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Germination, Seedling Growth and Biochemical Responses of Amaranthus (*Amaranthus tricolour L.*) and Sesame (*Sesamum indicum L.*) at Varying Chromium Concentrations

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Authors' contributions

This work was carried out in collaboration between all authors. Author NG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IPR and MM managed the analyses of the study. Author DS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The main objective of present investigation was to evaluate the impact of different concentrations of hexavalent chromium on germination and seedling growth responses of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*). Every treatment was replicated thrice in a randomized block design. Observations were made on germination rate, root and shoot length, fresh weight and dry weight of seedling, % phytotoxicity of root and shoot, sugar, and chlorophyll content in the leaves of both treated and control plants. Steady increase in Cr (VI) fixation under different concentration under various treatments significantly leads to inhibition of seed germination

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and other development parameters. Percentage of phytotoxicity demonstrated an increasing pattern with continuous increment in Cr VI concentrations for the entire *Amaranthus tricolor* L. and Sesame (*Sesamum indicum* L.) cultivars. Most extreme restraints of root development were recorded. Endeavors are being made in various research centers to build novel plants utilizing hereditary control innovations that may have a more noteworthy resistance o the nearness of heavy metals. The consequence of the present investigation may help in understanding the components included and their conceivable use in phytoremediation. The germination and seedling growth responses of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) were assessed in varying concentrations of $K_2Cr_2O_7$. Germination of both green Amaranthus and Sesame was significantly affected by the increasing $K_2Cr_2O_7$ concentrations. Root length and shoot length of both the green Amaranthus and Sesame were inhibited by the high $K_2Cr_2O_7$ concentrations as compared to those containing low $K_2Cr_2O_7$ concentrations and control treatment.

Keywords: Amaranthus (Amaranthus tricolor L.); Sesame (Sesamum indicum L.); phytotoxicity; Seedling Vigor Index; tolerance indices.

1. INTRODUCTION

Seed germination is the primary physiological process influenced by Cr (VI). The capacity of a seed to grow in a medium containing Cr (VI) would be demonstrative of its level of resistance to this metal. Rapid growths of Urbanization, Industrialization and Anthropogenic activities provide numerous benefits to society but have contributed significantly to the generation of large amounts of heavy metals and toxic chemicals in the environment. Chromium is an important heavy metal that is known to be highly toxic. Hexavalent chromium is toxic to many living organisms. However, it may be accumulated at first gear levels and since its accumulation is biomagnified at different trophic levels through food chain, this may affect on human wellness. Exposures to large amounts of heavy metals may result to damages and growth inhibition of most plant species [1]. Leather and paint manufacturing industries are the significant reason for the high deluge of chromium to the biosphere. Hexavalent chromium is utilized widely worldwide in different mechanical exercises is along these lines thought about a genuine ecological contamination and represents a risk to human wellbeing. Its presence in agricultural soils can be attributed to the use of organic wastes as fertilizer and the use of waste water for irrigation [2]. Chromium like others substantial metals don't degrade organically, it stays stable for a while in the dirt without changing its oxidation state. Cr (VI) is aggregated by plants and its amassing is biomagnified at various tropic levels through natural pecking order [3,4]. Large amounts of metals in soil can be phytotoxic. Danger of Cr to plants relies upon its valence state.

Most plant species expose to heavy metals may show different responses towards their exposure. Some plants may act as hyper accumulators of metals and may either be tolerant or sensitive to the heavy metals [5]. While other plant species may exhibit inhibition of germination and plant growth [6] and reduce crop yield [7]. Plant exposures to heavy metals may likewise have significant effects on shoot lengths, root lengths and seedling dry biomass [8]. Extreme level of overwhelming metals in the dirt condition antagonistically influence the germination of seeds, plant development, change the level of biomolecules in the cells and interfere with the exercises of many key proteins identified with typical metabolic and formative procedures [9,10].

The take-up, translocation and gathering of substantial metals in plants are intervened by coordinated system of physiological, biochemical and molecular systems. For the most part modern squanders incorporate overwhelming metals are one of the significant dangers for horticulture hones in light of the fact that above basic levels they may transform into poisons and cause restraint of development and advancement for the majority of the plant species and on occasion prompts demise additionally [11]. Overwhelming metal anxiety adversely influences the procedure related with biomass aggregation and general yield in all the major field developed harvests by harming a few metabolic pathways and if not yield, harm they may get joined in our sustenance supply through reaped crops. However plants have some barrier component to manage the overabundance of substantial metals in the dirt by which they can avoid or limit the take-up of metals or limit the harmful impacts through metal excluders, gatherers and pointers. They may restrict chose metals for the most part in roots and stems, or they may amass and store different metals in non-harmful structures for later conveyance and utilize [12].

Green Amaranthus (*Amaranthus tricolor L*) and Sesame (*Sesamum indicum L*) are important market vegetable and oil seeds in many Southeast Asian countries, where both crops are extensively cultivated. Both are excellent sources of nutrients and are used for Phytoremediation. Sesame is the good source of oil, it is very essential for human health. There are studies that indicate that both green Amaranthus (*Amaranthus tricolor L*) and Sesame (*Sesamum indicum L*) act as good metal and toxin accumulators. However, there is little information provided on the effects of these heavy metals particularly chromium on the Morphology and physiology among plants that are used for phytoremediation like Amaranthus and Sesame. The present study aims to investigate the germination and seedling growth responses of plants that are used as hyper accumulators of metals and toxins like green Amaranthus (*Amaranthus tricolor L*) and Sesame (*Sesamum indicum L*) to varying Chromium concentrations.

2. MATERIALS AND METHODS

2.1 Study Area

Hyderabad is situated in Telangana state in southern India and is the 6th biggest city in the nation. It contains various mandals, including the Greater Hyderabad Municipal Corporation (GHMC). Hyderabad is situated in the Musi sub-basin (11,000 km^2), which is some portion of the Krishna stream basin. Fast improvement, particularly in the data innovation (IT) division, has pulled in talented and untalented work from different parts of India, additionally expanding the city's populace. The soil sample for present investigation were collected from agricultural grounds of bandlaguda mandal which shown in Fig. A. All the experiments were conducted in the laboratory at Center for Environment and Climate Change (CECC), School of Environmental Sciences, Jawaharlal Nehru Institute of Advanced Studies (JNIAS) Secundrabad.

The collected composite soil sample was allowed for charecterisation and the results were depicted in Table 3.

2.2 Seed Selection and Seed Treatment

Seeds of green Amaranthus (*Amaranthus tricolor L*) and Sesame (*Sesamum indicum L*) were obtained from a local store where seeds are sterilized and vacuum packed in packets. Uniform size, color and weight seeds were surface sterilized with 0.1% AR grade mercuric chloride ($HgCl_2$) solution and washed 5-6 times with distilled water prior to the experiment. $K_2Cr_2O_7$ solutions were prepared at different concentrations (4 mg/L, 8 mg/L, 10 mg/L, 12 mg/L and 15 mg/L). The control solution contains

Fig. A. Study area and location of soil sample

distilled water. Forty (40) seeds for each plant species were placed and grown in earthen pots which having 2 kg of red soil. The seeds were irrigated with the test solutions and distilled water. Each treatment was replicated three times. The earthen pots were aerated during the course of seedling development. Seedlings were allowed to grow for 7 days then the number of seeds germinated in each treatment was counted on 7 days after sowing and the germination percentage was calculated. The root and shoot length of seedlings in various chromium concentrations were measured each day for each germinating seed [13].

2.3 Plant Sampling and Analysis

A seed was considered as germinated when root had emerged more than 2 mm. The number of germinated seeds per time was presented as seed germination rate. Germination percentage and tolerance indices determined by the following formula [14].

