

*Full Length Research Paper*

# Copper and manganese content of the leaves of pepper (*Capsicum annuum* L.) grown on different soil types

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The aim of this study was to determine the degree of copper (Cu) and manganese (Mn) uptake by pepper plants (*Capsicum annuum* L.) grown on four different soil types. The study was conducted in 2009 and 2010 under controlled conditions in a greenhouse. The experiment was set up according to a randomized block design with four treatments (soil types) in five replications. The results showed that the degree of Cu and Mn uptake by pepper plants was statistically significantly dependent upon the soil type used for pepper cultivation regardless of plant phenostage and year of the study. The degree of Cu uptake by pepper plants was highest in the treatment on chernozem, lower on fluvisol and pseudogley, and lowest on vertisol, while the degree of Mn uptake by pepper plants was highest on chernozem and lowest on pseudogley. The Cu content of pepper leaves in all the treatments was low as compared to related literature data irrespective of plant phenostage. Considering the potential antagonistic relationship between Cu and Mn in the soil solution, we can conclude that one of the reasons for the low copper uptake by pepper plants was the high concentration of Mn in all soil types tested.

**Key words:** Pepper, soil types, manganese, copper.

## INTRODUCTION

Peppers are vegetable crop traditionally grown in Serbia, particularly in the southern Serbian regions that offer exceptionally favorable conditions for their cultivation. The statistical data for the period of 2008 to 2011 showed that peppers in Serbia are cultivated on about 20,000 ha of land, being among the most common vegetable crops in Serbia. In terms of pepper cultivars, there has been an increasing use of cv. Dora in the last two years in Serbia. This cultivar is distinguished by its very long, large, finely-coloured bright yellow peppers primarily intended for

fresh consumption (Cvikić et al., 2010). Apart from having fine appearance, the peppers of cv. Dora are fleshy, tasty easily thermally processed and exhibit early crop maturity. These are additional advantages that encourage producers to grow this pepper cultivar.

Despite the long tradition of vegetable cultivation and favorable conditions for the development of vegetable production, pepper yields per unit area in Serbia are rather low as compared to the European average. This is partly due to high temperatures and insufficient rainfall amounts during the summer period when the water requirements of peppers are quite high, and partly due to the inadequate use of agro-technical measures, notably irrigation and fertilization, which have a substantial effect on pepper yield and quality. Apart from the above factors,

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successful pepper production also depends upon the type of soil used for the crop cultivation. Only soils that have a stable structure, show high biological activity, good aeration, water infiltration and retention capacity and contain a high level of available nutrients have the potential to become a medium for the cultivation of both vegetables and other agricultural crops (Resulović et al., 2008).

In terms of its suitability for use in agriculture, the soil potential of Serbia is grouped into eight quality classes; the first four including soils suitable for agricultural production, and the latter four classes cover mostly uncultivable soils (Hadžić et al., 2002). The most common soil types in Serbia include chernozems, pseudogleys, vertisols and alluvial soils or fluvisols (Antonović et al., 2010). Chernozems are characterized by a stable structure, favorable water and air relationships, good thermal properties, high biological activity and a high content of available nutrients (Živković and Đorđević, 2003), which classifies these soils as class I soils. In terms of soil suitability for agricultural production, vertisols are classified among class III soils. These soils are formed on substrates containing over 30% of clay, with the clay content largely defining the soil characteristics (Milivojević, 2003). In a soil saturated with water, clay swells and consequently, the soil has a very low drainage capacity. In contrast, dry soils result in clay contraction and hence the formation of deep cracks into which the soils from the horizon A surface fall. This type of soils was named vertisols (lat. Verto-turn) due to the so-called turnover of soils. Regardless of their markedly unfavorable physical characteristics, vertisols have exceptionally favorable chemical properties, neutral to slightly alkaline pH, a high adsorption capacity and a good nitrogen and potassium supply. If physically improved through the use of adequate cultural operations (tillage combined with irrigation and fertilization), these soils can become highly suitable media for the cultivation of agricultural crops (Finck and Venkateswarlu, 1982).

Along with vertisols, alluvial soils (fluvisols) are classified as class III soils according to their suitability for crop cultivation. Alluvial soils are formed as the result of fluvial deposits, and are quite diversified in terms of texture (Galić, 2006), being primarily dependent upon type of deposits, the power and amount of flood waters, and the human effect (Resulović, 2008).

