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The Ameliorative Role of 5-Aminolevulinic Acid (ALA) Under Cr Stress in Two Maize Cultivars Showing Differential Sensitivity to Cr Stress Tolerance

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Abstract

Heavy metal (HM) contamination of the environment is a serious threat to sustainable crop production. Among the HMs, chromium (Cr) is one of the most toxic HMs that is known to negatively affect growth and metabolic activities of diverse crop plants. The present study was designed to investigate the ameliorative role of 5-aminolevulinic acid (ALA) under Cr stress in two maize (*Zea mays* L.) cultivars showing differential sensitivity to Cr tolerance. ALA is a biosynthesis precursor and it has a dominant regulatory effect related to physiological, respiratory, and photosynthesis processes in various plant species. Three concentrations of Cr (0, 5, and 10 mg kg^{-1}) were tested under the graded levels of ALA application (0, 12.5, and 25 mg L^{-1}). The results indicated that Cr stress differentially reduced plant growth attributes, gas exchange characteristics, photosynthetic pigments, and biomass in both the cultivars. Oxidative stress increased as evidenced in the form of electrolyte leakage, malondialdehyde, and hydrogen peroxide (H_2O_2) accumulation in plants. The anti-oxidative enzyme activities, that is, catalase (CAT), superoxide dismutase (SOD), and peroxidase (POD) both in the leaves and roots of maize cultivars decreased due to Cr stress. The concentration of Cr increased in roots and shoots of maize under Cr levels without ALA. Under Cr stress, ALA exogenous application markedly enhanced plant growth, photosynthetic pigments, gas exchange capacity, and biomass. Furthermore, ALA application decreased the Cr-induced oxidative stress in maize cultivars by improving the activities of CAT, POD, and SOD in plants. After ALA application, the Cr concentrations and total Cr uptake by plants differently decreased in both cultivars. The 6103 cultivar of maize was found to be a tolerant cultivar against Cr stress due to its strong defensive system with a higher rate of antioxidant enzyme activities. On the other hand, the other maize cultivar (9108) was found to be a sensitive cultivar against Cr stress due to its weak defense system with higher contents of reactive oxygen species. These findings suggest that ALA can play a regulatory role in maintaining optimum plant growth and efficient photosynthetic processes under Cr-challenged habitats in maize. Thus, ALA application may be used as a sustainable remedial strategy to alleviate Cr-induced stress in maize cultivars.

Keywords Chromium · 5-Aminolevulinic acid · Maize · Photosynthetic pigment · Oxidative stress

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Introduction

Heavy metals (HMs) are non-essential, carcinogenic, and frequently enter into the food web by plant uptake and are passed to end consumers and cause serious health issues in humans (Wang and Chen 2009; Farid et al. 2018; Hussain et al. 2018a). The rapid industrialization and disposal of waste in the environment is a main threat to the agricultural ecosystem as well as growth and yield of crops (Wang et al. 2013). Among HMs, chromium (Cr) is one of the most non-essential toxic metals and the level of Cr is increasing in soil and water because of its common usage in industries (Ashfaque et al. 2017; Hussain et al. 2018b). Cr toxicity is causing serious problems in the soil, particularly in underdeveloped countries including Pakistan (Daud et al. 2014; Afshan et al. 2015) due to anthropogenic activities (Ali et al. 2013a; Hernández-Madrigal et al. 2018). Chromium is regarded as the 7th most abundant element in the Earth's crust and also classified under the top 20 hazardous substances by the Agency for Toxic Substances and Disease Registry (Oh et al. 2007). Chromium occupied the top slot as far as its carcinogenicity is concerned (Kishore et al. 2018). Chromium mainly exists in two oxidation states, that is, Cr(III) and Cr(VI) (Wu et al. 2016). Chromium(VI) is considered more toxic than Cr(III) owing to the high mobility and high oxidizing potential of Cr(III), therefore Cr(VI) causes deleterious effects on plant growth and productivity (Tripathi et al. 2012; Farid et al. 2017). The uptake of Cr in plants occurs along with uptake of water and other essential nutrients which leads to the alteration of different physiochemical systems of plants that ultimately reduce plant growth (Ranieri and Gikas 2014; Stambulska et al. 2018). Excess Cr usually induces the overproduction of reactive oxygen species (ROS), which leads to oxidative stress (Ahmad et al. 2010; Choudhary et al. 2012; Wu et al. 2018). Thus, Cr in plants caused oxidative stress, and as a result plants experience altered metabolic functions and cell death. Therefore, owing to its toxicity in the soil–plant system, this metal needs in-depth understanding in the plant soil continuum.