Germination percentage =

$$\frac{\text{Number of germinated seeds}}{\text{Total number of planted seeds}} \text{ X } 100$$

Tolerance indices =

$$\frac{\text{Mean root length of polluted area seeds}}{\text{Mean root length of control area seeds}}$$

The inhibition of seedling growth was expressed according to the formula [15].

Percentage of inhibition =

$$\frac{\text{Length of control} - \text{length of test}}{\text{Length of control}} \text{ X } 100$$

2.4 Seedling Vigor Index

Seedling vigor index are those properties of the seed which determine the level of activity and performance of the seed during germination and seedling emergence. It is a single measurable property like germination describing several characteristics associated with various aspects of the performance of seed. Seedling vigor index is calculated by following formula: [16,17]

SVI = Germination percentage × Seedling length

2.5 Percentage Phyto-toxicity

Percentage phytotoxicity of chromium on root and shoot growth Amaranthus (*Amaranthus tricolor L*) and Sesame (*Sesamum indicum L*) were calculated after 20, 30 and 40 days of seedling growth. The following formula was used for calculating the percentage phytotoxicity [18]

$$\%\, Phytotoxicity =$$

$$\frac{\frac{S}{R} length\ of\ control - \frac{S}{R}\ length\ of\ treatment}{\frac{S}{R} length\ of\ control}\ X\ 100$$

2.6 Estimation of Biochemical Attributes

Biochemical attributes were studied in term of photosynthetic pigments. The chlorophyll-a, chlorophyll-b and total chlorophyll (a + b) were determined spectrophotometrically. Leaves were cut into small pieces, mixed thoroughly and 0.25 g of leaves was taken into a mortar to grind them finely by pestle with 25 ml of 80% acetone for 5 minutes. The homogenate was filtered through filter paper (Whatman No.42) and was made a volume of 25 ml with 80% acetone. The total Carbohydrates were determined by Anthrone method, total proteins by Biuret method and peroxidise activity by O-diansidine method which is an enzymatic method [19,20].

2.6 Extract Monitoring by Spectro-photometer

After the extraction, chlorophyll contents were monitored by UV-Vis spectrophotometer [21]. The optical density/absorbance of each solution was measured at 663 and 645 nm against 80% acetone blank in 1 cm quartz cuvette at room temperature. The Arnon's equation was used to calculate the amount of chlorophyll-a, chlorophyll-b and total chlorophyll (a + b) [22,23]:

Chl a (mg·g−1) = [(12.7 × A663) − (2.69 × A645)] × ml acetone/mg leaf tissue
Chl b (mg·g−1) = [(22.9 × A645) − (4.68 × A663)] × ml acetone/mg leaf tissue
Total Chl = Chl a + Chl b

2.7 Statistical Analysis

Data were statistically analyzed using one-way ANOVA on Graphpad Prism 6.01 software [24]. The results are presented as means ± S.E. (standard errors) and data from the different treatments and control were compared by Duncan's multiple-range test at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Impact of Chromium Toxicity on Seed Germination

This study investigated the germination, root and shoot lengths of the green Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) seeds to varying $K_2Cr_2O_7$ solutions. The effect on germination of all seeds were trended with chromium accured from control to 15 mg/L with variations depending on Cr (VI) concentrations on both Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) taken for studies. The phytotoxin effect of Cr (VI) research carried out to examine the seed germination percentage of both Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) were shown in Fig. 1 and Fig. 2. The results concluded that the effect of chromium on seed germination percentage of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) shown negative effect. The germination percentages were recorded to be decreased gradually with progressive increase in chromium concentration. Seed germination, root and shoot lengths of water spinach (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) were highly decreased with the treatment of $K_2Cr_2O_7$ as compared to the control (Figs. 1 and 2). The seed germination of the green Amaranthus was likewise affected by the 4 mg/L to 15mg/L concentrations of $K_2Cr_2O_7$. The toxicity levels were high in Sesame (*Sesamum indicum L.*) compare to water spinach (*Amaranthus tricolor L.*). The numbers of seedlings were decreased as progressive increase in crop period in both Amaranthus and Sesame. The green Amaranthus root and shoot lengths were affected in treatments at 10 -15 mg/L concentration while the sesame root and shoot lengths were affected in both chromium treatments at 12 and 15 mg/L concentrations. These results were indicating higher concentrations of chromium produced toxic effect in seed germination. Increasing concentration of substantial metal essentially diminish the quality of germination as contrast with the most reduced convergence of overwhelming metal which have the slightest unsafe effect on the germination. The germination percentage significantly ($p < 0.05$) affected at all chromium concentrations in both cases. The reduction of germination of seed under Cr (VI) stress would be due to the depressive effect of Cr (VI) on the subsequent transport of sugars to the embryo axis [25]. Moreover, red uction of germination under Cr(VI) stress, is probably due to increase of protease activity and decrease in α- and β-amylase activities [25,26]. The amylase hydrolysis of starch is essential for sugar supply to developing embryos. A decrease in amylase activity under Cr treatment decreases sugar availability to developing embryo which may contribute to the inhibition of seed germination. The required sugar for developing embryos will obtain from hydrolysis of amylase. Therefore, the direct treatment of chromium treatment may reduce the availability of sugar which directly or indirectly hamper the seed germination [27]. There are several reports on the promontory and inhibitory effect of copper and chromium treatment on various plant species. Symptoms of Cr phytotoxicity include inhibition of seed germination or of early seedling development, reduction of root growth, leaf chlorosis and depressed biomass [28]. Low concentrations shows growth promotory and higher concentrations shows germination inhibitory effect in four varieties of *Vigna radiata*. Some heavy metals are essential micronutrients for plants but their excess may result in metabolic disorders and growth inhibition in most of the plant species [29].

3.2 Metal Tolerance Index and % Inhibition of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) Seedlings

Increasing chromium concentration had significant adverse effects on metal toxicity tolerance on Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) seedlings used in present experiments (Fig.3 & 4). Sesame (*Sesamum indicum L.*) seedlings tolerance significantly decreased by increase in chromium concentration than Amaranthus (*Amaranthus tricolor L.*) respectively. The % inhibition of Amaranthus (*Amaranthus tricolor L*) and Sesame (*Sesamum indicum L.*) seedlings were inversely proportional to chromium concentration. As concentration of chromium increasing the % inhibition were decreased in both the cases. Comparative examinations were completed in green gram affected by mercury [30], mung bean under lead acetic acid derivation [31], in green gram under the impact of cobalt [32]. Expanding convergence of Cr prompts diminishing seed germination was seen in *Hibiscus esculentus* and some essential pulses [33,34]. Hindrance of germination rate at higher concentrations of chromium was seen in soybean [35], mung bean [36], cowpea [37], groundnut [38], black gram [39], green gram [40] and paddy, black gram and soybean [41,42,43].

