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IMPACT OF FOLIAR SALICYLIC ACID ON NUTRIENT DYNAMICS IN TWO LENTIL VARIETIES UNDER COMBINED CHROMIUM AND SALINITY STRESS

Saeed Ahmed¹, Kanval Shaukat¹, Abdul Samad¹, Shamim Gul¹, Ayesha Mushtaq², Irshad Ali³, Attiq-ur-Rehman³, Misbah Manzoor⁴, Muhammad Farooq⁵, Tariq Ismail^{1*}

¹Department of Botany, University of Balochistan, Quetta, Pakistan

²Department of Chemistry, Sardar Bahadur Khan Women's University (SBKWU), Quetta, Pakistan

³Department of Chemistry, Faculty of Basic Sciences, University of Balochistan, Quetta, Pakistan

⁴Department of Botany, Sardar Bahadur Khan Women's University, Quetta, Pakistan

⁵Quality Control Department, Martin Dow Markar Ltd., Quetta, Pakistan

*Corresponding Author: Tariq Ismail. E. mail: tariqismail.dr@gmail.com



Abstract

A field experiment was conducted in the Botanical Garden, University of Balochistan, Quetta, Balochistan, Pakistan, to assess the tolerance potential of two lentil (*Lens culinaris* Medik.) varieties, i.e., Dasht-21 and Black-Panjgur, under single and combined chromium and salinity stress with exogenous supplementation of Salicylic acid (SA). Design of the experiment was RCBD under factorial with 3 replicates. After 25 days of germination, stress (2 levels of Chromium and salinity) was applied, and after one week of stress, foliar supplementation of SA was applied. Plants per treatment were harvested after 10 days of foliar supplementation to analyse the nutritional status of lentil varieties. Results revealed that both varieties exhibited high levels of sodium (Na⁺) and Chromium (Cr) under single and combined stress, while SA ameliorated the accumulation of Na (20-25%) and Cr (15-20%) in root and shoots of lentils. Considering the beneficial minerals, i.e., potassium (K) and magnesium (Mg), it was observed that the plants treated with SA had the maximum concentration of K (15-35%) and Mg (20-30%) in plant tissues even under stress, while K and Mg concentrations were hampered in plants without SA supplementation under stress. Thus, the present study recommends foliar application of SA to alleviate the impacts of salinity and chromium stress by balancing the nutrient status of plants.

Keywords: Chromium stress, Lentil varieties, Nutrient dynamics, Salinity, SA foliar supplementation

INTRODUCTION

Heavy metals possess harmful effects on plants, animals and humans. Industrialization and anthropogenic activities increases the concentration of heavy metals in the environment (1). Humans and animals face numerous health problems due to contamination of agricultural land by heavy metals (2, 3). Among heavy metals chromium (Cr) is a membrane permeable, very poisonous and non-essential heavy metal that disrupts cell functioning and impacts several physiological, morphological and biochemical traits of plants, ultimately resulting in plant death (4). It is major environmental threat and second most common metal contaminant in soil, ground water, and sediment (5). Photosynthesis, nutrient absorption and general plant growth are all negatively impacted by chromium (Cr) toxicity, which also changes antioxidant activities and promotes the production reactive oxygen species (ROS) (6). Due its greater stability, high water solubility, and rapid penetration of cell membranes Cr-VI is more toxic than Cr-III (7).

Soil salinity is one of the major abiotic stresses gradually increasing and establishing rapidly to adversely affect the arable and ultimately slicing/cutting the available agricultural land and production of crops (8, 9). Plants grown under salt stress commonly confront toxic ions accumulation and disrupt plant water relations (10). Additionally, soil salinity causes over production of reactive oxygen species (ROS) which results in oxidative stress thereby hampering plant growth and development (11). Furthermore, it causes water and oxygen deficiency and nutritional imbalance by disturbing plant metabolism (12, 13). Salinity reduces plant's ability to absorb nutrients from the soil which leads to nutritional imbalance (14)



hampered photosynthetic rate, chlorosis and necrosis (15). However, enzymes such as superoxide dismutase (SOD), peroxidase (POD) and ascorbate peroxidase (APX) are part of the defence mechanism which are produced in plants, especially in the mitochondria and chloroplast (16).

Salicylic acid (SA) is an important plant growth regulator that regulate many physiochemical processes under stress (17). Plant growth with respect to photosynthetic pigments improved and level of lipid peroxidation reduces by application of SA (18). Photosystem-II efficiency, relative efficiency of photosynthesis and potassium accumulations were high in leaves of mung bean under salicylic acid application, coupled with high relative water content, Fv/Fm, leaf area, Chl contents and index (17). A wide range of literature is available which shows that salicylic acid is key hormone that regulate plant metabolism under abiotic condition (19). Thus, SA applied as a growth promoting hormone under both favourable and unfavourable environment (20). In response to microbes, SA has significant role in regulating the signalling pathways in plants (21). Zhang *et al.*, (2023) reported that Cadmium toxicity and drought stress have detrimental impacts on membrane stability, growth, and photosynthesis which results in oxidative and osmotic stresses (22). SA acts as signalling molecule in plant defence mechanism against different biotic and abiotic stresses (23). As a plant growth regulator SA reduces oxidative damage and modulate stomatal behaviour (24), decrease metal uptake (25), scavenge reactive oxygen species (26) and regulate various biochemical and physiological processes (27). Foliar treatment of SA improves physiological and biochemical responses under cadmium and drought stress also in combined stress in *Caucasian wingnut* plant. These responses include relative water content, growth, osmotic potential, electrolyte leakage, ions accumulation, hydrogen peroxide level, lipid peroxidation level and antioxidant enzymes e.g. catalase, peroxidase etc. In addition, cadmium and drought stress also change ion accumulation in leaves of *Caucasian wingnuts* plant whereas SA application mitigates this negative effect (28) furthermore, it leads to reduced biomass, growth and yield of plants (29).