Different approaches have been used to alleviate the toxic impacts of various heavy metals in crops (Keller et al. 2015; Ahmad et al. 2016, 2017a, b; Rizwan et al. 2016; Qayyum et al. 2017; Farid et al. 2018). ALA exogenous application might have improved water transport efficiency of plants and recovered chloroplast injury under stressful environments (Gill et al. 2015; Herman et al. 2016). Plants can cope with various abiotic stresses with the application of plant growth regulators (PGRs). Exogenous application of PGRs to plants is one the effective means of boosting plant stress tolerance (Yiu et al. 2009; Dwivedi et al. 2018). 5-Aminolevulinic acid (ALA) is a common plant growth regulator (Bindu and Vivekanandan 1998; Akram and Ashraf 2013; Liu et al. 2016). ALA is a biosynthesis precursor, exists in bacteria, fungus, and amino acids of various plants and animals (Naeem et al. 2011; Xiong et al. 2018). It is known as a crucial plant growth regulator against the stress of various HMs (Ali et al. 2014). ALA has a dominant regulatory effect and it is related to physiological, respiratory, and photosynthesis processes in various plant species (Naeem et al. 2011; Xiong et al. 2018). ALA modulates key plant physiological processes such as seed germination (Wang et al. 2005; Han et al. 2018) rate of net photosynthesis (Wang et al. 2004; Xiaomeng et al. 2018), contributes to signaling of plastids to the nucleus (Czarnecki et al. 2012), and mediates plant abiotic stress tolerance (Akram and Ashraf 2013). Thus, these results suggest that ALA is an important signaling compound in mediating diverse plant processes under dynamic environmental pressures. Exogenous application of ALA has earlier been used to increase tolerance against cold stress in *Glycine max* (Balestrasse et al. 2010); *Solanum lycopersicum* (Liu et al. 2018), salt stress in *Brassica napus* (Naeem et al. 2012), and heat stress in *Cucumis sativus* (Zhang et al. 2012). Various activities of antioxidant enzymes can be controlled through the foliar application of ALA, so plants can be protected against a number of abiotic stresses in which salinity, low irradiance, cold and chilling are involved (Naeem et al. 2012). However, data are scarce on the effect of ALA-mediated Cr stress tolerance in maize cultivars. ALA exogenous application might have recovered cell injury due to Cr via reducing Cr mobility (Afshan et al. 2015; Ahmad et al. 2017a, b; Farid et al. 2018). Several studies reported the beneficial role of ALA under various stresses (Kosar et al. 2015; Air et al. 2018). Maize is the main concern of researchers due to its ability to survive in dynamic environmental regimes. The green fodder of maize is enriched with protein and its grains are enriched with edible oil. After wheat and rice crops, maize is a very important cereal crop in Pakistan. The metal stress had adverse effects on maize plants (Rehman et al. 2016; Rizwan et al. 2017). Chromium is known to induce a significant reduction in growth and yield of maize, and also depresses the antioxidant defense system (Anjum et al. 2017). Our hypothesis is that ALA may alleviate the Cr stress in maize plants under Cr stress conditions. The present study has been designed to highlight the impacts of exogenous ALA in alleviating Cr stress in two maize cultivars (6103 and 9108) with respect to biomass, photosynthesis, oxidative stress, antioxidants, and Cr uptake by plants.

Materials and Methods

Two maize cultivars including one tolerant (6103) and one sensitive (9108) were selected from our previous study (Habiba et al. 2018). The study was conducted in the Green House of the Government College University Faisalabad, Pakistan with a complete randomized design. The pots were filled with 7 kg of sandy clay loam soil having physicochemical properties as described (Table 1) with various Cr concentrations (0, 5, 10 mg kg^{-1}) by using $K_2Cr_2O_7$ as a source of Cr. Three concentrations of ALA (0, 12.5, and 25 mg L^{-1}) were selected for foliar application. The trial was conducted under natural conditions. After 15 days, thinning of plants was done and only morphologically homogenous plants were selected for further experiments. The selected levels of ALA were foliarly applied after 2 and 4 weeks of sowing the seeds. The experiment was harvested after 10 weeks of treatment. The growth characteristics including dry weights, leaf area, root length, plant height, number of leaves per plant, and leaves and stems dry weights were measured.

Chlorophyll Contents and Electrolyte Leakage

After 8 weeks of treatment, the chlorophyll and carotenoid contents were measured according to methodology of Porra et al. (1989), which was also antecedently described by Pei et al. (2010). The upmost abundantly stretched leaves were cut into small pieces and placed into test tubes in which deionized water was used up to 8 mL. Then the incubation was done at 32 °C for 2 h in a water bath and the EC1 was calculated. For electrolyte discharge, samples of plants were autoclaved at 121 °C for 20 min; then cooled at room temperature and later the EC2 calculated later (Dionisio-Sese and Tobita 1998). The electrolyte leakage (EL) was then calculated by using the following formula:

$$\text{Electrolyte Leakage} = (\text{EC1}/\text{EC2}) \times 100. \tag{1}$$

Table 1 Soil physicochemical properties

Texture	Sandy clay loam
Sand (%)	52.0
Silt (%)	24.0
Clay (%)	24.0
ECe (dS m^{-1})	2.86
pH (1/2.5 soil-to-water ratio)	7.65
Organic matter (%)	0.34
SAR ($mmol^{-1}$)1/2	5.60
HCO_3 (mmol L^{-1})	3.68
Available P (mg kg^{-1})	2.16
SO_4^{2-} (mmol L^{-1})	6.48
Cl^- (mmol L^{-1})	2.19
K^+ (mmol L^{-1})	0.03
Na^{2+} (mmol L^{-1})	3.48
$Ca^{2+}+Mg^{2+}$ (mmol L^{-1})	3.69
Available Zn^{2+} (mg kg^{-1})	0.72
Available Cu^{2+} (mg kg^{-1})	0.23
Available Cr^{6+} (mg kg^{-1})	0.17

Determination MDA and H_2O_2 Contents and Antioxidant Enzyme Activity

The MDA contents in roots and leaves were obtained by the method given by Heath and Packer (1968) through the reaction of thiobarbituric acid (TBA) and further modified by Dhindsa et al. (1981) followed by Zhang and Kirkham (1994). The samples of roots and leaves (0.25 mg) were mixed into 5 mL of 0.1% trichloroacetic acid. Hydrogen peroxide was measured by homogenizing the leaf and root tissues by use of 3 mL of phosphate buffer with a concentration of 50 mM and the pH was kept at 6.5. Afterwards, the homogenized samples were centrifuged for 25 min. The extracted solution (3 mL) was used with one milliliter of titanium sulfate of percentage 0.1% along with the H_2SO_4 20% (v/v) and it was centrifuged for 15 min. Then the absorbance was taken at 410 nm to calculate the supernatant intensity (Jana and Choudhuri 1981). The coefficient of extinction with 0.28 μmol^{-1} cm^{-1} was used for the calculation of H_2O_2 contents.