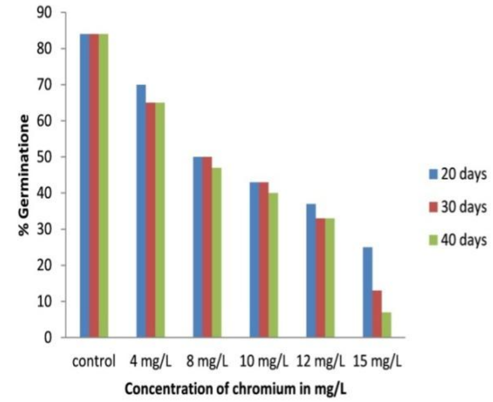

Figure-1: Effect of Chromium concentration on seed germination of Sesame (*Sesamum Indicum L*)

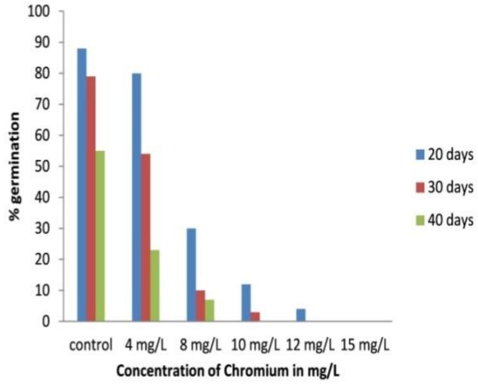

Figure-2: Effect of Chromium concentration on seed germination of Amaranthus (*Amaranthus tricolor L*)

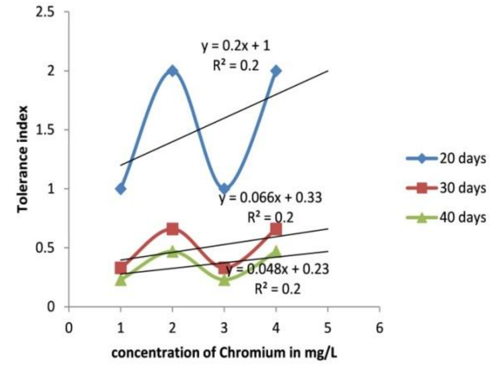

Figure-3: Tolerance index of Amaranthus (*Amaranthus tricolor L*) seedlings in response to Cr (VI) concentrations.

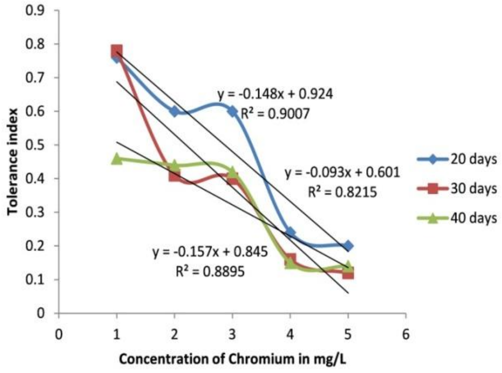

Figure-4: Tolerance index of Sesame (*Sesamum Indicum L*) seedlings in response to Cr (VI) concentrations.

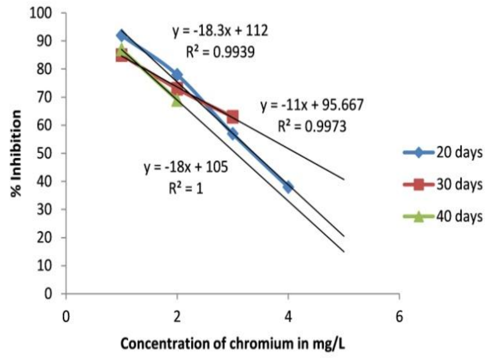

Figure-5: Percentage of inhibition of Amaranthus (*Amaranthus tricolor L*) seedlings in response to Cr (VI) concentrations

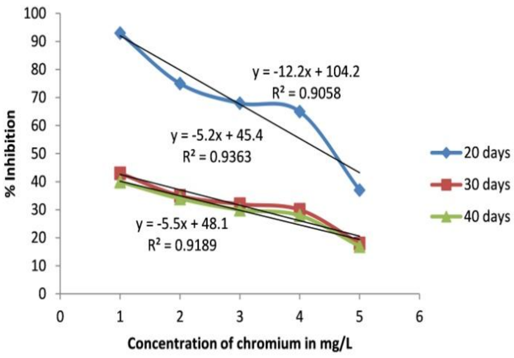

Figure-6: Percentage of inhibition of Sesame (*Sesamum Indicum L*) seedlings in response to Cr (VI) concentrations

3.3 Seedling Vigor Index

The increased chromium level adversely influence the seedling vigor index of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) shown in Figs. 7 & 8. Seedling vigor index of Amaranthus (*Amaranthus tricolor L*) and Sesame (*Sesamum indicum L.*) gradually decrease with increase chromium concentrations. Among the various treatments of chromium were found to be toxic at 8 mg/L – 15 mg/L in case of Amaranthus (*Amaranthus tricolor L.*) and seedling vigor index of Sesame (*Sesamum indicum L.*) found to be toxic at sub optimal (8 mg/L – 10 mg/L) above optimal (12 mg/L – 15 mg/L) concentrations. Similar type of results were reported by Hira Amin et al. [44] that there was reduction in vigor index in *Hibiscus esculentus* L and Ganesh et al. [45] that there was a reduction in vigor index in four genotypes of soybean at 5 - 200 mg/L concentration of chromium, with respect to control application.

3.4 Percentage Phyto-toxicity

The percentage of phytotoxicity of chromium at different concentrations on Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) was calculated and results were shown in Figs. 9 & 10. It can be seen that percentage of phytotoxicity on Amaranthus (*Amaranthus tricolor L*) at 4 mg/L and 10 mg/L chromium is about 7.1% and 43% respectively. While the percentage of phytotoxicity at 8 mg, 12 mg and 15 mg/L chromium is observed about 60%, 81% and 100% respectively. Thus at lower concentration chromium is least toxic while at high concentration shows maximum toxicity on the growth of Amaranthus (*Amaranthus tricolor L.*). From the results it is concluded that there is continuous increase in percentage of phytotoxicity with increase in time of treatment.

The percentage of phytotoxicity of chromium at different concentrations on Sesame (*Sesamum indicum L.*) seedling growth shown interesting observation that there is no phytotoxicity at all concentrations up to 20 days of treatment time. The phytototxicity were observed after 30 days treatment and least toxicity was observed with 4 mg/L chromium treated plants i.e. 12% and maximum toxicity observed at 10 mg/L chromium treated plants i.e. 19%. These results concluding that lower concentration of chromium enhance the growth of Sesame (*Sesamum indicum L.*)

3.5 Effect of Chromium Concentration on Root Growth

The Fig. 11, shows the effect of different concentrations of chromium on root growth of Amaranthus (*Amaranthus tricolor L.*) after 20, 30 and 40 days of growth. The results shown that there is significant reduction in root length over to control at all concentrations of chromium. The Fig. 12, shows the effect of different concentrations of chromium on root elongation of Sesame (*Sesamum indicum L.*) after 20, 30 and 40 days of growth. The results show that there is a significant reduction in root growth over to control at 10, 12 and 15 mg/L ($P < 0.01$) chromium concentrations. The observed results were concluding that the lower concentration of chromium does not show higher toxicity on root elongation of Sesame (*Sesamum indicum L.*) compare to Amaranthus (*Amaranthus tricolor L.*).

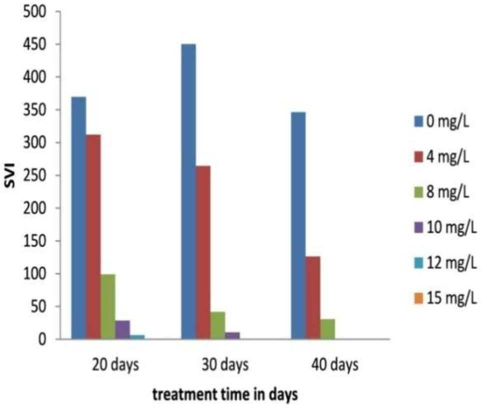

Figure-7: Effect of Chromium on seedling vigor in Amaranthus (*Amaranthus tricolor L*)

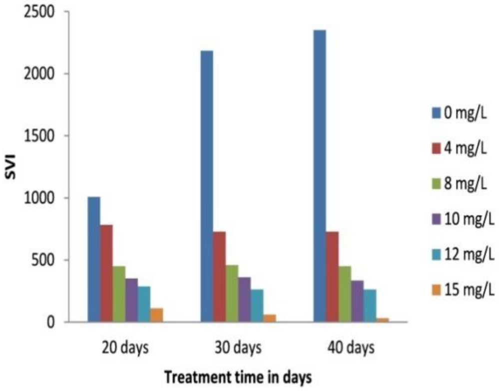

Figure-8: Effect of Chromium on seedling vigor in Sesame (*Sesamum Indicum L*)