Lentil (*Lens culinaris* Medik) is diploid ($2n=2X=14$) and self-pollinating crop with an average genomic size of about 4 Gbp (30). It grown in sandy loam soil, also referred as lentil, daal, or pulse. It is winter crop of the cool season. In Pakistan, lentils is the second most important winter legume crop (31). It is protein-dense less costly than animal protein and has high nutritional value. It is native to subcontinent and member of the Fabaceae family (32). In addition to macronutrients like proteins and dietary fibres lentils are also good source of micronutrients such as vitamins, minerals and phytochemicals (16). The current study was conducted to evaluate the nutritional dynamics of lentil varieties grown under combined stress of salinity and chromium and assess the efficacy of foliarly applied SA in ameliorating salinity and chromium stress among 2 lentil varieties.

MATERIALS AND METHODS

EXPERIMENT LAYOUT

A field experiment was conducted in the Botanical Garden, University of Balochistan, Quetta, Pakistan to assess the tolerance potential of two lentil (*Lens culinaris* Medik.) varieties i.e., Dasht-21 and Black-Panjgur under single and combined chromium and salinity stress with exogenous supplementation of Salicylic acid (SA). These varieties were developed by ARI Quetta Balochistan, no prior data regarding the abiotic stress was reported. These varieties were selected to evaluate the tolerance potential of both varieties to combined stress of heavy metal and salinity, so the tolerant and better performing variety can be recommended for cultivation in areas of Balochistan facing salinity or heavy metal stress. Field area of 90 × 30 (2700 sq feet) was used for experiment. Design of the experiment was RCBD under factorial with 3 replicates per treatment. Experimental layout consists of 2 varieties × 2 stresses × SA levels. A single row with 4 × 1 (4 sq feet) represented the one replicate per treatment. 8-10 seeds were sown in every row for each variety. After 25 days of germination, stress (2 levels of Chromium (200 and 250µM) and salinity (50 and 100mM) was applied and after a week of stress application the foliar supplementation of SA (200 and 250µM) was applied once. Plants per treatment were harvested after 10 days of foliar supplementation to analyze nutrient status of lentil varieties (plants were under stress for about 17 days; 7 days before SA foliar

supplementation and 10 days after SA supplementation then harvested for nutrient analysis). Nutrient were analyzed in the inorganic lab of Department of Chemistry, and a few were performed in Quality Control (QC) of Martin Dow Markar Quetta.

SOURCES OF SEEDS

Seeds of two varieties of lentil (*Lens culinaris* Medik.) namely Dasht-21 and Black Panjgur were supplied by Directorate of Pulses ARI, Quetta.

SODIUM, POTASSIUM, MAGNESIUM, CHROMIUM ANALYSIS

After the digestion of plant samples in nitric acid, these nutrients (Magnesium, Chromium) were analyzed by using Atomic Absorption Spectrophotometer (AAS) while nutrients (Sodium, Potassium) on Flame Photometer.

STATISTICAL ANALYSIS

“STATISTIX 8.1” software was used to analyze the data statistically ANOVA $p > 0.05$. The graph preparation, mean and standard deviation calculation was done by using “MS EXCEL”

RESULTS

SHOOT CHROMIUM

Data regarding the concentration of Chromium (Cr) in shoots of two varieties of lentil (*Lens culinaris* Medik.) under salinity and chromium stress showed statistically significant results $p < 0.05$. Results show that maximum (4.99 ppm) chromium (Cr) was observed in shoots of plants treated with Cr 250 μ M + NFS, while minimum (1.66 ppm) was noted in shoots of plants subjected to NaCl 50mM + Cr 250 μ M + SA 250 μ M treatment in variety Dasht-21 (Fig. 1A). In variety Black Panjgur highest quantity (4.58 ppm) of Chromium (Cr) was observed in Cr 250 μ M + Water Spray treatment, while it was noted lowest (1.55 ppm) under NaCl 50mM + SA 250 μ M treatment (Fig. 1B). Overall, it was noted that plants of both varieties had reduced growth under high level of Chromium (Cr), while application of salicylic acid (SA) a scavenging compound improved tolerance potential of plant.

ROOT CHROMIUM

Results regarding the concentration of Chromium (Cr) in roots of two varieties of lentil (*Lens culinaris* Medik.) obtained under salinity and chromium stress showed statistically significant results $p < 0.05$. Results showed that the maximum (8.7 ppm) Chromium (Cr) was observed in roots of plants treated with NaCl 100mM + Cr 250 μ M + water spray, while minimum (2.21 ppm) was noted in roots of plants subjected to control + SA 250 μ M in variety Dasht-21 (Fig. 1C). In variety Black Panjgur highest quantity (7.48 ppm) of Chromium (Cr) was observed in NaCl 50mM + Cr 250 μ M + water Spray treatment, while it was noted lowest (1.9 ppm) under control + SA 250 μ M treatment (Fig. 1D). Similar to shoot chromium results, variety Black Panjgur performed better thus stating better tolerance potential compared to variety Dasht-21 (Fig. 1CD).

