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BRIEF COMMUNICATION

Evaluation of health risk to humans in consumption of wheat grown in nickel-contaminated soils

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ABSTRACT

In this research, accumulation and distribution of nickel in root, leaves and stem and grains of wheat were studied to assess the health of wheat grain for human consumption. A greenhouse experiment was conducted based on randomized complete block design with three replications. Wheat was grown under two nickel concentrations in soil (0.0 and 100 mg kg^{-1}). At maturity, wheat was divided into its parts (root, leaves and stem, grain) and nickel concentrations were measured in plant parts. Results indicated that the highest nickel (132.8 mg kg^{-1} plant tissue) was accumulated in roots which was 12 times more than nickel accumulated in shoots, suggesting that no actual remediation was occurred by wheat. Under high concentrations of nickel, wheat grains are not suitable for human consumption, because health risk index was achieved 130.27 and 169.40 for adults and children, respectively. However, because wheat was able to grow under high concentrations of nickel, this plant can be considered as a tolerant plant to nickel stress. Further research is needed to determine the ultimate limit of nickel concentrations in soils where the accumulation of nickel in the grains is not such a high amount that it threatens human health.

Keywords: Concentration Factor, Heavy Metal, Plant Part, Wheat Grain

Introduction

Nickel, is considered as an essential heavy element which plants need for their optimum growth and development.[1] However, the amount of nickel needed by plants is low (0.01-5µg g^{-1} dry weight) and this heavy metal is considered as a micronutrient.[2] Despite of positive effects of low quantities of nickel on the plants developmental mechanisms, high concentration of nickel is toxic for most plant.[3]

There are several methods for removal of heavy metals from soil environment. However, some of these methods, such as soil washing, are so expensive[4] and some others, such as using chemical materials, impose negative effects on biological activity of soil.[5] Phytoremediation is a low cost and eco-friendly method for reduction of heavy metals concentration in soil.[6] In phytoremediation, various green plants are used to remove contaminants from soils.

Although some researchers suggested that canola (*Brassica napus* L.) is the best plant for removal of excess nickel from agronomical soils,[7, 8] another research reported that wheat accumulates higher concentrations of nickel in its tissues compared with canola.[9] However, it is crucial to detect that how heavy metals are accumulated in the tissues of a plant used for phytoremediation to answer the following questions: i, can wheat grains be consumed without having risk for human health? ii, high accumulation of nickel in roots reveals that nickel remediation by wheat has not actually occurred, because wheat roots cannot be removed from soils, therefore, nickel will return to soil after root decomposition.

The efficiency of phytoremediation in heavy metal removal is determined by concentration factor (CF) which is the ratio of heavy metal amount in the above-ground parts of a plant to the concentration of heavy metal in the soil.[10] This factor measures the uptake and translocation of heavy metal from soil to above soil parts of plants.[11]

The goal of current experiment was determination of the amount of nickel in different parts of wheat including root, stem and

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grain to assess more the uptake mechanisms of nickel by wheat and also health of wheat grains for human consumption.

Materials and Methods

A green-house experiment based on randomized complete block design with three replications was conducted during 2017 to evaluate the accumulation of nickel heavy metal in different parts of wheat. The experimental soil was clay-loam which its pH and EC (ds cm^{-1}) were 7.97 and 1.4, respectively. Initial concentration of nickel in soil sample was 0.14 mg kg^{-1}. Two levels of nickel concentration in soil (0.0 and 100 mg kg^{-1}) were compared in this research. The research included six plots (two factors and three replications). Half of the plots were filled with contaminated (100 mg kg^{-1}) soil and the other half filled with non-contaminated (0.0 mg kg^{-1}) soil. Seeds of wheat were sown in plots based on 400 plant m^{-2}. To avoid heavy metal leaching from soil, drainage water was used for the next irrigations.

At maturity, wheat was harvested and divided into its parts: grain, leaves and stems and roots. The concentration of nickel in all parts of wheat was measured. Concentration factor (CF) was measured for all treatments using the following equation:[12]

$$CF = H_s/H_{pt}$$

In which CF is concentration factor, H_s is heavy metal concentration in soil and H_{pt} is heavy metal concentration in plant tissue.

The risk of nickel heavy metal uptake for human health was evaluated by health risk index (HRI):[13]

$$HRI = DIM/R_fD$$

In which, HRI is health risk index, DIM is daily intake of heavy metal and R_FD is reference value. R_FD is 0.02 (mg kg^{-1} day^{-1}) for nickel.[14] DIM was measured as follow:[13]

$$DIM = [C_m.\ C_f.\ C_{fo}] / B_{av}$$

In which DIM is daily intake of heavy metal, C_m is heavy metal concentration in grain (mg kg^{-1}), C_f is conversion factor for converting fresh weight to dry weight and was considered as 0.085, [15] C_{fo} is daily consumption of heavy metal considered as 289 g for kids and 380 g for adults[16] and B_{av} is mean weight of human considered as 32.7 kg for kids and 55.9 for adults.[16]

Analysis of variance of the data (ANOVA) and mean comparison according to Duncan's multiple range test, using MSTATC statistical software.