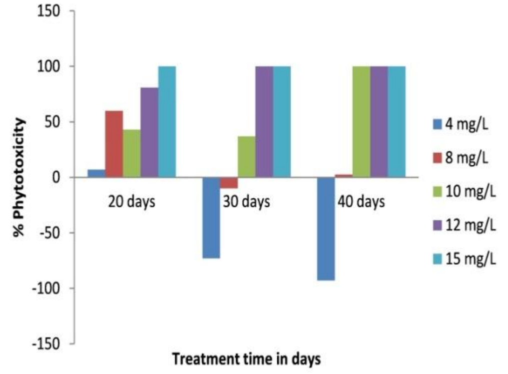

Figure-9: Effect of Chromium on % Phytotoxicity in Amaranthus (*Amaranthus tricolor L*)

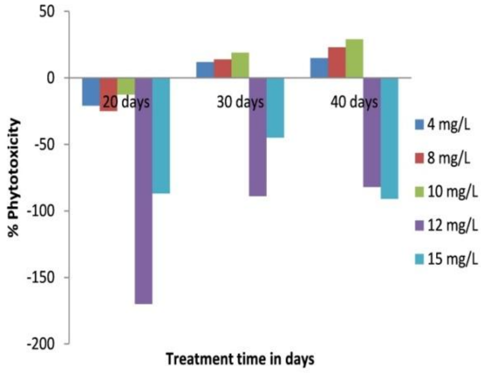

Figure-10: Effect of Chromium on % Phtotoxicity in Sesame (*Sesamum Indicum L*)

Comparative outcomes were acquired by Jamal et al. [46] with two wheat (*Triticum aestivum*) assortments named Anmol and Kiran treated with chromium. This metal has been accounted for not to restrain germination but rather hinder the development of new roots and seedling foundation [47]. Diminishments of 32– 57% in sugarcane bud germination was seen with 20 furthermore, 80 mg/L Cr, separately [48]. Truth be told, roots were watched shorter and tanish and displayed less number of roots hairs in chromium-treated plants rather than the control, in which thin, extended roots were shaped. The root length and shoot length of *Arachis hypogea* were observed to be influenced by the increasing the concentration of Cr (VI) [49] have likewise been accounted for that root development was relatively more repressed than shoot of rice (*Oryza sativa L.)* cultivars.

3.6 Effect of Chromium Concentration on Shoot Growth

The effect of different concentrations of chromium on shoot length of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) were shown in Fig. 13 and Fig. 14 respectively. From the results it is observed that there is significant reduction in shoot length of Amaranthus (*Amaranthus tricolor L*) over to control at all treatments except 4 mg/L chromium concentration. The significant reduction in shoot length of Sesame (*Sesamum indicum L.*) over to control observed from 10 mg/l to 15 mg/L. these results concluding that Sesame (*Sesamum indicum L.*) seedling can resist up to 9 mg/L chromium concentration. There was steady abatement in shoot and root length with the increase in Cr concentration from 0 to 15 mg/L.

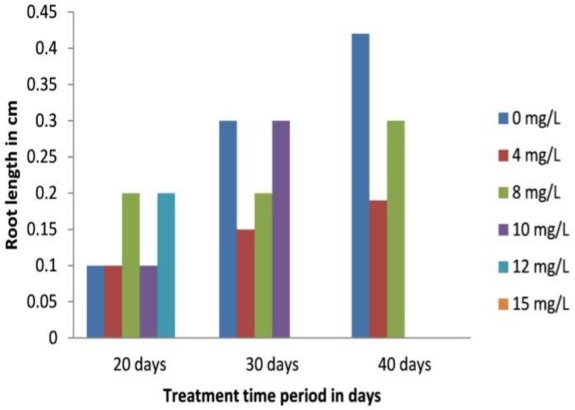

Figure-11: Effect of Chromium concentration on root elongation of Amaranthus (*Amaranthus tricolor L*) after 20, 30 and 40 days of growth.

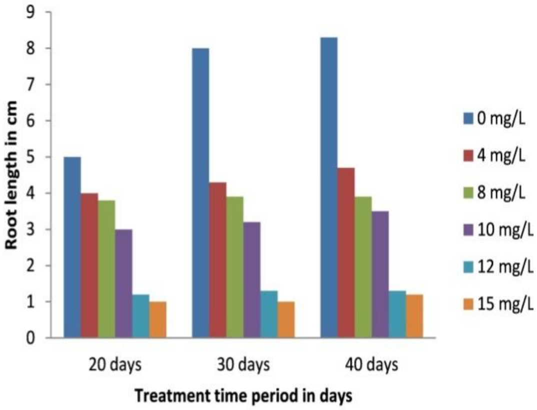

Figure-12: Effect of Chromium concentration on root elongation of Sesame (*Sesamum Indicum L*) after 20, 30 and 40 days of growth.

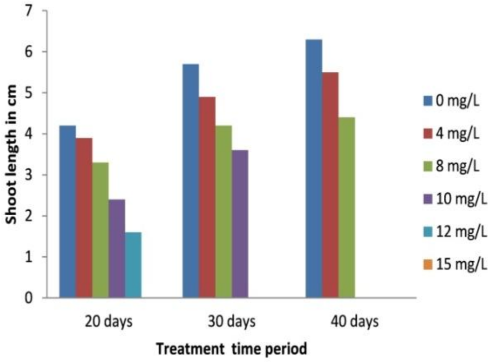

Figure-13: Effect of Chromium concentration on shoot elongation of Amaranthus (*Amaranthus tricolor L*) after 20, 30 and 40 days of growth.

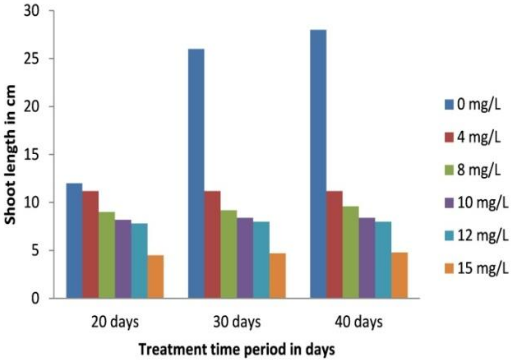

Figure-14: Effect of Chromium concentration on shoot elongation of Sesame (*Sesamum Indicum L*) after 20, 30 and 40 days of growth.

The impact of chromium in shoot and root lengths were steady abatement in melon plant [50]. In cobalt treatment progressive decrease in shoot and root lengths with increase in cobalt concentration [51] in chick pea. Abdul Ghani, 2011 [52] has been accounted for that expanding concentrations of chromium caused noteworthy decrease in root length and shoot length of *Brassica juncea* L. Bishoni, 1993 [53] announced that Cr(VI) did not influence the rate germination but rather smothered the development of radical and plumule, altogether and its impact was more articulated on roots than on the shoots. Arduini et al. [54] have announced that root development of miscanthus was less influenced than shoot development, however root morphology changed definitely. Also, Samantary [55] have revealed that the improvement of lateral roots and root number was influenced by Cr exposure. In addition, underlying roots of *Zea mays L.* treated with Cr (VI) were shorter and earthy and exhibited less number of roots hairs [56]. Decrease in root development in presence of Cr (VI) can be clarified by restraint of root cell division or potentially stretching, which may have happened because of tissue fall and ensuing inadequacy of the roots to assimilate water and supplements from the medium [57]. The diminishing in plant height could be because of the decreased root development and resulting diminished supplements and water transport to the higher parts of the plant which effected by chromium dosages. In addition, Cr transport to the elevated piece of the plant can specifically affect cell digestion of shoots adding to the diminishment in plant stature [58].