SHOOT SODIUM

Data regarding the concentration of sodium (Na⁺) in shoots of two varieties of lentil (*Lens culinaris* Medik.) namely Dasht-21 and Black Panjgur were obtained under salinity and chromium stress showed statistically non-significant results ($p > 0.05$). These results further evaluate that the highest quantity (14.6 mg/g DWT) of sodium (Na⁺) was observed in NaCl 100mM + Cr 250 μ M + H₂O Spray treatment, while lowest quantity (1.2 mg/g DWT) was noted in plants subjected to Cr 200 μ M + SA 250 μ M treatment in variety Dasht-21 (Fig. 2A). In variety Black Panjgur highest quantity (15.93 mg/g DWT) of sodium (Na⁺) was also observed in NaCl 100mM + Cr 250 μ M + H₂O Spray treatment, while it was noted lowest (3.06 mg/g DWT) under control + SA 250 μ M as well as in control + SA 200 μ M treatment (Fig. 2B). Further data from graphs revealed that SA in its both concentration SA 250 μ M and SA 200 μ M decreases the level of sodium (Na⁺) in plants of both varieties. H₂O Spray treatment also contributed slightly in the reduction of sodium

(Na⁺) level in plants of both varieties. Variety Black Panjgur performed better as compared variety Dasht-21 accumulating lower sodium (Na⁺) under SA foliar spray (Fig. 2AB).

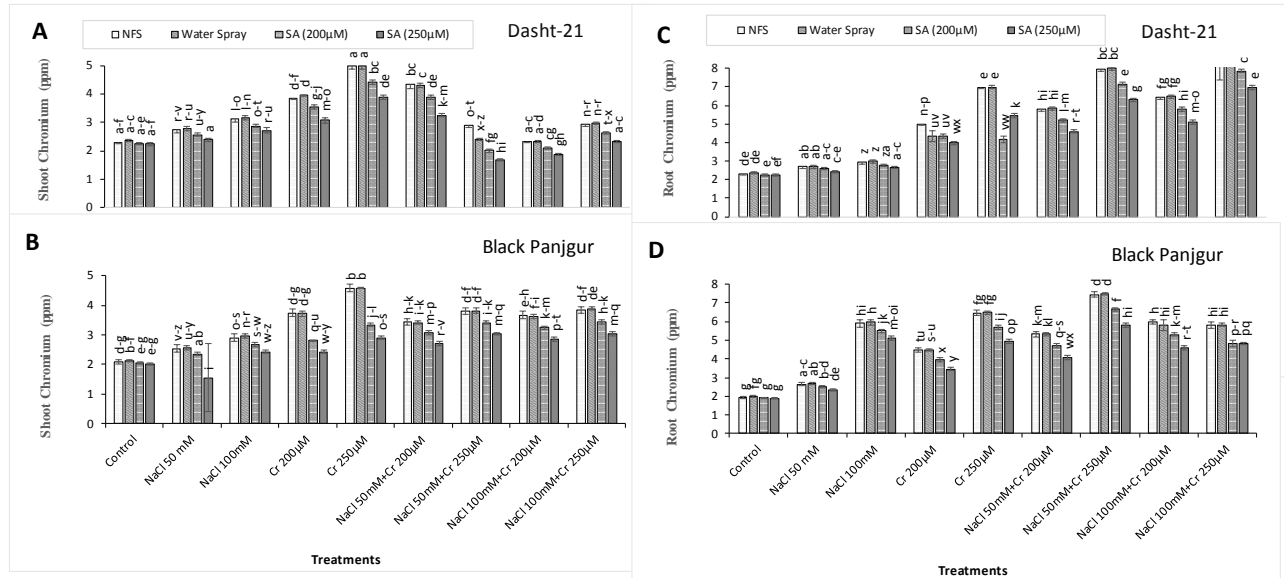


Fig. 1. Minerals **A=** shoot chromium of variety Dasht-21, **B=** shoot chromium of variety Black Panjgur, **C=** root chromium of variety Dasht-21, **D=** root chromium of variety Black Panjgur of lentil (*Lens Culinaris* Medik.) affected by SA under salinity and chromium stress. Each bar in the graph represents the mean value of three replicates (\pm SD). Different letters represent significant different among treatments using LSD at $p < 0.05$

