

INFLUENCE OF ROOTSTOCK CULTIVAR COMBINATION ON THE CONTENT OF HEAVY METALS, MICRO AND MACROELEMENTS IN THE LEAVES OF PLUMS

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Abstract

The research was conducted to evaluate the effect of rootstock combinations on the content of heavy metals, micro, and macronutrients in the leaves of plums. The study was conducted in Brestnik village, situated at a 3.5 km distance from the source of pollution - the Non-Ferrous Metal Works near Plovdiv, Bulgaria. Three plum cultivars of "Stanley", "Jojo" and "C. Lepotica" were studied on the rootstocks of GxN15, GF677, Wavit, Ishtara and Prunus cerasifera for the content of heavy metals, micro, and macroelements in the leaves of plums. Heavy metal concentrations (Zn, Cd, and Pb) in plum orchard soils were below maximum permissible concentrations. The content of micro and macroelements in the leaves differs for each rootstock combination, depending on the cultivar. Phosphorus, potassium and calcium were within the optimum values for leaves, and iron content was below the average. The range of heavy metal and microelement concentration in plum leaves was Fe (58.0–137 mg/kg), Mn (111.7–398.9 mg/kg), Zn (17.2–33.1 mg/kg), Cu (4.3–8.0 mg/kg) and Pb (6.2–14.7 mg/kg). Leaf Cd concentration was below the detection level. The effect of rootstocks on the accumulation of micro and macroelements (K, Ca, Mg, Fe, Zn, Cu, Mn and B) was significant. The results showed that the rootstocks strongly affected the leaf and fruit element uptake of plums.

Keywords: plum, cultivars, rootstock combination, heavy metals, micro and macroelement content, leaves

1. INTRODUCTION

Prunus domestica is a fruit crop of the genus *Prunus*. The high dietary value of plums is due to the carbohydrates (mono- and disaccharides, pectin, dietary fibre) (Stecewicz-Sapuntzakis et al., 2001), antioxidant compounds, phenolic acids, flavonoids, vitamins, proteins, fats, etc. contained in them (Auger et al. 2004). Also, plums contain K, Na, Ca and Mg (Nergiz & Yýldýz, 1997), B and Fe (Yagmur & Taskin, 2011, Jaroszewska, 2011).

Many authors report that the macronutrient content of plums depends on the cultivar, soil-climatic conditions, harvest time (Nergiz & Yýldýz, 1997), irrigation regime and fertilization (Jaroszewska 2011), as well as rootstock. The choice of suitable rootstock is of utmost importance for fruit cultivars, as it determines their adaptation to different soil types, the ability to control growth vigour, productivity and fruit quality (Sosna, 2006; Rato et al., 2008, Daza et al., 2008, Sosna & Licznar-Małańczuk, 2012). Rootstocks can also influence tree longevity (Dimitrova, 2001). The genetic endowments of each rootstock combination and their physiological and biochemical interactions with the environment are unique, necessitating their study under different soil and climatic conditions. According to Iqbal & Lajber (2010), and Osmanovic et al. (2014), plants grown in polluted areas have a higher concentration of heavy metals than those grown in a non-polluted environment. Uptake and accumulation of heavy metals in plants depend on several factors such as soil pH, absorption capacity, distance from the source of contamination, exposure time, etc. (Kabata Pendias, 2001).

There is a lack of information on the influence of rootstock-cultivar combinations in the content of elements in plum leaves in areas with industrial pollution.

The main objective of the present study is to conduct a comparative study which will allow us to determine the influence of rootstock-cultivar combinations on the content of heavy metals, micro and macro elements in plum (*Prunus domestica* L.) leaves when grown on soils slightly contaminated with heavy metals, and to evaluate the best rootstock-cultivar combination for the production of plum fruits with the highest mineral content.