The specific process of formation and the environmental conditions occurring during the process induce considerable differences in both chemical and physical properties of fluvisols. Specifically, most fluvisols occurring in Serbia show both moisture excess during certain parts of the year and moisture deficiency during certain periods. In order to turn these fluvisol subtypes into suitable media for the successful cultivation of agricultural crops, irrigation should be used during dry periods and soil drainage during humid weather (Hadžić et al., 2002). Only if these conditions are satisfied and if

the other cultural operations essential for plant development are performed can satisfactory yields and quality of agricultural crops be realistically expected.

Pseudogley soils commonly occur in Serbia, but in terms of their suitability for crop cultivation they are classified as class IV soils. These soils have unfavorable water/air relationships and thermal properties (Rakočević-Bošković, et al., 2004), as induced by profile structure; the characteristic sequence of horizons. The top horizons on pseudogleys are composed of loam and clay, whereas lower horizons are highly colloidal and clayey and hence of low porosity. Consequently, under excessive moisture conditions, water stagnates in certain horizons, adversely affecting the soil water/air relationship. Unfortunately, the chemical properties of pseudogleys are likewise unfavorable. These soils are mostly acidic in reaction (pH 5 to 5.5), exhibit a low adsorption capacity and have a low supply of plant nutrients (Đurić et al., 2010). Pepper cultivation in Serbia is mostly practiced on chernozems, vertisols, fluvisols and pseudogleys, hence the use of these soils in the present study.

The aim of this study was to determine the content of Cu and Mn in the leaves of pepper (*Capsicum annuum* L. cv. Dora) grown on four different soil types, in order to evaluate the effect of soil type on the uptake of these nutrients. Copper and manganese are dealt with in this study due to their vital role during photosynthesis. The intensity and efficiency of the photosynthetic process have a direct effect on crop yield and quality. The role of Mn is closely associated with water photolysis and electron transport to photosystem II (Nešković et al., 2003), whereas Cu is a component or activator of many enzymes taking part in the electron transport from photosystem II to photosystem I (Kralova et al., 1994; Lombardi and Maldonado, 2011). Moreover, copper has the ability to increase chlorophyll stability (Vukadinović and Lončarić, 1997). These reasons serve as an indication of the high importance of this element during photosynthesis.

## MATERIALS AND METHODS

This study was conducted in 2009 and 2010 under controlled greenhouse conditions at the Faculty of Agronomy in Čačak. The material used in the study included pepper plants cv. Dora and 9.5 L pots filled separately with one of the following soil types: chernozem, vertisol, fluvisol and pseudogley. Soil samples were collected from plots located in a wider region of the Moravica district. The soil was sampled from different plot zones at a depth of up to 40 cm and mixed thereafter to obtain uniformity of each soil type tested. Immediately upon soil delivery to the greenhouse, the pots were filled with adequate soil types for pepper plants to be transplanted. The pepper plants (*Capsicum annuum* cv. Dora) used in the experiment were produced at a certified nursery located near the Faculty, and showed no substantial difference in terms of size and appearance.

The study also involved chemical analysis of the test soil types to evaluate soil pH and Cu and Mn content. Soil pH was determined

**Table 1.** pH value and average Cu and Mn content of the test soil types.

Soil type	Element content (ppm)		pH value
	Cu	Mn	
Chernozem	37.0	400.1	6.3
Vertisol	58.0	490.1	7.1
Fluvisol	35.2	447.0	6.0
Pseudogley	34.1	512.0	5.3