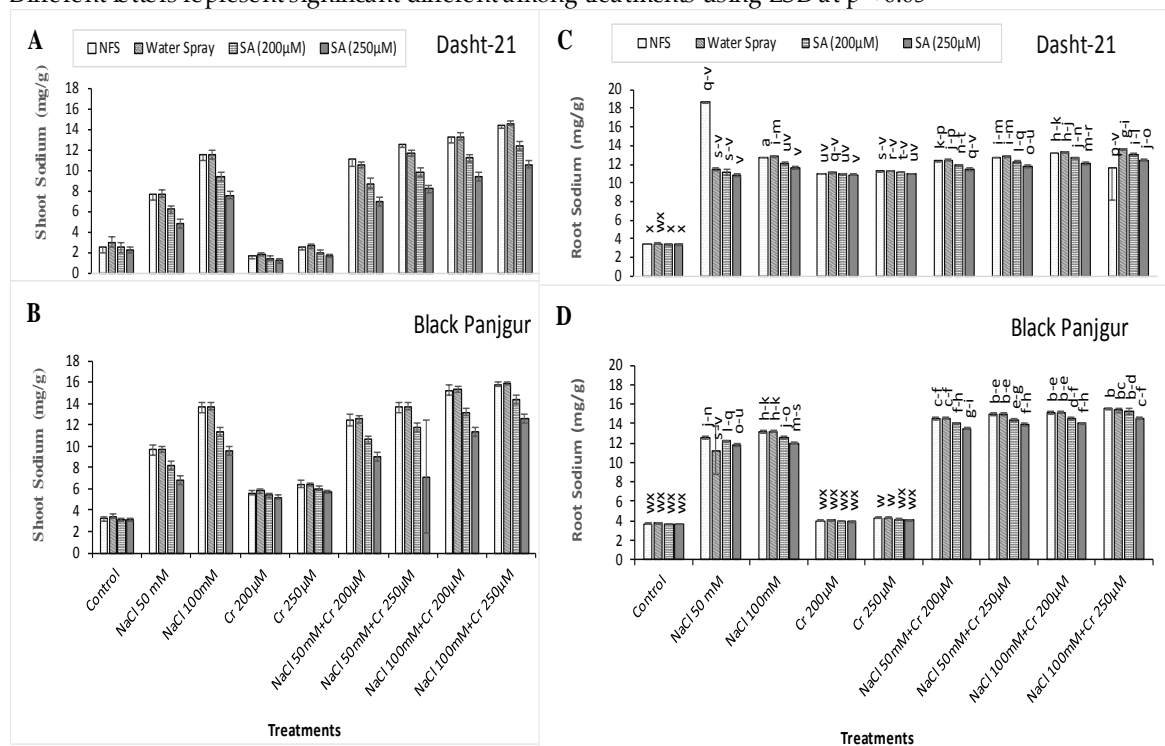


Fig. 2. Minerals **A=** shoot sodium of variety Dasht-21, **B=** shoot sodium of variety Black Panjgur, **C=** root sodium of variety Dasht-21, **D=** root sodium of variety Black Panjgur of lentil (*Lens Culinaris* Medik.) affected by SA under salinity and chromium stress. Each bar in the graph represents the mean value of three replicates (\pm SD). Different letters represent significant different among treatments using LSD at $p < 0.05$

ROOT SODIUM

Data regarding the concentration of sodium (Na⁺) in roots of two varieties of lentil (*Lens culinaris* Medik.) under salinity and chromium stress showed statistically significant results ($p < 0.05$). Maximum (18.68 mg/g DWT) sodium (Na⁺) was observed in roots of plants treated with NaCl 50mM + NFS, while minimum (3.37 mg/g DWT) was noted in roots of plants subjected to control + SA 250µM as well as in control + SA 200µM treatment in variety Dasht-21 (Fig. 2C). In variety Black Panjgur highest quantity (15.26 mg/g DWT) of sodium (Na⁺) was observed in NaCl 100mM + Cr 250µM + SA 200µM foliar Spray treatment, while it was noted lowest (3.60 mg/g DWT) under control + SA 250µM as well as in control + SA 200µM



treatment (Fig. 2D). Further data from graphs revealed that SA in its both concentration SA 250 μ M and SA 200 μ M decreases the level of sodium (Na⁺) in roots of plants of both varieties. Similar to sodium shoot trend the variety Black Panjgur root too performed better to compared variety Dasht-21 hampering Na concentration under SA supplementation (Fig. 2CD).

SHOOT MAGNESIUM

Data was obtained for concentration of Magnesium (Mg⁺) in shoots of two varieties of lentil (*Lens culinaris* Medik.) under salinity and chromium stress showed statistically non-significant results ($p > 0.05$). These results revealed that highest concentration (3.55mg/g DWT) of Magnesium (Mg⁺) was noted in control + SA 250 μ M foliar spray treatment, while lowest amount (3.05 mg/g DWT) was detected in plants grown under NaCl 100mM + Cr 250 μ M + NFS treatment in variety Dasht-21(Fig. 3A). In variety Black Panjgur maximum (4.99 mg/g DWT) Magnesium (Mg⁺) was also observed in control + SA 250 μ M foliar spray treatment, while it was minimum (3.26 mg/g DWT) under NaCl 100mM + Cr 250 μ M + NFS treatment (Fig. 3B).

In a nut shell, Magnesium (Mg⁺) level in shoots of plants of both varieties decreased under salinity and chromium stress as compared to control, while Mg concentration improved under SA application.

ROOT MAGNESIUM

Data obtained for concentration of Magnesium (Mg⁺) in roots of two varieties of lentil (*Lens culinaris* Medik.) under salinity and chromium stress showed statistically non-significant results ($p > 0.05$). Results revealed that the highest concentration (2.08 mg/g DWT) of Magnesium (Mg⁺) was noted in control + SA 250 μ M foliar spray treatment, while lowest amount (1.32 mg/g DWT) was detected in plants grown under NaCl 100mM + Cr 250 μ M + NFS treatment in variety Dasht-21(Fig. 3C). In variety Black Panjgur maximum (2.79 mg/g DWT) Magnesium (Mg⁺) was also observed in control + SA 250 μ M foliar spray treatment, while it was minimum (1.46 mg/g DWT) under NaCl 50mM + Cr 250 μ M + Water Spray treatment (Fig. 3D).

Concludingly, Magnesium (Mg⁺) level in roots of plants of both varieties decreased under different treatments of salinity and chromium stress as compared to control however SA application improved Mg concentration in root tissues.

