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Chelate-assisted Phytoextraction of Chromium in Drought Resistant and Drought Succeptible variety of Rice

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Abstract

Due to its wide industrial use, Cr is considered a serious environmental pollutant. Toxicity of Cr varies with its valence state (Cr^{+3} and Cr^{+6}). In the present study, the uptake of Cr^{+6} were studied in drought resistant and drought susceptible variety of rice by applying two concentrations of Cr 10mg and 50mg/Kg of soil supplementing with various chelators such as Ethylene Diamine Tetracetic Acid (EDTA), Salicylic Acid(SA) and Citric Acid(CA). Accumulation of chromium showed an increasing trend with gradual increase in chromium concentration from 10mg to 50mg/kg of soil. Both the varieties of plants were grown under water logged and drought condition. Supplementation with chelating agents also showed an increase trend of chromium accumulation in presence of EDTA than SA and CA. The drought resistant variety showed more Cr-uptake than the drought susceptible variety when grown under both drought condition and water logged condition. The treatment of Cr 50mg with EDTA depicts more uptake or Cr than all the treatments. The result of the present study may help in phytoremediating heavy metal pollutants from the environment.

Keywords: Chromium, chelate-assisted phytoextraction, rice cultivars, drought resistant, drought succeptible.

Introduction

Chromium was first discovered in the Siberian red lead ore (crocoite) in 1798 by the French chemist vauquelin. The toxicity of chromium depends on its valence state. Cr^{+6} is highly toxic and mobile where as Cr^{+3} is less toxic and mobile. Cr^{+3} is mainly found bound to organic matter in soil and aquatic environment as reported by Becquer et al[1], Panda and Patra[2]. The first interaction of Cr has with a plant is during its uptake process. Cr is a toxic and non essential element to plants; hence they don't possess specific mechanisms for its uptake. Therefore, the uptake of this heavy metal is through carriers used for the uptake of essential metals for plant metabolism. Bioaccumulation involves the uptake of contaminants by plant roots, followed by their translocation through the xylem and accumulation in the shoots and leaves. Ghosh and Singh[3] reports soil contamination is a major environmental concern due to dispersal of industrial and urban wastes generated by human activities. Phyto accumulation has normally been applied to polluted soils. The method relies on the identification, cultivation and harvesting of known contaminant tolerant plants. For the process to be economically viable, a cultivated plant must hyper accumulate the contaminants and produce large biomass.

Behbahaniania et al[4] reports heavy metals are detrimental because of their non-biodegradable nature and long biological half-life and their potential to accumulate in different body parts.

The enhancement of metal on bioavailability in soil by addition of metal chelates is an essential component of chelate-assisted phytoextraction. Because of the high binding capacity for metallic micronutrient by soil particles, plants have evolved several strategies for increasing their soil bioavailability by producing metal chelating compounds.

The metal appears to move to shoot, as a metal chelate complex. After chelate assisted induction the plant becomes a wick, which drives the chelated metal from the soil solution into the leaves. The operation of the wick relies on a first surface area collection system provided by the roots and by the efficient capillary system inside the plant. Recent reports have demonstrated that through the proper application of chelating agents to the soil, relatively insoluble element can be solubilised and metal available for plant uptake.

Irrigation of crops with an appropriate chelate is a possible method of enhancing contaminant bioavailability and root to shoot translocation, particularly in the case of trace metals reported by Huang et al[5]. Without destroying the soil structure and fertility, the best method of reratingsoil contamination is phytoextraction or phytoaccumulation.

Material and Methods

Rice (oryza sativa L.) cultivars sahabhagi and Lalat were chosen for the present research as drought resistant and drought succeptible variety respectively. Potassium dichromate was used as the source of hexavalent chromium. Graded dry uniform seeds of rice were surface sterilized by soaking in 0.1% $HgCl_2$ solution for 5 minutes and then thoroughly washed with tap water and distilled water. Then the seeds were germinated in various pots containing Cr 10mg and 50mg / kg of soil both in the presence and absence of different chelating agents such as EDTA, SA and CA. Separate sets of plants were grown both under water logged condition and drought condition. The water logged condition was maintained by dipping the lower level of the stem of the plant. The water level was increased with growth of the plant. Water was supplied to the plant under drought condition only once at the time of germination.

