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The effect of cadmium and lead pollution on growth and physiological parameters of field beans (*Vicia faba*)

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Abstract. Research on the impact of soil contamination on crops is important as plants directly take up heavy metals from the soil through the roots, so heavy metals can enter the food chain. The aim of this study was to investigate the impact of cadmium (Cd) and lead (Pb) pollution on growth and physiological parameters of field beans. Plants in the vegetation experiment were grown under controlled conditions. Changes in growth and physiological parameters were studied at five levels of Cd (0–25 mg L^{-1}) and at 6 levels of Pb in substrate: from (0–1,000 mg L^{-1}) at the first day of the experiment, to (0–2,000 mg L^{-1}) at the end of the experiment after gradual Pb additions after every sample collecting day. Methods used for analysing the plant material: the content of amino acid proline and photosynthetic pigments were determined by spectrophotometry; chlorophyll *a* fluorescence parameters – using continuous excitation chlorophyll fluorimeter. The fresh weight of plant above-ground parts and roots was detected. The growth and development of field beans was slightly influenced by increasing amount of Cd and Pb in substrate only at the end of the experiment. The highest Cd treatments (Cd20 and Cd25) caused 2.5 and 1.3 times increased proline concentration in bean leaves. The chlorophyll *a* + *b* content and chlorophyll *a* fluorescence parameter F_v/F_m changed differently throughout the experiment. In general, during the experiment, there was a tendency for the content of proline in leaves for Pb treatments to be increased compared to control. At the end of the experiment the content of proline in field bean leaves of the highest Pb treatments (Pb600 + 100 + 400 + 500, Pb800 + 100 + 400 + 500 and Pb 1,000 + 100 + 400 + 500) was 1.66, 1.44 and 1.55 times higher, respectively, than that of the control plant leaves. The negative impact of exposure to Pb on chlorophyll *a* + *b*, chlorophyll *a* fluorescence parameter P_{Index} and F_v/F_m in bean leaves was less pronounced compared to Cd. The obtained results confirm that field beans until their flowering stage can grow and develop in the presence of a large amount of Cd and Pb in substrate without significant growth inhibition and detrimental impact on physiological parameters, if optimal cultivation conditions are provided.

Key words: heavy metals, *Vicia faba*, photosynthesis parameters, proline.

INTRODUCTION

With the development of agriculture and industry, research on the impact of soil contamination on crops is of vital importance not only in Europe but throughout the world (Pourrut et al., 2011; Van Liedekerke et al., 2014, Fu et al., 2017). Plants directly take up heavy metals from the soil through the roots, so heavy metals can enter the food chain, thus affecting human health (Peralta-Videa et al., 2009). In Europe the most frequently occurring contaminant groups in soil are heavy metals and mineral oils – 35% and 24%, respectively (Van Liedekerke et al., 2014). Heavy metals (for example, Cd and Pb) can enter the soil as the result of human activities, for example, using plant fertilizers in agriculture (Grant et al., 1998; Peralta-Videa et al., 2009; Swartjes, 2011). Therefore, it is important to pay attention to the questions of phytoremediation – on how to recover the soil from heavy metal pollution. In this aspect it is relevant to find out plants with high capacity to accumulate heavy metals. Previous studies have shown that hyperaccumulants are able to accumulate up to 100 times more heavy metals in leaves than other plants (Rascio & Navari-Izzo, 2011). On the other hand, studies on tolerance/sensitivity and distribution models of heavy metals in plants are of great value also for crop plants taking into account food safety issues.

Increased amounts of heavy metals in the environment can cause detrimental changes in physiological and biochemical processes in plants, thus affecting growth and productivity (Loi et al., 2012; Loi et al., 2014). The impact of heavy metals on plant growth and development is species-specific and tissue specific, for example, in vegetables heavy metals reduce shoot – root biomass ratio (Martin et al., 2006). It is noteworthy that heavy metal transport from soil to plants are affected by different factors as soil properties (soil pH, organic matter content, granulometric composition etc.), plant species specificity, the physical and chemical properties of the elements, growing conditions, environmental biotic factors and others (Titov et al., 2007; Loi et al., 2014). It is known that under different environmental stress conditions, including heavy metal contamination, the plants may show changes both in the amount of chlorophyll *a* + *b* and in the chlorophyll *a* fluorescence parameters (Zarco-Tejada et al., 2002; Sayed, 2003; Pourrut et al., 2011). Heavy metal induced alteration in photosynthetic pigments influenced the biosynthesis of photoassimilates which resulted in decreased biomass production and stunted plant growth (Titov et al., 2007; Sengar et al., 2008; Capelo et al., 2012).