3.7 Effect of Chromium Concentration on Fresh and Dry Weight

The root and shoot fresh weight of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) were severely affected due to increase chromium concentration in soil (Fig. 15 & Fig. 16). Results shows that chromium treatment 8, 10, 12 and 15 mg/L shown significant affect on fresh weight of biomass however at 4 mg/L was not significantly ($p > 0.05$) affect on fresh weight at 20, 30 and 40 days in case of Amaranthus (*Amaranthus tricolor L.*). However, the fresh weight of Sesame (*Sesamum indicum L.*) was significantly ($p < 0.05$) affected at all treatments Comparative outcomes were accounted for by Fozia et al. [59] on a progressive diminishing of root and shoot new weight in *Helianthus annus* L., with increase in chromium concentrations. The lethal impact of chromium on the root and shoot fresh weight in eight-day old seedling of *Brassica oleracea* L. var. acephala DC (kale) were accounted for by Ozdener et al. [20], treated with different concentrations of chromium in the development medium.

The root and shoot dry weight of of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) were decreased with increase in chromium levels. The results were shown in Fig. 17 & Fig. 18. From the results it is observed that there is no significant affect on dry weight of biomass at all treatments compare to control with both the seeds used in present experiment up to 20 days treatment period. There is significant affect observed on dry weight of biomass at 30 and 40th day treatment period. It was accounted for by Ganesh et al. [45] that there was a diminishment in development, dry weight in four genotypes of soybean at 5 - 200 mg/L grouping of chromium, concerning control application. In an examination directed on *Vallisneria spiralis* to assess the chromium aggregation and harmfulness in connection to biomass creation, Vajpayee et al. [60] was discovered that dry matter generation influenced by chromium fixation over 2.5 mg/L Ag in supplement medium.

3.8 Effect of Chromium Concentration on Biochemical Response

To find out the biochemical response of the Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) at different chromium concentrations the biomass allowed to check total Carbohydrates (Anthrone Method), Total Proteins (Biuret Method) and Peroxidase Activity (O- Dianisidine Method). The results were shown in Figs. 19-24. From the results it is observed that Total carbohydrates and proteins were decreased with increase in chromium concentration in soil compare to control. The sever affect on total carbohydrates and proteins were found at 10 -15 mg/L chromium concentration in both conditions. The peroxidase enzyme activity increased with increase in treatment time and shown significant affect. Increase in peroxidase activity with increase in chromium concentration is due to high toxicity of chromium on biochemical metabolism of Amaranthus (*Amaranthus tricolor L.*) and Sesame (*Sesamum indicum L.*) at different chromium concentrations.

3.9 Effect of Chromium Toxicity on Chlorophyll Contents

The effects of chromium on photosynthetic pigments of Amaranthus (*Amaranthus tricolor L.*) leaves were determined on 40th day (Table 1). The photosynthetic pigment chlorophyll-a, chlorophyll-b and total chlorophyll of Amaranthus (*Amaranthus tricolor L.*) were decrease with increased chromium treatments. The chlorophyll-a in Amaranthus

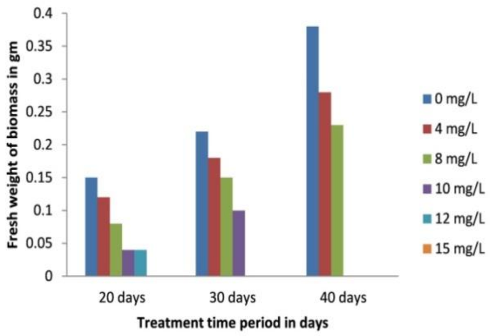

Figure-15: Effect of Chromium concentration on root and shoot fresh weight of Amaranthus (*Amaranthus tricolor L*)

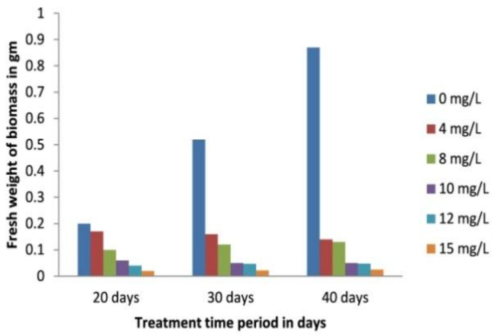

Figure-16: Effect of Chromium concentration on root and shoot fresh weight of Sesame (*Sesamum Indicum L*)

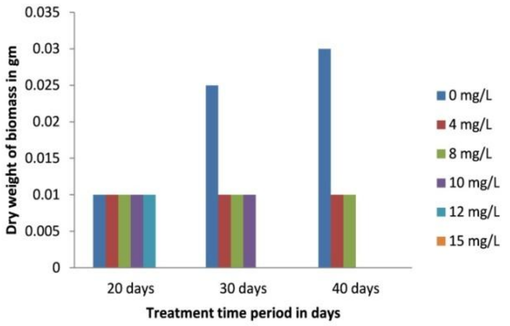

Figure-17: Effect of Chromium concentration on root and shoot dry weight of Amaranthus (*Amaranthus tricolor L*)

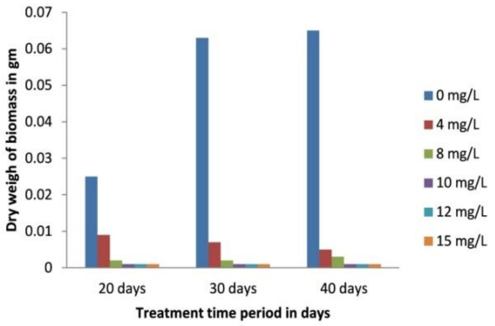

Figure-18: Effect of Chromium concentration on root and shoot dry weight of Sesame (*Sesamum Indicum L*)

(*Amaranthus tricolor L.*) leaves were significantly ($p < 0.05$) decrease from 6.36 ± 0.05, 4.81 ± 0.04, 3.43 ± 0.05 and 1.24 ± 0.06 respectively. Similarly, the chlorophyll-b in Amaranthus (*Amaranthus tricolor L.*) leaves were decrease significantly ($p < 0.05$) from 6.73 ± 0.00, 4.55 ± 0.00, 2.47 ± 0.00 and 1.68 ± 0.02 respectively. The total chlorophyll content significantly ($p < 0.05$) affected at high chromium concentration from 13.09 ± 0.05, 9.36 ± 0.04, 5.90 ± 0.05 and 2.92 ± 0.07 respectively. Some other studies have the same conclusion that the chlorophyll contents were decrease if kept under Cr (VI) stress (10 - 40 mg/L) [20]. Therefore, it has been observed that the degradation of photosynthetic pigments is absolutely concentration dependent phenomenon [61]. Almost similar observation was reported by Mondal et al. [62,63] in their earlier work on mercury and cadmium. Many previous research highlighted that chromium can reduce the total chlorophyll content in leaves [64,65]. This decrease indicates that the chlorophyll synthesis system and chlorophyllase activity were affected by the exposure to high chromium concentrations [66]. The depletion in chlorophyll content under Cr stressed is also attributed to reduced δ-aminolevulinic acid dehydratase activity, an enzyme involved in the chlorophyll biosynthetic pathway. Moreover, chromium can interfere by substituting Mg at the active site of the enzyme [67]. This loss of pigment causes deficiency in light-harvesting capacity and consequently a decrease in photosynthetic capacity of the plant. Bioaccumulation of Cr and its toxicity to photosynthetic organelle and pigments in various crops and trees is well documented [8,68]. Disorganization of the chloroplast ultrastructure and inhibition of electron transport processes due to Cr and a diversion of electrons from the electron donating side of PSI to Cr (VI) is a possible explanation from Cr-induced decrease in photosynthetic rate [61]. However, on the other hand, Van Assche and Clijsters [66] reported that the overall impact of chromium ions on photosynthesis and

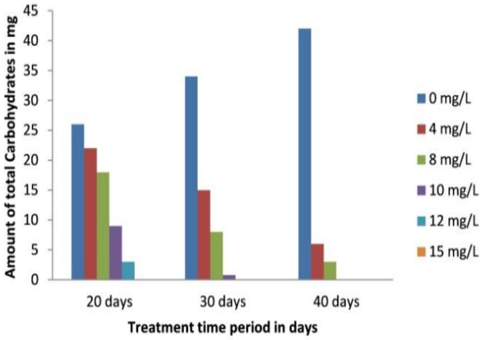

Figure-19: Effect of Chromium Concentration on total Carbohydrate content of Amaranthus (*Amaranthus tricolor L*) at different time intervals.

