

## **Ecophysiological and Biochemical Changes in *Abelmoschus esculentus* (L.) Moench under Chromium stress**

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### **ABSTRACT**

Increasing concentrations of chromium caused reduction in growth, chlorophyll contents and mineral nutrients of bhendhi. At increasing concentrations of chromium, all the attributes were found to be reduced. Chromium is one of the toxic elements discharging from tannery industry. The long disposal of tannery effluent to the agricultural land causes serious damages in the soil texture; reduce the growth of microorganisms and agricultural crops. Large areas of Vellore district of Tamilnadu was seriously affected by the tannery effluent irrigation to the agricultural land. The present study was conducted to identify the phytotoxic effect and physiological changes of *Abelmoschus esculentus* (L.) Moench under the treatment of different concentrations of chromium solutions (2.5, 5, 10, 25, 50, 75 and 100 mg/l). The result shows that there was a gradual reduction in the morphological parameters (root length, shoot length, fresh weight and dry weight). Similarly the photosynthetic pigments (Chlorophyll and carotenoid) and biochemical parameters such as protein, amino acid, and sugars were also gradually decreased with increasing concentrations of chromium.

**Keywords:** *Abelmoschus esculentus*; chromium; biochemical parameters

### **1. INTRODUCTION**

Water is the most precious thing for all living organisms in the world. Nowadays, most of our water resources are gradually becoming polluted by various human activities. Water pollution may be defined as a natural or induced change in the quality of water which renders it unusable or dangerous as regard to food, human and animal health, industry, agriculture and fishing (Manna and Das, 2004). The addition of huge amount of sewage, industrial and agricultural effluents is the main cause for water pollution. The effluent discharging industries are tanneries, textile mills, sugar mills, chemical industries, electroplating, distilleries, pharmaceuticals, dairy etc., cause the water and soil pollution. Among the effluent discharging industries, tannery industry plays a major role in polluting the environment. It is one of the

oldest cottage industries of India, which stands third largest producer of leather in the world and earn a lot of country's economy (Dadhich *et al.*, 2002)

The major pollutants are sodium chloride, sodium sulphate, lime, chromium, proteinaceous matter and so on (Gomathi *et al.*, 2004). Tannery effluent also contains large amounts of other pollutants such as protein, hair, salt, lime, sludge and acid. Among them, chromium is a main constituent of the tannery effluent. Chromium merits a special reference for its toxic potential. In addition, it is released from electroplating, textile printing and metal finishing industries (Sankar Ganesh *et al.*, 2006). Chromium exists in two forms: Hexavalent chromium and trivalent chromium. Hexavalent Cr is more toxic than trivalent Cr because of its soluble nature in water. The long-term disposal of tannery wastes onto land can indeed lead to accumulation and transport of water (Sethunathan *et al.*, 2005). Even lower concentration of chromium (> 2 ppm) has also been reported to be inhibitory for plant growth. In addition, its presence in excess amount within the plant caused stunted growth, roots develop poorly and leaves appear discolored (Nath *et al.*, 2005). The present study was aimed to find out the phytotoxic effect and physiological changes of *Abelmoschus esculentus* grown under different concentrations of chromium solution.

## 2. MATERIALS AND METHODS

The experimental crop bhendi (*Abelmoschus esculentus* (L.) Moench.) was collected from Authorized Private Agro Centre, Chidambaram, Cuddalore district, Tamil Nadu.

A known weight (5.912 g) of potassium dichromate ( $K_2Cr_2O_7$ ) salt was dissolved in 1000 ml of distilled water. This is equal to 1000 ml/l of chromium. From this stock solution, different concentrations (2.5, 5.0, 10.0, 25.0, 50.0 mg/l) of chromium solution were prepared and they were used for both the experiments.