The changes in the accumulation of amino acid proline in plants under different biotic and abiotic stresses are widely documented (Hare & Cress, 1997; Kavi Kishor et al., 2005; Verbruggen & Hermans, 2008; Szabados & Savoué, 2010). The increased proline accumulation in plants can be caused by heavy metals, drought, oxidative stress, high light and UV irradiation, high salinity, high/low temperature, atmospheric pollution and also biotic stresses (Schat et al., 1997; Trovato et al., 2008; Verbruggen & Hermans, 2008; Szabados & Savoué, 2010; Karlsons, 2011). Proline accumulation in plants can also be a stress signal that affects plant adaptive responses like as stabilizing the structure of proteins, providing a way to buffer cytosolic pH and balance cell redox status (Verbruggen & Hermans, 2008). Schat et al. (1997) have reported that the plant water balance declines under exposure to heavy metals (especially Cd). In the conditions of osmotic stress the growth of plants is inhibited, stomata closed and the rate of photosynthesis decreased (Trovato et al., 2008). Proline as essential osmolite participates in osmotic stress tolerance protecting plant cells against osmotic stress damage (Hare & Cress, 1997; Trovato et al., 2008). The initial amount of proline in plants can be species specific (Verbruggen & Hermans, 2008).

According to the regulation of the European Union starting from 2015 farmers can get a payment for agricultural practices beneficial for the climate and the environment (called: 'greening payment') (Regulation (EU) No 1307/2013, 2013; Hart et al., 2017). Diversification of crops in Latvia is a mandatory requirement from 2015. The aim of diversification of crops is to promote enhanced environmental protection, especially in the area of soil quality improvement. Field beans are one of the crops used for 'greening' to improve soil quality in Latvia (The Rural Support Service, 2018). However, so far, there is little research on field bean physiological and adaptive responses to different stress conditions, including soil contamination with heavy metals.

The aim of this study was to investigate the impact of Cd and Pb pollution on growth and physiological parameters of *Vicia faba*, to find out the changes in biomass production, photosynthesis and chlorophyll *a* fluorescence parameters as well as changes in the accumulation of amino acid proline.

MATERIALS AND METHODS

The vegetation experiment was carried out with the field bean (*Vicia faba,* cv. 'WITKIEM') as a model object. Plants were grown in 1 L polyethylene containers from seeds; quartz sand was used as a growing substrate. The following controlled conditions were provided for plant growth: photoperiod light/dark 16/8 h, moisture of substrate 60–65%, day/night temperature + 20/18 °C and a photon flux density of 160 μmol m^{-2} s^{-1} supplied by fluorescent tubes. To ensure sufficient moisture level in the substrate, it was regularly gravimetrically watered using deionized water.

Changes in growth and physiological parameters were studied at five levels of Cd in substrate: 0, 10, 15, 20, 25 mg L^{-1}. The experiment was arranged with the following 6 levels of Pb in substrate at the first day of the experiment: 0, 200, 400, 600, 800, 1,000 mg L^{-1}. To find out changes in growth and physiological parameters under conditions of variable Pb amount in substrate, the amount of Pb in the substrate was gradually added after every sample collecting day during the experiment. Thereby, after the 14th, 21st, and 28th day of the experiment 100 mg L^{-1} Pb, 400 mg L^{-1} Pb and 500 mg L^{-1} Pb, respectively, was added in substrate for every Pb treatment. Abbreviations of treatments for experiment with Pb supply in the substrate are given in the Table 1.