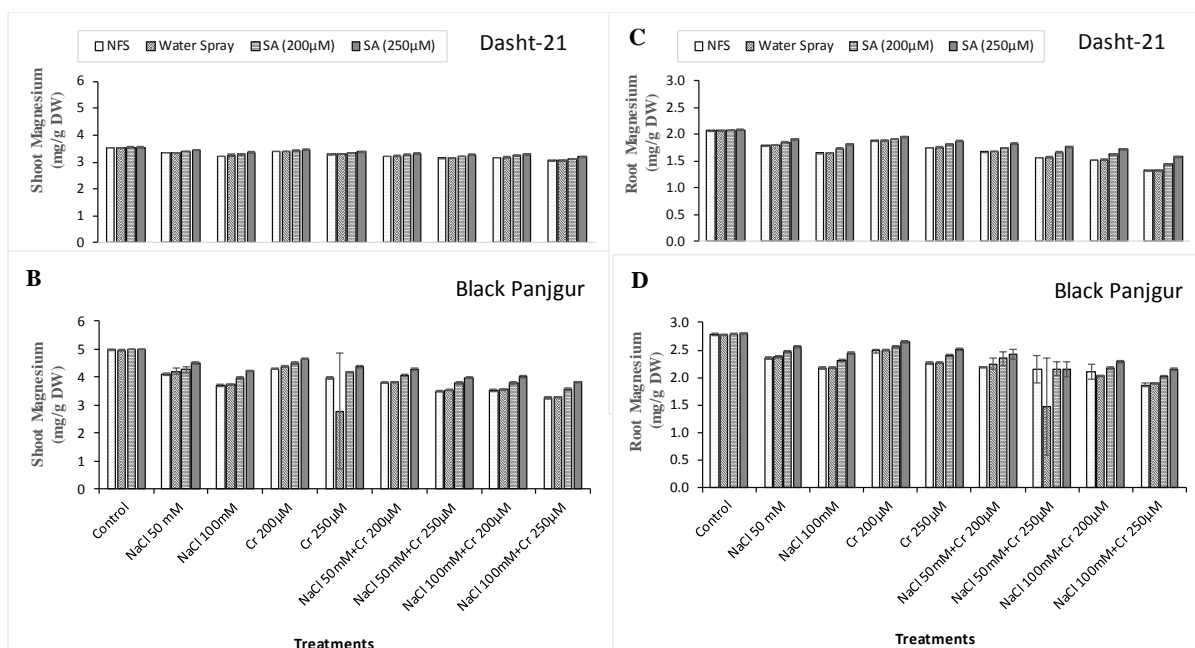


Fig. 3. Minerals **A=** shoot magnesium of variety Dasht-21, **B=** shoot magnesium of variety Black Panjgur, **C=** root magnesium of variety Dasht-21, **D=** root magnesium of variety Black Panjgur of lentil (*Lens Culinaris* Medik.) affected by SA under salinity and chromium stress. Each bar in the graph represents the mean value of three replicates (\pm SD). Different letters represent significant different among treatments using LSD at $p < 0.05$

SHOOT POTASSIUM

Data recorded for concentration of potassium (K) in shoots of two varieties of lentil (*Lens culinaris* Medik.) under salinity and chromium stress showed statistically non-significant results ($p > 0.05$). Maximum concentration (2.95%) of potassium (K) was noted in control + SA 250 μ M foliar spray treatment, while lowest amount (0.94%) was detected in plants grown under NaCl 100mM + Cr 250 μ M + NFS treatment in variety Dasht-21 (Fig. 4A). In variety Black Panjgur maximum (2.54%) potassium (K⁺) was also observed in control + SA 250 μ M foliar spray treatment, while it was minimum (1.11%) under NaCl 100mM + Cr 250 μ M + NFS treatment (Fig. 4B). Further data revealed that SA improved the concentration of potassium (K) in plants of both varieties.

In a nutshell, shoot potassium (K) decreased under different treatments of salinity and chromium stress however SA foliar application significantly improved. Moreover, variety Black Panjgur performed better as compared variety Dasht-21 in accumulating greater concentration of potassium (K) under stress and SA foliar spray (Fig. 4AB).

ROOT POTASSIUM

Data obtained for concentration of potassium (K) in roots of two varieties of lentil (*Lens culinaris* Medik.) under salinity and chromium stress showed statistically non-significant results ($p > 0.05$). These results revealed that highest value (1.36%) for potassium (K) level was observed in control + SA 250 μ M foliar spray treatment, however it was recorded lowest (0.40%) in plants grown under NaCl 100mM + Cr 250 μ M + NFS treatment in variety Dasht-21 (Fig. 4C). In variety Black Panjgur maximum (0.97%) potassium (K) was also observed in Cr 250 μ M + SA 250 μ M foliar spray treatment, while it was minimum (0.10%) under NaCl 100mM + NFS treatment (Fig. 4D).

Potassium (K) level in roots of plants of both varieties decreased under salinity and chromium stress as compared to control, while SA application improved K in roots (Fig. 4CD).

