Combined application of Citric acid and 5-aminolevulinic acid assisted phyto-management of chromium contaminated soil by sunflower (*Helianthus annuus* L.)

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Phytoremediation assisted with different amendments, is receiving much attention around the world due to its high efficiency, low cost and ease of handling. The present study was performed to assess the combine role of citric acid (CA) and 5-aminolevulinic acid (5-ALA) in enhancing chromium (Cr) extraction through sunflower. Healthy seeds of sunflower were grown in Cr spiked soil (0, 5, 10 & 20 $mgkg^{-1}$) and exogenously supplied with CA (0, 2.5 & 5mM) and 5-ALA (0, 10, 20 mgL^{-1}) at juvenile stage. Plants were harvested after 8 weeks of treatments. The results showed a significant reduction in agronomic traits and biomass of sunflower. In response to Cr stress, higher production of reactive oxygen species (ROS) such as malondialdehyde (MDA) hydrogen peroxide (H_2O_2) and electrolyte leakage significantly reduced the photosynthetic pigments (Chlorophyll a & b), soluble proteins, gas exchange attributes (stomatal conductance, transpiration rate water use efficiency) and the activities of anti-oxidant enzymes. Increasing concentration of Cr (0 to 10 $mgkg^{-1}$) significantly enhanced the activities of ascorbate (APX), catalases (CAT), superoxide dismutase (POD) and peroxidases (POD) while theses activities tend to decrease at higher Cr level (20 $mgkg^{-1}$). The combine addition of CA and 5-ALA significantly alleviated the Cr induced toxic effects on sunflower. Citric acid and 5-ALA enhanced plants' agronomic and physiological attributes by lowering ROS and electrolyte leakage. Further, the addition of CA and 5-ALA significantly up regulated the activities of antioxidant enzymes both in leaves and roots of sunflower. Increasing Cr concentration in soil enhanced Cr uptake and accumulation in all parts of sunflower which was further boosted up by the combined application of CA and 5-ALA. Thus, the present study suggested that the sunflower along with CA and 5-ALA could be utilized to decontaminate the Cr contaminated soils.

Keywords: accumulation, chromium, chelator, sunflower