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INFLUENCE OF ROOTSTOCK CULTIVAR COMBINATION ON THE CONTENT OF HEAVY METALS, MICRO AND MICROELEMENTS IN THE FRUITS OF PLUMS

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Abstract

The research was conducted to evaluate the effect of rootstock cultivar combinations on the content of heavy metals, micro, and macronutrients in the fruits of plums. The study was conducted in Brestnik village, situated at 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, GF 677, Wavit, Ishtara and Myrobalan for the content of heavy metals, macro, and microelements in the fruits of plums. The content of heavy metals, macro and microelements in the fruits are different for each rootstock combination, depending on the cultivar. Plum fruits tested negative for the presence of Cd, whereas Pb levels were within maximum permissible concentration. The effect of rootstocks on the accumulation of macro and microelements (K, Ca, Mg, Fe, Zn, Cu, Mn and B) was significant. The results showed that the rootstocks strongly affected the fruit element uptake of plums

Keywords: plum, cultivars, rootstock combination, heavy metals, macro and microelements content, fruits.

INTRODUCTION

European plum (Prunus domestica) is a fruit tree of the genus Prunus. The high dietary value of plums results from their content of carbohydrates (mono- and disaccharides, pectin, dietary fiber), antioxidant compounds, phenolic acids, flavonoids, vitamins, proteins, fats, etc. (Stacewicz-Sapuntzakis et al., 2001; Auger et al., 2004). Also, plums contain K, Na, Ca, Mg, B and Fe (Nergiz and Yyldyz, 1997; Yagmur and Taskin, 2011; Jaroszewska, 2011).

Many authors report that the content of microelements in plums depends on the cultivar, soil and climatic conditions, harvest date (Nergiz and Yyldyz, 1997), irrigation and fertilization regime5, as well as on rootstocks. The choice of a suitable rootstock is of great importance for the varieties of fruit trees, since it depends on their adaptation to different soil types, the ability to control the growth power, productivity and quality of fruits (Sosna, 2006; Daza et al., 2008; Rato et al., 2008; Sosna and LIcznar-Małańczuk, 2012). Rootstocks can also affect the life span of a tree (Dimitrova, 2001). The genetic properties of each cultivar-rootstock combination and their physiological and biochemical interaction with the environment are unique, which necessitates their study under different soil and climatic conditions. According to many authors (Angelova et al., 2003; Iqbal and Lajber, 2010; Osmanovic et al., 2014; Angelova et al., 2018) plants grown in contaminated sites have a higher concentration of heavy metals than those grown in an uncontaminated environment. The uptake and accumulation of heavy metals in plants depends on a number of factors, such as soil pH, absorption capacity, distance from the source of contamination, exposure time, etc. (Kabata-Pendias and Pendias, 2011).

In literature there is no information about the influence of cultivar-rootstock combinations on the production of orchard species in areas with industrial pollution.

The main objective of this study is to conduct a comparative study that will allow us to determine the effect of rootstock cultivar combinations on the content of heavy metals, macro- and microelements in fruits of plums (Prunus domestica L.) in their cultivation on poorly heavy metal contaminated soils, as well as to evaluate the best cultivar-rootstock combination for the production of plum fruits with the highest mineral content.

MATERIALS AND METHODS

The study was carried out in a nursery garden in the area of the Training and Testing Base of the University of Agriculture, Plovdiv, located in the village of Bresnik, 3.5 km away from the source of heavy metal contamination (KCM Plovdiv - Non-Ferrous Metal Works). The soils are characterized by a low alkaline reaction (pH 7.6), an average organic carbon content (2.24%) and an average nutrient reserve (0.22% N, 387.3 mg.kg^{-1} P, 6780 mg.kg^{-1} K). Lead content in soils reaches 83.1 mg.kg^{-1}, Cd - 4.0 mg.kg^{-1}, Zn - 215.3 mg.kg^{-1}, Cu - 71.3 mg.kg^{-1}, Fe - 29581.9 mg.kg^{-1}, Mn - 884.2 mg.kg^{-1}, Ca - 18065 mg.kg^{-1}, Mg - 10040.1 mg.kg^{-1}. Of the heavy metals, only the Cd content exceeds the maximum permissible concentrations (3.0 mg.kg^{-1} Cd) in soils.

Three plum cultivars "C. Lepotica", "Stanley" and "Jojo" were studied on five rootstocks: Myrobalan (Prunus cerasifera seedling), Ishtara, Wavit, GF677 and GxN15.

All trees were grown under the same conditions with drip irrigation. Fruits from all cultivar-rootstock combinations replicated six times were taken for analysis in August. The fruits were analyzed in a fresh condition for content of macro-, microelements and heavy metals.

