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RESEARCH ARTICLE

Phytoremediation potential of *Pisum sativum L.*: Iron and Chromium uptake efficiency

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Abstract

Soil plays a vital role in agricultural production, and its pollution poses a significant threat, especially in areas affected by industrial activities or military actions. This study evaluates the phytoremediation potential of pea plants (*Pisum sativum L.*) for heavy metals, particularly Iron (Fe) and Chromium (Cr), in the Forest-Steppe of Ukraine. Research was conducted at the Sumy National Agrarian University near a busy road, where soil contamination was likely. Soil samples were collected from different layers (0 cm-10 cm, 10 cm-20 cm, and 20 cm-30 cm) before pea sowing and after crop maturation. X-ray fluorescence analysis identified the concentrations of various heavy metals. Statistical analysis using ANOVA and Duncan's test revealed a significant decrease in Iron content in the soil, especially in the 0 cm-10 cm and 20 cm-30 cm layers, after growing peas. However, the decrease in Chromium concentration was not statistically significant. The findings suggest that peas are effective in reducing soil Iron content, though their ability to absorb Chromium is limited. In conclusion, peas show potential for phytoremediation of Iron-contaminated soils in Ukraine, though further studies are required to better understand their capacity for absorbing other heavy metals like Chromium.

Keywords: Phytoremediation, Pea, Heavy metals, Trace elements, Soil contamination, Iron absorption, Chromium absorption, Pollution

Introduction

Soil plays a crucial role in agricultural production. That is why it is so important to maintain its fertility and timely detect possible pollution threats. Soil pollution can arise from unsustainable agricultural practices, man-made disasters, or current military activities, that occur now in Ukraine (Zakharchenko et al., 2022; Datsko et al., 2024; Hryhoriv et al., 2024).

Pea (*Pisum sativum L.*) is a globally recognized crop, highly esteemed for its nutritional significance and widespread culinary applications. Its value is derived from the substantial protein content in the beans. Additionally, the presence of nodule bacteria on the roots of these plants, as highlighted by (Karpenko et al., 2020; Radchenko et al., 2024), is a crucial aspect that contributes to its importance in agricultural production. Furthermore, its high suitability for use in phytoremediation is an essential characteristic of this crop.

For instance, many scientists have proven that peas are suitable for absorbing heavy metals. Research by (Hattab et al., 2009; Karbivska et al., 2020) has shown that peas can be phytoremediators of Cadmium and, to a lesser extent, are suitable for Copper absorption. Suitability for uranium uptake by pea plants was proven in the study of (Gupta et al., 2020; Karpenko et al., 2021; Hryhoriv et al., 2023), the highest amount of it was absorbed by the roots compared to the shoots. One of the heavy metals that can also be absorbed by peas is Lead. The study of (Hegedűsová et al., 2021; Kovalenko et al., 2023) suggests that in combination with ethylene-diamine-tetra-acetic acid, the crop can absorb quite a large amount of this metal.

Therefore, the purpose of this study was to establish the possibilities of peas for the absorption of heavy metals in the conditions of the Forest Steppe of Ukraine.

Materials and Methods

The research took place at the fields of Sumy National Agrarian University (Ukraine). As the purpose was to evaluate the absorption of heavy metals, a site near the busy road was chosen. The soil in the studied field is Chernozem Chernic on the loess deposit. Soil fertility indicators include the following characteristics: organic carbon content 1.66%, pH(H_2O)6.3% amount of easily hydrolyzed nitrogen 19.7 mg/kg of soil, amount of mobile phosphorus 122.1 mg/kg of soil, the amount of exchangeable potassium 133.2 mg/kg of soil.

The content of heavy metals was identified in layers each 10 cm to a depth of 30 cm before the sowing of peas and at the phase of full ripeness of the crop. Using a Thermo Scientific Niton XL2 for X-ray fluorescence analysis, soil samples were first dried and ground before being analyzed (Tab. 1).