Table 1. Abbreviations of treatments for the experiment with Pb supply in the substrate in during the experiment

The day of sampling	14	21	28	35
Treatment 1 (control)	Pb 0	Pb 0	Pb 0	Pb 0
Treatment 2	Pb 200	Pb 200 + 100	Pb 200 + 100 + 400	Pb 200 + 100 + 400 + 500
Treatment 3	Pb 400	Pb 400 + 100	Pb 400 + 100 + 400	Pb 400 + 100 + 400 + 500
Treatment 4	Pb 600	Pb 600 + 100	Pb 600 + 100 + 400	Pb 600 + 100 + 400 + 500
Treatment 5	Pb 800	Pb 800 + 100	Pb 800 + 100 + 400	Pb 800 + 100 + 400 + 500
Treatment 6	Pb 1,000	Pb 1,000 + 100	Pb 1,000 + 100 + 400	Pb 1,000 + 100 + 400 + 500

Cd was added as $Cd(NO_3)_2$ $4H_2O$ solution in substrate and Pb was added as $Pb(CH_3COO)_2$ $3H_2O$ solution in substrate. Nutrient solution was added in substrate for control groups and for all treatment groups, it contained optimal concentrations of macronutrients and micronutrients (in mg L^{-1}: N 120, P 60, K 150, Ca 800, Mg 50, S 60, Mn 1.5, Zn 1, Cu 0.5, Mo 0.02, B 0.2, Fe 30) (Osvalde, 2011). Ca was added as two grams of $CaCO_3$ in substrate of each container at the beginning of the experiment. As the Cd standard solution contains nitrogen, adjustments were done to prepare the complete nutrient solutions for Cd treatments by reducing the content of ammonium nitrate.

The experiment lasted 35 days; plants were collected on the day of 14th, 21st, 28th and 35th of the experiment. Field bean fresh weight was determined for all sampling dates. The fresh weight of plant above-ground parts and root system was separately detected.

The content of chlorophyll *a* + *b* was determined in the first fully expanded leaves of field beans. Photosynthetic pigments were determined by spectrophotometry method using JENWAY 6300 Spectrophotometer (JENWAY, UK). Pigments were extracted with 20 mL of 96% ethanol, extracts were centrifuged and absorbances were measured at 470, 649 and 664 nm. Lichtenthaler (1987) equitation was uesd to calculate amount of chlorophyll *a* + *b*.

Chlorophyll *a* fluorescence parameters such as the variable fluorescence (F_v/F_m) and Performance Index (P_{Index}) were determined with continuous excitation chlorophyll fluorimeter Handy PEA system (Hansatech, UK). *Vicia faba* leaves were dark-adapted with leaf clips for 20 minutes.

The content of amino acid proline was determined by spectrophotometry method, adjusting the method with ninhydrin (Bates et al., 1973). Fresh plant material was homogenized in sulfosalicylic acid. Two milliliters of acid ninhydrin and glacial acetic acid was added to the extract, it was heated for 1 h at 100 °C and then the mixture was extracted into a toluol (Karlsons, 2011). Absorbances were measured at 520 nm using JENWAY 6300 Spectrophotometer (JENWAY, UK).

The statistical analysis of results was done using MS Excel 2013. Standard errors (SE) were calculated in order to reflect the mean of the results.

RESULTS AND DISCUSSION

Accumulation of biomass is the key factor for evaluating plant responses to various environmental stresses. There were different changes in the fresh weight of the above-ground parts and roots of the *V. faba* under exposure to increasing Cd and Pb levels in sand substrate. Laboratory experiments showed that the fresh weight of the above-ground parts of field beans cultivated under different Cd treatments varied similarly to the control variant throughout the experiment (Fig. 1, A). In general, the effect of the Cd contamination in substrate on the fresh weight of the above-ground parts of field beans was found to be insignificant ($p < 0.1$). Thus, on the last day of the experiment, the fresh weight of bean leaves and stems at the highest contamination level (Cd 25 mg L^{-1}) was only 1.81 g lower (i.e., 9.58% lower) than that of the control plants (Cd0).

Unlike to the above-ground parts, significant effect of Cd pollution in substrate on the fresh weight of roots was found ($p < 0.05$). Field bean exposure to Cd10, Cd20 and Cd25 treatments lead to an increasing reduction in the fresh weight of roots throughout the experiment (Fig. 1, B). The treatment of Cd 25 mg L^{-1} resulted in the 1.51 g lower (i.e., 14.5% lower) fresh weight of roots than that of the control level at the last sampling time (the 35th day).

More pronounced inhibition on the fresh weight of roots under heavy metal pollution could be mainly explained by root direct contact with the contaminated substrate (Pourrut et al., 2011). Thus, the negative effects of Cd could first affect plant roots.

