 1999). They threat organisms by causing damages and ecosystems by disturbing the balance of chemicals and processes. They are derived from several sources such as traffic, industrial and agricultural activities. Associated with urbanization, industrialization and population increase, metal pollution became one of the basic problems in ecosystems. Metals in agricultural fields basically come from traffic, pesticides and fertilizers in most regions. Because of its importance, numerous studies were carried out on metal pollution on the accumulation of metals in different plants (Sharma *et al.* 2008), biomonitoring the pollution (Karavin *et al.* 2014), determining the effects of metal sources (Alagić *et al.* 2015), and their effect on organisms and environment (Zheng *et al.* 2007). There are a few studies on resorption of metals which are quite important in order to determine their accumulation in plants and health of plants (Killingbeck and Costigan 1988, Nieminen and Helmisaari 1996). In contrast to N and P resorption, metal resorption in plants is undesirable. More metal resorption from senescent organs means more metal accumulation in plant tissues.

Fruits and leaves of *V. vinifera* L. are used as food and raw material for vine, cosmetics and medicines. Determining the rates of metal resorption in different organs of *V. vinifera* is important for growth, crop quality and health. Accumulation of metals in plant tissues year by year may cause increased heavy metal concentrations in plant tissues and this may cause damages in plants and organisms and even death of plants in the long term. Additionally, resorption mechanism is important for sustainability of ecosystems because this process determines the amount of elements which added to the soil by means of abscission. So, the objectives of the study were (1) to determine how metals mobilize and accumulate in different parts of *V. vinifera* and

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(2) the resorption rates of metals in various organs. It was hypothesised that metals may be absorbed from senescent organs and these may cause accumulation of metals in durable tissues of *V. vinifera*.

Material and Methods

This study was carried out in three vineyards in Nevşehir, Turkey. Leaf, stem, root and tendril samples were collected from eight grapevines in each vineyard in mature green and senescence periods. Fruit samples were collected only in the green period. Organ samples of green and senescence periods were collected from same grapevines. Organ samples were dried in a drying oven at 75 °C until constant weight was reached and milled. For each organ, two of the eight samples were pooled and mixed. The metal analyses were done in these four mixtures of organ samples. The microwave method was applied to milled organ samples for dissolution (ALTUNDAĞ and TÜZEN 2011). Metal concentrations were determined by ICP-OES. RE of metals were calculated as

$$RE\ (\%) = \frac{Mgreen - Msenescent}{Mgreen} \times 100$$

where the RE, Mgreen and Msenescent expressed resorption efficiency (%), metal concentration of plant tissues in the mature green period ($\mu g \cdot g^{-1}$) and in the senescence ($\mu g \cdot g^{-1}$), respectively. Resorption proficiency (RP) of metals ($\mu g \cdot g^{-1}$) was determined as residual metal concentrations in senescent leaves (YUAN *et al.* 2005). Since there isn't any direct relationship between soil nutrient content and resorption of nutrients and metals, soils of the vineyards weren't analyzed (MADEJON *et al.* 2004, TANG *et al.* 2013).

Statistical analyses were done by using SPSS (20). The differences in metal concentrations between green and senescent periods were determined by Independent sample T-test. Differences in metal concentrations among organs were examined by one-way ANOVA and Tukey post-hoc test.

Results

All the metal concentrations varied among organs both in the green and senescence period (Fig. 1). In the green period, maximum accumulation occurred in roots for Co and Fe, in leaves for Cu, Mn and Pb, and in stem for Cr. In the senescence period, maximum metal accumulation occurred in leaves for almost all of the metals.