Table 1. Mean concentrations of heavy metals in the soil before the beginning of the study, ppm.

Soil layer (cm)	Ba	Zr	Sr	Rb	Zn	Fe	Mn	Cr	V	Ti
0-10	348	597	100	73	39	17107	391	23	18	3988
10-20	386	594	101	70	45	17079	393	21	62	4232
20-30	370	590	99	74	38	17566	380	10	55	4006

Statistical analysis of the data was performed using Statistica 10.0. ANOVA and Duncan's test were used to determine significant differences.

Results and Discussion

The data obtained indicate that only the Iron and Chromium content decreased compared to the control soil samples (at the time of sowing). That is why the results of only these elements will be displayed in the article.

Iron as microelement is very important in crops nutrition, influencing various physiological processes within plants. For instance, in calcareous soils this element is immobile, making it difficult for plants to absorb this essential nutrient. That is why the plants which grows on such kind of fields could exhibit such signs as yellowing of leaves in the upper part of the crops or chlorosis (Lucena & Hernandez-Apaolaza, 2017). In its turn it could affect the crop health, productivity or grain quality.

Amount of Iron in soil all around the world could vary within the range from 20000 mg/kg up to 40000 mg/kg (Colombo et al., 2014). Despite of that in Ukraine this quantity could be even lower (Fatieiev & Pashchenko, 2003).

In turn, an excessive amount of Iron can cause phytotoxicity. Thus, for example, the study of (Bartakova et al., 2001) indicates, that high amount of Iron in soil could reduce the ability of seeds of *Lactuca sativa L.* for germination. In soils which have high acidity or organic matter Iron is getting more available for plants and its phytotoxicity could damages the membranes that surround plant cells, which inhibits growth, yield, and general health.

Data, fig. 1 indicates a decrease in the amount of Iron in the 0 cm-30 cm soil layer, also known as the root containing layer for control and pea cultivated samples. The control samples show a tendency for concentration to increase with depth, especially at the deepest level (20 cm-30 cm), where the concentration reaches a peak. However, after peas growing, the Iron content is obviously lower compared to the control.

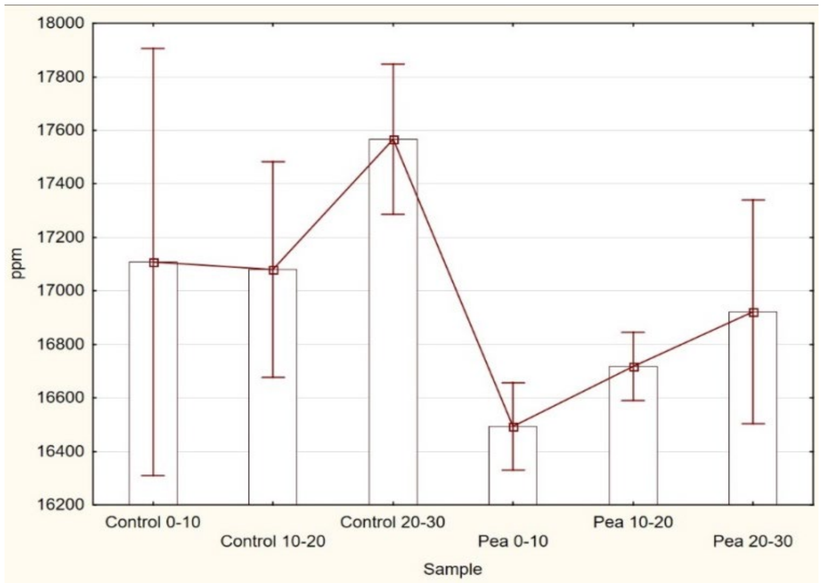

Figure 1. Iron content in soil layers at the time of sowing and at the time of full ripeness of pea.