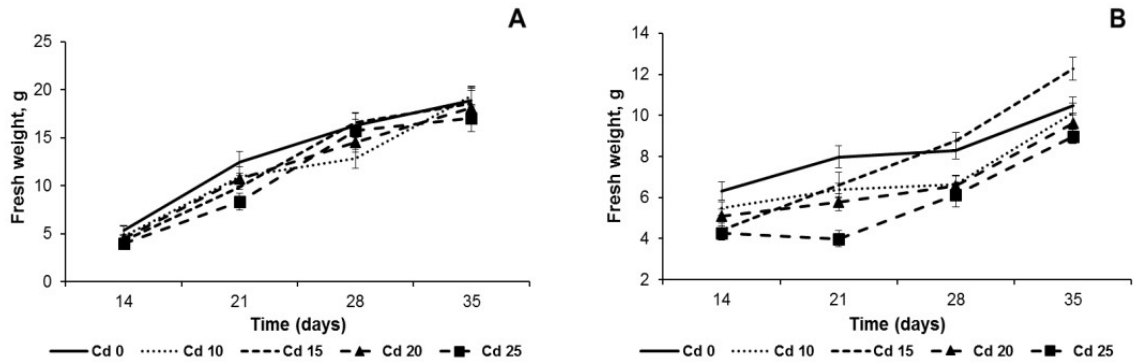


Figure 1. Fresh weight of the above-ground parts (A) and roots (B) of *V. faba* at five levels of Cd added in substrate, ±SE.

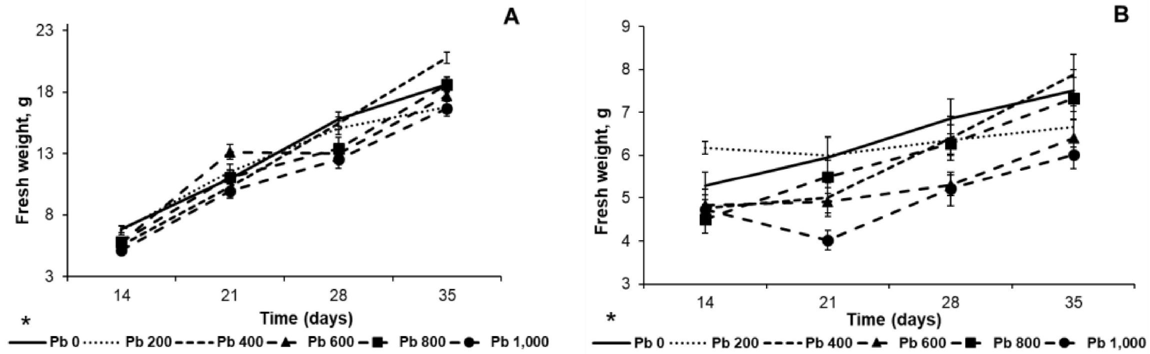
There was similar pattern of Pb impact on the fresh weight of above-ground parts and roots of *V. faba* as described for Cd treatments (Fig. 2, A, B) despite the fact that the level of Pb in the substrate during the experiment was gradually increased for all treatment variants.

Overall, a significant effect of Pb in substrate on fresh weight of field bean roots ($p < 0.05$) was observed.

On the last day of the experiment, fresh weight of the above-ground parts was 10.44% lower than that of the control plants at the highest contamination level (Pb 1,000 + 100 + 400 + 500 mg L^{-1}) in the substrate (Fig. 2, A). For roots this reduction reached 20% (Fig. 2, B).

Thus, no significant inhibitory effect of Cd and Pb on the fresh weight of the above-ground parts of *V. faba* was found until flowering stage. Only a slight trend of reduction was stated. In general, there is contradictory evidence about the effect of Cd on field bean weight. Sajwani et al. (1996) have found that Cd, Ni and Se did not affect the biomass on *Phaseolus vulgaris*. Likewise, Loi et al. (2014) have reported no significant Cd impact on the *Faba vulgaris* dry mass for treatments with Cd 0, 25, 50 and 75 mg L^{-1} in substrate. Similar conclusion is made by Jin at al. (2017) in the study on effect of Cd stress on broad bean. In contrast, Simek & Tuma (2016) reported about stimulating impact of Cd (Cd 2 and 20 mg kg^{-1}) on the production of *Phaseolus vulgaris* biomass.