Most of the metals mobilized from one organ to another and their concentrations varied between green and senescent periods (Fig. 1). Decrease in element concentrations in the senescent period compared with the green period indicates resorption of elements from senescent organs. Metal con-

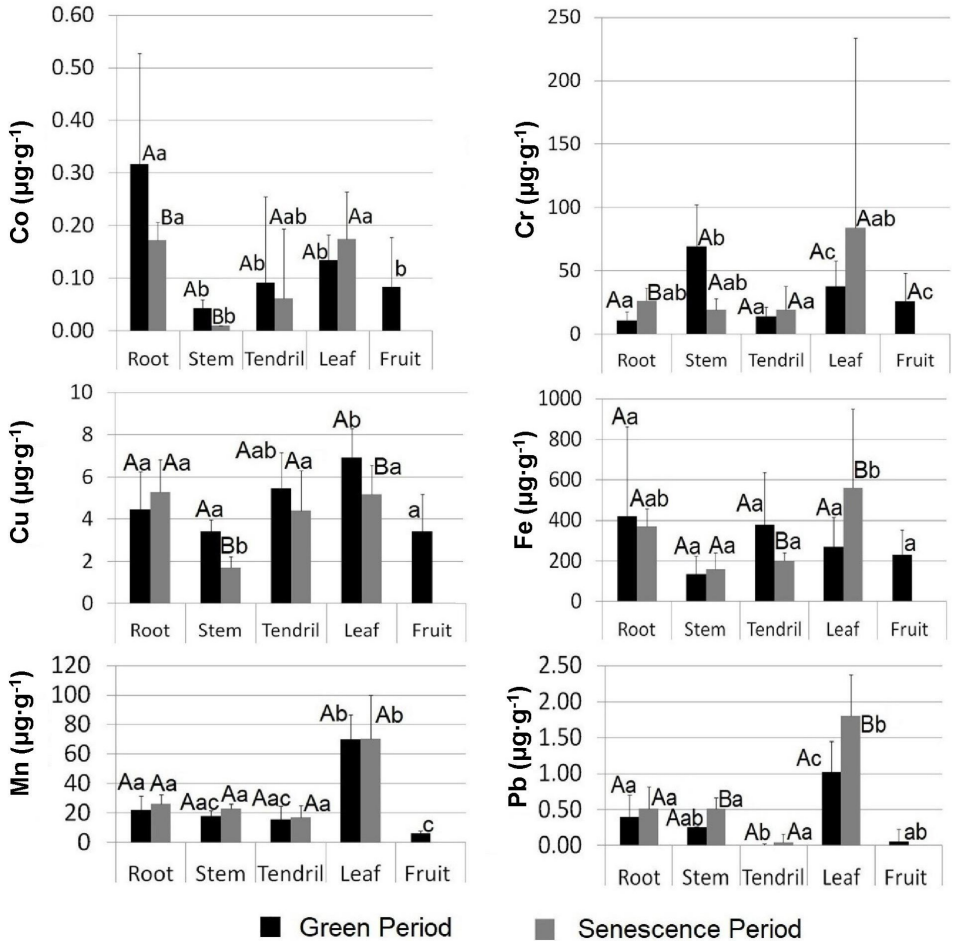

Fig. 1: Mean metal contents of *V. vinifera* organs in green and senescence period. Different big letters indicate the significant differences in metal concentrations of organs between green and senescent period and different small letters indicate the significant variation in metal concentrations among organs at $P \leq 0.05$ level.

centrations in senescent organs indicate also resorption proficiency.

According to the results, except Mn and Pb, other metals were translocated from various organs to anothers. Mn and Pb tended to accumulate in organs, especially in leaves (Fig. 2). Co was resorbed from roots (46 %), stems (77 %) and tendrils (33 %). Cr resorption occurred only in stems (72 %).Cu was resorbed from stems (51 %), tendrils (19 %) and leaves (25 %). Fe was resorbed from roots (12 %) and tendril (47 %).

Discussion

According to the results, Cr was in toxic levels while the other metals in different organs were within normal values which was reported by Kabata-Pendias and Mukherjee (2007). There isn't any Cr uptake mechanism because Cr is not an essential element and it is taken up along essential elements (Singh *et al.* 2013). High Cr accumulation in plants causes reduction in growth and biomass, and structural damages (Singh *et al.* 2013). Cr toxicity is important both for crop quality and health of organisms. Additionally, Cr toxicity affects seed germination, seedling growth, senescence, pigment status, and nutrient contents of crop plants (Bishnoi *et al.* 1993, Sharma and Agrawal 2005). Cr toxicity also influences other organisms which feed on *V. vinifera*, especially humans.