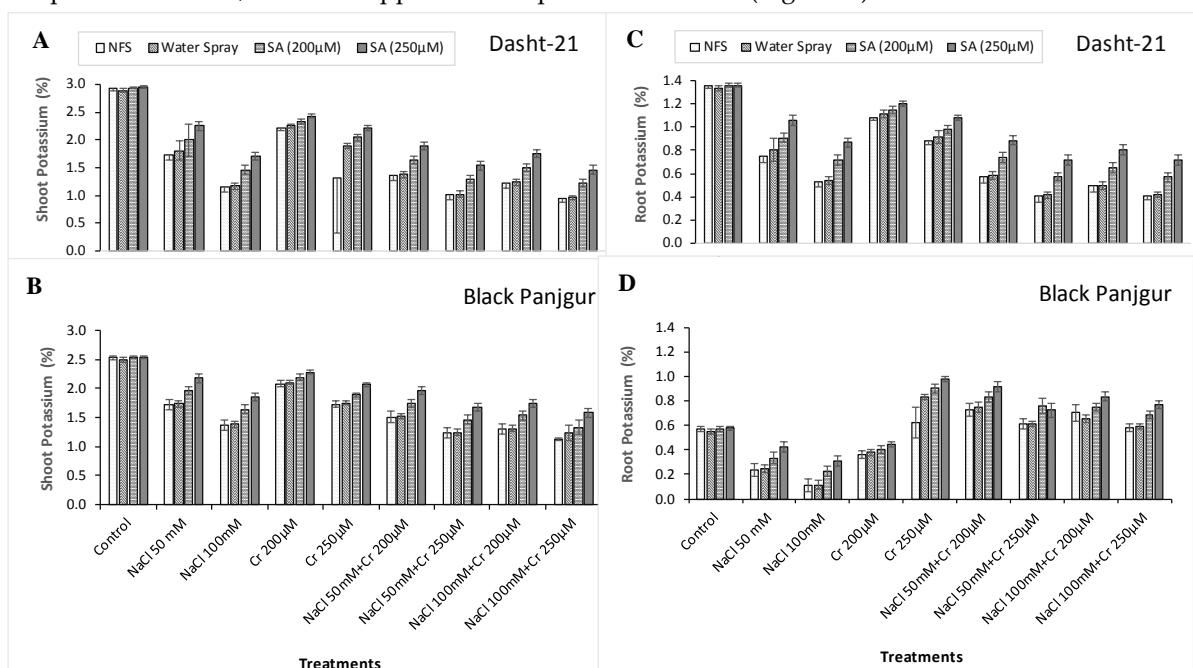


Fig. 4. Minerals **A**=shoot potassium of variety Dasht-21, **B**=shoot potassium of variety Black Panjgur, **C**= root potassium of variety Dasht-21, **D**= root potassium of variety Black Panjgur of lentil (*Lens Culinaris* Medik.) affected by SA under salinity and chromium stress. Each bar in the graph represents the mean value of three replicates (\pm SD). Different letters represent significant different among treatments using LSD at $p < 0.05$

DISCUSSION

The present research was conducted to assess the nutritional dynamics of two lentil (*Lens culinaris* Medik.) varieties, i.e., Dasht-21 and Black-Panjgur, under single and combined chromium and salinity stress with exogenous supplementation of Salicylic acid (SA). Considering the concentration of chromium (Cr) of present study, it was observed that in shoots and roots highest amount was observed under high chromium stress (250 μ M) i.e. (4.99 ppm) in shoots and (6.98 ppm) in roots of variety Dasht-21 (Fig. 1AC) while it was

noted highest in shoots (4.57 ppm) and in roots i.e. (6.46 ppm) in variety Black Panjgur which indicates that amount of chromium (Cr) is increased under high chromium (Cr) stress in shoots as well as in roots of both lentil varieties (Fig. 1BD). However, the concentration of chromium (Cr) also increased under salinity as well as under the combined stress of chromium and salinity in both varieties of lentil (Fig. 1A-D). Findings of our research are in agreement with the study of Sulistiani *et al.*, (2021), who reported that chromium accumulation decreased upto 19% in kale stems under chromium toxicity (3ppm) (33). The research of Huda *et al.*, 2016 supports the results of the present study that the concentration of Chromium (Cr) increases in shoots and roots of the rice plants under chromium toxicity (100 μ M) in comparison to the control, exhibiting a higher concentration in roots than shoots (34). The present study is in agreement with the report of Gupta and Seth, (2021) that exhibited an increased accumulation of chromium (IV) with an increase in chromium (IV) (50-100 mg/kg soil) concentration in shoots and roots of *Solanum lycopersicum* L. Roots accumulated more chromium (IV) than shoots (35). However, SA (250 μ M) decreased the chromium concentration in shoots, i.e. (3.89 ppm) and in roots, i.e. (5.4 ppm) in variety Dasht-21 (Fig. 1AC), while in variety Black panjgur it was reduced up to (2.89 ppm) in shoots and (4.95 ppm) in roots (Fig. 1BD). Thus, SA has a great impact in alleviating chromium toxicity in plants. Findings of Huda *et al.*, (2016) are in line with the present study that the application of SA significantly decreased the chromium concentration in shoots and roots of rice plants under chromium stress (100 μ M) (34). Gupta and Seth, (2021) in their study revealed that exogenously applied SA ameliorated the chromium toxicity by decreasing the chromium accumulation in shoots and roots of the tomato variety Pusa Ruby compared to non-stress conditions, as was also observed in our study (35).