**Table 2.** Average Cu content of pepper (*Capsicum annum* L. cv. Dora) leaves.

Soil type	Average Cu content of pepper leaves ( $\mu\text{g/g}$ dry matter)			
	Stage of development			
	Flowering		Full maturity	
	2009	2010	2009	2010
Chernozem	4.208 <sup>ab</sup>	4.378 <sup>a</sup>	2.960 <sup>d</sup>	3.015 <sup>cd</sup>
Vertisol	3.954 <sup>b</sup>	4.049 <sup>ab</sup>	2.976 <sup>cd</sup>	2.990 <sup>cd</sup>
Fluvisol	3.204 <sup>cd</sup>	3.345 <sup>c</sup>	2.983 <sup>cd</sup>	2.919 <sup>d</sup>
Pseudogley	3.053 <sup>cd</sup>	2.544 <sup>e</sup>	2.946 <sup>d</sup>	2.944 <sup>d</sup>
F - test	Significant			
LSD <sub>0.05</sub>	= 0.383			

by a digital pH meter (ISO 10390, 1994), and Cu and Mn levels in the soil samples were assessed by the AAS- method (ISO 11047,1998). The objective of this part of the analysis was to measure the Cu and Mn content in the soil prior to the experiment. The experiment on the effect of soil type on Cu and Mn content in pepper leaves was set up in a randomized block design in four treatments (soil types) and five replications. Each treatment included ten pepper plants, making up a total of 200 plants. The trial design was identical in both years. Throughout the experiment, all pepper plants received identical care, irrigation, fertilization, and other cultural operations vital for successful plant growth. Fertilization involved soil mineral fertilization depending on the plot treated, as follows: the fertilizers applied had an increased content of nitrogen at the beginning of the pepper growing season, an identical content of nitrogen, phosphorus and potassium (20-20-20) in the middle of the growing season, and a high content of potassium and calcium (5-20-30 + Ca) at the end of the season. The Cu and Mn content of pepper leaves was determined at both the flowering and full maturity phenostage using the AAS method (Hanlon, 1998).

The data obtained were subjected to standard methods of the analysis of variance (ANOVA) and multiple test (LSD test) using Microsoft Excel 2003 and Statistica 5.0 programs. The data analysed were used to interpret the results of the study and draw corresponding conclusions.

## RESULTS AND DISCUSSION

The results of the chemical analysis of the test soil types are presented in Table 1. The average Cu content of pepper leaves at different plant development stages as dependent upon the type of soil used for pepper cultivation is outlined in Table 2. The results presented in Table 2 show that the Cu content in pepper leaves during

both stages of plant development was significantly affected by the type of soil used for pepper cultivation. The highest Cu content in pepper leaves in both years was found in the treatment involving pepper cultivation on chernozem, regardless of the fact that the copper amount was not highest in this type of soil. Obviously, the degree of Cu uptake from this soil was highest as compared to the other types of soil, being primarily due to favorable physical and chemical properties of chernozem. Chernozem soils are characterized by favorable water/air relationships and thermal properties, as well as by a high content of available nutrients (Škorić et al., 1985), which eventually lead to an increased uptake of Cu by the plant.

The results presented in Table 2 also show that pepper plants grown on vertisol had the highest leaf Cu content after plants cultivated on chernozem. However, given the fact that this type of soil was found to contain at least 30% more copper prior to the experiment as compared to the other soil types, the analysis suggests that the high leaf Cu content in pepper plants cultivated on vertisol was, in fact, negatively correlated with Cu uptake. The lower Cu uptake by the plant in this case cannot be attributed to a low vertisol supply with copper, but rather to unfavorable soil pH. The soil tested had a pH of 7, which made it unsuitable for copper uptake. Copper availability is higher in slightly acidic soils (Chaignon et al., 2009; Aref, 2011), as confirmed by the results of this study. In addition, Table 2 reveals that no statistically significant difference was observed in leaf copper content between pepper plants grown on fluvisol and those cultivated on pseudogley, irrespective of the plant pheno-

**Table 3.** Average Mn content of pepper (*Capsicum annuum* L. cv. Dora) leaves.

Soil type	Average Mn content of pepper leaves ( $\mu\text{g/g}$ dry matter)			
	Stage of development			
	Flowering		Full maturity	
	2009	2010	2009	2010
Chernozem	24.061 <sup>a</sup>	23.993 <sup>a</sup>	20.008 <sup>cd</sup>	19.960 <sup>d</sup>
Vertisol	23.719 <sup>a</sup>	24.036 <sup>a</sup>	19.518 <sup>d</sup>	19.201 <sup>d</sup>
Fluvisol	23.261 <sup>a</sup>	23.956 <sup>a</sup>	18.216 <sup>e</sup>	17.666 <sup>ef</sup>
Pseudogley	20.521 <sup>bc</sup>	20.951 <sup>b</sup>	16.988 <sup>fg</sup>	16.591 <sup>g</sup>
F - test	Significant			
LSD <sub>0.05</sub> = 0.843				

stage and year of the study. The soil chemical analysis showed no significant difference between the two soil types in terms of the Cu content in the soil, suggesting a similar degree of copper uptake by pepper plants grown on fluvisol and those on pseudogley under the present trial conditions.