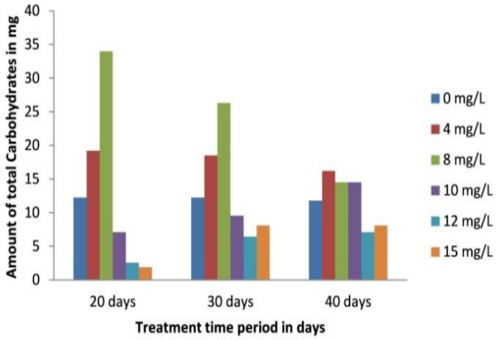

Figure-20: Effect of Chromium Concentration on total Carbohydrate content of Sesame (*Sesamum Indicum L*) at different time intervals.

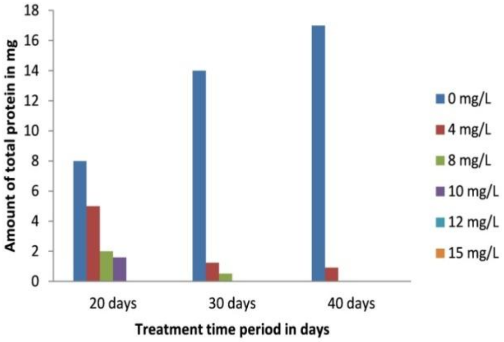

Figure-21: Effect of Chromium Concentration on total Protein content of Amaranthus (*Amaranthus tricolor L*) at different time intervals.

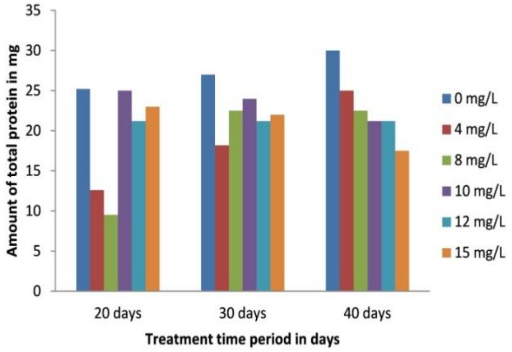

Figure-22: Effect of Chromium Concentration on total Protein content of Sesame (*Sesamum Indicum L*) at different time intervals.

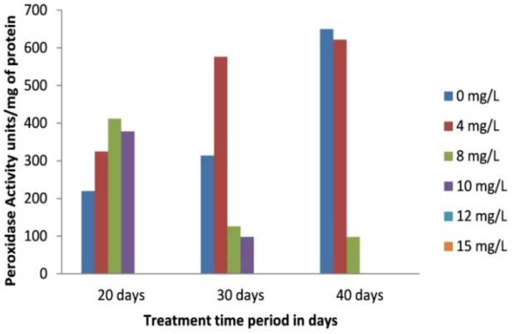

Figure-23: Effect of Chromium Concentration on Peroxidase activity of Amaranthus (*Amaranthus tricolor L*) at different time intervals.

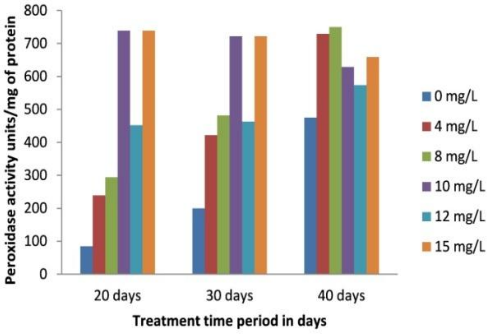

Figure-24: Effect of Chromium Concentration on Peroxidase activityof Sesame (*Sesamum Indicum L*) at different time intervals.

Table 1. Effect of different chromium concentration on chlorophyll contents (a, b, total) in Amaranthus (*Amaranthus tricolor L*)

Cr conc. (mg/L)	Chl. a (mg/g f.wt.)	Chl. b (mg/g f.wt.)	Total Chl. (mg/g f.wt.)
Control	6.71 ± 0.03	9.13 ± 0.00	15.84 ± 0.03
4	6.36 ± 0.05	6.73 ± 0.00	13.09 ± 0.05
8	4.81 ± 0.04	4.55 ± 0.00	9.36 ± 0.04
10	3.43 ± 0.05	2.47 ± 0.00	5.90 ± 0.05
12	1.24 ±0.06	1.68 ±0.02	2.92 ±0.07
15	0	0	0

excitation energy transfer could also be due to Cr(VI)-induced abnormalities in the chloroplast ultrastructure like a poorly developed lamellar system with widely spaced thylakoid and fewer grana.

The effects of chromium on photosynthetic pigments of Sesame (*Sesamum indicum L.*) leaves were determined on 40th day (Table 2). The photosynthetic pigment chlorophyll-a, chlorophyll-b and total chlorophyll of Sesame (*Sesamum indicum L.*) were decrease with increased chromium treatments. The chlorophyll-a in Sesame (*Sesamum indicum L.*) leaves were significantly ($p < 0.05$) decrease from 5.63 ± 0.05, 4.81 ± 0.04, 2.43 ± 0.05, 2.24 ± 0.06 and 0.98 ±0.06 respectively. Similarly, the chlorophyll-b in Sesame (*Sesamum indicum L.*) leaves were decrease significantly ($p < 0.05$) from 4.73 ± 0.00, 4.55 ± 0.00, 2.47 ± 0.00, 1.89 ± 0.02 and 0.12 ±0.02 respectively. The total chlorophyll content significantly ($p < 0.05$) affected at high chromium concentration from 10.36 ± 0.05, 9.36 ± 0.04, 4.90 ± 0.05, 4.13 ± 0.07 and 01.1 ± 0.08 respectively. Some other studies have the same conclusion that the chlorophyll contents were decrease if kept under Cr (VI) stress (10 - 40 mg/L) [17].

The examinations show that substantial metals and metalloids have consequences results for chlorophyll and amino acid substance in plants. Heavy metals are known to interfere with chlorophyll synthesis either through direct hindrance of an enzymatic advance or by inciting inadequacy of a basic supplement [42].

Table 2. Effect of different chromium concentration on chlorophyll contents (a, b, total) in Sesame (*Sesamum Indicum L*)

Cr conc. (mg/L)	Chl. a (mg·g−1 f.wt.)	Chl. b (mg·g−1 f.wt.)	Total Chl. (mg·g−1 f.wt.)
Control	9.71 ± 0.03	8.13 ± 0.00	17.84 ± 0.03
4	5.63 ± 0.05	4.73 ± 0.00	10.36 ± 0.05
8	4.81 ± 0.04	4.55 ± 0.03	9.36 ± 0.07
10	2.43 ± 0.05	2.47 ± 0.00	4.90 ± 0.05
12	2.24 ±0.06	1.89 ±0.02	4.13 ±0.07
15	0.98 ±0.06	0.12 ±0.02	01.1 ±0.08

Table 3. Physicochemical characteristics of soil used in present study

S. no	Parameter	Average value
01	pH	7.17 ± 0.005
02	Electro Conductivity (µs/cm)	487 ± 0.655
03	TDS (mg/L)	230 ± 0.575
04	Organic matter (%)	0.24 ± 0.001
05	Moisture (%)	20.85 ± 0.05

4. CONCLUSION

The dangerous impact of heavy metal on plant development relies upon the measure of lethal metal taken up from the predefined condition. The broad utilization of chromium in a substantial number of items and mechanical process has brought about extreme natural sullying. Chromium poisonous quality has turned out to be huge because of its consistent increment in the earth. Expanding convergence of chromium metal fundamentally decreases seed germination, development and biochemical trait of (*Amaranthus tricolor* L.) and Sesame (*Sesamum indicum* L.). The general inhibitory impact of chromium calculated as resistance record which was more articulated in (*Amaranthus tricolor* L.) and Sesame (Sesamum indicum L.) seedlings. This data can be viewed as a contributing advance in investigating and finding the resistance furthest reaches of (*Amaranthus tricolor* L.) and Sesame (*Sesamum indicum* L.) at various concentrations of chromium. Aftereffects of the investigation are helpful pointers of chromium resistance to some degree for plantation of (*Amaranthus tricolor* L.) and Sesame (*Sesamum indicum* L.) in chromium defiled zones.

