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GROWTH RESPONSE OF MAIZE (*ZEA MAYS* L.) TO DIFFERENT NICKEL CONCENTRATIONS IN DIFFERENT TEXTURED SOILS

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ABSTRACT

Background Maize (*Zea mays* L.) is an important fodder and grain crop in the world. Animals feed on nickel (Ni) contaminated fodder may accumulate high amount of Ni which subsequently can affect the human health. A field experiment was conducted to investigate the effect of different Ni concentrations on maize growth in different textured soils.

Methodology Experimental plan comprised of four Ni concentrations (0, 40, 80 and 120 ppm) and two soil textural classes (sandy and clayey) with three replications.

Results Application of various levels of Ni markedly reduced plant growth characteristics in term of fresh and dry leaf, root and shoot weight as well as number of leaves plant^{-1}. Minimum values of leaf fresh weight, number of leaves plant^{-1}, and shoot dry weight were found at 80 ppm Ni while rest of maize growth characteristics showed maximum reduction at 120 ppm Ni. Among both textural classes, sandy soil exhibited greater decline in maize growth at all levels of Ni application compared to clayey soil. Chemical analysis experimental soil after maize harvesting showed an increase in Ni concentration, with maximum increase at highest Ni level (120 ppm).

Conclusion Increase in the external Ni concentration significantly decreased the vegetative growth of maize as compared to control in both textural classes. Ni toxicity was more injurious to maize growth in sandy soil at all levels of Ni application.

INTRODUCTION

Maize is the 3rd major cereal crop in world, after rice and wheat (Singh et al. 2005), and grown for both fodder and grain purposes. It belongs to family Poaceae, and is known due to its adaptation to versatile agro-climatic zones all over the world. Maize grain has high nutritional value and it provides raw material to industries (Afzal et al. 2009). In cereals, it occupies very important position to provide staple food for majority of communities by contributing 20% diet calories (Braimoh and Vlek 2006). Maize production in Pakistan is very low as compared to advanced countries. This might be due to high temperature and water deficiency which are responsible for lesser productivity (Tester and Bacic 2005). Elevated production of agricultural crops by the use of synthetic fertilizers and soil amendments may result in heavy metal accumulation in soil (Adriano 2001). Contamination of soil with heavy metals is a worldwide problem, reducing agricultural yield.

Nickel (Ni) stands 24th in the list of most abundant elements in earth crust, and is present as 3% of earth composition. Firstly Ni was discovered in 1975 as a urease enzymes component which is present in number of plant species (Takishima et al. 1988). Many plant biochemical and physiological processes might be affected when excess Ni is taken-up (de Queiroz Barcelos et al. 2017). In the presence of high Ni concentration, plants show different symptoms including chlorosis and inhibition of respiration (Fatemeh et al. 2012; Georgiadou et al. 2018). In the list of heavy metals in earth crust, Ni has exceptional place. Being micronutrient, it is important for plant growth and development, and is a component of urease enzyme which is indispensable in higher plants for N

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metabolism. Plants need trace elements to perform their metabolic functions normally. However, when concentration of trace elements is more than required it will become hazardous due to interference with plant physiological as well as biological processes (Seregin and Kozhevnikova 2006). Nickel is accumulated in seed and vegetative tissues to threat the plant productivity (Boominathan and Doran 2002). Satish et al. (2015) also reported Ni toxicity in plants at higher concentration. In present study, pot experiment was conducted to evaluate the effect of different Ni concentrations on maize growth characteristics in different textured soils.

MATERIALS AND METHODS

Site of experiment

A pot experiment was planned to estimate the effect of different concentration of Ni on growth of maize crop grown in different textured soils (sandy and clayey).

Collection of soils having different texture

Soil was collected from two different locations of Punjab province. Clayey soil was collected from Sargodha and sandy soil from District Mianwali. The collected soils of both texture were air dried and passed through 2 mm sieve. The experimental pots were filled with 10 kg of soil in each pot.

Experimental design and treatments

The experiment was laid out according to completely randomized design with factorial arrangement having four replications comprised of eight treatments *viz*; four Ni concentrations (0, 40, 80 and 120 ppm) and two soil textural classes (sandy and clayey). Nickel was applied as nickel sulfate, and thoroughly mixed in soil before filling the pots.