The content of chlorophyll $a + b$ in *V. faba* leaves varied throughout the experiment, both in treatment with Cd and Pb (Fig. 3, A, B). The negative impact of Cd on chlorophyll $a + b$ in bean leaves was more pronounced compared to Pb.



* Abbreviations;

Days

14	21	28	35
Pb 0	Pb 0	Pb 0	Pb 0
Pb 200	Pb 200 + 100	Pb 200 + 100 + 400	Pb 200 + 100 + 400 + 500
Pb 400	Pb 400 + 100	Pb 400 + 100 + 400	Pb 400 + 100 + 400 + 500
Pb 600	Pb 600 + 100	Pb 600 + 100 + 400	Pb 600 + 100 + 400 + 500
Pb 800	Pb 800 + 100	Pb 800 + 100 + 400	Pb 800 + 100 + 400 + 500
Pb 1,000	Pb 1,000 + 100	Pb 1,000 + 100 + 400	Pb 1,000 + 100 + 400 + 500

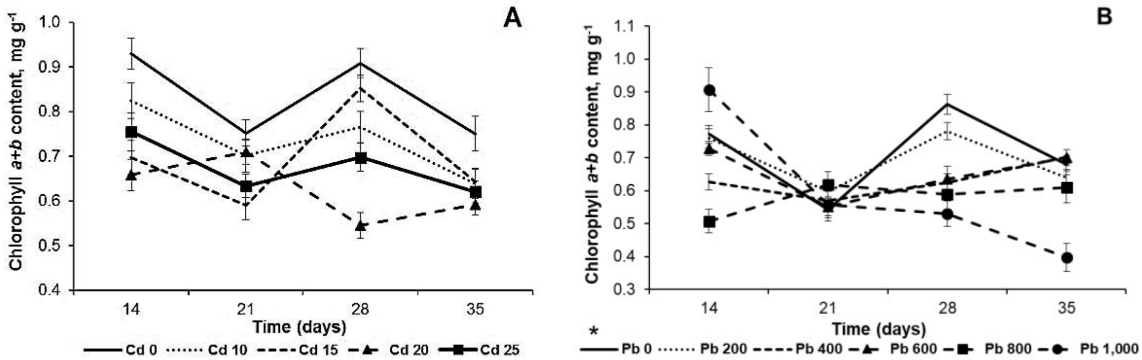
Figure 2. Fresh weight of the above-ground parts (A) and roots (B) of *V. faba* at 6 levels of Pb added in substrate, ±SE.

In general, a significant effect of Cd pollution in the substrate on chlorophyll $a + b$ content in leaves of *V. faba* ($p < 0.05$) was observed. During the experiment, the chlorophyll $a + b$ content in plant leaves for all Cd treatments was lower than that in control plants (Fig. 3, A).

Unlike to Cd, the content of the chlorophyll $a + b$ in bean leaves for Pb treatments was lower than that of the control plants mainly in the second half of the experiment, that is, from the 28th to 35th day of the experiment (Fig. 3, B). It should be noted that, the chlorophyll $a + b$ content in plants in the variants Pb400 + 100 and Pb600 + 100 changed uniformly from day 21 to day 35 of the experiment.

On the 21st day of the experiment, a decrease in the content of chlorophyll $a + b$ was observed for almost all treatments (except only: Cd20, Pb800 + 100), including control. This may be due to a certain stage of plant development or probably due to the impact of environmental factors. After this point, the decrease in chlorophyll content was mainly found in the conditions of higher pollution doses.

According to Masarovičová et al. (2010), heavy metal toxicity resulted in reduction of total chlorophyll content and, consequently, in photosynthesis inhibition in plants. Pb and Cd was reported to disrupt photosynthesis by changed chloroplast ultrastructure, reduced synthesis of chlorophyll, plastoquinone, carotenoids, disturbed electron transport (Seregin & Ivanov, 2001; Cheng, 2003; Titov et al., 2007). In general, various stress conditions can also cause chlorophyll hydrolysis to chlorophyllides and phytol (Pshibytko et al., 2004). Loi et al. (2012) studies have shown that Cd in the substrate has a negligible effect on the photosynthesis process in the *Faba vulgaris,* indicating on the tolerance of beans to heavy metal pollution.