Pot culture experiments were conducted in Botanical garden, Department of Botany, Annamalai University. The pots were filled with 5 kg of garden soil. Then, ten seeds of bhendi were sown in each pot. The pots were irrigated with equal volume of different concentrations of chromium solution (2.5, 5, 10, 25, 50, 75 and 100 mg/l). The control set was maintained with borewell water. After one week, thinning was done by allow to grow 5 seedlings per pot. Five plants were randomly selected from each treatment for the observation of the morphological growth parameters. The shoot length, root length, number of leaves, total leaf area, fresh weight and dry weight were recorded at every 25 days *viz.*, 25, 50 and 75 DAS. The yield parameters were observed and recorded at the time of harvest.

The photosynthetic pigments such as chlorophylls and carotenoid contents were measured by using the standard procedure mentioned by Arnon (1949) and Kirk and Allen (1965) respectively. Simultaneously the biochemical parameters such as Amino acid (Moore and Stein, 1948), Protein (Lowry *et al.*, 1951), reducing, sugar Non-reducing sugar and total sugar (Nelson, 1944) were also calculated at 25, 50 and 75 DAS.

### 2. 1. Soil Analyses

The soil samples were collected from each pot and labelled separately after harvesting of Bhendi. The physico-chemical properties of, chromium polluted soil. The various soil properties such as pH, electrical conductivity, nitrogen (Subbiah and Asija, 1976), phosphorus (Jackson, 1958), potassium (Jackson, 1958), copper, zinc, iron, manganese and chromium (Piper, 1966) were analysed and reported.

### 3. RESULT AND DISCUSSION

#### 3. 1. Shoot length and root length (cm/plant)

The effect of different concentrations of chromium on shoot length and root length of bhendi crop at various stages of its growth is given in Table 1. The highest root length (8.36, 15.5, 17.5 cm/plant), shoot length (26.0, 37.5, 58.5 cm/plant) were observed at (25, 50, 75 DAS) in control. The minimum range of root length (3.40, 9.20, 11.20 cm/plant) and shoot length (9.64, 21.5, 38.5 cm/plant) were observed at (25, 50, 75 DAS) in 50 mg/l concentration of chromium treated bhendi crop. The reduction in plant height might be mainly due to the reduced root growth and consequent lesser nutrients and water transport to the above parts of the plant. In addition to this Cr transport to the aerial part of the plant have a direct impact on the shoot metabolism contributing to the reduction in plant height (Shankar *et al.*, 2005).

**Table 1.** Effect of various concentrations of chromium on root length and shoot length (cm/plant) of *A. esculentus* at various stages of its growth.

Chromium concentration (mg/l)	Root length			Shoot length		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
Control	8.36 ± 0.418	15.5 ± 0.775	17.5 ± 0.875	26.0 ± 1.300	37.5 ± 1.875	58.5 ± 2.925
2.5	8.10 ± 0.405	13.2 ± 0.660	16.2 ± 0.810	19.20 ± 0.960	36.2 ± 1.810	57.0 ± 2.850
5	6.40 ± 0.320	13.0 ± 0.650	14.5 ± 0.725	17.70 ± 0.885	32.0 ± 1.600	53.2 ± 2.660
10	5.96 ± 0.298	12.5 ± 0.625	13.00 ± 0.650	16.00 ± 0.800	28.5 ± 1.425	50.1 ± 2.660
25	4.80 ± 0.240	10.8 ± 0.540	12.30 ± 0.615	12.44 ± 0.622	23.2 ± 1.160	47.3 ± 2.365
50	3.40 ± 0.170	9.2 ± 0.460	11.20 ± 0.560	9.64 ± 0.482	21.5 ± 1.075	38.5 ± 1.925

### 3. 2. Number of leaves and total leaf area

The effect of different concentrations of chromium on number of leaves and total leaf area of bhendi crop at various stages of its growth is shown in Table 2. The higher amount of leaves (5.0, 6.0, 7.0 leaves/plant) and the lower number of leaves (3.0, 4.0, 5.0 leaves/plant) were observed in control at 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> days respectively. The maximum leaf area (66.0, 138.6, 255.74 cm<sup>2</sup>/plant) and the minimum leaf area (18.37, 27.72, 79.5 cm<sup>2</sup>/plant) were observed in 50 mg/l concentration of chromium treated plant at 25, 50, 75 DAS respectively. The reduced cell size and decreased intracellular spaces were largely responsible for reduction in leaf area. The size of the areoles decreased in plants treated with chromium and this may be due to the decrease in leaf area (Joshi *et al.*, 1999).