The present investigation reveals that Sesame plants more tolerant towards high concentration of chromium compare to amaranthus. However, in the toxic metal contaminated areas, further research is needed to determine the effect of different level of metals in the environment and various parts of the plant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kochian L. Phytoremediation: Using plants to clean up soils. Agricultural Research Journal. 2002;48(6):36-40.
2. Pillay AE, Williams JREL, Mardi MO, Al-Lawati SMH, Al-Hadabbi MH, Al-Hamdi A. Risk assessment of chromium and arsenic in date palm leaves used as livestock feed. Environment International. 2003;1048:1-5.
3. Kotas J, Stasicka Z. Chromium occurrence in the environment and methods of its speciation. Environment Pollution. 2000;107:263-283.
4. Rogival D, Scheirs J, Blust R. Transfer and accumulation of metals in a soil diet-wood mouse food chain along a metal pollution gradient. Environmental Pollution. 2007;145:516-528.
5. Chatterjee J, Chatterjee C. Phytotoxicity of cobalt, chromium and copper in cauliflower. Environmental Pollution. 2000;109:69-74.
6. Shafiq M, Iqbal MZ. The toxicity effects of heavy metals on germination and seedling growth of *Cassia* siamea. Lamark. Journal of New Seeds. 2005;7:95-105.
7. Rashid P, Mukhirji S. Effect of foliar application of lead on the growth and yield parameters of wheat. Pakistan Journal of Scientific and Industrial Research. 1993;36:473-475.
8. Joseph LU, Andrea LC, Mai TK. Effects of lead contamination on the growth of *Lythrum salicaria*. Environmental Pollution. 2002;120(2):319-323.
9. Zhang H, Lian C, Shen Z. Proteomic identification of small, copper responsive proteins in germinating embryos of *Oryza sativa*. Ann. Bot. 2009;103:923-930.
10. Rahoui S, Chaoui A, Ferjani E El. Reserve mobilization disorder in germinating seeds of *Vicia faba* L. exposed to cadmium. Journal of Plant Nutrition. 2010;33:809-817.
11. Weiqiang L, Khan Mohammad A, Shinjiro Y, Yuji K. Effects of heavy metals on seed germination and early seedling growth of Arabidopsis thaliana. Plant Growth Regulation. 2005;46:45–50.
12. Aydinalp C, Marinova S. The effects of heavy metals on seed germination and plant growth on Alphalfa Plant (*Medicago sativa*). Bulgarian Journal of Agricultural Science. 2009;15(4):347-350.
13. Gandhi N, Sirisha D, Smita Asthana. Germination of seeds in soil samples of heavy traffic zones og Hyderabad, Telangana, India. Environmental Science-An Indian Journal. 2015;10(6):204-214.

14. Iqbal MZ, Rahmati K. Tolerance of Albizia lebbeck to Cu and Fe application. Ekologia (CSFR). 1992;11:427-430.
15. Chou CH, Muller CH. Allelopathic Mechanism of *Arctostaphylos glandulosa*, var. zacaensis. Am. Midl. Nat. 1972;88: 324-347.
16. Abdul Baki A, Anderson JD. Vigour Determina- tion in Soybean Seed by Multiple Criteria. Crop Science. 1993; 13(6):630-633.
17. Bewly JD, Black BM. Physiology and Biochemistry of Seeds in Relation to Germination. Springer Ver- lag, New York. 1982;40-80.
18. Gang A, Vyas A, Vyas H. Toxic effect of heavy metals on germination and seedling growth of wheat. Journal of Environmental Research and Development. 2013;8(2): 206–213.
19. Ganesh KS, Baskaran L, Chidambaram AA, Sundaramoorthy P. Influence of chromium stress on pro- line accumulation in soybean (*Glycine max* L. Merr.) Genotypes. Global Journal of Environmental Research. 2009;3(2):106-108.
20. Ozdener Y, Aydin BK, Fatma Aygun S, Yurekli F. Effect of hexavalent chromim on the growth and physiological and biochemical parameters on *Brassica oleracea* L. var. *acephala* DC. Acta Biologica Hungarica. 2011;62(4):463-476.
21. Hira Amin, Basir Ahmed Arain, Farah Amin, Muhammad Ali Surhio. Phytotoxicity of chromium on germination, growth and biochemical attributes of *Hibiscus esculentus* L. American Journal of Plant Sciences. 2013;4:2431-2439.
22. Arnon DI. Copper enzymes in isolated chloroplasts, polyphenol oxidase in *Beta vulgaris.* Plant Physiology. 1949;24:1-15.
23. Peralta JR, Gardea JL, Torresdey KJ, Tiemann E, Gomez S. Arteaga, Rascon E. Uptake and effects of five heavy metals on seed germination and plant growth in Alfalfa (*Medicago sativa* L.). Bulletin of Environmental Contamination and Toxicology. 2001;66(6):727-734.
24. Gandhi N, Sirisha D, Smita Asthana.. Phytoremediation of lead contaminated soil by using Sorghum bicolour. Research and Reviews in Biosciences, 2015;10(9): 333-342.
25. Zeid IM. Responses of *Phaseolus vulgaris* to chromium and cobalt treatments Biol. Planta. 2001;44(1):111-115.
26. Parmar NG, Vithalani SD, Chanda SV. Alteration in growth and peroxidase activity by heavy metals in phaseolus seedlings. Acta Physiol. Plant. 2002;24(1):89-95.
27. Dey SK, Jena PP, Kundu SJ. Antioxidative efficiency of *Triticum aestivum* L. exposed to chromium stress Environ. Biol. 2009;30(4):539-554.
28. Sharma DC, Chatterjee C, Sharma CP. Chromium accumulation by barley seedlings (*Hordeum vulgare* L,). Journal of Experimental Botany. 1995;25:241-251.
29. Claire LC, Adriano DC, Sajwan KS, Abel SL, Thomas DP, Driver JT. Effects of selected trace metals on germinating seeds of six plant species. Water, Air and Soil Poll. 2000;59:231-240.
30. Jagatheeswari D, Ranganathan P. Influence of mercuric chloride on seed germination, seedling growth and biochemical analysis of green gram (*Vigna radiate* (L.) Wilczek. Var. Vamlan-3. IJPBA. 2012;3(2):291-295.
31. Gautam MS, Singh R, Garg SK, Sengar K, Chaudhary R. Effect of lead on seed germination, seedling growth, chlorophyll content and nitrate reductase activity in mung bean (*Vigna radiate* L.). Research Journal of Phytochemistry. 2008;2(2):61-68.
32. Hussain M, Yasin G, Ali A, Ahmed R. Amelioration of toxic effects of lead (Pb) and chromium (Cr) in four black grams [(*Vigna mungo* L.) HEPPER] cultivars with the application of kinetin, Pak. J. Agri. Sci. 2007;44(2):251-258.
33. Amin H, Arain BA, Amin F, Surhio MA. Phytotoxicity of chromium on germination, growth and biochemical attributes of *Hibiscus esculentus* L. American Journal of Plant Sciences. 2013;4:2431-2439.
34. Jun R, Ling T, Guanghua Z. Effects of chromium on seed germination, root elongation and coleoptile growth in six pulses. International Journal of Environmental Science and Technology. 2009;6(4):571-578.
35. Sidharthan M, Lakshmanachary AS. Efficacy of chromium on germination, growth and biochemical studies on *Glycine max* var. CO 1. In: Environment and Biodiversity, Jha, P. K., Ghirmire, G. P. S., Kamacharya, S. B., Baral, S. R., and Lacoul, P. (eds.), Ecological Society, Katmandu, Nepal. 1996;326-328.
36. Rout GR, Samantary MS, Das P. Differential chromium tolerance among

eight mung bean cultivars grown in nutrient culture. J. Plant Nutr. 1997;20:473-483.