* Abbreviations;

Days

14	21	28	35
Pb 0	Pb 0	Pb 0	Pb 0
Pb 200	Pb 200 + 100	Pb 200 + 100 + 400	Pb 200 + 100 + 400 + 500
Pb 400	Pb 400 + 100	Pb 400 + 100 + 400	Pb 400 + 100 + 400 + 500
Pb 600	Pb 600 + 100	Pb 600 + 100 + 400	Pb 600 + 100 + 400 + 500
Pb 800	Pb 800 + 100	Pb 800 + 100 + 400	Pb 800 + 100 + 400 + 500
Pb 1,000	Pb 1,000 + 100	Pb 1,000 + 100 + 400	Pb 1,000 + 100 + 400 + 500

Figure 3. Chlorophyll $a + b$ content (mg g^{-1}) in *V. faba* leaves at five levels of Cd (A) and at 6 levels of Pb (B) added in substrate, ±SE.

Chlorophyll *a* fluorescence parameters are sensitive to changes in photosynthesis process depending on the environmental impact, so they are used to describe photosynthesis process of plants (Sayed, 2003; Kalaji et al., 2014). Chlorophyll *a* fluorescence parameter P_{Index} and F_v/F_m during the experiment changed differently depending on Cd level in the substrate (Fig. 4, A, B). The relative values of the parameter P_{Index} for all treatments (Cd10, Cd15, Cd20 and Cd25) were lower than that of the control variant. A similar situation was found for the relative values of the parameter F_v/F_m. On the 35th day of the experiment, there was a significant increase of the relative values of P_{Index} for all variants compared to the 28th day of the experiment: P_{Index} values increased 1.9 times for Cd0 plants, 2.0 times for Cd10, 2.2 times for Cd15 and Cd20, and 2.3 times for Cd25 (Fig. 4, A). Conversely, on the last day of the experiment, rapidly reduced values of F_v/F_m for plants of all variants were found: for control variant plants the F_v/F_m value decreased to 0.827, while for Cd treatments they ranged from 0.817 to 0.823 (Fig. 4, B). It is assumed that 0.8 is the limit of F_v/F_m value between optimal and stress conditions (Gailite, 2012). Since none of the treatments had a F_v/F_m value lower than 0.8, Cd as a stress factor probably did not cause photo-inhibition for field beans.

In general, a significant effect of Cd on P_{Index} values was observed during the experiment ($p < 0.05$). As P_{Index} represents vitality of plants, our results showed that at the flowering phase (end of the experiment) vitality of the field beans increased for all Cd treatments, indicating possible adaptation to stress conditions.

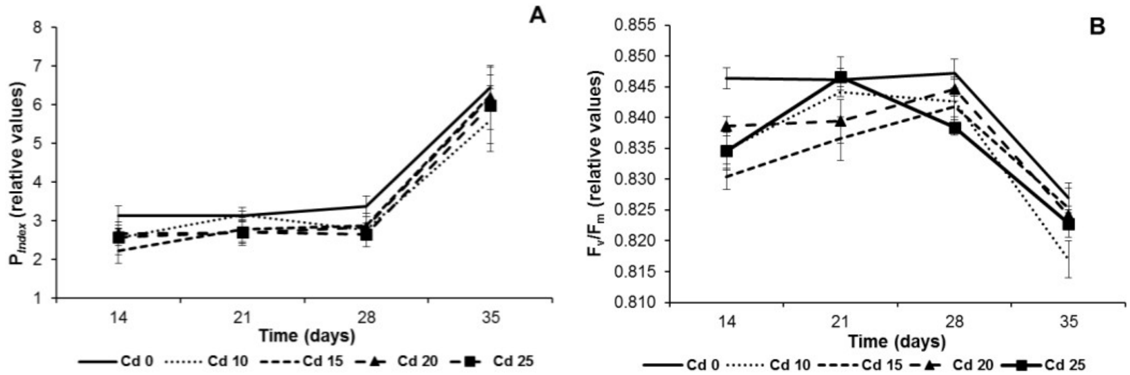
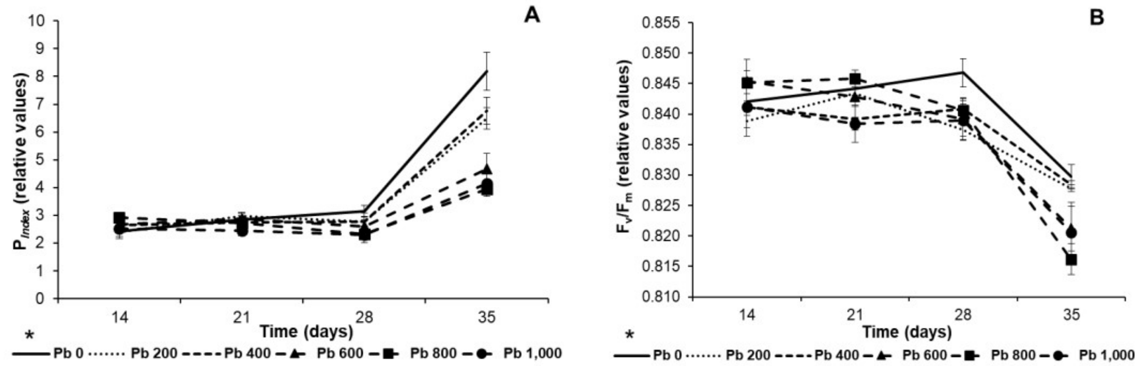


