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The effects of nickel toxicity on seedling growth of *Vigna radiata* (L.) R. Wilezek

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ABSTRACT

Nickel is a trace element and required in small quantity for plant growth. The rapid industrialization, automobile, anthropogenic, society developmental activities entering different types of pollutants in environment and producing variable types of toxic effects on quality of air, water and soil. The addition of many heavy metals in environment and impact on agricultural crop cover has attracted widespread attention in developed and developing countries. The high concentration of nickel produced phytotoxic effect on plant growth and little work is done on this aspect in developing countries. Therefore, this paper describes the effects of nickel salt on the seedling growth performances of legume crop, *Vigna radiata* (L.) R. Wilezek. The results of this pot experiment showed that Nickel (Ni) element treatment at 100 mM was found highly sensitive for seedling growth performance of mung bean. The treatment of different concentration of nickel at 25 to 100 mM affected seedling height, leaf length, leaf breadth and leaf area of mung bean as compared to control (without nickel). Nickel treatment at all concentrations produced less harmful effects on shoot growth as compared to root growth of mung bean. The seedlings of mung bean showed high tolerance indices 111.20% in response to nickel treatment at 50%. The seedlings of mung bean showed decrease in percentage of tolerance indices at 75% of nickel treatment as compared to control.

Keywords: Dry weight, fresh weight, germination, green gram, root, seedling length

1. INTRODUCTION

Pollution by metal significantly affected ecosystem. Nickel is heavy metal and has atomic number 28, atomic weight 58.69 and molecular symbol as Ni^{+2}. Nickel is a solid silver white hard transition element (PUBCHEM, 2018). Nickel (Ni) element is found in environment due to industrial and anthropogenic activities. The main sources of nickel in the environment are use of pesticide, stainless steel, coin and jewelry products. The researchers are working on the impact of heavy metals on plant growth since last few years due to environmental pollution problems. The addition of the heavy metals in the environment are responsible for lessening the productivity of agricultural crops. An inhibition in seed germination, photosynthesis, plant growth, metabolism and development in higher plants due to nickel toxicity reported earlier by different researchers (Baccouch et al., 2001; Boominathan and Doran, 2002; Pandey and Sharma, 2002; Gajewska et al., 2006; Seregin and Kozhevnikova, 2006; Yılmaz, 2007; Ahmed et al., 2009; Gajewska and Sklodowska, 2010; Adhikari and Kumar, 2012; Parlak, 2016; Kumar et al., 2022). Among the heavy metals nickel causes toxic effects to plant (Sethy and Ghosh, 2013). The wide spread use of organic and inorganic compounds to increase the production of agricultural crop has created environmental related issues (Sharma et al, 2013). Effects of nickel on growth and composition of metal micronutrients in Barley plants grown in nutrient solution recorded (Rahman et al., 2005). The $25^{-\mu g\ ml^{-1}}$ nickel treatment was found sensitive for seed germination of *Eruca sativa* (Ozdener and Kutbay, 2009). Ni 50 μM treatment inhibited root and coleoptile length with significant reduction in chlorophyll ‘a’ and chlorophyll ‘b’ of Zea *mays* (Negi, 2016). The high concentrations of trace element associated with health issues and produced toxic effects on photosynthetic pigments, carotenoids and phenols contents and seedling growth (Krzesłowska, 2011; Shafiq and Iqbal, 2012).

Agriculture is backbone of Pakistan economy. Mung bean is an important pulse crop of Asia and harvest after two months interval and can be grow between two crops which provide economic benefit to farmer (WVC, 2020). Pulses are the most important source of vegetable protein in Pakistan. The popular legume grain is cultivated on 5% of the total cropped area. Mung bean is an annual legume bean crop and contributing its important share in agricultural economy of Pakistan. The indiscriminate use of agricultural chemical and environmental pollution issues decreasing the productivity of agricultural crops. The unwise use of chemical input to improve the crop productivity and to control the insect and pest also deteriorating the current environment condition and crop production. Little research is known about the effects of nickel on growth of mung bean. This paper gives information about the effects of nickel (Ni^{+2}) on seedling growth performance of mung bean (*Vigna radiata* (L.) R. Wilezek).

2. MATERIALS AND METHODS

In order to analyze the effect of nickel toxicity on seedling growth of mung bean, a pot experiment was conducted in green house of the Department of Botany, University of Karachi, Pakistan, during 29th August - 10th October 2022. The growth experiment was conducted in pots filled with garden loam. The garden loam was passed through 2.00 mm sieve to remove gravels and other material. The soil was filled up to 2/3 in plastic pots measuring 7.3 cm in diameter and 9.6 cm in height. The certified seeds of mung bean (*Vigna radiata* (L.) R. Wilezek) were bought from the local seed store, Karachi and were surface sterilized with 0.86% solution of sodium hypochlorite (NaOCl) solution for one minute to avoid any fungal contamination.