2. MATERIALS AND METHODS

2.1. Materials

The study was carried out in an experimental field at the University of Plovdiv in the village. Bresnik, 3.5 km away from the source of heavy metal contamination (KCM-Plovdiv). The soils are characterized by slightly alkaline reaction (pH 7.6), average organic carbon content (2.24%) and average nutrient supply (0.22% N, 387.3 mg/kg P, 6780 mg/kg K). Soil Pb content reaches 83.1 mg/kg, Cd -4.0 mg/kg, Zn 215.3 mg/kg, Cu -71.3 mg/kg, Fe- 29581.9 mg/kg, Mn- 884.2 mg/kg, Ca- 18065 mg/kg, Mg -10040.1 mg/kg. Of the heavy metals, only the Cd content exceeds the maximum allowable concentrations (3.0 mg/kg Cd) in soils.

Three cultivars “Čačanska Lepotica”, “Stanley” and “Jojo” were studied on five rootstocks Myrobalan (*Prunus cerasifera* seedlings), Ishtara, Wavit, GF677 and GxN15.

All trees were grown under identical conditions with drip irrigation. Plant material (leaves) of all rootstock combinations in six replications was collected for analysis in August. The leaf samples were dried at room temperature to obtain air-dry mass and then dried at 105°C.

2.2. Methods

Total content of metals in soils was determined by ISO 11466. Weigh 3 g of air-dry soil to the nearest 0.001 g and moisten with 1 cm³ H₂O. Add 28 cm³ of HCl: HNO₃ mixture (3:1). The sample is left for 16 hours at room temperature. Place on a sand bath and heat for 2 hours at 180 to 200°C. Quantitatively transfer the residue to a volumetric flask by filtering through a blue band filter and bring the volume to 50 cm³.

The contents of heavy metals (Pb, Zn and Cd) in the plant material (leaves) were determined by microwave mineralization. A Milestone 1200 MEGA microwave system with 10 MRD 300 rotors (10 positions) was used. 0.2 g of the dried and well-homogenized sample was weighed to the fourth digit and transferred to Teflon dishes, after which 5 cm³ HNO₃ and 1 cm³ H₂O₂ were added to each. The mineralization program includes three stages: (i) 5 minutes of 250 W non-pulsating irradiation, (ii) 5 minutes of 400 W pulsing irradiation, and (iii) 5 minutes of 600 W pulsing irradiation. After ventilation for 1 minute, cool the sample and transfer quantitatively to a 25 cm³ volumetric flask.

The quantitative measures were carried out by the ICP method (Jobin Yvon Emission - JY 38 S, France).

Digestion and analytical efficiency of ICP were validated using standard reference material of apple leaves (SRM 1515, National Institute of Standards and Technology, NIST).

3. RESULTS

Figure 1 presents the results obtained for the heavy metal, micro and macroelement contents in the leaves of plum cultivars of the rootstock combinations.