**Table 2.** Effect of various concentrations of chromium on number of leaves and total leaf area (cm<sup>2</sup>/plant) of *A. esculentus* at various stages of its growth.

Chromium concentration (mg/l)	Number of leaves			Total leaf area		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
Control	5.0 ± 0.250	6.0 ± 0.300	7.0 ± 0.350	66.0 ± 3.300	138.6 ± 6.930	255.74 ± 12.787
2.5	5.0 ± 0.250	6.0 ± 0.300	6.0 ± 0.300	57.75 ± 2.887	95.04 ± 4.752	178.20 ± 8.910
5	4.0 ± 0.200	5.0 ± 0.250	6.0 ± 0.300	36.96 ± 1.848	57.75 ± 2.887	158.40 ± 7.920
10	4.0 ± 0.200	5.0 ± 0.250	6.0 ± 0.300	32.34 ± 1.617	49.5 ± 2.475	126.72 ± 6.336
25	3.0 ± 0.150	4.0 ± 0.200	6.0 ± 0.300	20.79 ± 1.039	36.96 ± 1.848	110.88 ± 5.544
50	3.0 ± 0.150	4.0 ± 0.200	5.0 ± 0.250	18.37 ± 0.918	27.72 ± 1.386	79.5 ± 3.975

### 3. 3. Fresh weight and dry weight (g/plant)

The effect of different concentrations of chromium on fresh weight and dry weight of bhendi crop at various stages of its growth is given in Table 3. The highest amount of fresh weight (2.152, 5.328, 9.750 g/plant) and dry weight (1.120, 2.106, 3.235 g/plant) were observed in control at 25, 50 and 75 DAS. The minimum amount of fresh weight (0.513, 2.300, 5.323 g/plant) and dry weight (0.168, 0.885, 1.955 g/plant) were observed in 50 mg/l concentration of chromium treated plant at 25, 50, 75 DAS respectively. The concentration of soluble protein provide an evidence that chromium is responsible for enhanced degradative pathways as it occurs in tissues during cellular breakdown of the constituents.

**Table 3.** Effect of various concentrations of chromium on fresh weight and dry weight (g/plant) of *A. esculentus* at various stages of its growth.

Chromium concentration (mg/l)	Fresh weight			Dry weight		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
Control	2.152 ± 0.1076	5.328 ± 0.2664	9.750 ± 0.4875	1.120 ± 0.056	2.106 ± 0.1053	3.235 ± 0.1617
2.5	1.856 ± 0.0928	4.742 ± 0.2371	9.380 ± 0.469	0.832 ± 0.0416	2.060 ± 0.103	3.162 ± 0.1581
5	1.630 ± 0.0815	4.311 ± 0.2155	8.112 ± 0.4056	0.513 ± 0.0256	1.723 ± 0.0861	2.478 ± 0.1239
10	1.516 ± 0.0758	3.260 ± 0.163	7.355 ± 0.3677	0.420 ± 0.021	1.620 ± 0.0810	2.315 ± 0.1157
25	0.865 ± 0.0432	3.175 ± 0.3677	6.412 ± 0.3206	0.283 ± 0.0141	1.123 ± 0.0561	2.100 ± 0.1050
50	0.513 ± 0.0256	2.300 ± 0.115	5.323 ± 0.2661	0.168 ± 0.0084	0.885 ± 0.0442	1.955 ± 0.977