Three seeds of maize hybrid DK-919 were sown in each pot. When the germination has been completed, only one healthy plant was maintained in each pot and other germinated plants were manually uprooted and incorporated in the same pots. Irrigation was done as per requirement of maize crop using tap water throughout the growth period. Recommended dose of nitrogen as urea, phosphorus (P as triple superphosphate and potassium as potassium) sulfate was applied at the time of sowing. Maize plants were harvested at thirty days after germination. Root, shoot and leaves were collected and put into paper bags after washing with distilled water. Data for plant fresh and dry weight as well as nickel (Ni) concentration in leaves and soil were collected. All the collected data were analyzed statistically using Statistix 8.1 computer software. The significance of treatment means was tested using least significant difference (LSD) test at probability level < 0.05.

RESULTS AND DISCUSSION

Leaf fresh weight

Leaf fresh weight was significantly ($p < 0.05$) affected by Ni application in both soil textural classes. Individual assessment of treatment means presented in Figure 1 indicated that maximum leaf fresh weight was observed in clayey soil at 120 ppm Ni. It was statistically similar to 0 ppm Ni in clayey soil. Treatment effect mean comparison presented maximum leaf fresh weight at 120 ppm Ni in both sandy and clayey soils. Statistically similar value of leaf fresh weight was found in control, 40 ppm and 120 ppm Ni. Minimum leaf fresh weight was recorded at 80 ppm Ni which was statistically non-significant with respect to 40 ppm Ni. These results were in alliance with Bashmakov et al. (2005) who stated that with an increase in the concentration of heavy metals suppressed the growth processes of maize. Seregin and Kozhevnikova (2006) also reported that high concentration of Ni in cells and peri-cycle inhibited the cell division, leading to reduced plant growth.

Leaf dry weight

Results presented in Figure 2 showed that different doses of Ni applied significantly ($p < 0.05$) affected the leaf dry weight of maize. Individual evaluation of treatment means indicated maximum leaf dry weight at 80 ppm Ni in clayey soil. It was statistically at par with 0 ppm Ni in clayey soil. Fatemeh et al. (2012) demonstrated that Ni toxicity caused a marked decline in plant growth and yield due to its interference with respiration, photosynthesis and chlorophyll synthesis. Satish et al. (2015) also found a reduction in plant growth characteristics in the presence of higher Ni concentration. Parida et al. (2003) studied the effects of Ni toxicity in fenugreek (*Trigonella corniculata* L.) and found that Ni toxicity could decrease the plant productivity due to its toxic effect on plant physiology and ionic homeostasis. Rathor et al. (2014) investigated the effect of Ni on maize growth, and found that lower level of Ni could improve plant growth characteristics but Ni at higher levels caused toxicity which appeared in the form of chlorosis, reduction in chlorophyll synthesis, photosynthesis, all these led to a marked reduction in plant productivity. Ahmad et al. (2010) reported the toxic effects of Ni in sunflower in term of disturbed ionic balance. Treatment effect mean comparison indicated maximum leaf dry weight at 80 ppm Ni in both sandy and clayey soils. Similar value of leaf dry weight was observed in control, Ni 40 ppm and Ni 120 ppm. Minimum leaf dry weight was noted at 80 ppm Ni, it was at par to 40 ppm Ni.