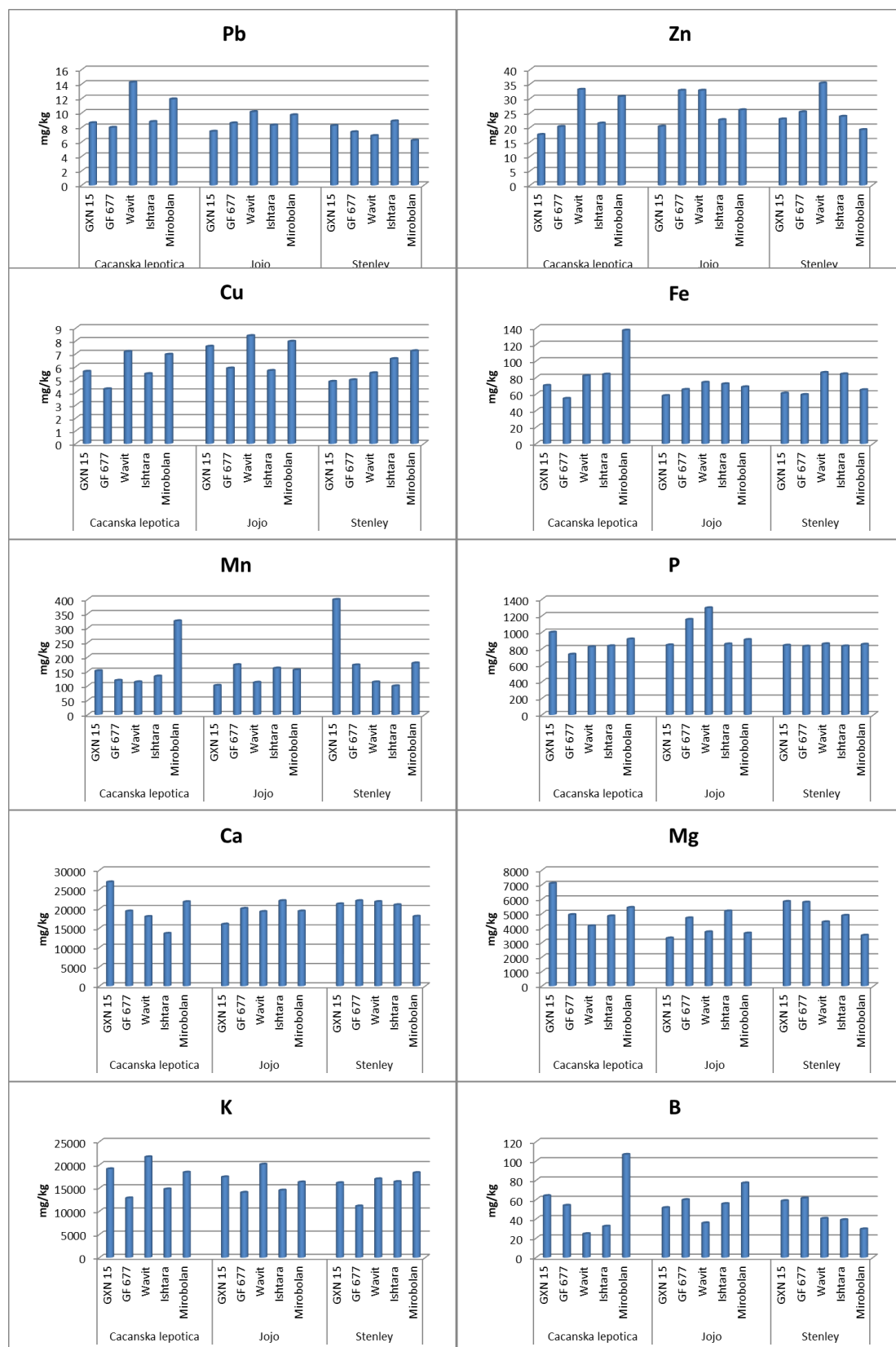


Fig. 1. Content of heavy metals, micro and macroelements (mg/kg) in leaves of plum rootstock combinations (rootstock 1-GxN15, 2-GF677, 3-Wavit, 4-Ishtara, 5-Mirobolan)

4. DISCUSSION

Significant differences were observed in the content of micro and macroelements in the leaves of plum trees in the studied rootstock combinations, following the results of other authors (Milosevic & Milosevic, 2012).

The P content in plum leaves ranged from 732.1 to 1294.9 mg/kg, and the highest P content was found in the leaves of trees of cv. "Jojo" in combinations with rootstocks Wavit and GF677. The values found for P in leaves were lower than the optimum content for P in leaves (0.14-0.25%). Studies by Milosevic & Milosevic (2012) showed significantly higher P content in plum leaves due to excessive P fertilization during cultivation. This trend has also been found in stone fruit trials (Jiménez et al., 2004; Zarrouk et al., 2005).

Leaf K content ranged from 11082.3 to 21688 mg/kg, with the highest P content found in the leaves of cv. "Čačanska Lepotica" and cv. "Jojo" in combination with Wavit rootstock. The leaf K values found were within the optimum range for leaf K content (1.6%-3.0%), except for the tested cultivars with GF 677 rootstock combinations. Variation in leaf K content (lower and higher than the optimum) has also been found by other authors (Sánchez-Alonso & Lachica, 1987) due to excessive K fertilization under the growing conditions (Milosevic & Milosevic, 2012).