### 3. 4. Yield parameters

The effect of different concentrations of chromium on yield parameters of bhendi crop is given in Table 4. The maximum number of fruits (15.0 /plant) fruit length (13.5 cm /fruit),

fruit weight (3.25 g/fruit), number of seeds (45.5 /fruit) and 100 seed weight (8.88 g) were noted in control. The minimum amount of fruit number (6.0/plant), fruit length (6.0 cm/fruit), fruit weight (1.00 g/fruit), number of seeds (18.0 /fruit) and 100 seeds weight (2.15 g) were observed in 50 per cent of chromium concentrated bhendi crop. Cr on plant processes during early growth and development culminates in reduction of yield and total dry matter as a consequence of poor production, translocation and partitioning of assimilates to the economic parts of the plant (Sharma and Sharma, 1993).

**Table 4.** Effect of different concentrations of chromium on yield parameters of *A. esculentus*.

Chromium concentration (mg/l)	Number of fruits per plant	Fruit length (cm/fruit)	Fruit weight (g/fruit)	Number of seeds per fruit	100 seed weight (g)
Control	15.0 ± 0.75	13.5 ± 0.67	3.250 ± 0.1625	45.5 ± 2.275	8.880 ± 0.444
2.5	14.0 ± 0.70	12.2 ± 0.61	3.100 ± 0.1550	40.2 ± 2.010	7.680 ± 0.384
5	12.0 ± 0.60	10.5 ± 0.52	2.780 ± 0.1390	35.0 ± 1.750	6.210 ± 0.310
10	10.0 ± 0.50	9.6 ± 0.48	2.150 ± 0.1075	26.2 ± 1.310	5.000 ± 0.250
25	8.0 ± 0.40	8.2 ± 0.41	1.520 ± 0.0760	20.5 ± 1.025	4.320 ± 0.216
50	6.0 ± 0.30	6.0 ± 0.30	1.000 ± 0.0500	18.0 ± 0.900	2.150 ± 0.107

### 3. 5. Photosynthetic pigments

The effect of various concentrations of chromium on chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid content (mg/g fr. wt.) of bhendi crop at 25<sup>th</sup> and 75<sup>th</sup> days are shown in Table 5. The higher amount of chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid content (0.4973, 0.3921, 0.8894 and 0.6297 mg/g fr. wt.) were observed at 75<sup>th</sup> days of control plant. Similarly, the lowest values of chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid content (0.1591, 0.0914, 0.2533 and 0.2215 mg/g fr. wt) were observed at in 50 mg/l concentration of chromium irrigated bhendi crop. The impaired  $\alpha$ -amino laevulinic acid dehydratase activity leading to reduced photosynthetic pigments has been observed in chromium treated *Nymphaea alba* (Vajpyee *et al.*, 2000). Besides, lipid peroxidation also caused the degradation of photosynthetic pigments (Rai *et al.*, 2004). The reduction photosynthetic pigments may also be due to the disruption of chloroplast phosphorylation observed in various plants as suggested by Jana and Choudhari (1992); Chandra and Kulshrentha (2004); Singh and Sinha (2005).

**Table 5.** Effect of various concentrations of chromium on photosynthetic pigments (mg/g fr. wt) of *A. esculentus* at various stages of its growth.