Total content of metals in soils was determined in accordance with ISO 11466 (1995). The contents of heavy metals, macro and microelements in the fruits were determined by the method of the microwave mineralization. The quantitative measures were carried out by ICP method (Jobin Yvon Emission - JY 38 S, France).

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

RESULTS AND DISCUSSION

The content of macro-, microelements and heavy metals in the fruits of the rootstock cultivar combinations in plums is presented in Table 1 and Fig. 1. It was established that the content of heavy metals, macro- and microelements has been found to be higher in plum leaves than in fruits, (Mclaughlin et al., 1999; Li et al., 2006; Boskovic-Rakocevic et al., 2014) and in most cases, there is a relationship between the absorption of metals from plants and their content in soil (Agyarko et al., 2010).

The results obtained show that in plum fruits, macroelements (K, P, Mg, Ca) predominate, followed by Fe, Mn, Zn and Cu. The plum fruits also contain the toxic metal Pb.

The average content of Pb in plum fruits reaches 0.024 mg.kg^{-1} and Cd is below the limit of detection. The content of toxic metals in most foods is regulated by Commission Regulation (EC) № 1881/2006 of 2006. According to European standards, the content of Cd and Pb in fruits should not exceed values of 0.05 mg.kg^{-1} of fresh weight for Cd and 0.1 mg.kg^{-1} of fresh weight for Pb.

The content of Pb and Cd in plum fruits in all cultivar-rootstock combinations studied grown 3.5 km from KCM (Non-Ferrous Metal Works) does not exceed the maximum permissible limits.

The average content of Zn in plum fruits reaches 0.74 mg.kg^{-1}, Cu - up to 0.62 mg.kg^{-1}, Fe - up to 1.56 mg.kg^{-1}, Mn - up to 0.64 mg.kg^{-1}, K - up to 1143.9 mg.kg^{-1}, Ca - up to 42.5 mg.kg^{-1}, Mg – up to 57.4 mg.kg^{-1} and P – up to 106.3 mg.kg^{-1}.

Table 1. Content of heavy metals, macro- and microelements (mg.kg^{-1}) in fruits of plum rootstock cultivar combinations

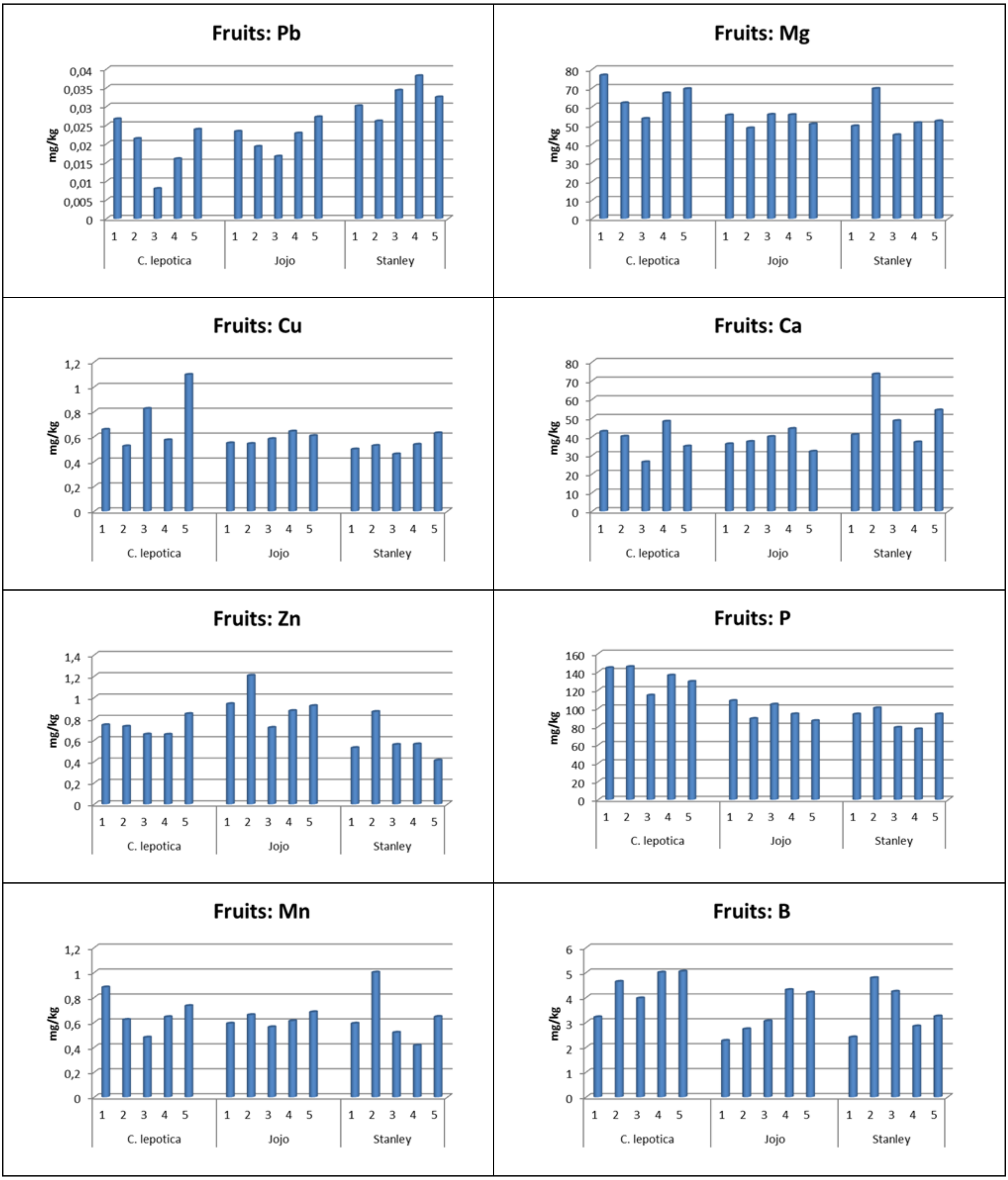
	Min	Max	Average
Pb	0.008	0.038	0.024
Zn	0.41	1.21	0.74
Cu	0.46	1.10	0.62
Fe	1.01	2.88	1.56
Mn	0.41	1.00	0.64
P	77.19	145.47	106.3
Ca	26.32	73.40	42.50
Mg	44.80	76.79	57.40
K	878.6	1417.8	1143.95
B	2.26	5.04	3.73