Number of leaves plant^{-1}

Resulted presented in Figure 3 indicated that number

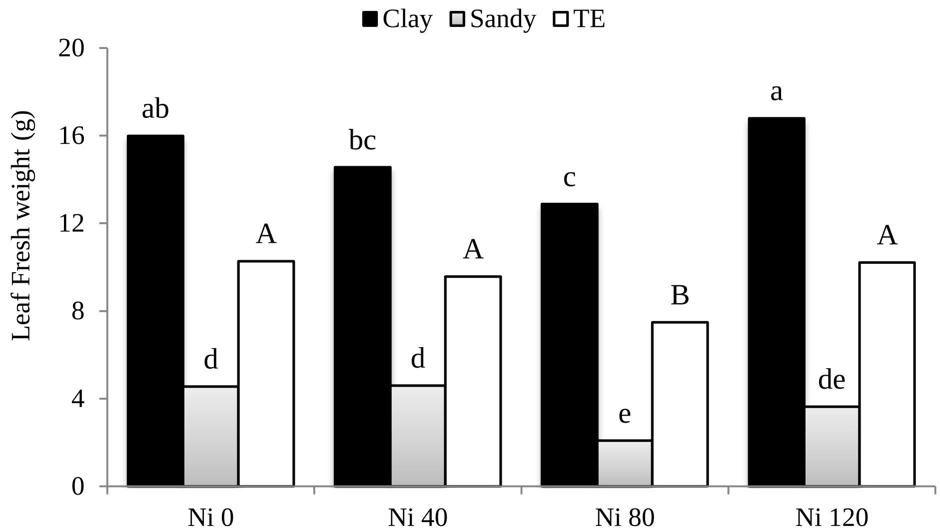

Figure 1 Leaf fresh weight of maize (*Zea mays* L.) grown at different Ni levels in two different textured soils.

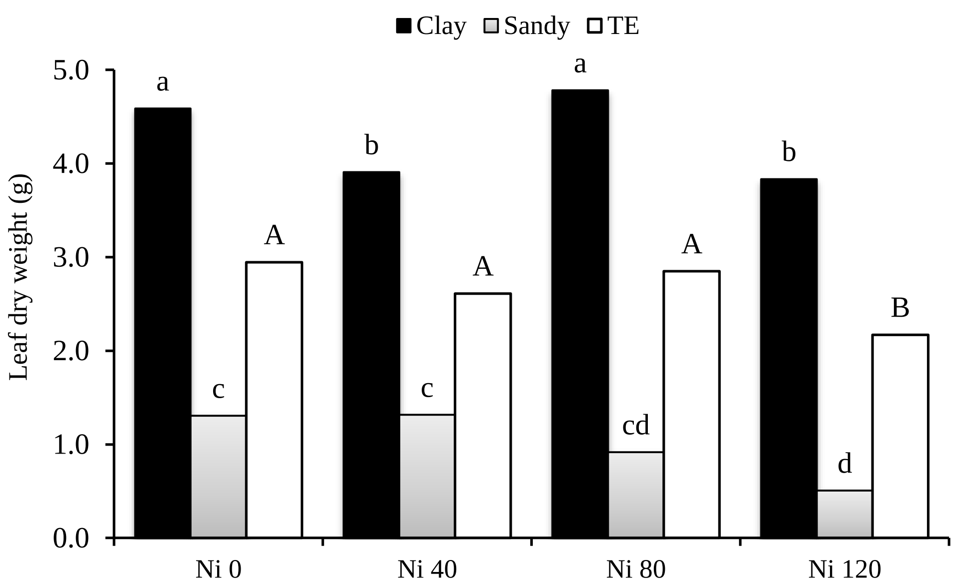

Figure 2 Leaf dry weight of maize (*Zea mays* L.) grown at different Ni levels in two different textured soils.

of leaves per plant was significantly ($p < 0.05$) affected by the application of Ni compared to control. Maximum number of leaves per plant was observed at 80 ppm Ni in sandy soil. Treatment effect mean comparison indicated maximum number of leaves per plant at Ni 80 ppm in both sandy and clayey soil, and was followed by control, Ni 40 ppm. These findings were matched with the results of Molas (1997) who reported decreased leaf area in *Brassica oleracea* with increased application of Ni. Similarly, Sharma and Dhiman (2013) stated that Ni toxicity caused a decrease in the development of viable seed due to inhibition in the growth of embryo.

Shoot fresh weight

Results presented in Figure 4 revealed that shoot fresh weight of maize significantly ($p < 0.05$) affected by the Ni application. Individual comparison of treatment means indicated maximum fresh weight of shoot in clayey soil + 0 ppm Ni. Minimum shoot fresh weight