The activities of superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD) in roots and leaves were measured by a spectrophotometer via the given procedure of Zhang (1992). The activity of CAT was examined via the use of the Aebi (1984) method.

Chromium Concentration

The digestion of plants (1.0 g each) was done in HNO_3:$HClO_4$ (3:1, v:v) as reported by Rehman et al. (2015). An atomic absorption spectrophotometer was used to determine the Cr concentration in maize.

Statistical Analysis

The data were evaluated by SPSS (a statistical software) by using a multivariate post hoc test and followed by the Duncan test to check the interaction between the significant values. A significant difference between the values was defined at $P < 0.05$ and shown by different letters.

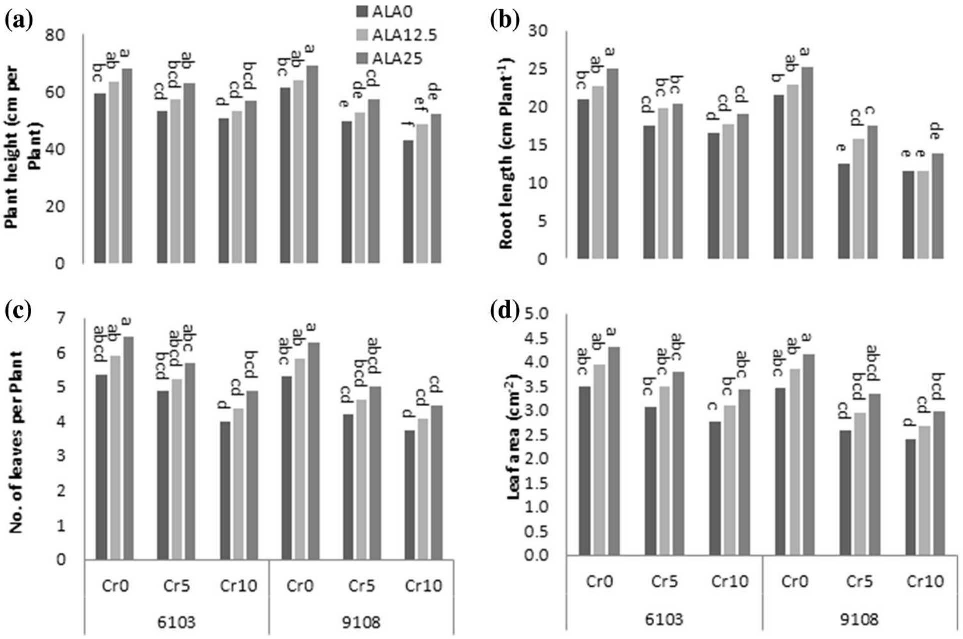

Fig. 1 Impact of chromium on plant height, root length, no. of leaves, and leaf area in two different hybrids of maize, one is tolerant (6103) and other is sensitive (9108), cultivated in soil along with three different chromium levels (0, 5, and 10 mg kg^{-1}) and three different 5-aminolevulinic acid levels (0, 12.5, 25 mg L^{-1}) with three replicates. The significant difference between the values is at $P < 0.05$ which is shown by different letters

Results

Plant Growth Traits

The data regarding plant growth in terms of plant height, root length, number of leaves per plant, and leaf area are shown in Fig. 1. The results indicated that maximum root and shoot length, number of leaves per plant, and leaf area were observed in control plants without Cr application. The maximum reduction in all of these attributes was observed under 10 mg kg^{-1} Cr concentration. As indicated in Fig. 1, with increasing concentration of Cr, the above plant parameters gradually reduced; however, this reduction was more severe in the 9108 than in the 6103 cultivar of maize. The application of ALA markedly enhanced plant height, root length, and number of leaves per plant in all concentration of Cr. The root length increased by 19 and 15% in Cr 0 and 5 mg kg^{-1}, respectively, at ALA 25 mg L^{-1} level in 6103, and increased by 16 and 40% in Cr 0 and 5 mg kg^{-1}, respectively, at ALA 25 mg L^{-1} level in 9108.

Cr toxicity significantly reduced the dry weight of roots, leaves, and stems as shown in Fig. 2. Cr stress reduced the dry weight of shoots in both cultivars and this reduction was more severe in 9108 as compared to 6103. The dry weights of leaves and roots also reduced under Cr stress. The foliar use of ALA enhanced the dry weight of roots, leaves, and stems in both stressed and control plants of both cultivars. The dry weights of stems increased by 17, 25, and 33% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at ALA 25 mg L^{-1} level in 6103, and increased by 18, 25, and 35% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at ALA 25 mg L^{-1} level in 9108.