The four different $NiSO_4.6H_2O$ solutions (25, 50, 75 and 100 millimole) were prepared in deionized water. The 0% nickel solution was considered as control. Six seeds of mung bean were sown in each pot and when 50% growth of seedlings was observed, the seedlings were exposed to different concentration of nickel using nickel sulphate 0, 25, 50, 75 and 100%. One seedling of same sizes was selected and transplanted into each pot. The irrigation medium was tapping water and the seedlings were subjected to the respective Ni^{+2} treatment of 0, 25, 50, 75 and 100%. The treatment was given twice a week. During the experiment the range of minimum and maximum temperature and relative humidity were in between 32.7 to 28ºC and 65 to 74% respectively. The experiment was completely randomized block design consist of three replicates. After six weeks, the seedlings were harvested after desired Ni^{+2} treatment and different growth parameters were analyzed including root, shoot, seedling height, leaf length, leaf breadth and leaf area. Observation regarding visibility of symptoms of toxic effects of nickel were taken on daily basis.

The metal tolerance percentage indices were determined by the following formula:

$$Metal\ tolerance\ index = \frac{mean\ root\ length\ in\ nickle\ \ treatment}{mean\ root\ length\ without\ metal\ treatment}\ X\ 100$$

Statistical analysis

The obtained data was statistically analyzed for one-way Analysis of variance (ANOVA) and Duncan’s Multiple Range Test (DMRT) using personal computer software packages SPSS version 14.0. Level of significance for these tests was at $P < 0.05$ level.

3. RESULTS AND DISCUSSION

The effects of nickel pollution on plant growth have been reported in some studies over the last few years. The accumulation of nickel in plant exhibited phytotoxicity effects on plant growth (Kieling-Rubio et al., 2012; Jaishankar et al., 2014). This paper gives information about the impact of nickel toxicity on seedling growth performance of commercially an important bean crop mung bean *Vigna radiata* (L.) R. Wilezek of Pakistan. An increase in concentration of metal pollution generally effects on growth variable of plants. The plant under abiotic stress conditions is most likely to be affected by heavy metals accumulation. In present studies the treatment of nickel influenced on seedling growth performances of mung bean. The treatment of different (0, 25, 50, 75 and 100%) concentrations of Ni^{+2} as nickel sulfate indicated variable response of decrease in seedling growth characteristics of mung bean (Table 1).

Table 1 Effects of different concentration (0, 25, 50, 75, 100%) of nickel on seedling growth characteristics of mung bean.

Treatments $NiSO_4.6H_2O$ solutions (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (sq.cm)
00	5.00 a	26.60 a	31.69 a	5.60 a	4.23 a	15.70 a
25	2.96 a	19.60 b	24.16 b	4.40 b	1.73 b	5.13 b
50	5.56 a	22.40 b	25.80 b	4.00 b	1.73 b	5.13 b
75	3.36 a	21.53 b	23.10 b	3.54 b	1.60 b	3.74 b
100	3.90 a	22.50 b	25.40 b	3.63 b	1.70 b	4.30 b
L.S.D.	3.05	2.74	3.70	0.90	1.06	3.51
Statistical difference determined by ANOVA. Mean values followed by the same letter in a row are not significantly different ($p<0.05$) according to Duncan's multiple range test.						

The results indicated that nickel treatment at 25% significantly ($p < 0.05$) reduced seedling length (19.60 cm) of mung bean as compared to control (31.69 cm). An increased in concentration of Ni^{+2} at 75 and 100% increased shoot length of mung bean as compared to 25% nickel concentration. Nickel treatment at all level highly deceased shoot length of mung bean as compared with the root length of control. The treatment of Ni^{+2} showed more adverse effects on shoot growth of mung bean. Nickel treatment at 25% concentration significantly reduced the shoot length of mung bean as compared with the root length of control. Ni^{+2} treatment at 25-100% did not significantly affected root length of mung bean as compared to control. The toxicity of metals depends upon the level and duration of dose to the living organism. The nickel treatment at 25% significantly ($p < 0.05$) decreased shoot length of mung bean. Nickel is involved in metabolic processes (Mulrooney and Hausinger, 2003). Georgiadou et al., (2018) reported the influence of Ni on nitro-oxidative stress in Basil (*Ocimum basilicum* L.) plants. Nickel has toxic potential to plants growth and development (Sengar et al., 2008). Nickel treatment at 25 ppm did not produce any significant effect on root which might be due to its resistance to nickel. Ni^{+2} treatment showed that leaf size in terms of leaf length, breadth and area of mung bean was decreased with increase in concentration at 25 to 100% as compared to control (0%). Results showed that leaf length was declined with increase in concentration of nickel from 25 to 100%.