Overall, the results outlined in Table 2 indicate that copper uptake by pepper plants is largely affected by soil type. With the data on soil Cu content considered, the results show that the highest degree of Cu uptake was observed in pepper grown on chernozem, somewhat lower on fluvisol and pseudogley, and the lowest on vertisol. Another important fact suggested by the results is that pepper leaves were found to have very low copper levels, regardless of the soil type used for pepper cultivation. The average copper values found in the plant dry matter as reported by many researchers range from 2 to 20 ppm, whereas the Cu content in the present study did not exceed 4 ppm in any treatment. This is due to the competitive relationship between Cu uptake by the root system and manganese (Nautival and Chatterjee, 2002). Accordingly, the decrease in Cu uptake in all soil types was most likely induced by high Mn levels. Antagonistic relationships between Cu and Mn were also reported by other authors in a similar research (Haldar and Mandal, 1982; Padua et al., 2010).

The average content of Mn in pepper leaves in different plant development stages, as dependent upon soil type used for pepper cultivation, is presented in Table 3. The results presented in Table 3 suggest that as in the case with copper, the Mn content of pepper leaves was significantly affected by the type of soil used for pepper cultivation, regardless of plant phenostage and year of the study. The highest leaf Mn content was found in the treatment using chernozem soil for pepper cultivation, although this soil exhibited the lowest Mn content before the start of the experiment. This finding is sufficient to confirm the qualitative characteristics of this soil type and, hence, the justifiable classification of chernozem among class I soils according to its suitability for use in agriculture. As regards the effect of vertisol and fluvisol on the Mn content of pepper leaves, the results given in

Table 3 show no statistically significant difference in leaf Mn content between the pepper plants grown on the two soil types. However, as Mn levels were more than 20% higher in vertisol than in fluvisol prior to the experiment, it is clear that under the trial conditions fluvisol is much more favorable as a pepper growing medium in terms of Mn uptake. The disadvantage of vertisol used in this study is its unfavorable pH (pH 7.1), a major reason for the very low degree of Mn uptake by the plants in this type of soil. In general, manganese availability markedly declines in neutral and alkaline environments, but increases with increasing soil acidity (Millaleo et al., 2010).

A low degree of Mn uptake by pepper plants was also determined in the treatment using pseudogley for pepper cultivation. The disadvantageous properties of pseudogley as a medium for pepper cultivation are further enhanced by the fact that Mn content in this soil type was significantly higher as compared to the other soil types tested. In terms of the effect of soil pH on Mn uptake, the above results are relatively unexpected, since the low pH of pseudogley should favor Mn uptake. However, apart from being largely dependent upon pH, Mn availability is also strongly governed by the soil oxido-reduction potential (Vukadinović and Lončarević, 1997), with the percentage of reduced readily absorbable forms of Mn (water soluble  $\text{Mn}^{2+}$  and exchangeable sorbed  $\text{Mn}^{2+}$ ) in the pseudogley tested being most likely very low.

## Conclusion

The study on the effect of soil type on the copper and manganese content of pepper leaves suggests the following: the Cu and Mn content of pepper leaves was statistically significantly dependent upon the type of soil used for pepper cultivation, regardless of the plant phenostage and year of the study. Under the trial conditions, the degree of Cu uptake by pepper plants was highest on chernozem, somewhat lower on fluvisol and pseudogley, and lowest on vertisol. A similar trend was observed for Mn uptake, with the degree of uptake being, however, lowest on pseudogley.

The comparison of the leaf Cu content in pepper plants

in the present study with those reported in the related literature suggests that a very low copper concentration in pepper leaves was found in the present experiment, regardless of both plant phenostage and the type of soil used for pepper cultivation. Given the antagonism between Cu and Mn levels in the soil solution, one of the reasons for the low degree of copper uptake by the plant was most likely the high molybdenum concentration in all soil types.

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