Photosynthetic Parameters

The exposure of maize cultivars to Cr stress minimized the studied photosynthetic parameters (Fig. 3). Cr stress reduced stomatal conductance, net photosynthetic rate, and transpiration rate in both cultivars in a concentration-dependent manner. The maximum reduction in these parameters was observed at 10 mg kg^{-1} of Cr concentration; however, this reduction was maximum in 9108 than 6103 cultivar. The application of ALA enhanced the photosynthetic parameters at all concentration of Cr. The most beneficial level of ALA was 25 mg L^{-1} in all Cr levels applied. The net photosynthetic rate was enhanced by 10, 15, and 14% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at ALA of 25 mg L^{-1} in 6103, and increased by 12, 14, and 15% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at ALA of 25 mg L^{-1} in 9108.

Chlorophyll Contents and Carotenoids

Photosynthetic pigments and carotenoids were reduced under Cr stress (Fig. 4). The highest reduction was observed at the 10 mg kg^{-1} Cr concentration as compared with their relative controls. It was also noticed that 9108 was a Cr susceptive cultivar because it showed the maximum reduction in chlorophyll pigments at both (5 and 10 mg kg^{-1}) levels of Cr. The foliar supply of ALA markedly enhanced the chlorophyll pigments in stressed and non-stressed plants. The total chlorophyll contents were enhanced by 13, 10, and 17% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at the ALA 12.5 mg L^{-1} level in 6103, and increased by 10, 12, and 17% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at the ALA 12.5 mg L^{-1} level in 6103.

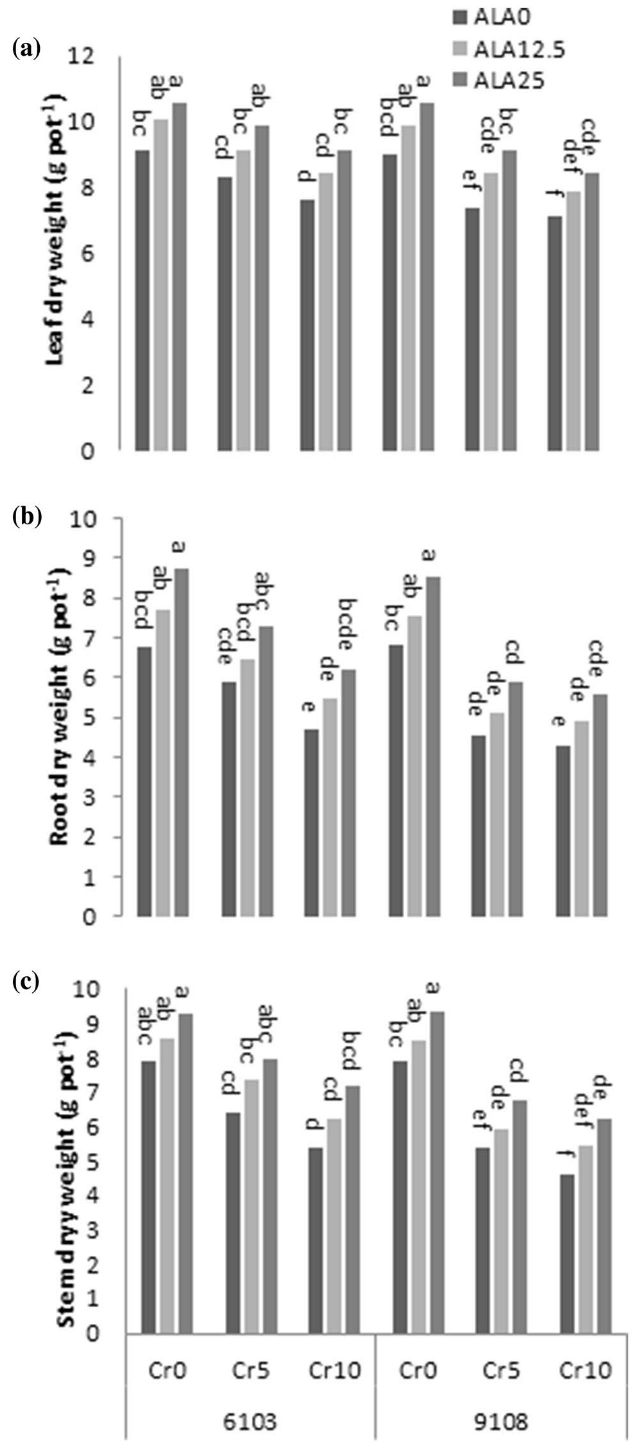

Fig. 2 Impact of chromium on root, stem, and leaves dry weights (**c, b, a**), respectively, in two different hybrids of maize, one is tolerant (6103) and other is sensitive (9108), cultivated in soil along with three different chromium levels (0, 5, and 10 mg kg^{-1}) and three different 5-aminolevulinic acid levels (0, 12.5, 25 mg L^{-1}) with three replicates. The significant difference between the values is at $P < 0.05$ which is shown by different letters