Furthermore, considering Na concentration in lentil varieties (shoot and root) under Cr and salinity stress data revealed that under high salinity (100 mM+ NFS) the concentration of sodium (Na^+) increased in shoots (11.6 mg/g DWT) and in roots (12.78 mg/g DWT) of variety Dasht-21 (Fig. 2AC) while in variety Black Panjgur it was (13.66 mg/g DWT) in shoots and (13.19 mg/g DWT) in roots (Fig. 2BD) however concentration of sodium (Na^+) was intensively increased in shoots and roots of both varieties of lentil under combined stress of salinity and chromium (Fig. 2A-D). Findings of Alharbi *et al.*, (2022) are in correlation with the present study that salinity at the (400 mM) level built up maximum sodium (Na^+) concentration in leaves of pea plant (*Pisum sativum*) (36). However, the study of Ebrahimi and Bhatla (2011) is in line with the fact that under 80-160 mM NaCl level the accumulation rate of sodium (Na^+) increases in roots of sunflower during 20-30 days of growth, while in shoots it was pronounced more under (10-20 mM) treatments during 10-20 and 20-30 days of growth (37). Literature available corresponds with the present findings that concentration of sodium (Na^+) and Cl^- increased in shoots and roots of lentil plants grown under salt stress (75mM) (38). Previous findings also affiliate with our research study in red clover (*Trifolium pratense*) species of forage crop, where the amount of sodium (Na^+) increases in shoots, roots and leaves under salinity (100mM) (39). Furthermore, in present study it has been noted that SA (250 μ M) reduced the amount of sodium (Na^+) (7.6 mg/g DWT) in shoots and (11.58 mg/g DWT) in roots of variety Dasht-21 (Fig. 2AC) and in variety Black Panjgur it was reduced upto (9.6 mg/g DWT) in shoots and (12 mg/g DWT) in roots (Fig. 2BD) moreover, foliar spray of SA also decreased the concentration of sodium (Na^+) in shoots and roots of both varieties of lentil under combined stress of salinity and chromium (Fig. 2A-D). Additionally, the study of Bouallegue *et al.*, (2025) reported that application of SA (0.1 mM) and H_2O_2 (0.1 mM) significantly reduced the concentration of sodium (Na^+) in shoots and roots of lentil plants grown under salinity stress, as reported in the present research (38). Results of our study validate earlier findings that foliar application of SA on leaves of canola plants to examine the macro- and micro-elements, suggested that SA treatment decreased the concentration of sodium (Na^+) in leaves of canola plants grown under salinity stress while increasing the concentration of other nutrients such as K, N, Ca and Mg significantly (40).

Study of Talaat *et al.*, (2023a), Talaat *et al.*, (2023b) elaborates that different mechanisms have been reported in plants for mitigation of salinity stress through SA application, such as leaf water contents, chlorophyll contents, osmolyte accumulation and amelioration of oxidative stress by enhancing the activity of antioxidant enzymes (41, 42). Likewise, when Na^+ accumulation increases, the N, P, and K uptake are

reduced under salt stress, but SA application enhanced the N, P, and K levels and reduced the Na⁺ concentration in plant tissues.

In case of magnesium (Mg⁺) results of present study revealed that the concentration of magnesium (Mg⁺) reduced under salinity (100mM + NFS) in shoots (2.23 mg/g DWT) and roots (1.65 mg/g DWT) of variety Dasht-21 (Fig. 3AC) while in second variety i.e. Black Panjgur it was reduced upto (3.7 mg/g DWT) in shoots and roots (2.16 mg/g DWT) (Fig. 3BD). However, the amount of magnesium (Mg⁺) also decreased under chromium stress, but decreased intensively under the combined stress of salinity and chromium (Fig. 3A-D). The research of Sharavdorj *et al.*, (2022) supports our findings that concentration of magnesium (Mg²⁺) and potassium (K) decreases in stems and leaves of red clover (*Trifolium pratense*) species of forage crop, while it was lowest in roots under salinity (39). The study of Sulistiani *et al.*, (2021) reported contradictory that chromium (3 ppm) increased the magnesium (Mg⁺) absorption by 7%, as compared to chromium (1 ppm), which increased it to a small extent (33). According to (43), magnesium concentration was reduced in shoots and roots of two barley cultivars (Gairdner and CM72) under salinity compared to the control. The study of Ali *et al.*, (2012) agreed with the present findings that chromium toxicity (100 μM) decreased the Ca, Mg and K concentration in shoots and roots of rice seedlings under chromium stress compared to the control (44). Furthermore, SA (250 μM) enhanced the amount of beneficial mineral i.e. Mg in shoots (3.35 mg/g DWT) and roots (1.81 mg/g DWT) of variety Dasht-21 grown under salinity (100mM + NFS) (Fig. 3AC) while in other variety (Black Panjgur) it was also reduced in shoots (4.21 mg/g DWT) and roots (2.44 mg/g DWT) (Fig. 3BD). SA (250 μM) not only improved the amount of magnesium in salinity but also under chromium, as well as under combined stress of salinity and chromium (Fig. 3A-D). The study of Yildirim *et al.*, (2008) correlates with a recent study that increasing concentration of SA (0.25, 0.5, 1 mM) significantly decreased the Na concentration and increased the mineral contents (K, Ca, Mg) in shoots and roots of cucumber under salt stress compared to control (45). In addition, our results are also in line with the findings of Gunes *et al.*, (2007) that increasing concentration of SA (0.1, 0.5, 1 mM) increased the amount of magnesium in maize plants, but here, contrary to this, salinity also increased the concentration of magnesium in plants (46). Previous findings also validate that exogenous application of SA (0.5 mM) increases magnesium concentration in maize plants under salinity, as found in the present study (47).