Chromium concentrations (mg/l)	25 DAS				75 DAS			
	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll	Carotenoid	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll	Carotenoid
Control	0.3289 ± 0.0164	0.2359 ± 0.1179	0.5705 ± 0.0282	0.4832 ± 0.0241	0.4973 ± 0.0248	0.3921 ± 0.0196	0.8894 ± 0.0444	0.6297 ± 0.0314
2.5	0.3185 ± 0.0159	0.2058 ± 0.0102	0.5298 ± 0.0249	0.4316 ± 0.0215	0.4071 ± 0.0203	0.3610 ± 0.0180	0.7375 ± 0.0368	0.6976 ± 0.0348
5	0.2118 ± 0.0105	0.1014 ± 0.0050	0.3168 ± 0.0158	0.3015 ± 0.0150	0.3975 ± 0.0198	0.2923 ± 0.0146	0.5890 ± 0.0294	0.6520 ± 0.0326
10	0.1949 ± 0.0097	0.1013 ± 0.0506	0.2996 ± 0.0149	0.2738 ± 0.0136	0.2750 ± 0.0137	0.1924 ± 0.0096	0.3752 ± 0.0187	0.4971 ± 0.0248
25	0.1932 ± 0.0096	0.0923 ± 0.0046	0.2889 ± 0.0144	0.2338 ± 0.0116	0.2075 ± 0.0103	0.1250 ± 0.0002	0.3074 ± 0.0153	0.3720 ± 0.0186
50	0.1591 ± 0.0079	0.0914 ± 0.0045	0.2533 ± 0.0126	0.2216 ± 0.0110	0.1694 ± 0.0084	0.1095 ± 0.0054	0.2973 ± 0.0148	0.2590 ± 0.0129

### 3. 6. Protein (mg/g fr. wt.)

The influence of different concentrations of chromium on protein content of bhendi at 25<sup>th</sup> and 75<sup>th</sup> day of its growth is given in Table 6.

The maximum protein content of various parts of bhendi (leaf 2.9702, stem 1.0741, root 3.9740 mg/g fr. wt.) was observed in 25<sup>th</sup> day of control plants irrigated with tap water.

The minimum protein content (leaf 0.8973, stem 0.6294, root 1.2973 mg/g fr. wt.) was recorded at 75<sup>th</sup> day of its growth in 50 mg/l concentration of chromium treatment.

The degradation in protein content might be the result of increased activity of the protease or other catabolic enzymes under chromium stress (Vajpayee *et al.*, 2001; Rai *et al.*, 1992). During transport of heavy metals in plants, sulphhydryl group of protein may be reduced causing deleterious effect in the normal protein form.

**Table 6.** Effect of different concentrations of chromium on protein content (mg/g fr. wt) of *A. esculentus* at two stages of its growth.

Chromium concentrations (mg/l)	25			75		
	Leaf	Stem	Root	Leaf	Stem	Root
Control	2.9702 ± 0.1485	1.0741 ± 0.0537	3.9740 ± 0.1987	3.2175 ± 0.1608	1.3890 ± 0.0694	4.1273 ± 0.2063
2.5	2.7301 ± 0.1365	0.9736 ± 0.0486	3.6607 ± 0.1830	2.9381 ± 0.1469	1.2940 ± 0.0647	3.7940 ± 0.1897
5	1.7940 ± 0.0897	0.9372 ± 0.0468	3.2940 ± 0.1647	2.5701 ± 0.1285	1.0794 ± 0.0539	2.9731 ± 0.1486
10	1.0761 ± 0.0538	0.8713 ± 0.0435	2.1720 ± 0.1086	1.9047 ± 0.0952	0.9764 ± 0.0488	2.7690 ± 0.1384
25	0.9786 ± 0.0489	0.8601 ± 0.0430	2.0621 ± 0.1031	1.2714 ± 0.0635	0.8731 ± 0.0436	2.9902 ± 0.1495
50	0.6317 ± 0.3150	0.5250 ± 0.0262	1.0731 ± 0.0536	0.8973 ± 0.0048	0.6294 ± 0.0314	1.2973 ± 0.0648

### 3. 7. Amino acid (mg/g fr. wt.)

The effect of various concentrations of chromium on amino acid content (mg/g fr. wt.) of bhendi at 25<sup>th</sup> and 75<sup>th</sup> day of its growth is given in Table 7.

The maximum amount of amino acid content (leaf 4.7804, stem 1.7674, root 3.9701 mg/g fr. wt) was observed in 75<sup>th</sup> days of control plants.