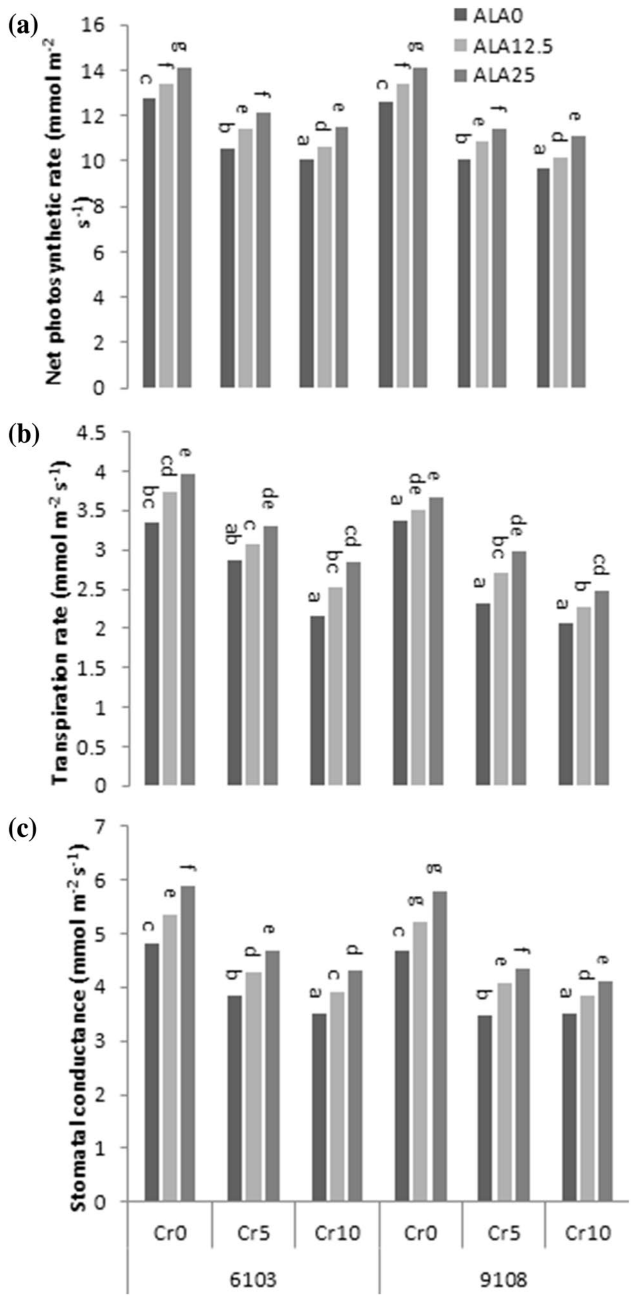

Fig. 3 Impact of chromium on net photosynthetic rate, stomatal conductance, and transpiration rate (**c, b, a**), respectively, in two different hybrids of maize, one is tolerant (6103) and other is sensitive (9108), cultivated in soil along with three different chromium levels (0, 5, and 10 mg kg^{-1}) and three different 5-aminolevulinic acid levels (0, 12.5, 25 mg L^{-1}) with three replicates. The significant difference between the values is at $P < 0.05$ which is shown by different letters

Antioxidant Enzyme Activities

The leaf and root enzymatic activities are shown in Fig. 5. The Cr stress potentially disturbs the enzymatic actives in maize plants. Cr stress (5 and 10 mg kg^{-1}) reduced the activities of SOD, POD, and CAT in both roots and shoots

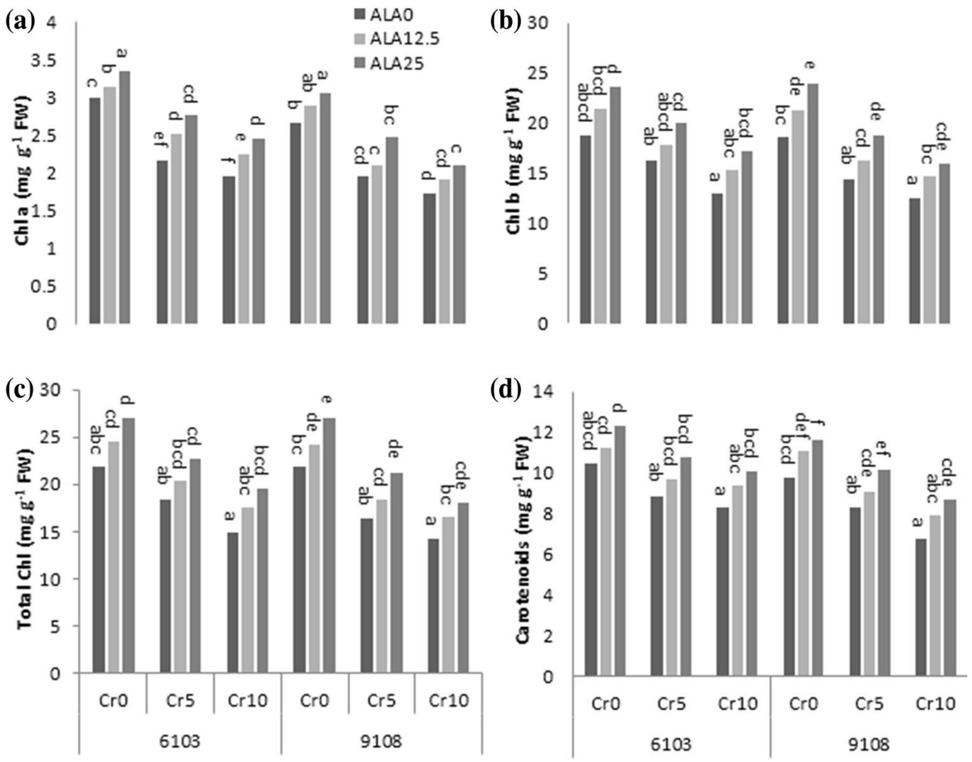

Fig. 4 Impact of chromium on Chl (**a, b**, total) and carotenoids (**a, b, c, d**), respectively, in two different hybrids of maize, one is tolerant (6103) and other is sensitive (9108), cultivated in soil along with three different chromium levels (0, 5, and 10 mg kg^{-1}) and three different 5-aminolevulinic acid levels (0, 12.5, 25 mg L^{-1}) with three replicates. The significant difference between the values is at $P < 0.05$ which is shown by different letters

of maize when compared to their relative controls; however, this reduction was maximum in the 9108 cultivar compared to 6103 which demonstrated that 9108 is a susceptive cultivar. The greatest reduction was noted at the 10 mg kg^{-1} Cr concentration in both varieties. Application of 25 mg L^{-1} ALA was found to be the best for significantly increasing the activities of SOD, POD, and CAT in both roots and shoots at all concentrations of Cr. The POD activities in plant roots increased by 25, 32, and 36% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at the ALA 25 mg L^{-1} level in 6103 and increased by 22, 29, and 39% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at the ALA 25 mg L^{-1} level in 9108.