It is important to note that, according to Duncan's test, the data for layers 0-10 cm and 20 cm-30 cm are statistically significant (Tab. 2). However, the amount of Iron in the soil layer is 10 cm-20 cm lower compared to the control, but it is not statistically significant.

Table 2. Results of Duncan's test for iron.

Variants	Pea 0-10	Pea 10-20	Pea 20-30
Control 0-10 cm	0.024[a]	-	-
Control 10 cm-20 cm	-	0.155[b]	-
Control 20 cm-30 cm	-	-	0.016[a]
	$p<0.05$		

Note: a – the value is significantly lower than the control option, b – the value does not have a statistically significant difference compared to the control.

Chromium is an element that contains in Earth's crust in the measures around 100 mg/kg, however, in European soils its mean content is 5 mg/kg –68 mg/kg (Gonnelli & Renella, 2013). The biological role of Chromium in plant organisms has not been thoroughly studied. However, there are many claims that this element can cause phytotoxicity. Chromium inhibits plant growth and development through biochemical, molecular, cytotoxic, genotoxic, and hormonal changes. In recent years, research has shown that Chromium slows seed germination, reduces root, branch, and leaf growth (Wakeel & Xu, 2020).

The obtained results indicate fig. 2 variations in concentrations depending on the type of sample (control or pea) and depth, which may indicate different effects of treatment on the distribution of concentrations in the soil profile.

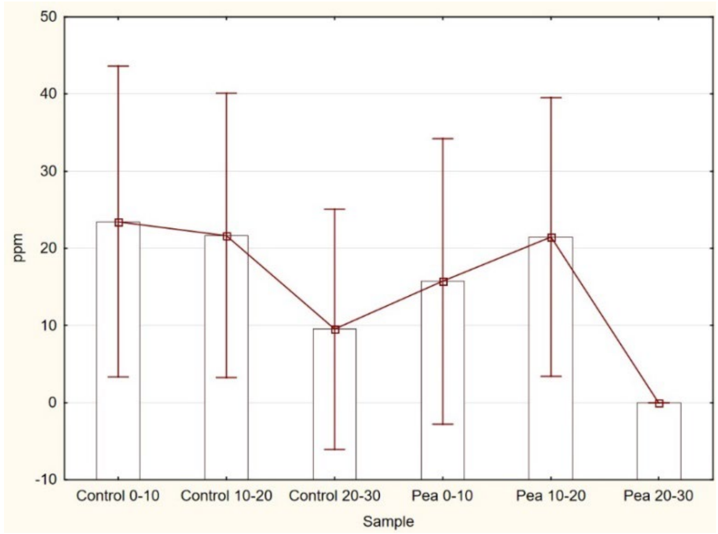

Figure 2. Chromium content in soil layers at the time of sowing and at the time of full ripeness of pea.

Even though the Chromium content in the soil samples decreased for none of the layers, this amount is not statistically significant. This is confirmed by the results of the statistical analysis in tab 3.

Table 3. Results of Duncan's test for chromium.

Variants	Pea 0-10	Pea 10-20	Pea 20-30
Control 0-10 cm	0.446[b]	-	-
Control 10 cm-20 cm	-	0.983[b]	-
Control 20 cm -30 cm	-	-	0.306[b]
		p<0.05	

Note: b – the value does not have a statistically significant difference compared to the control.

Conclusions

The study showed that peas (*Pisum sativum L.*) have the potential for phytoremediation of heavy metals, in particular Iron and Chromium, in the conditions of the Forest Steppe of Ukraine. It was found that after growing peas, the Iron content in the soil significantly decreased compared to the control samples, especially in the upper (0-10 cm) and deeper (20 cm–30 cm) soil layers. The difference was statistically significant, as confirmed by Duncan's test. As for Chromium, although its content also decreased, the changes were not statistically significant in any soil layer. This indicates that peas are less efficient at absorbing Chromium compared to Iron. Overall, the results suggest that peas can be effective in reducing soil Iron, further research is needed for a more detailed justification of phytoremediation using peas.

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