Figure 4. Chlorophyll *a* fluorescence parameter P_{Index} (relative values) (A) and F_v/F_m (relative values) (B) of *V. faba* at five levels of Cd added in substrate, ±SE.

It was found that the relative values of P_{Index} and F_v/F_m in the experiment with Pb pollution in the substrate changed similarly to those stated in the Cd experiment (Fig. 5, A, B). In general, the effect of Pb on changes in chlorophyll *a* fluorescence parameters were less pronounced than they were in the Cd variants even under conditions when Pb level of pollution in the substrate, gradually increased during the experiment, was very high reaching 1,200, 1,400, 1,600, 1,800, 2,000 mg L^{-1} at the end of the experiment.

Thereby, field bean as an experimental model object showed high adaptation potential to stress conditions in the case of Cd and Pb contamination in the growing medium.



* Abbreviations;

Days

14	21	28	35
Pb 0	Pb 0	Pb 0	Pb 0
Pb 200	Pb 200 + 100	Pb 200 + 100 + 400	Pb 200 + 100 + 400 + 500
Pb 400	Pb 400 + 100	Pb 400 + 100 + 400	Pb 400 + 100 + 400 + 500
Pb 600	Pb 600 + 100	Pb 600 + 100 + 400	Pb 600 + 100 + 400 + 500
Pb 800	Pb 800 + 100	Pb 800 + 100 + 400	Pb 800 + 100 + 400 + 500
Pb 1,000	Pb 1,000 + 100	Pb 1,000 + 100 + 400	Pb 1,000 + 100 + 400 + 500

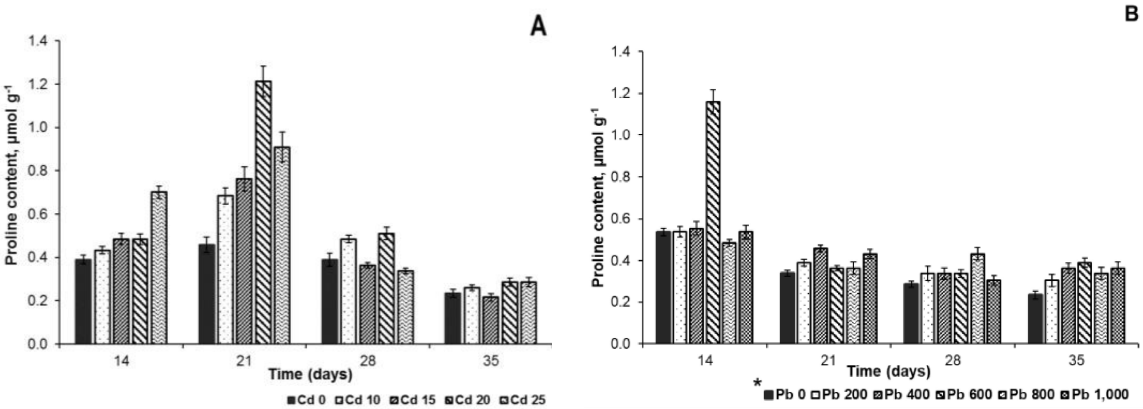
Figure 5. Chlorophyll *a* fluorescence parameter P_{Index} (relative values) (A) and F_v/F_m (relative values) (B) of *V. faba* at 6 levels of Pb added in substrate, ±SE.