Electrolyte Leakage, MDA, and H_2O_2 Contents

The oxidative stress parameters like EL, MDA, and H_2O_2 contents were analyzed to determine the oxidative stress in maize cultivars under different concentrations of Cr (Fig. 6). The results demonstrated that under Cr stress EL, MDA, and H_2O_2 contents markedly increased; however, this effect was maximum at 10 mg kg^{-1} Cr concentration. It was also noticed that EL, MDA, and H_2O_2 contents were high in 9108, indicating that 9108 is a Cr susceptive cultivar. Application of ALA minimized EL, MDA, and H_2O_2 contents in both cultivars at all concentration of Cr when compared to their relative controls. The EL contents in plant leaves were decreased by 15, 19, and 18% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at the ALA 25 mg L^{-1} level in 6103, and decreased by 12, 17, and 19% in Cr 0, 5, and 10 mg kg^{-1}, respectively, at the ALA 25 mg L^{-1} level in 9108.

Cr Concentration in Different Parts of Plant

The endogenous concentration of Cr markedly increased in both parts of the maize plants with increasing exogenous Cr concentrations (Fig. 7). The values of Cr in leaves were 50.32 mg kg^{-1} in 6103 and in 9108 it was 54.66 mg kg^{-1} at the higher Cr concentration (10 mg kg^{-1}). The Cr concentration was higher in roots as compared to the leaves in both cultivars. When foliar ALA was applied in both cultivars, it markedly decreased the Cr uptake in both parts of the plants such as, values of Cr in roots were recorded as 41.32 mg kg^{-1} in 6103 and in 9108 the values were noted as 48.65 mg kg^{-1} in comparison with the respective Cr concentrations alone.

Discussion

Chromium treatments alone reduced the morpho-physiological parameters and dry weights in both cultivars (Figs. 1, 2). This reduction might be due to the inhibitory impacts of Cr on plant growth and biomass (Ahmad et al. 2017a, b; Farid et al. 2017; Hussain et al. 2018b). The reduction in plant biomass and growth has been noticed in various crops (Saleem et al. 2015; Tassi et al. 2017). However, ALA