Results and Discussion

Results indicated that main effects of nickel concentration in soil and plant part and interaction of nickel concentration in soil × plant part were significant (P≤0.01) on the content of nickel in wheat parts including root, stem and leaves and grains (Table 1). In 0.0 mg kg^{-1} treatment in which primary concentration (0.014 mg kg^{-1}) existing and no further nickel was added, the highest nickel accumulation in wheat was 12.48 mg kg^{-1} dry matter seen in roots of wheat which was more than 2 times higher than nickel accumulation in stem and leaves (Table 2). The amount of nickel in wheat grains was so low that it could not be measured (Table 2). At initial concentration of nickel in the soil (0.14 mg kg^{-1}), the highest concentration factor (CF) was recorded for roots which was 2.8 times more than that of shoots.

Table 1. Analysis of variance for nickel accumulation in wheat parts

Source of Variance	df	Mean Square	
		Ni amount	Transfer Factor
Replication	2	96.62^{ns}	55.37^{ns}
Concentration (C)	1	9228.97**	8090.98**
Plant Part (P)	2	8804.53**	2724.69**
C×P	2	6366.73**	2551.31**
Error	10	46.83	17.53
CV (%)		46.83	19.28

ns: not significant' **: significant at P≤0.01

At high concentrations of nickel in the soil (100.0 mg kg^{-1}), the highest amount of nickel was also accumulated in roots. Grains of wheat had the lowest nickel accumulation (Table 2). Concentration factor (CF) for roots was more than one (Table 2). Higher CF shows a greater tendency of a plant for a metal absorption.[13] The overall range of CF for nickel is 0.1-1.0.[17] In this experiment, the CF for wheat root was 1.32 which was more than that of overall range of nickel CF. Soil pH and clay amount are two factors affecting nickel uptake by plants, where at higher pH and clay amount, lower nickel uptake occurs.[18] However, despite relatively high clay and pH of the soil of the experiment, it seems that in this research, nickel uptake by wheat was not affected by these parameters, since CF of wheat root was more than normal range, confirming the higher the concentrations of nickel the higher the absorption of nickel by wheat.

Table 2. Effect of nickel concentration in the soil on accumulation of nickel in wheat parts

Nickel concentration in the soil (mg kg^{-1} soil)	Plant part	Nickel amount in plant parts (mg kg^{-1} plant part dry matter)	Concentration Factor (CF)
0.14	Root	12.48b	89.14a
	Stem+ leaves	4.52c	32.26b
	Grain	Nm	---
100.14	Root	132.8a	1.32c
	Stem+ leaves	16.54b	0.17c
	Grain	4.51c	0.045c

Nm: not measured because of negligible amount; different letters in each column indicate Significant difference at P≤0.01

According to FAO and WHO standards, the tolerance limit of nickel for human nutrition is 1.6 mg kg^{-1}.[19] When no nickel was added to the soil, tolerance limit was lower than permissible limit, confirming that wheat grains produced under such conditions have no risk for human health. However, in contaminated soil (when 100 mg kg^{-1} nickel was added to the soil) the amount of nickel in wheat grain reached 4.51 mg kg^{-1} which is 2.8 times more than tolerance limit. Heal risk index (HRI) confirmed these results (Figure 1). The risk of heavy metal uptake by plant for human health is measured by HRI.[5] Values larger than one for HRI are indicative of risk of heavy metals for human health.[13] HRI for nickel was much more than one. HRI was 130.27 and 169.40 for adults and children, respectively. Thus, wheat grains produced under high concentration of nickel (100 mg kg^{-1}) are not suitable for human consumption.

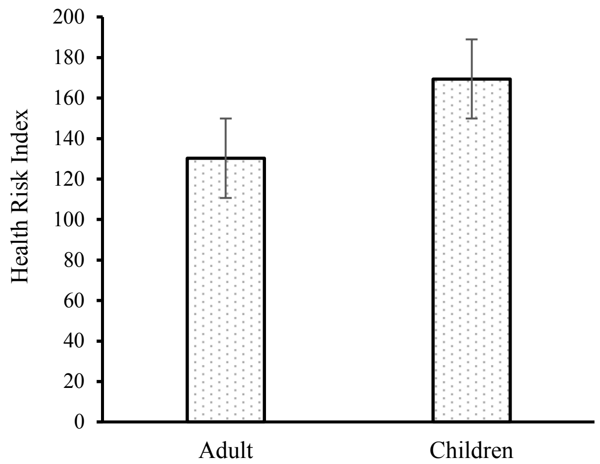

Fig. 1. HRI for nickel accumulation in wheat grains.

Conclusion

The results of this experiment showed that wheat grain produced under high concentrations of nickel (100 mg kg^{-1}) is a great danger for human health and should not be consumed by human. Furthermore, nickel remained largely in the roots of wheat, indicating that no remediation was actually occurred by wheat. However, wheat was able to grow under high concentration of nickel and seems to be a tolerant plant for nickel stress. Regarding wheat grain consumption under nickel heavy metal stress, the ultimate limit of nickel concentrations in soils where the accumulation of nickel in the grains is not such a high amount that it threatens human health requires further research.

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