Analysis of Cr content: 15 days old rice seedlings were collected from culture pots and oven dried. Root and shoot weight was measured separately. To the weighed dried plant samples HNO_3 and $HClO_4$, in the ratio 10:1 was added and kept for 24 hours. Then the acid mixed plant samples were digested on a hot plate maintaining temperature at 60^0C. The acid digestion process was continued until all the plant materials were completely digested. Then the acid digested solution was filtered and the final volume was made upto 25ml. The dilute solution was then analysed with the help of an Atomic Absorption Spectrophotometer to measure what amount of chromium was accumulated in plant parts under different treatment conditions.

Results and Discussion

The uptake of Cr was increased with increase in the Cr concentrations from Cr 10mg to Cr 50mg/kg of soil in both drought resistant and drought succeptible variety of rice (figure-1 to 4). At both the concentrations of Cr (10mg and 50mg), the Cr-uptake of the seedlings treated with Cr EDTA combination was increased as compared to the seedlings treated with Cr-SA and Cr-CA combinations respectively in both the verities of rice. The uptake of Cr was more in the drought resistant variety than the drought succeptible variety. Total Cr content was found to be more in the root than the shoot in both the varieties grown under both water logged and drought conditions.

Discussion: In the present study the drought resistant rice cultivatar "Sahabhagi" exhibited higher Cr uptake than the drought succeptible "Lalat" both grown under water logged and drought conditions. The drought resistant Sahabhagi seedlings showed more Cr-uptake in drought condition than the water logged condition.

Bahmanyer[6] reported that more chromium was accumulated in the root of rice than the whole shoot and grain. Low concentration of Cr in the grains than roots of rice was reported by Sauerbeck[7]. The poor translocation of Cr from roots to aerial parts in temperate trees was reported by Pulford et al[8.]

Davies et al[9] reported that the uptake and translocation of chromium to shoot was enhanced by mycorrhizae and organic acids (citric and oxalic) playing important role in phytorenediation of Cr-comuninated soil. Low toxicity multidentate chelating agents such EDTA are used to enhance the bioavailability of heavy metal for plant uptake was reported by Leyval et al[10] and Turnau[11]. Nowack et al[12] reported that the chelating agents have high metal extraction potential. The uptake of metal with and without chelating agents depend on the plant species and may vary considerably, as reported by several researchers as Mohanty and Patra[13], Cao et al[14], Zhao et al[15], and Evangelou[16].

Conclusion

The present study was envisaged to assess the accumulation of Cr^{+6} in different plant parts of rice that may be transferred to humans through food chain, particularly in contaminated areas. Transport of metal chelate complexes within plants plays a pivotal role in chelate-assisted metal accumulation in plants. The capability of the plants to absorb and accumulate metals in their tissues from the contaminated soil is called phytoextraction or phytoaccumulation. In chelate-assisted phytoextraction, the mobility and uptake of metal is enhanced by adding different chelators to the soil. This study revealed the effective role of chelating agents in enhancing Cr-bioaccumulation in root and shoots. It is confirmed that the drought resistant variety of rice 'Sahabhagi' mobilises more chromium from the soil than the plants of drought succeptible variety 'Lalat'.