Metal concentrations in senescent organs were also resorption proficiency values of metals. Lower metal concentrations in senescent leaves indicate more proficient usage of metals and high resorption rate of metals. Because RP is not dependent on temporal variation and sampling date, it is reported as a more useful resorption parameter than RE (Killingbeck 1996). However, this may be useful for other nutrients such as N and P because the resorption of these elements was examined by various studies (Aerts 1990, Kutbay *et al.* 2003, Kumar 2005, Fife 2008). But, resorption of metals is still unclear and there isn't any determinant value that indicates proficient usage of metals. So, comparing metal concentration in green and senescent plant parts may provide useful information about resorption of metals. Because of this reason, resorption rate was mostly evaluated by considering RE values of metals in the current study. The remobilization rate of metals in *V. vinifera* varied widely. Only Cu was resorbed from the leaves of *V. vinifera*. It was also resorbed from stems and tendrils and accumulated in roots. Because it is an essential nutrient, the resorption of

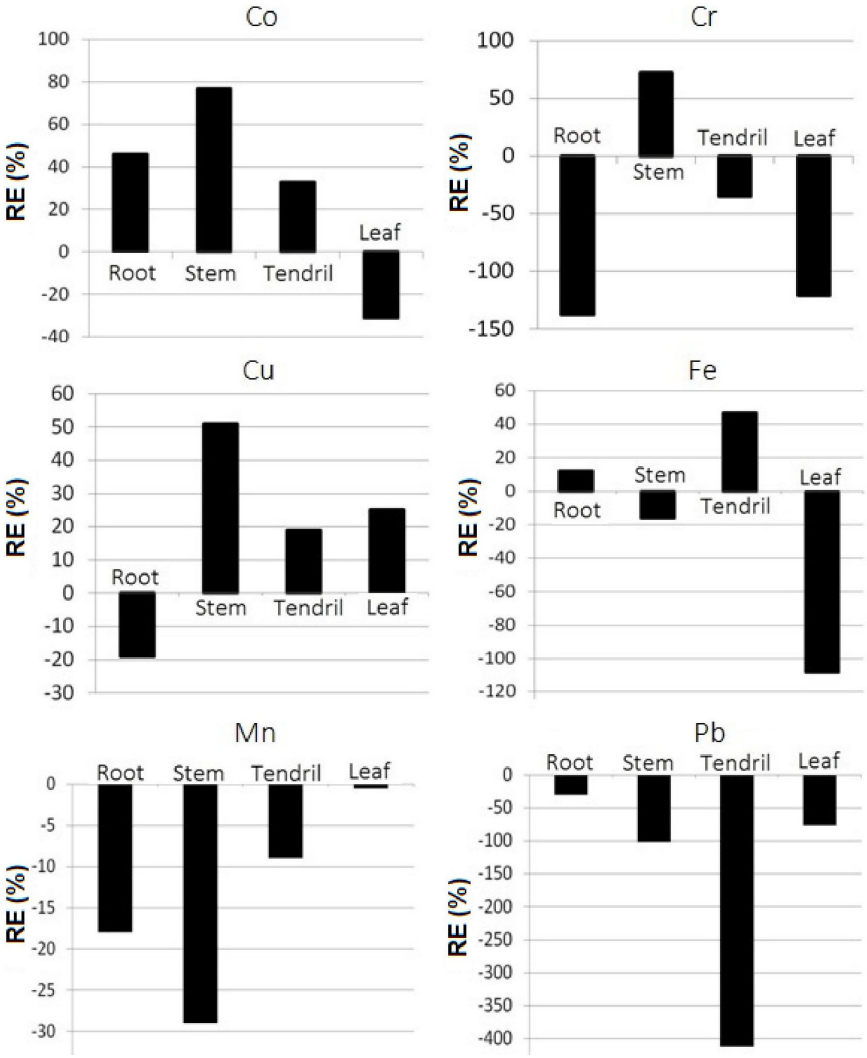

Fig. 2: Mean RE (%) values of metals in organs of *V. vinifera.*

Cu is important and useful for plant growth. Cu is required for chlorophyll formation, effective in photosynthesis by regulating CO_2 uptake and as component of enzymes, co-factor for some of the metalloproteins etc. (Saleem *et al.* 2020). By its resorption mechanism, *V. vinifera* becomes less-dependent to new Cu uptake in the growing season. Several factors may decrease Cu uptake such as soil structure, amount of organic materials and usage of fertilizers. In such a case, resorption of Cu provides an advantage to *V. vinifera*. However, resorption of Cu also leads to accumulation in *V. vinifera* tissues. Because it is also a toxic element in high concentrations for plants, this mechanism may lead to Cu toxicity later especially in polluted environments. In this study, mean Cu concentrations were below the average content of Cu for plants (10 $\mu g \cdot g^{-1}$ dry weight) (Baker and Senef 1995, Yruela 2005). So, there was no Cu toxicity for *V. vinifera*.

Cu resorption from leaves of different plant species was also reported by Killingbeck and Costigan (1988) and Harvey and Driessche (1999). In the study of Maillard *et al.* (2015), Cu was widely remobilized in most of the species. However, Shi *et al.* (2011) did not determine leaf Cu resorption in nine deciduous and evergreen species. Nieminen and Helmisaari (1996) found an increase in Cu content in senescent leaves of *Pinus sylvestris* L.

Co resorption was determined in roots, stems and tendrils of *V. vinifera.* It tended to accumulate in leaves. As a result, considerable amount of Co was removed from *V. vinifera* tissues by means of litterfall.

Cr was only resorbed from stems and accumulated in roots, tendrils and especially leaves. Cr toxicity in *V. vinifera* might be decreased by means of fall of tendrils and leaves.

