Phyto-extraction of Chromium from Polluted Terrestrial Environments by *Talinum triangulare* (Ceylon Spinach) and the effect of External Chelators on the Chromium Extraction Potential

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Abstract
The study was carried out to investigate the potential of Talinum triangulare (Ceylon Spinach) to remediate Cr contaminated soil under greenhouse conditions. In primary studies, T. triangulare showed significant resistance to Cr toxicity, however the amount of metal extracted was not sufficient enough to consider it as a potential phyto-extractor. Further pot experiments were conducted to find out the effect on Cr accumulation using EDTA as chelant under 2.0, 4.0, 6.0, 8.0 and 10.0 mmol kg^{-1} chelator concentrations.

EDTA had virtually a significant effect on uptake of the metals by the plant and elevated Cr concentrations in plant organs as compared with the control. Optimum phytoextraction was observed when 2.0 mmol kg^{-1} EDTA was added with relatively high biomass production of plant species. EDTA modifies the uptake and the translocation of Cr by plants but the results concerning the uptake and the accumulation depend on the available Cr concentration in soil.

Keywords: Phytoextraction, chromium, EDTA, soil, heavy metals.

Introduction
Heavy metal-contaminated soils constitute a serious environmental problem because of their adverse effects on human health. Among heavy metals, chromium (Cr) has become a major environmental issue due to its toxicity and high reported concentrations in the soil and water resulting from various industrial and agricultural activities such as leather tanning industries, electroplating and steel production works, manufacture of dyes, paints and pigments etc[2]. Thus, introduction of effective remediation methods to clean up Cr contaminated lands has become a necessity.

Phytoremediation is a cost-effective plant-based approach to cleanup contaminated sites and it maintains the biological activity and physical structure of soil better than the conventional physicochemical methods and also offers the possibility of biorecovery of metals[5,24]. Among various types of phytoremediation techniques, phytoextraction where metals are removed from soils through harvesting the metal-accumulating plant biomass, is regarded as a complete metal clean-up strategy. Hence it has become a more appealing environment remediation method in recent decades. The success of phytoextraction as a potential environmental cleanup technology depends on several factors including metal availability for uptake as well as the ability of plants to absorb and accumulate metals in their aerial parts[7].

Plants that are capable of accumulating heavy metals in their above ground tissues without developing any toxicity symptoms under natural conditions are known as "hyperaccumulators" and hyperaccumulators of Cr have generally been defined as plants containing over 1000 mg kg^{-1} (0.1 %) Cr in the dry matter[4]. The use of biological remediation technologies such as bioremediation for the cleanup of Cr-contaminated areas has received increasing interest from researchers worldwide.

Several methods have been suggested and experimentally tested with varying degrees of success. However, Cr hyperaccumulator plants have not been reported to remediate Cr from contaminated terrestrial environments to date[7]. Therefore, identification of a moderate Cr accumulator plant and chelant-assisted phytoextraction by applying suitable chelants is proposed as an alternative approach for removal of Cr from contaminated environments[1].

EDTA (ethylenediaminetetraacetic acid), a synthetic chelating agent has been reported as an effective chelant to increase the metal (Cr, Mn, Ni, Cu and Cd) uptake capability in plants[6,17]. Addition of EDTA as a chelant has enhanced Cr accumulation in roots of grasses (Bermuda grass, switchgrass) than shoots phytostabilization purpose[9]. Further studies on the grass (*Eleusine indica* L. Gearth) have been used to suggest EDTA for the phytostabilization purpose[14]. Addition of single dose of EDTA has shown effective extraction of Cr than split dose of EDTA which reduces the leaching out of metal from the soil[15].

Echinochloa crus galii(L.) has been introduced as a new approach for Cr and EDTA phyto-extraction because addition of EDTA has affected significantly on uptake of Cr by the plant with an optimal of 5 mmol kg^{-1} of EDTA in a single dosage 60 days after the plant cultivation[13]. But another study on Sorghum plant on Cr contaminated soil has shown the use of EDTA (5 mmol dm^{-3}) was not significantly enhanced on phytoextraction of Cr on Sorghum plant though it increased of the plant shoot weight[3].