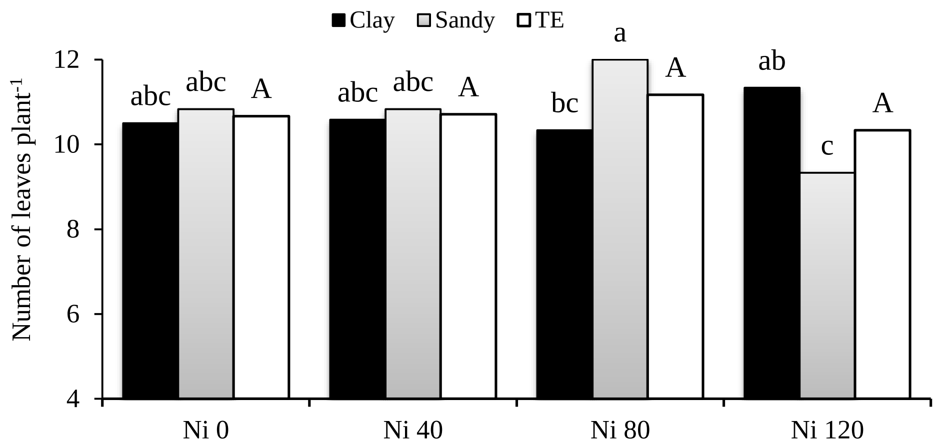

Figure 3 Number of leaves plant^{-1} in maize (*Zea mays* L.) grown at different Ni levels in two different textured soils.

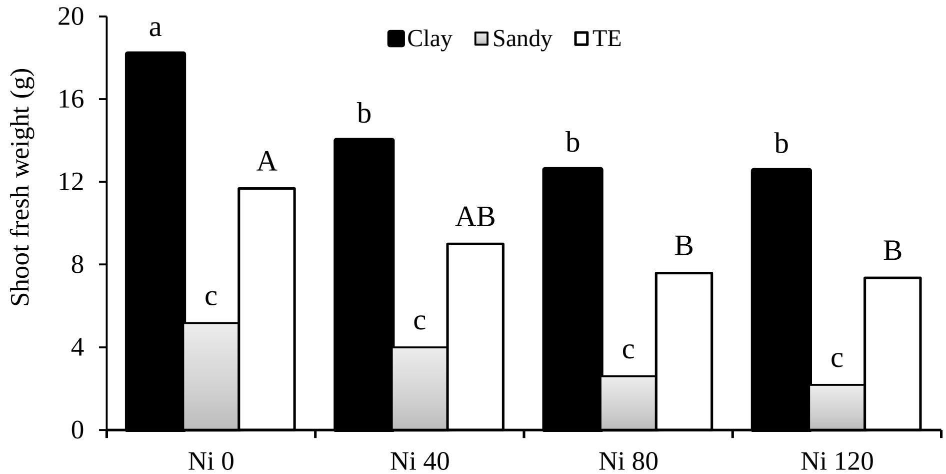

Figure 4 Shoot fresh weight of maize (*Zea mays* L.) grown at different Ni levels in two different textured soils.

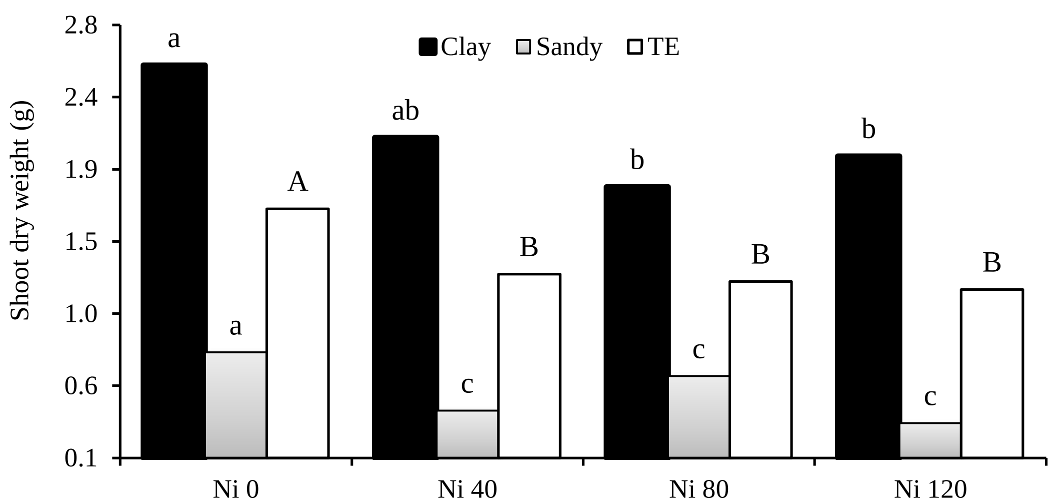

Figure 5 Shoot dry weight of maize (*Zea mays* L.) grown at different Ni levels in two different textured soils.