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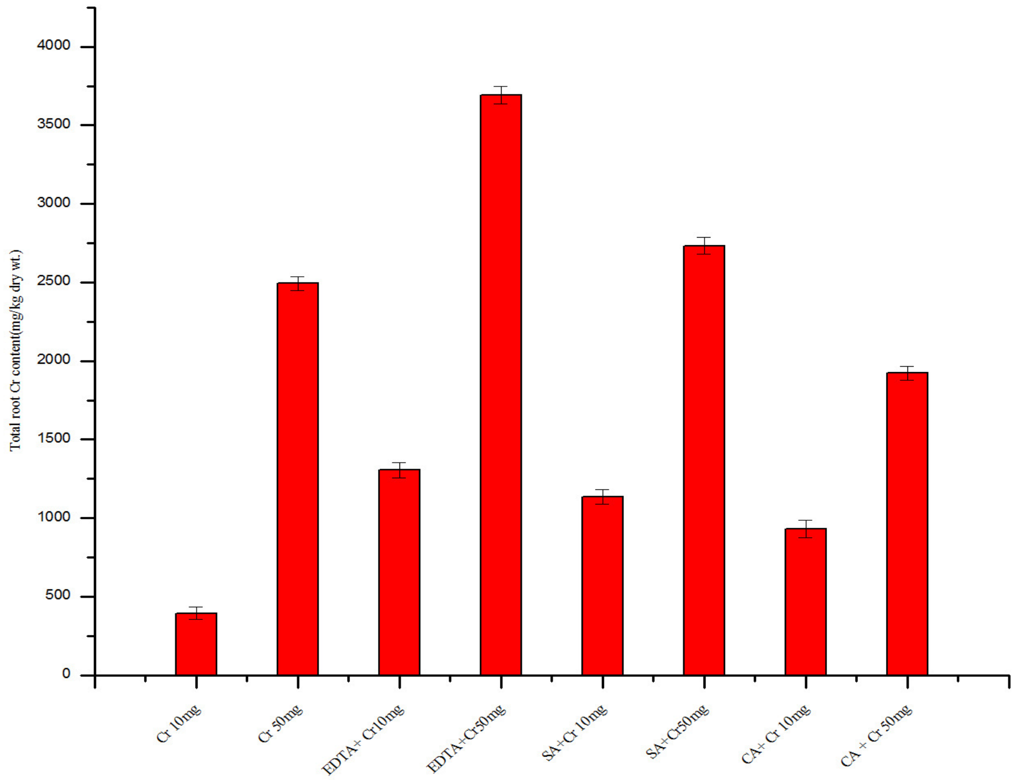
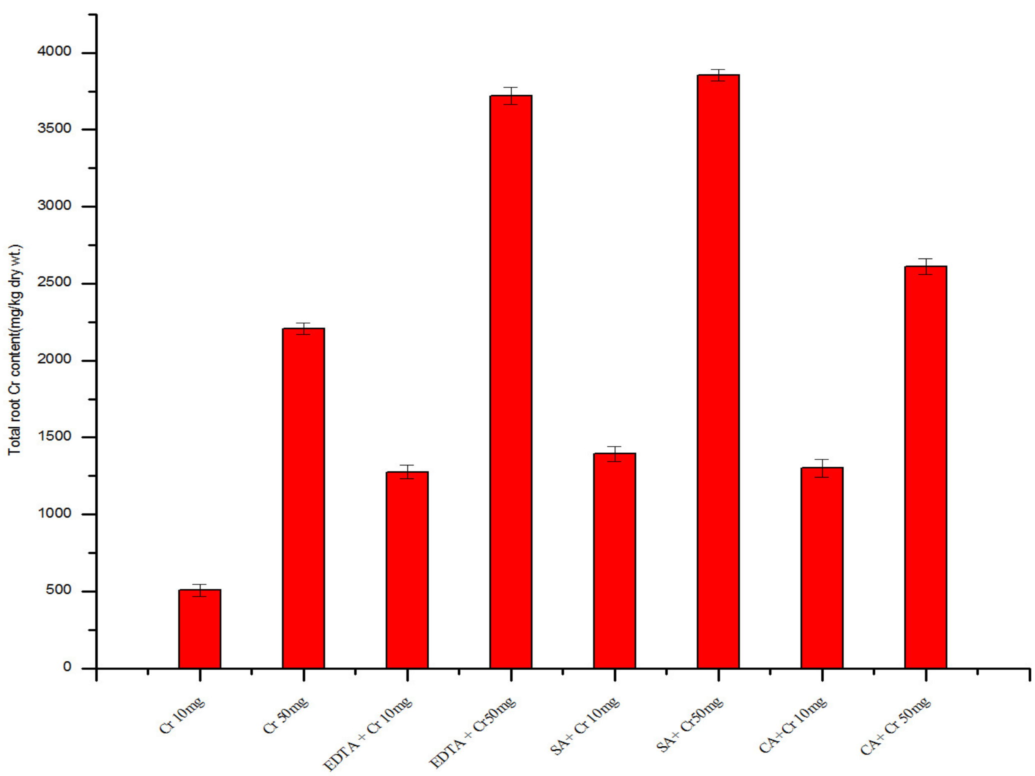