Leaf Ca content ranged from 13590.2 to 26907.6 mg/kg, with the highest content found in cv. "Čačanska Lepotica". The values found for Ca in leaves were within the optimum range for Ca content in leaves (1.5-3.0%). Milosevic & Milosevic (2012) found Ca content in leaves cv. "Čačanska Lepotica" and "Stanley" were lower than the optimum. According to the authors, this can be explained by the low Ca mobility in the plant, suggesting low Ca uptake and Ca storage as Ca pectate (von Bennewitz et al., 2011). It is also possible that Ca deficiency is induced by antagonism with some elements such as Mg (Zarrouk et al., 2005). However, in the leaves of the rootstock-cultivar combinations we studied, the Ca content was within the optimal range.

Leaf Mg contents ranged from 3299.9 to 7078.8 mg/kg, with the highest values found in cv. "Čačanska Lepotica" rootstock GxN15. The values found for Mg in leaves were within the optimum range for Mg content in leaves (0.3-0.6%), except for the variety "Čačanska Lepotica" with rootstock GxN15, where the content was high.

There is a high variability of results in terms of Mg in plum cultivars (Sánchez-Alonso & Lachica, 1987). Milosevic & Milosevic (2012) found a lower than normal content of Mg in leaves, which is not confirmed by our results.

The Fe content in leaves ranged from 54.6 to 137.1 mg/kg, with the highest values found in the cultivar "Čačanska Lepotica" with rootstock GxN15. The values found for Fe in leaves were lower than the optimum content for Fe in leaves (100-250 mg/kg) except for the variety "Čačanska Lepotica" in combination with Myrobalan rootstock. Similar results were obtained by Boskovic-Rakocevic et al. (2014) (16.95- 173.01 mg/kg Fe).

Leaf Mn content ranged from 99.5 to 398.9 mg/kg, and the highest values were found in cultivar "Stanley" with GxN15 rootstock. The values found for Mn in leaves were within the optimum range for Mn content in leaves (40-150 mg/kg), except for the cultivar "Čačanska Lepotica" in combination with Myrobalan rootstock and the cultivar Stanley in combination with GxN15 rootstock, where the content was high. Similar results were obtained by Boskovic-Rakocevic et al. (2014) (Mn 19.88-61.60 mg/kg).

The Zn content in the leaves varied from 17.4 to 35.3 mg/kg, with the highest values found in the Stanley cultivar Wavit rootstock. The values found for Zn in leaves were within the optimum range for Zn content in leaves (20-50 mg/kg), except for the cultivar "Čačanska Lepotica" in combination with GxN15 rootstock and the cultivar "Stanley" in combination with Myrobalan rootstock where the content was lower than normal. Similar results were obtained by Boskovic-Rakocevic et al. (2014) (Zn 15.35-34.71 mg kg). The Cu content in the leaves ranged from 4.3 to 8.4 mg/kg, with the highest values found in cultivar "Jojo" in combination with Wavit rootstock. The values found for Cu in leaves are within the optimal range for Cu content in leaves (6-16 mg/kg), except for cultivar

“Čačanska Lepotica” in combination with rootstock GF677, and cultivar “Stanley” in combination with rootstock GxN15 where the content is lower than normal. Similar results were obtained by Boskovic-Rakocevic et al. (2014) (Cu 5.88-11.59 mg/kg) in leaves. The lead content in the leaves ranged from 7.36 to 11.9 mg/kg, probably due to aerosol contamination. Our results are higher than those found by Boskovic-Rakocevic et al. (2014) (Pb 1.15- 7.47 mg/kg)

The leaf cadmium content was below the detection limit, which is consistent with Boskovic-Rakocevic et al. (2014).

A slightly alkaline soil reaction (pH 7.6) was responsible for decreasing the mobility of heavy metals in the soil, resulting in reduced translocation of elements from roots to aerial parts. The soil takes heavy metals through the root cells, passes through the plasma membrane and enters the cell via plant transporters. Mobility from roots to leaves and fruits is limited by an internal detoxification system (Cieśliński et al. 1996) which can reduce the movement of these elements, thus reducing their levels in aboveground parts and, consequently, to a reduction in their toxicity to plants.