Taking into account the potassium, the concentration of potassium (K) decreased under high salinity (100mM + NFS) in shoots (1.15%) and roots (0.53%) of variety Dasht-21 (Fig. 4AC), while in second variety i.e. Black Panjgur it was reduced upto (3.7 %) in shoots and roots (2.16 %) (Fig. 4BD). However, the amount of potassium (K) decreased under chromium stress but decreased intensively under the combined stress of salinity and chromium (Fig. 4A-D). Furthermore, the findings of (38) also correlate with the present study that salinity (75 mM) decreased the amount of potassium (K) and Calcium (Ca²⁺) in shoots and roots of lentil plants. However, the study of Sharavdorj *et al.*, (2022) also reported decreased concentration of magnesium (Mg²⁺) and potassium (K) stems and leaves of red clover (*Trifolium pratense*) species of forage crop, while it was observed to be lowest in roots under salinity (39). Under salinity maximum amount of potassium (K) was also noted in leaves of plants (36). Findings of Bouallegue *et al.*, (2025) reported that supplementation of SA (0.1 mM) and H₂O₂ (0.1 mM) increased the amount of potassium (K) in shoots and roots of lentil plants grown under salinity (75 mM) (38). Furthermore, findings of Sarker and Oba (2020) are also in line with the present study findings that salt stress decreased the concentration of potassium (K⁺) and increased sodium (Na⁺) contents in roots and leaves of lentil plants (48). Thus reduced potassium (K⁺)/sodium (Na⁺) ratio. Findings from study of Azooz, (2009) also correlate with the present study that the amount of Potassium (K⁺) decreased and increased sodium (Na⁺) in root and shoot of two faba bean genotypes namely genotype-125 and genotype-115 under salinity. Potassium (K⁺) content was significantly reduced in genotype-125. Sodium (Na⁺) concentration was lower in shoots than in roots of both genotypes, while Potassium (K⁺) content was higher in genotype-115 than in genotype-125(49). The present study also correlates with the findings of Islam *et al.*, (2016) that the amount of nutrients, e.g. potassium (K) and Iron (Fe), was significantly affected under chromium toxicity in maize plants (50). The amount of potassium (K) was significantly reduced in plants grown under Cr stress (50 ppm) as compared to control plants. In addition

the results of our study also showcase that SA (250 μM) enhances the amount of beneficial mineral potassium (K) in shoots (3.35%) and roots (1.81 %) of variety Dasht-21 grown under salinity (100mM + NFS) (Fig. 4AC) while in other variety (Black Panjgur) it was also reduced in shoots (1.36%) and roots (0.1%) (Fig. 4BD). SA (250 μM) not only improved the amount of potassium (K) in salinity but also under chromium, as well as under combined stress of salinity and chromium in both lentil varieties (Fig. 4A-D). Contrary to our findings, the study of (51) reported that pre-treatment of SA reduced the potassium concentration in leaves of tomato plants under salinity. Study of Azooz, (2009) correlates with present research that application of SA reduces sodium (Na^+) and increases Potassium (K^+), which increases the Na^+/K^+ ratio in both genotypes of faba bean (49). In a nutshell, under both single and combined stress of salinity and chromium, the level of sodium and chromium increased, and the concentration of magnesium and potassium decreased. SA supplementation played a vital role in mitigating the impact of salinity and chromium stress by decreasing the sodium and chromium levels and enhancing the concentration of potassium and magnesium in shoots and roots of the lentil variety seedlings.

Alghamdi *et al.*, (2023) reported in their findings that the combined stress of salinity and cadmium heavy metal caused >50 % reduction in plant growth parameters, chlorophyll contents, and stomatal conductance compared to control plants of quinoa (*Chenopodium quinoa* Wild) (52). It also caused 11-fold reactive oxygen species hydrogen peroxide and 61% decrease in membrane stability and reduced uptake of potassium ion (K^+) due to accumulation of Na^+ and Cd^{2+} ions in tissues. Furthermore, SA supplementation (0.1 mM) helped quinoa plants in better adaptation under combined cadmium and salinity stress, i.e. reduction of Na^+ and Cd^{2+} ions in plant tissues, enhanced activities of antioxidant enzymes such as superoxide dismutase (SOD), peroxidase (POD), ascorbate peroxidase (APX) and catalase (CAT).

CONCLUSION

The present study demonstrated that the nutrients/ minerals were affected by under-salinity as well as chromium stress. Sodium (Na^+) and chromium (Cr) increased under stress, while potassium (K^+) and magnesium (Mg^+) decreased under these stresses. Application of SA, a signalling molecule, played a vital role in mitigating the salinity and chromium stress by enhancing magnesium (Mg^+) and potassium (K^+) levels and reducing the Sodium (Na^+) and chromium (Cr) concentrations in roots and shoots of lentil (*Lens culinaris* Medik.) varieties. The study recommends SA foliar supplementation in mitigating the impacts of salinity and chromium toxicity. Further research on the underlying physiological and molecular mechanisms may provide valuable insights for developing lentil genotypes better adapted to heavy metal and salinity co-stress environments.

Conflict of interest:

Authors declared no conflict of interest.

Authors' contribution:

SA Data collection, writing original draft; KS Conceptualization, supervision, review & editing; AS Review & editing; SG Review writing & editing; TI Research field, review & editing; IA, AR and MF Mineral analysis; AM Review.

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