In addition, Fe resorption occured in roots and tendrils and it tended to accumulate in leaves. A certain amount of Fe was lost through defoliation. When it is thought that Fe is an essential element for plant growth, removal of it by this way indicated no efficient usage by *V. vinifera*.

Accumulation of metals in plant tissues are threatening plant survival. Because Mn and Pb are toxic elements, the lack of Mn and Pb resorption from senescent organs to durable organs in *V. vinifera* is advantageous for growth (Bora *et al.* 2020). Accumulation in leaves provided decrease in Mn and Pb concentration through abscission. Thus, these harmful elements were removed from plant tissues.

It was known that relationships among elements affect mineral content of plant tissues. There are synergistic and antagonistic relationships between elements. These relationships may play a role in mineral uptake, translocation and remobilization of plants and cause differences in RE and RP of elements.

Residual metal concentrations in senescent organs indicate metal addition to the soil by means of abscission. High amounts of metals in senescent organs are good for plant health, but detrimental to soil and ecosystems. Plant litter which contains high amounts of metals such as leaves of *V. vinifera* decompose and metals are released to soil. On the other hand, metals in plant litter may cause slow decomposition. Several studies reported lower decomposition rates based on metal pollution and it was found that polluted litter decomposed more slowly than unpolluted litter (Berg *et al.* 1991). In *V. vinifera*, most of the metal content was found in senescent leaves. Tendrils also contained metals. By considering this, leaves and tendrils, which constitute most of the above ground litter layer may decompose more slowly because of their metal content. Metals in plant litter may inhibit microbial activity in soils and cause a decrease in decomposition rate.

Conclusion

In contrast to essential elements, resorption of metals is undesirable for plant growth and health (Narendrula-Kotha *et al.* 2020). This study provides useful detailed information about metal status of *V. vinifera* which is one of the most important crops in the world. Except for Mn and Pb, other metals tended to be resorbed in several organs of *V. vinifera* in this study. Because of its strong toxicity, lack of Pb resorption is very important for growth of *V. vinifera*. Less accumulation of metals in fruits and high accumulation of metals in leaves are vital for organisms that feed on *V. vinifera*. High accumulation of metals in senescent leaves is good for growth, but it is harmful for ecosystems because of metal addition to the environment through abscission of leaves. Metal resorption from leaves, roots, stems and tendrils of *V. vinifera,* which has never been reported previously, were demonstrated in this study. It was thought that results will provide useful information for future studies.

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