The research revealed a significant increase in the content of amino acid proline in the field bean leaves with increase of Cd in the substrate till the 21st day of the experiment (Fig. 6, A).

The highest Cd treatments Cd20 and Cd25 caused 2.5 and 1.3 times, respectively, increased proline concentration in *V. faba* leaves. Further in the course of the experiment, this plant biochemical response significantly decreased. Nevertheless, on the last day of the experiment, the content of proline in the treatments Cd20 and Cd25 was 22% higher than that in the control variant plants.

There are evidences in the literature (Loi et al., 2014) that the content of proline in field beans in Cd treatments (Cd 2, 5, 10, 20 and 50 mg kg^{-1} in soil) is similar to the content of proline in the control variant plants on the 21st day of the experiment.

In experiment with Pb pollution, only one treatment (Pb600) induced massive accumulation of free proline in field bean leaves on the 14th day of the experiment. It is notable that in the conditions of Pb800 this impact was lost and the content of proline in the leaves was even 9.68% lower than that of the control plants (Fig. 6, B).



* Abbreviations;

Days

14	21	28	35
Pb 0	Pb 0	Pb 0	Pb 0
Pb 200	Pb 200 + 100	Pb 200 + 100 + 400	Pb 200 + 100 + 400 + 500
Pb 400	Pb 400 + 100	Pb 400 + 100 + 400	Pb 400 + 100 + 400 + 500
Pb 600	Pb 600 + 100	Pb 600 + 100 + 400	Pb 600 + 100 + 400 + 500
Pb 800	Pb 800 + 100	Pb 800 + 100 + 400	Pb 800 + 100 + 400 + 500
Pb 1,000	Pb 1,000 + 100	Pb 1,000 + 100 + 400	Pb 1,000 + 100 + 400 + 500

Figure 6. Proline content (µmol g^{-1}) in *V. faba* leaves at five levels of Cd (A) and at 6 levels of Pb (B) added in substrate, ±SE.

On the 35th day of the experiment the content of proline in the field bean leaves of the highest treatments: Pb600 + 100 + 400 + 500, Pb800 + 100 + 400 + 500 and Pb 1,000 + 100 + 400 + 500 was 66.67%, 44.44% and 55.56%, respectively, higher than that of the control plant leaves. In general, during the experiment, there was a tendency for the content of proline in the leaves for Pb treatment variants to be increased compared to control. Thus, Cd and Pb showed impact on proline biosynthesis in *V. faba* leaves. Increased proline accumulation could be regarded as *V. faba* adaptive response to Cd and Pb pollution in growing medium. Pb induced increase in proline content was also reported for cowpea (*Vigna unguiculata*) (Krishnaveni et al., 2015).

CONCLUSIONS

Summarizing the results, it can be concluded that in laboratory experiment in sand substrate cultivated *V. faba* showed different changes in the fresh weight of the above-ground parts and roots under increasing Cd and Pb levels in substrate. It is evident that both Cd and Pb significantly decreased root fresh weight, while Cd pollution had negative effect also on the fresh weight of above-ground parts. Increase of Cd and Pb in the substrate showed slight impact on the photosynthetic performance of *V. faba*. The negative impact of exposure to Cd on chlorophyll $a + b$, chlorophyll a fluorescence parameter P_{Index} and F_v/F_m in bean leaves was more pronounced compared to Pb. In general, chlorophyll a fluorescence parameter P_{Index} and F_v/F_m during the experiment changed differently depending on Cd and Pb level in the substrate and plant development stage. Since none of the treatments had a F_v/F_m value lower than 0.8, Cd and Pb as a stress factor probably did not cause photo-inhibition for field beans. According to the results, Cd and Pb showed stimulative impact on proline biosynthesis in *V. faba* leaves. Increased proline accumulation could be regarded as *V. faba* adaptive response to Cd and Pb pollution in growing medium. Thereby, field beans showed high adaptation potential to stress conditions in the case of Cd and Pb contamination in the growing medium.

As the results on the content of Cd and Pb in the above-ground parts and roots of the field beans is still in the process of determining, discussion about possible use of field beans for forage or in phytoremediation from/of polluted territories is the subject of next paper.

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