Nickel is a heavy metal and getting global concern due to its toxicity impact on plant growth at higher concentration. The treatments of nickel at 75% also decreased leaf breadth 1.60 cm of mung bean over control 4.23 cm. Ni^{+2} treatment at all concentration influenced the leaf breadth of mung when treated with different concentration of nickel and was reduced to 1.73 and 1.60 at 50 and 75% concentration as compared to control (4.23 cm). Whereas, Ni^{+2} treatment at 100% concentration slightly increased leaf breadth of mung as compared to 25, 50 and 75% Ni^{+2} treatment. Mujeeb et al., (2019) noted the nickel treatment at 2.4 mM significantly ($p < 0.05$) decreased number of leaves of *Ricinus communis* (L.). Nickel (0.0004, 0.04- and 0.08-mM Ni) in the nutrient solution treatment reduced the biomass and disturbed the balance and accumulation of macronutrients (N, P, K, Ca, Mg, S) status in spring wheat (*Triticum aestivum* L.) Zebra cv. (Matraszek et al., 2016). Results indicated that reduction was observed in leaf area of mung bean with the increase in concentration nickel particularly at 75%. The treatments of nickel at 75% significantly decreased leaf area of mung bean to 3.74 sq. cm as compared to control 15.70 sq. cm. The seedlings of mung bean were also tested for nickel tolerance. The seedlings of mung bean showed lowest percentage of tolerance indices for 25% of nickel treatment as compared to control. The seedlings of mung bean showed high tolerance indices 111.20% in response to nickel treatment at 50% (Figure 1).

V. radiata seedlings showed moderate tolerance indices at 50 and 75% Ni treatment. In present study, there was a reduction in seedling growth of mung bean was recorded with increasing concentrations of Ni^{+2} in the medium. Toxic effects of Ni on germination and plant growth might be due to its interference with other essential metal ions and induction of oxidative stress (Chen et al., 2009). This suggests that, over time, Ni must have interfered more strongly with the metabolic processes of the plant. Metals are significant environmental pollutants and their toxicity is a problem for all living organisms (Oukarroum, 2016).

In present study, nickel toxicity showed differences in seedling growth parameter of *V. radiata* L. Yang and Zhao, (2013) recorded the effect of Ni^{2+} treatment on all indexes of growth stage of oilseed rape (*Brassica napus* L.). The reduction in the shoot growth of *V. radiata* with the increase in concentration of nickel in substrate a 25% provides further evidence that the nickel in excess may be inhibitory to plant growth and development. Metal ions enter in cells the same processes as essential micronutrient metal ions. The changes in the permeability of the cell membrane and replacement of essential ions in the presence of metals results in phytotoxicity (Patra et al., 2004) and the exact amount of accumulation depends upon the availability of the pollutants in the soil.

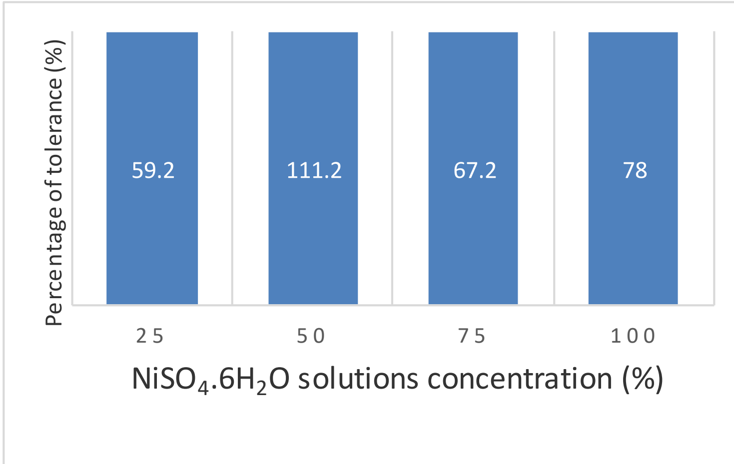

Figure 1 Percentage of tolerance in *V. radiata* using different concentration (25, 50, 75, 100%) of nickel.

4. CONCLUSION

The seedlings of mung bean were responded differently for nickel stress tolerance. It was concluded that the nickel treatment at 25% concentration produced significant ($p < 0.05$) effects on shoot and leaf growth of mung bean (*Vigna radiata*). Similarly, the tolerance to nickel treatment decreased the tolerance indices for mung bean seedlings as compared to control. The level obtained of tolerance index in response to nickel toxicity should be considered while mung bean cultivating in nickel contaminated areas.

Author's contribution

Muhammad Zafar Iqbal designed and supervised the experiment. Amber Anjum performed the experiment and recorded the experimental data. Muhammad Shafiq prepared and draft the manuscript and surveyed the literature. All authors read and approved the final version.

Ethical Approval

The certified seeds of mung bean (*Vigna radiata* (L.) R. Wilezek) from the local seed store, Karachi, Pakistan was used in the study. The ethical guidelines for plants & plant materials are followed in the study for experimentation.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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