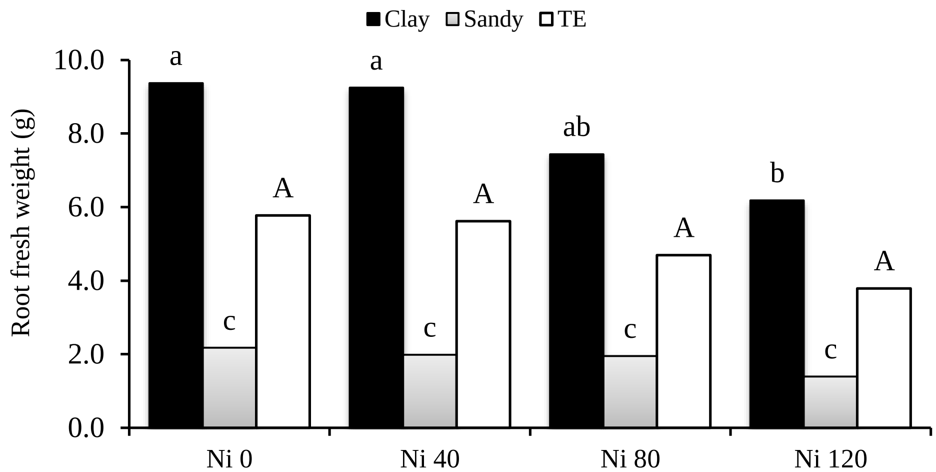

Figure 6 Root fresh weight of maize grown at different Ni levels in two different textured soils.

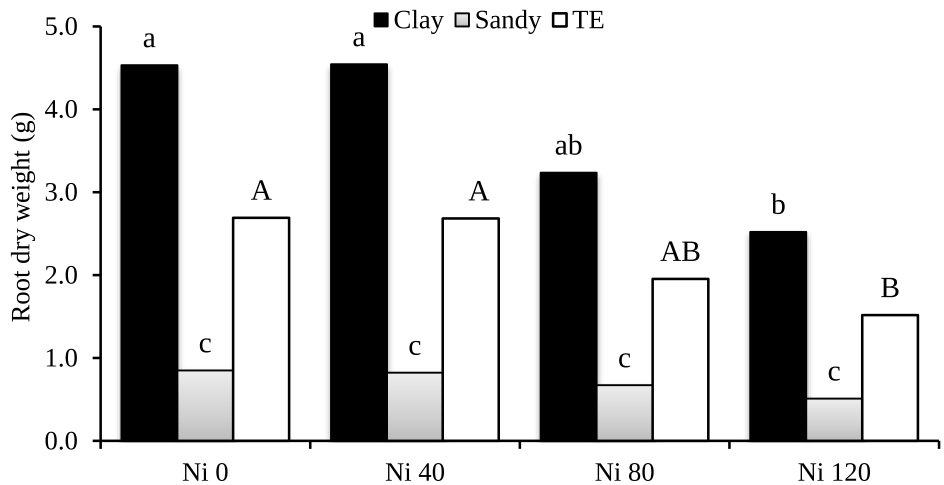

Figure 7 Root dry weight of maize grown at different Ni levels in two different textured soils.