37. Lalitha K, Balasubramanian N, Kalavathy S. Studies of impact of chromium on *Vigna unguiculata* (L.) Walp. var. Long. J. Swamy Bot. Cl. 1999;16:17-20.
38. Subramain A, Sundaramoorthy P, Saravanan S, Selvaraj M, Lakshmanachary AS. Screening of groundnut cultivars for chromium sensitivity. Ecoprint. 1999;6:61-65.
39. Lakshmi S, Sundaramoorthy P. Effect of chromium on germination and biochemical changes in blackgram. J. Ecobiol. 2003;15: 7-11.
40. Samantary S, Deo B. Studies on chromium toxicity in mung bean (*Vigna radiata* L.). Adv. Plant Sci. 2004;17:189-194.
41. Sankar Ganesh K, Sundaramoorthy P, and Chidambaram ALA. Chromium toxicity effect on blackgram, soybean and paddy. Poll. Res. 2006;25:257-261.
42. Sundaramoorthy P, Sankar Ganesh K, Rajasekaran S, Baskaran L, Sumathi K. Studies on the effect of chromium on germination and growth of soybean (*Glycine max*) cultivars. Bull. Agric. Sci. 2006a;4:91-94.
43. Sundaramoorthy P, Sankar Ganesh K, Baskaran L, Sumathi K, Rajasekaran S. Germination behaviour of some agricultural crops under chromium treatment. Bull. Biol. Sci. 2006b;4:99-101.
44. Hira Amin, Basir Ahmed Arain, Farah Amin, Muhammad Ali Surhio. Phytotoxicity of chromium on germination, growth and biochemical attributes of *Hibiscus esculentus* L. American Journal of Plant Sciences. 2013;4:2431-2439.
45. Ganesh KS, Baskaran L, Chidambaram AA, Sundaramoorthy P. Influence of chromium stress on pro- line accumulation in soybean (*Glycine max* L. Merr.) genotypes. Global Journal of Environmental Research. 2009;3(2):106-108.
46. Jamal SN, Iqbal MZ, Athar M. Phytotoxic effect of aluminum and chromium on the germination and early growth of wheat (*Triticum aestivum*) varieties Anmol and Kiran. International Journal of Environmental Science and Technology. 2006;3(4):411-416.
47. Rellén-Álvarez R, Ortega-Villasante C, Álvarez-Fernández A, del Campo FF, Hernández LE. Stress response of *Zea mays* to cadmium and mercury. Plant and Soil. 2006;279:41-50.
48. Jain R, Srivastava S, Madan VK, Jain R. Influence of chromium on growth and cell division of sugarcane. Indian Journal of Plant Physiology. 2000;5:228-31.
49. Rajalakshmi K, Kumar P, Saravanakumar A, Aslam A, Shahjahan A, Ravikumar R. Arachis bioassay for soil contaminated with hexavalent chromium. Recent Research in Science and Technology. 2010;2(6):110-115.
50. Akinci IE, Akinci S. Effect of chromium toxicity on germination and early seedling growth in melon (*Cucumis melo* L.). African Journal of Biotechnology. 2010;9(29):4589-4594.
51. Khan MR, Khan MM. Effect of varying concentration of nickel and cobalt on the plant growth and yield of chickpea. Australian Journal of Basic and Applied Sciences. 2010;4(6):1036-46.
52. Abdul Ghani. Effect of chromium toxicity on growth, chlorophyll and some mineral nutrients of *Brassica juncea* L. Egypt. Academic Journal of biological Sciences. 2011;2(1):9-15.
53. Bishoni NR. Effect of chromium on seed germination, seedling growth and yield of peas. Agric. Ecosyst. Environ. 1993;47: 47-57.
54. Arduini I, Masoni A, Ercoli L. Effects of high chromium applications on miscanthus during the period of maximum growth. Environmental and Experimental Botany. 2006;58:234-243.
55. Samantary S. Biochemical responses of Cr-tolerant and Cr sensitive mungbean cultivars grown on varying levels of chromium. Chemosphere. 2002;47(10): 1065-1072.
56. Mallick S, Sinam G, Kumar Mishra R, Sinha S. Interactive effects of Cr and Fe treatments on plants growth, nutrition and oxidative status in *Zea mays* L. Ecotoxicology and Environmental Safety. 2010;73(5):987-995.
57. Barcel OJ, Poschenrieder C, Gunse J. Effect of chromium (VI) on mineral element composition of bush beans. Journal of Plant Nutrition. 1985;8:211-217.
58. Oliveira H. Chromium as an environmental pollutant: Insights on induced plant toxicity. Journal of Botany. Article ID 375843, 2012;8.
DOI: 10.1155/2012/375843.

59. Fozia A, Muhammad AZ, Zafar MK. Effect of chromium on growth attributes in sunflower (*Helianthus annuus* L.). Journal of Environmental Sciences. 2008;20(12): 1475-1480.
60. Vajpayee P, Rai UN, Ali MB, Tripathi RD, Yadav V, Sinha S. Chromium induced physiological changes in *Vallisneria spiralis* L. and its role in phytore mediation of tannery effluent. Bulletin of Environmental Contamination and Toxicology. 2001;67(2):246-256.
61. Hayat S, Khalique G, Irfan M, Wani AS, Tripathi BN, Ahmad A. Physiological changes induced by chromium stress in plants: An overview Protoplasma. 2012;249:599-611.
62. Mondal NK, Das C, Roy S, Datta JK, Banerjee A. Effect of varying cadmium stress on chickpea (*Cicer Arietinum* l) seedlings: An ultrastructural study Ann. Environ. Sci. 2013;7:59-70.
63. Mondal NK, Das C, Datta JK. Effect of mercury on seedling growth, nodulation and ultrastructural deformation of *Vigna radiata* (L) Wilczek Environ. Monit. Assess. 2015;187:1-14.
64. Gupta K, Gaumat S, Mishra K. Chromium accumulation in submerged aquatic plants treated with tannery effluent at Kanpur Ind. J. Environ. Biol. 2011;32:591-597.
65. Panda SK, Choudhury S. Chromium stress in plants Braz. J. Plant Physiol. 2005;17: 95-102.
66. Assche VFV, Clijsters H. Effects of metals on enzyme activity in plants. Plant Cell Environ. 1990;13:95-206.
67. Vajpayee P, Tripathi RD, Rai UN, Ali MB, Singh SN. Cr (VI) accumulation reduces chlorophyll biosynthesis, nitrate reductase activity of protein content in *Nymphaea alba* L Chemosphere. 2000;41:1075-1082.
68. Sinha P, Dube BK, Chatterjee C. Amelioration of chromium phytotoxicity in spinach by withdrawal of chromium or iron application through different modes. Plant Sci. 2005;169:641-646.

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