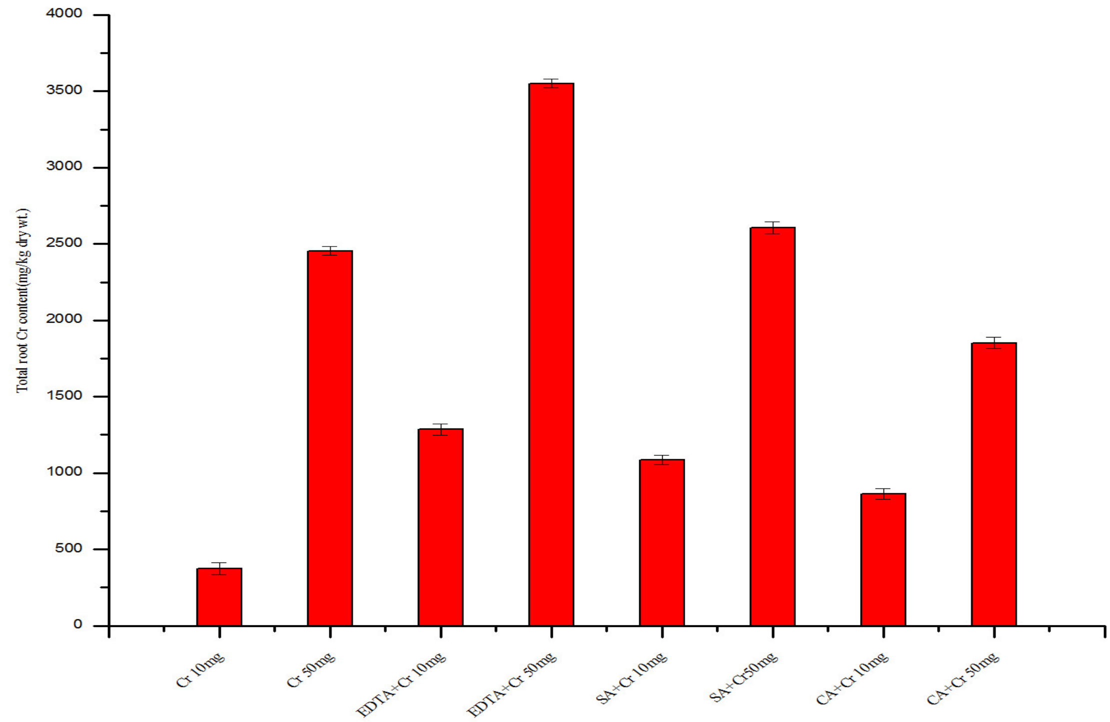
1A



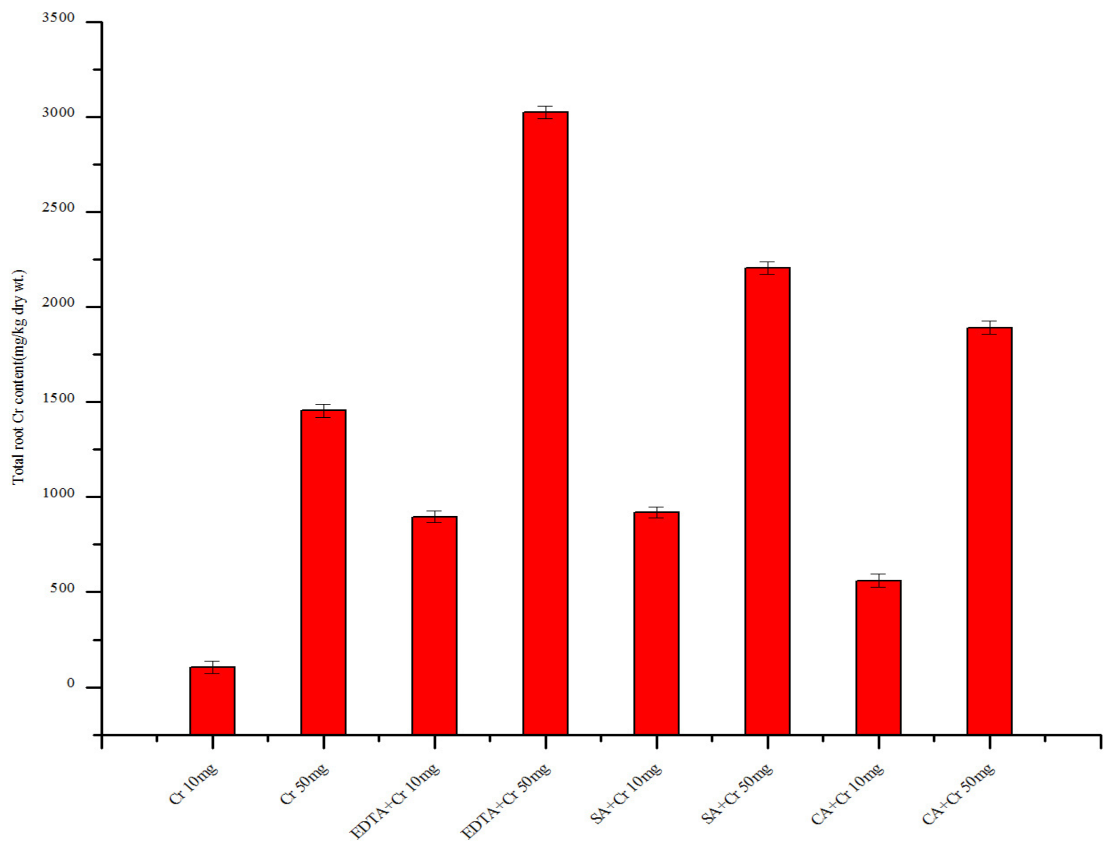
1B

Figure-1

A, B :Effect of Cr^{+6} and chelating agents on total root chromium content of 15 days old drought resistant rice seedlings grown under water logged and drought condition respectively