Significant cultivar differences in the plum fruit composition are observed, with the rootstock also having an effect (fig. 1). The highest content of K is established in the "C. Lepotica" cultivar in combination with GxN15 rootstock (1417.8 mg.kg^{-1}), while the highest content of P is with GF677 (145.5 mg.kg^{-1}) and GxN15 (144.3 mg.kg^{-1}) rootstocks. The content of Mg is highest in plum fruits of the "C. Lepotica" cultivar with GxN15 rootstock (76.79 mg.kg^{-1}), and Ca content is highest with the "Stanley" cultivar with GF677 rootstock (73.4 mg.kg^{-1}).

It has been found that in plum fruits, K prevails 3.22%, which is confirmed by our results. Potassium is known to regulate alkalinity in cells. Increasing K intake lowers blood pressure, so plums are recommended for people with hypertension (Zlatkovic, 2000). Bozovic et al. (2017) found 1160 mg.kg^{-1} of K in fruits, while significantly higher results were obtained by Nergiz, and Yyldyz (1997) for K content (1893–2199 mg.kg^{-1}).

Milosevic and Milosevic (2012) found that Mg content in plum fruits ranges from 74.88 to 123.66 mg.kg^{-1} and Ca from 77.07 to 196.84 mg.kg^{-1}. Jacimovic and Bozovic (2011) reported 150 mg.kg^{-1} of Ca and 90 mg.kg^{-1} of Mg, whereas Zlatkovic (2000) established 170 mg.kg^{-1} Mg.

When comparing the published results with the data we obtained, it is found that the content of macro- and microelements in the fruits in the studied cultivars is lower, except for Zn, which is probably due to environmental and geographical



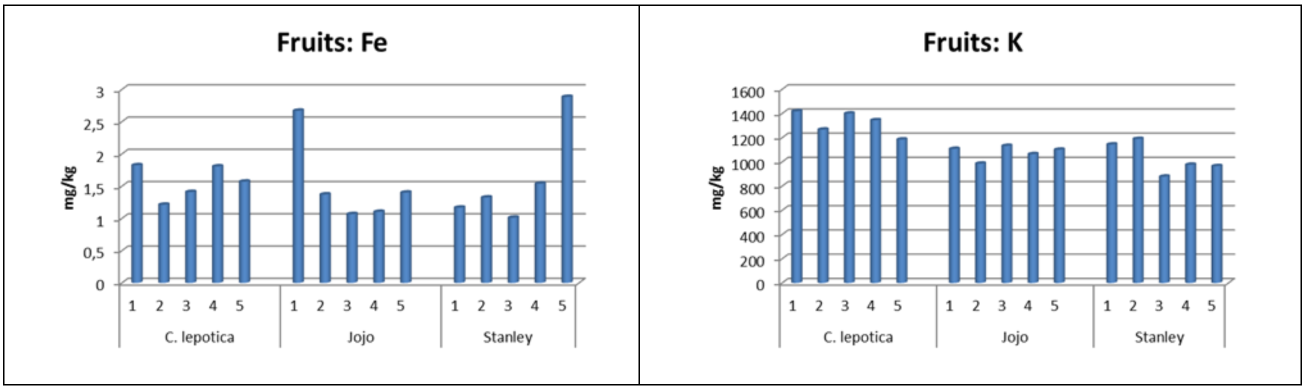


Fig. 1. Content of heavy metals, miaro- and microelements (mg.kg-1) in fruits of plum rootstock cultivar combinations (rootstocks: 1-GxN15, 2-GF677, 3-Wavit, 4-Ishtara, 5-Mirobalan)

factors, rootstocks used, etc.