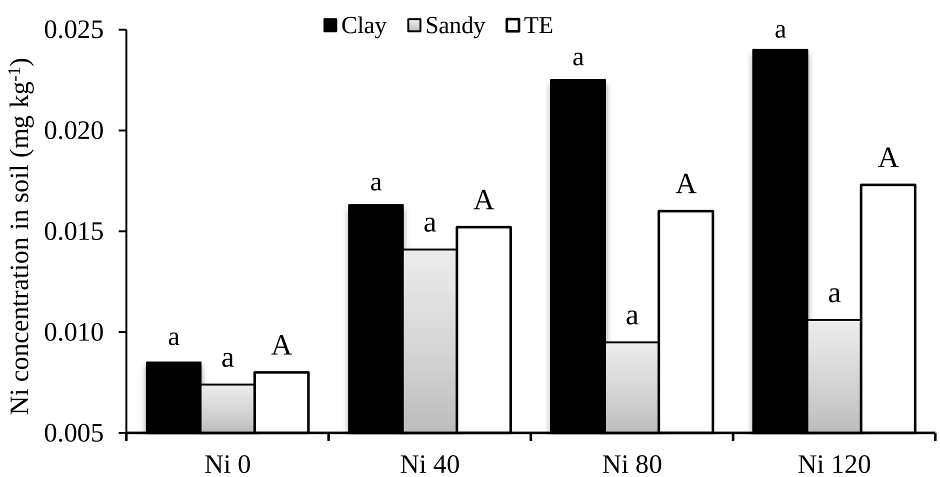

Figure 8 Ni concentration in soil after the harvesting of maize grown at different Ni levels in two different textured soils

was recorded in case of sandy soil at 120 ppm Ni. Treatment effect mean comparison presented maximum fresh weight of shoot at 0 ppm Ni in both sandy and clayey soils. Findings were found in line with Rathore et al. (2014) who found that Ni application reduced the maize growth. Athar and Ahmad (2002); Ahmad et al. (2010) also reported that increasing application of Ni decreased the shoot weight as compared to control. Some other studies, for example, Lin and Kao (2005), Seregin and Kozhenikova (2006) and Tariq et al. (2007) reported the toxic effects heavy metals on plant metabolism.

Shoot dry weight

Individual comparison of treatment means presented in Figure 5 indicated maximum shoot dry weight in clayey soil at 0 ppm Ni. It was statistically similar to 40 ppm Ni in clayey soil. Minimum shoot dry weight was recorded at 120 ppm Ni in both textural classes. These results were supported by the findings of Parida et al. (2003); Seregin and Kozhenikova (2006); Rathore et al. (2014) who stated that Ni applications reduced the shoot dry weight of target species.

Root fresh weight

Data presented in Figure 6 revealed that root fresh weight of maize significantly ($p < 0.05$) affected by the Ni application. Individual comparison of treatment means indicated maximum root fresh weight in control (0 ppm Ni in clayey soil) which decreased variably with increasing Ni application. Treatment effect mean comparison indicated maximum root fresh weight in control treatment (both sandy and clayey soils with 0 ppm Ni) and was followed by 40 and 80 ppm Ni. Minimum leaf fresh weight was recorded at 120 ppm Ni. These results were similar to Tariq et al. (2007); Ahmad et al. (2010) who found that Ni in growth medium reduced root fresh weight.

Root dry weight

Results presented in Figure 7 showed that by the application of different doses of Ni, root dry weight of maize was significantly ($p < 0.05$) affected. Individual comparison treatment means showed maximum root dry weight in control (clayey soil having 0 ppm Ni). These results were in agreement with the findings of Lin and Kao (2006) that root dry weight decreased with increasing Ni in the growth medium.

Nickel concentration in soil

Results showed that Ni applied in different concentrations to maize plants had a marked effect on Ni accumulation in soil compared to control. It was pragmatic that pots that received higher dose of Ni had higher Ni concentration in soil after crop harvesting. Data presented in Figure 8 showed that maximum Ni concentration in soil was observed in the treatment where 120 ppm Ni was applied in clayey soil followed by clay soil with 80 ppm Ni. Minimum soil Ni concentration was found in clayey soil with 0 ppm Ni. Results were in synchronization with the results of Bencko (1983) that soil Ni increased with increasing the application of Ni from external source. It was also reported that Ni accumulation in soil also disturbed soil properties, particularly soil microbial activities, leading to reduced plant growth and yield. Similar results were reported by Georgiadou et al. (2018).

CONCLUSIONS

Maize growth characteristics in term of fresh and dry weights of roots and shoots and number of leaves plant^{-1} grown at different Ni levels were significantly ($p<0.05$) affected by Ni levels and soil textural classes. It was found that Ni concentration above 80 ppm caused a marked reduction in maize growth. When comparing two textural classes, sandy soil showed greater reduction in maize growth characteristics compared to clayey soil. In contrast, Ni concentration was more in clayey soil after the harvesting of maize.

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