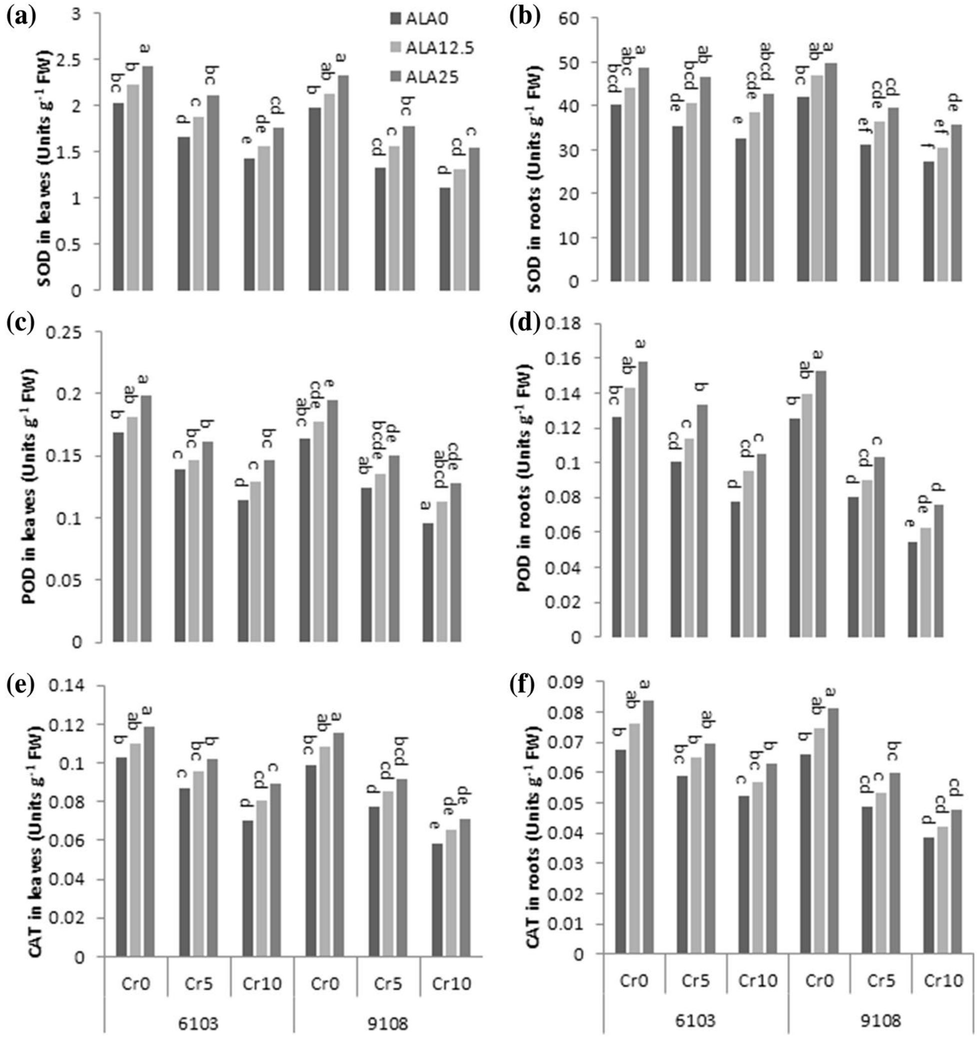

Fig. 5 Impact of chromium on SOD leaf and root (**a, b**), POD leaf and root (**c, d**), and CAT leaf and root (**e, f**) in two different hybrids of maize, one is tolerant (6103) and other is sensitive (9108), cultivated in soil along with three different chromium levels (0, 5 and 10 mg kg^{-1}) and three different 5-aminolevulinic acid levels (0, 12.5, 25 mg L^{-1}) with three replicates. The significant difference between the values is at $P < 0.05$ which is shown by different letters

exogenous application potentially reduced the Cr toxic effect and improved plant biomass and growth in a dose-additive manner in both studied maize cultivars. Several studies reported the beneficial role of ALA under various stresses (Kosar et al. 2015; Ahmad et al. 2017a, b; Air et al. 2018). ALA exogenous application might have recovered cell injury due to Cr via reducing Cr mobility (Afshan et al. 2015; Farid et al. 2018).

Photosynthetic parameters, chlorophyll contents, and carotenoids were also reduced under Cr treatments alone as shown in Figs. 3 and 4. The reduction in photosynthetic parameters might be due to the lower efficiency to transport the water from roots to upper parts of plants due to Cr toxicity. This type of reduction in photosynthetic parameters has been described in plants under heavy metal stress (Shakoor et al. 2014; Farid et al. 2018). The reduction in chlorophyll contents and carotenoids might be due to chloroplast destruction (Mohanty et al. 1989; Balasaraswathi et al. 2017) or electron transport chain inhibition (Vassilev et al. 1995; Srivastava et al. 2018). Similar responses of Cr have been demonstrated in Brassica under Cr toxicity (Ali et al. 2015; Nafees et al. 2018). However, ALA exogenous application potentially reduced the Cr toxic effect and improved plant photosynthesis, chlorophyll contents, and carotenoids in both maize cultivars. ALA exogenous application might have improved water transport efficiency of plants and recovered chloroplast injury under stress (Gill et al. 2015; Herman et al. 2016).

Our results depicted that the activities of antioxidant enzymes were reduced, whereas reactive oxygen species were enhanced in both cultivars under Cr treatments alone (Figs. 5, 6). The reduction in the enzyme activities might be due to the overproduction of reactive oxygen species due to Cr toxicity (Tauqeer et al. 2016) and enhancement in reactive oxygen species might be due to plants poor defensive mechanism due to Cr toxicity (Farid et al. 2017). However, ALA exogenous application potentially reduced the Cr toxic effect and improved plant enzyme activities while scavenging reactive oxygen species in both maize cultivars. ALA exogenous application might