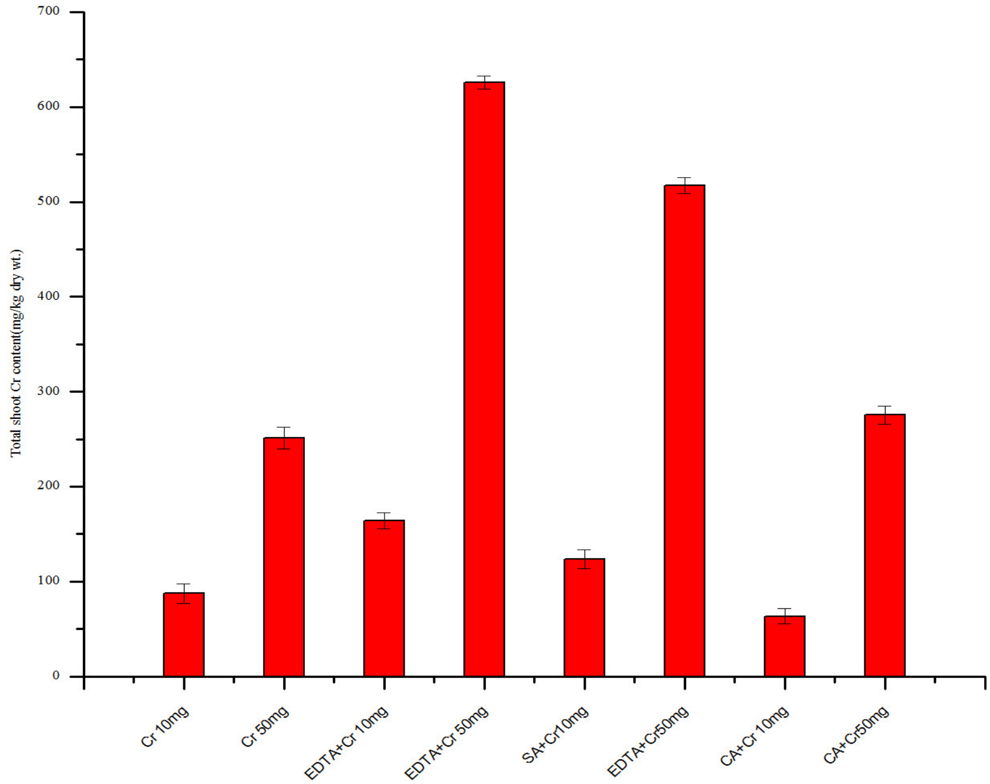
2A



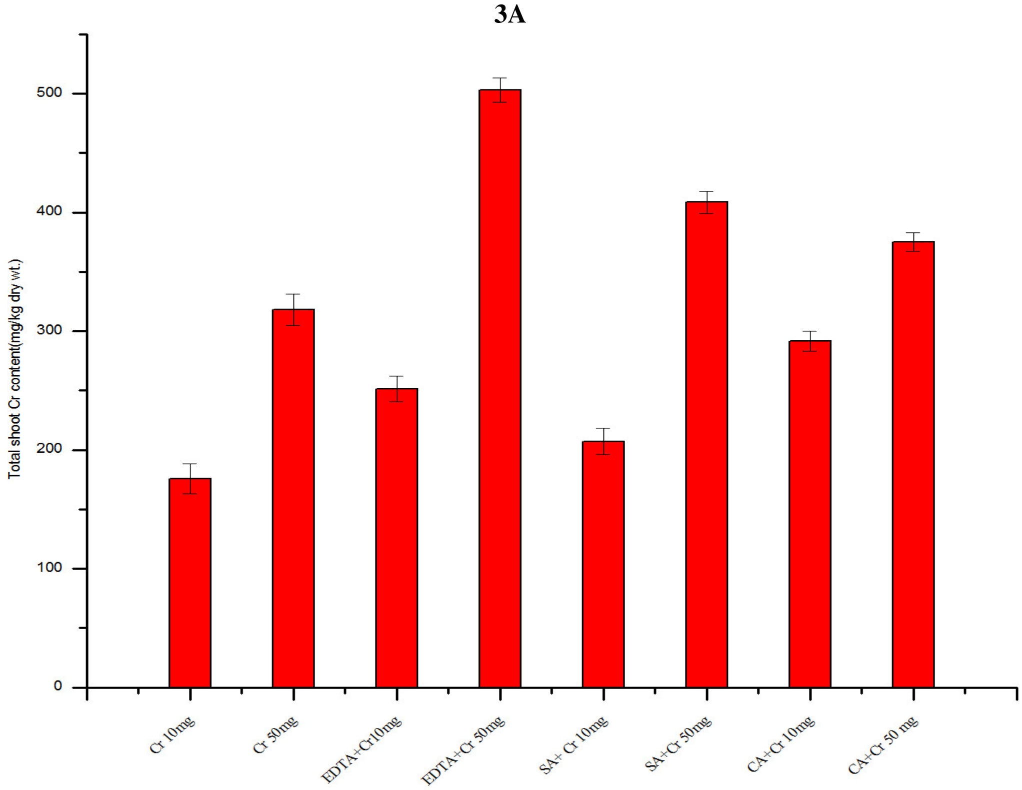
2B

Figure 2

A, B : Effect of Cr^{+6} and chelating agents on total root chromium content of 15 days old drought susceptible rice seedlings grown under water logged and drought condition respectively