The content of macroelements in plum fruits decreases in the following order: K> P> Ca> Mg (Table 1). Our results are consistent with those of Caliir et al. (2005), who report that K is the dominant mineral, followed by Ca and Mg.

However, according to Milosevic and Milosevic (2012), the content of macroelements accumulated in fully ripe plums decreases in the following order: K> N> Mg> Ca> P. Differences between these results for some macroelements and those obtained by Milosevic and Milosevic (2012) are due to different cultivar-rootstock combinations and environmental conditions.

On the other hand, Rato et al. (2008) reports that the contents of some of the elements may be affected by soil type and plum cultivar. Plum fruits have been found to contain significant amounts of Ca and Mg, which is in agreement with some previous studies conducted on plums (Jaroszewska, 2011). Nergiz and Yyldyz (1997) established that the content of macroelements in plum fruits depends not only on a specific parameter (rootstock, cultivar), but also on their combination.

The rootstocks influence the absorption of nutrients in plum fruits. 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.

No significant difference is observed in the absorption of Mg with GxN15, GF677, Ishtara and Myrobalan rootstocks, of B with GF677, Ishtara and Myrobalan rootstocks, of P with GxN15 and GF677 rootstocks, and of Fe with GxN15 and Wavit rootstocks. Similar results are obtained from Thorp et al. (2007) and Milosevic and Milosevic (2012), who found that rootstocks influence differences in tree energy and play an important role in nutrient absorption in fruits and leaves. According to the authors, some rootstocks are obviously able to absorb nutrients from the soil better than others, regardless of their effect on the growth power of trees. A similar observation is reported by Daza et al. (2008).

With respect to the cultivars, the fruits of the "C. Lepotica" cultivar have a higher content of Cu, K, Mg, P, B and Na, the fruits of the "Jojo" cultivar have a higher content of Zn, while there is no difference between the cultivars in the average content of Fe and Mn. The contents of the macro- and microelements in this study in plums are significantly lower than those found by Yagmur and Taskin (2011) and Milosevic and Milosevic (2012). This may be due to differences in the tested rootstocks and cultivars, as well as the environmental conditions.

The results we obtained show that the content of microelements in plum fruits decreases in the following order: B> Fe> Zn> Mn> Cu (Table 1), which is in accordance with the results of Milosevic and Milosevic (2012): B> Fe> Zn> Mn> Cu. These results are in good agreement with those reported by Stacewicz-Sapuntzakis et al. (2001), who emphasize that plums are an important source of B.

The influence of the cultivar and the type of rootstock on the absorption of macro- and microelements from the leaves and fruits of the plums has been established. This shows the great importance of the right selection of rootstocks to maximize the potential performance of a cultivar (Thorp et al., 2007). The results show that the cultivar-rootstock combinations have a significant influence on the absorption of macro- and microelements in plum fruits. GxN15 rootstock on the "C. Lepotica" cultivar affects K, Mg, P and Fe absorption, GF677 rootstock on the "Stanley" cultivar affects B, Mg, and Mn absorption and on the „Jojo" cultivar - Zn absorption. Myrobalan rootstock on the “C. Lepotica”cultivar affects the absorption of B and Cu and, on the “Stanley” cultivar – the absorption of Fe. Ishtara rootstock on “C. Lepotica” cultivar affects Mg and B absorption.

CONCLUSIONS

Based on the obtained results, the following conclusions can be made:

1. The content of Pb and Cd in plum fruits in all cultivar-rootstock combinations studied grown 3.5 km from KCM (Non-Ferrous Metal Plant) does not exceed the maximum permissible limits.

2. The rootstocks influence the absorption of nutrients in plum fruits. 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 fruits of the “C. Lepotica” cultivar have a higher content of Cu, K, Mg, P, B and Na, the fruits of the “Jojo” cultivar have a higher content of Zn, while there is no difference between the cultivars in the average content of Fe and Mn.

4. The cultivar-rootstock combinations have a significant influence on the absorption of macro- and microelements in plum fruits. GxN15 rootstock on the “C. Lepotica” cultivar affects K, Mg, P and Fe absorption, GF677 rootstock on the “Stanley” cultivar affects B, Mg, and Mn absorption and on the „Jojo” cultivar - Zn absorption. Myrobalan rootstock on the “C. Lepotica”cultivar affects the absorption of B and Cu and, on the “Stanley” cultivar – the absorption of Fe. Ishtara rootstock on “C. Lepotica” cultivar affects Mg and B absorption.

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