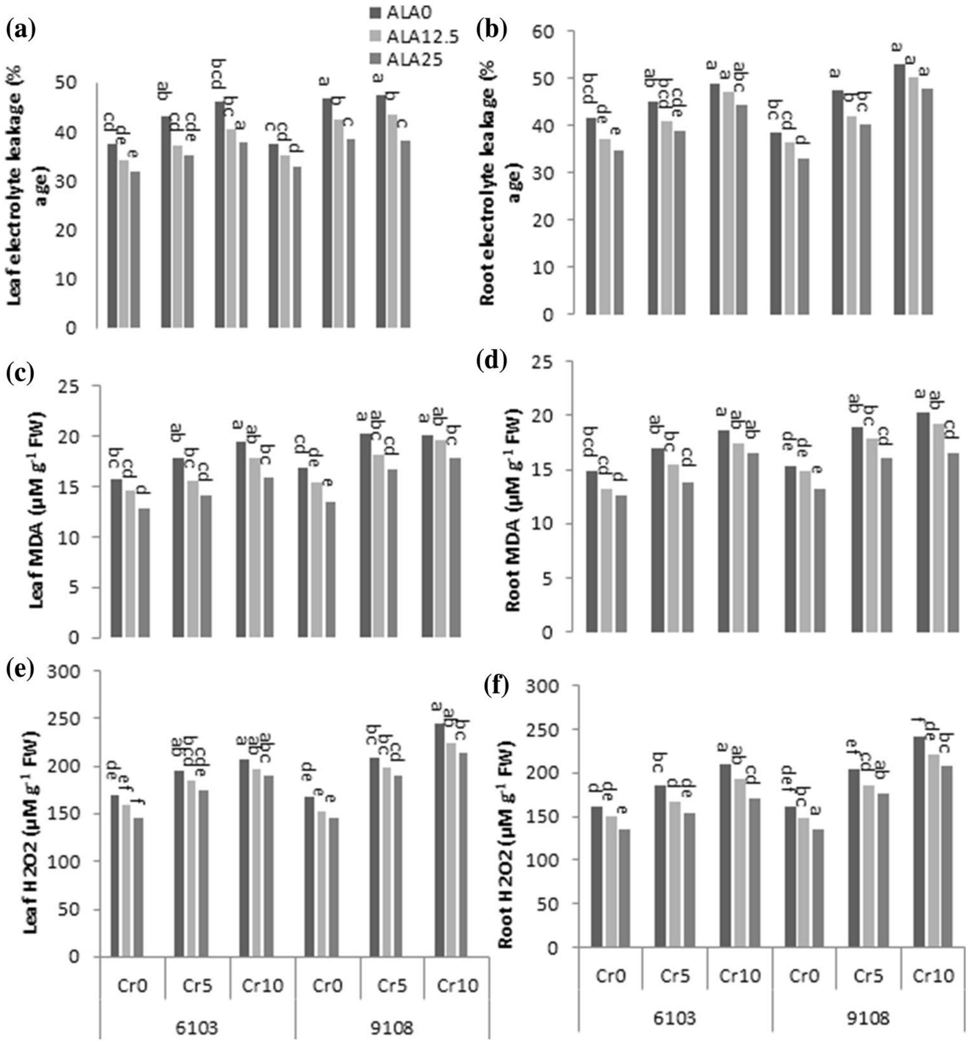

Fig. 6 Impact of chromium on leaf EL (**a**), root EL (**b**), leaf MDA (**c**), root MDA (**d**), leaf H_2O_2 (**e**), and roots H_2O_2 (**f**) in two different hybrids of maize, one is tolerant (6103) and other is sensitive (9108), cultivated in soil along with three different chromium levels (0, 5, and 10 mg kg^{-1}) and three different 5-aminolevulinic acid levels (0, 12.5, 25 mg L^{-1}) with three replicates. The significant difference between the values is at $P < 0.05$ which is shown by different letters

have improved the plant self-defense system by promoting antioxidant enzyme activities and scavenging oxygen reactive species (Ali et al. 2015; Gill et al. 2015).

Both the uptake and translocation of Cr increased with increasing concentrations of Cr alone in a dose-additive manner both in leaves and roots of both maize cultivars (Fig. 6). Similar results have been found in various crops (Gill et al. 2015; Jabeen et al. 2016; Ahmad et al. 2017a, b) under Cr stress. However, ALA exogenous application potentially lowered the Cr uptake and translocation in both maize cultivars. This reduction in metal uptake is due to the ameliorative role of ALA towards heavy metals under stressful conditions (Gill et al. 2015; Farid et al. 2017). Moreover, ALA might have recovered plant injuries by improving their defense system. More Cr uptake was observed in 9108 as compared with 6103 which showed that 9108 is more sensitive towards Cr stress tolerance than 6103.

Conclusion

The Cr-only treatment markedly reduced plant growth, photosynthesis, antioxidant enzyme activities, and enhanced ROS contents in both cultivars. ALA exogenous application significantly reduced Cr-induced stress by reducing Cr translocation to shoots in both studied cultivars (9108–6103). ALA foliar application decreases the oxidative stress and increased the activities of antioxidant enzymes under Cr toxicity. Hence, exogenous application of ALA is beneficial to alleviate heavy metal toxicity in maize and probably in other plants. However, further studies are needed to understand the ALA detailed mechanisms under heavy metals stress in different plants species.

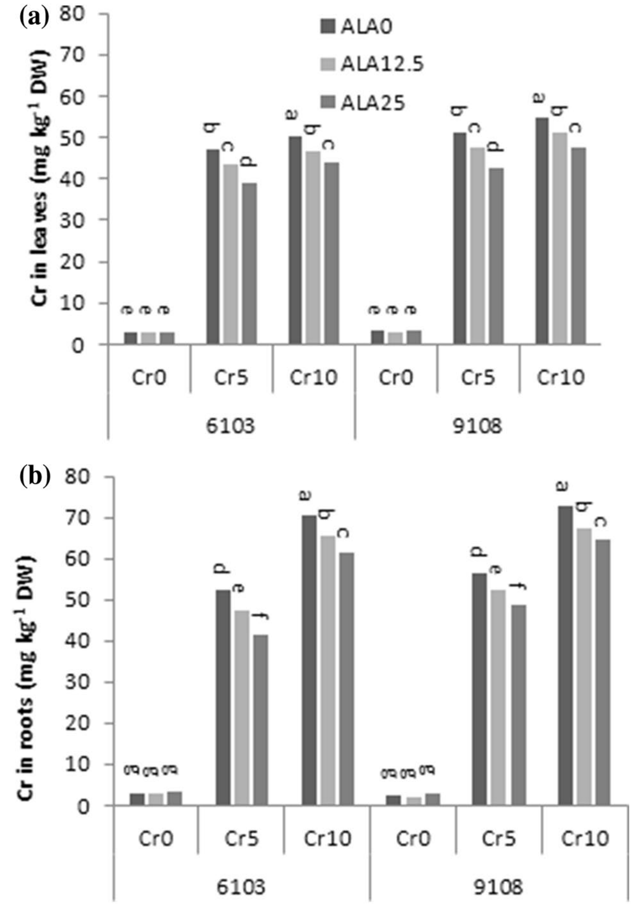

Fig. 7 Chromium uptake in leaves (**a**) and roots (**b**) in two different hybrids of maize, one is tolerant (6103) and other is sensitive (9108), cultivated in soil along with three different chromium levels (0, 5, and 10 mg kg^{-1}) and three different 5-aminolevulinic acid levels (0, 12.5, 25 mg L^{-1}) with three replicates. The significant difference between the values is at $P < 0.05$ which is shown by different letters

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Compliance with Ethical Standards

Conflict of interest All the authors do not have any conflicts of interest.

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