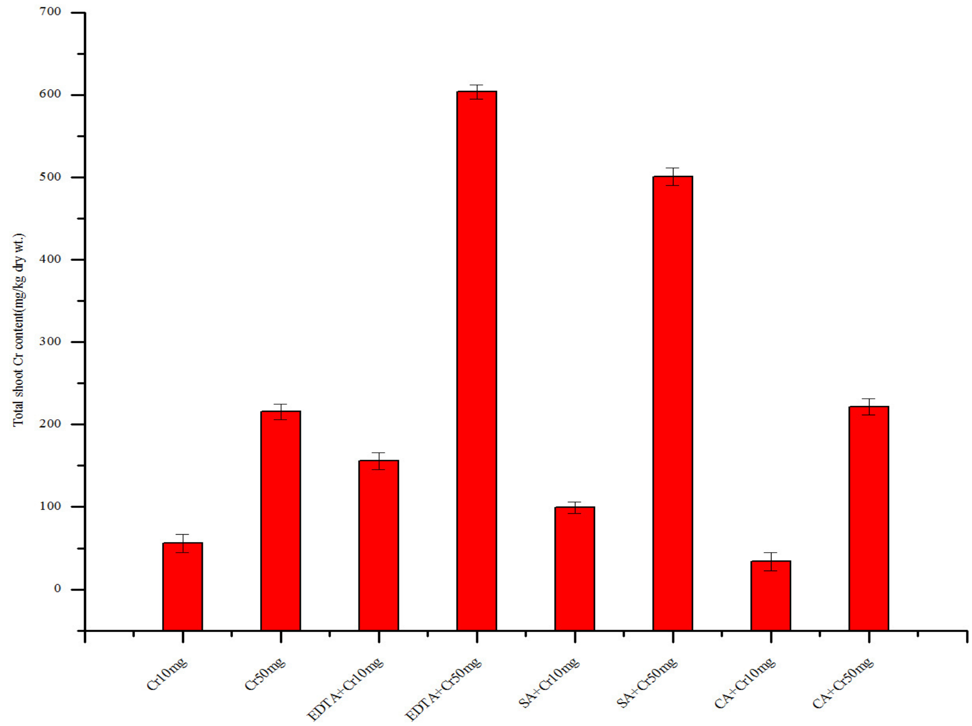
3A



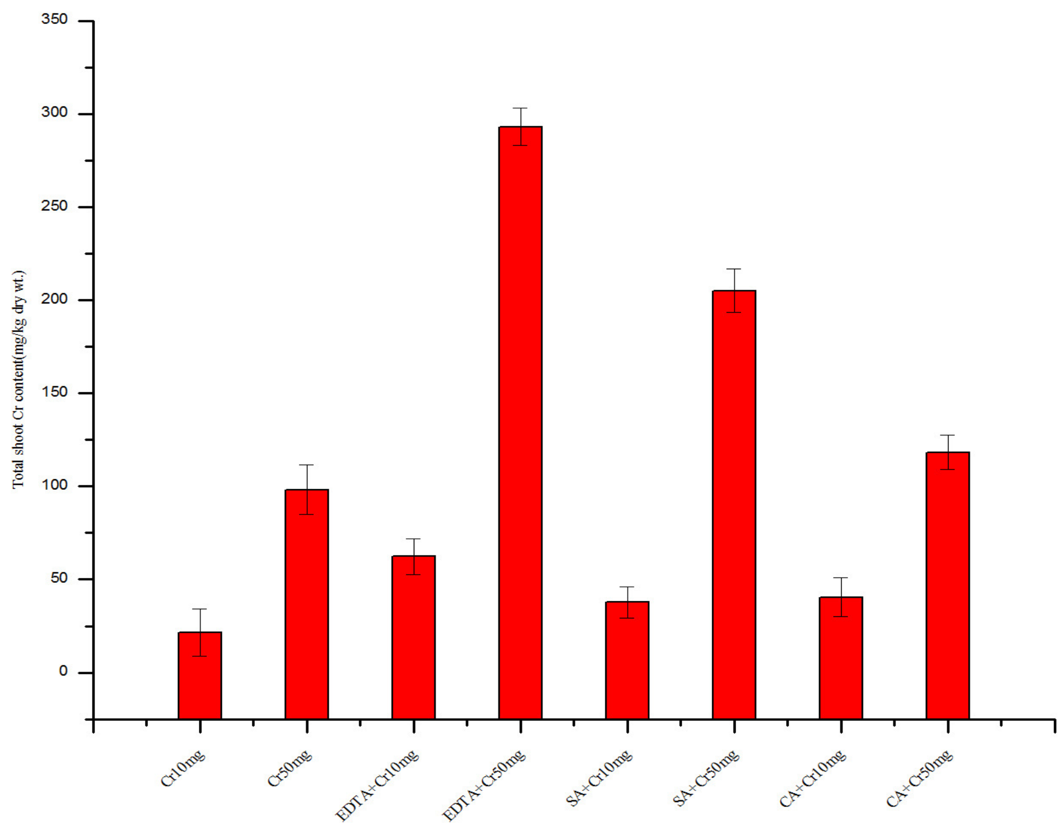
3B

Figure-3

A, B :Effect of Cr^{+6} and chelating agents on total shoot chromium content of 15 days old drought resistant rice seedlings grown under water logged and drought condition respectively



4A



4B

Figure-4

A, B : Effect of Cr^{+6} and chelating agents on total shoot chromium content of 15 days old drought susceptible rice seedlings grown under water logged and drought condition respectively

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