The rootstocks affect the uptake of nutrients in plum leaves. GxN15 rootstock resulted in significantly higher uptake of Mn, Ca and Mg, GF677 rootstock in substantially higher uptake of Mg and Ca, Wavit rootstock in Cu, Zn, Fe, P and K, and Myroblan rootstock in significantly higher uptake of Cu, Zn, Fe and B.

There was no significant difference in Mg uptake for rootstocks Myrobalan and Ishtara, Zn uptake for rootstocks GF677, Wavit and Myroblan, Ca uptake for rootstocks GxN15 and GF677, and Fe uptake for rootstocks Wavit, Ishtara and Myroblan.

Regarding the influence of cultivars, leaves of “Čačanska Lepotica” had higher contents of Fe, Mg, K, Na and B, leaves of trees of the cultivar “Jojo” had higher contents of Zn, P and B, and leaves of trees of cultivar “Stanley” had higher contents of Cu, Mn and Ca. At the same time, there were no differences among cultivars in Zn and Ca contents.

The results showed that rootstock-cultivar combinations significantly influenced the uptake of macro- and micronutrients in the leaves of plum trees. The combination of rootstock GxN15 and cultivar “Čačanska Lepotica” influenced the uptake of Ca and Mg and on “Stanley” - for Mn. The combination of rootstock GF677 and “Stanley” cultivar influenced Ca and Mg uptake, and “Jojo” cultivar - Zn uptake. The combination of Myroblan rootstock and “Čačanska Lepotica” cultivar affected Zn, Fe and B uptake, on “Jojo” - Cu uptake. The combination of Ishtara rootstock and “Stanley” cultivar influenced Fe uptake.

Rootstocks affect nutrient uptake in plum fruits. GxN15 rootstock resulted in significantly higher Fe, P, K and Mg uptake, GF677 rootstock resulted in significantly higher Zn, Mn, P, Ca, Mg, and B uptake and Myrobalan rootstock resulted in significantly higher Cu, Fe and B uptake.

There was no significant difference in Mg uptake for GxN15, GF677, Ishtara and Myrobalan rootstocks, B uptake for GF677, Ishtara and Myrobalan rootstocks, P uptake for GxN15 and GF677 rootstocks, and Fe uptake for GxN15 and Wavit rootstocks. Similar results were obtained by Milosevic & Milosevic (2012) and Thorp et al., (2007). They found that rootstocks affect differences in tree vigour and play an essential role in nutrient uptake in fruits and leaves. According to the authors, some rootstocks are apparently able to absorb nutrients from the soil better than others, regardless of their effect on tree energy. A similar observation was reported by Daza et al. (2008).

5. CONCLUSIONS

1. Significant differences were observed in the content of micro and macro elements in the leaves of plum trees in the studied rootstock-cultivar combinations.
2. The rootstocks influence the absorption of nutrients in plum leaves of “Čačanska Lepotica” have higher contents of Fe, Mg, K, Na and B, leaves of trees of the cultivar “Jojo” have higher contents of Zn, P and B, leaves of trees of the cultivar “Stanley” have higher contents of Cu, Mn and Ca. At

the same time, there are no differences between cultivars in zinc and Ca contents. GxN15 rootstock leads to significantly higher absorption of Fe, P, K and Mg, GF677 rootstock to significantly higher absorption of Zn, Mn, P, Ca, Mg and B, and Myrobalan rootstock to significantly higher absorption of Cu, Fe and B.

3. The rootstock-cultivar combinations significantly influence the absorption of macro- and microelements in plum leaves. The combination of rootstock GxN15 and cultivar “Čačanska Lepotica” influenced the uptake of Ca, Mg, and Mn on “Stanley”. Combination of rootstock GF677 and “Stanley” cultivar influenced Ca and Mg uptake, and on “Jojo” cultivar - Zn uptake. The combination of Myrobalan rootstock and “Čačanska Lepotica” cultivar influenced Zn, Fe and B uptake on “Jojo”- Cu uptake. The combination of Ishtara rootstock and “Stanley” cultivar influenced Fe uptake.

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