The minimum amount of amino acid content (leaf 1.8740, stem 0.5470, root 1.4076 mg/g fr. wt) was recorded in 25<sup>th</sup> day of its growth at 50 mg/l chromium concentration.

The decline in amino acid cysteine may result in the degradation of sulphate reducing enzymes leading to toxic effects (Vajpayee *et al.*, 2001).



**Table 7.** Effect of different concentrations of chromium on amino acid content (mg/g fr. wt) of bhendi (*A. esculentus*) at two stages of its growth.

Chromium concentrations (mg/l)	25 DAS			75 DAS		
	Leaf	Stem	Root	Leaf	Stem	Root
Control	4.224 ±0.2112	1.2902 ± 0.0645	3.8970 ± 0.1948	4.7804 ± 0.2390	1.7674 ± 0.0883	3.9701 ± 0.1985
2.5	3.682 ± 0.1841	1.2902 ± 0.0645	3.2731 ± 0.1636	3.9709 ± 0.1985	1.3844 ± 0.0692	3.487 ± 0.1743
5	3.524 ± 0.1762	1.0840 ± 0.0542	3.0740 ± 0.1537	3.8021 ± 0.1901	1.1707 ± 0.0585	3.2670 ± 0.1633
10	2.996 ± 0.1498	0.6180 ± 0.0309	2.4570 ± 0.1228	3.6974 ± 0.1848	0.9671 ± 0.0483	2.9741 ± 0.1487
25	2.587 ± 0.1293	0.7621 ± 0.0381	1.9670 ± 0.0983	2.2840 ± 0.1142	0.8812 ± 0.0440	2.3174 ± 0.1158
50	1.874 ± 0.0937	0.5470 ± 0.0273	1.4076 ± 0.0703	2.0701 ± 0.1035	0.7381 ± 0.0369	1.0793 ± 0.0539

### 3. 8. Sugar (mg/g fr. wt.)

The impact of different concentrations of chromium on reducing sugar content (mg/g fr. wt.) in various parts of bhendi in 25<sup>th</sup> and 75<sup>th</sup> day is given in Table 8. The highest amount of reducing sugar of leaf (2.6640), stem (1.5000), root (1.4120 mg/g fr. wt.) was observed in control plant at 75<sup>th</sup> day. The lowest content of reducing sugar of leaf (1.4940 mg/g fr. wt.), stem (0.5160 mg/g fr. wt.), root (0.5000 mg/g fr. wt.) were recorded at 25<sup>th</sup> days of growth in 50 mg/l concentration of chromium irrigation. The maximum non-reducing sugar content of leaf (7.146 mg/g fr. wt.), stem (6.215 mg/g fr. wt.), and root (5.000 mg g<sup>-1</sup> fr. wt.) were recorded at 75<sup>th</sup> days of control plant. The lowest amount of non-reducing sugar in leaf (1.598 mg/g fr. wt.), stem (0.726 mg/g fr. wt.), root (0.785 mg g<sup>-1</sup> fr. wt.) were noted at 25<sup>th</sup> days of its growth in 50 mg/l concentration of chromium irrigation (Table 9). The higher amount of total sugar content in various parts like (leaf 13.258, stem 10.877, root 9.102 mg/g fr. wt.) were noted in 75<sup>th</sup> days of control plant.

**Table 8.** Effect of different concentrations of chromium on reducing sugar content (mg/g fr. wt) of *A. esculentus* at two stages of its growth.

Chromium concentrations (mg/l)	25 DAS			75 DAS		
	Leaf	Stem	Root	Leaf	Stem	Root
Control	2.664 ± 0.1332	1.500 ± 0.075	1.412 ± 0.0706	6.112 ± 0.3056	4.662 ± 0.2331	4.102 ± 0.2051
2.5	2.382 ± 0.1191	1.326 ± 0.0663	1.212 ± 0.0606	6.015 ± 0.3007	4.106 ± 0.2053	3.737 ± 0.1868
5	2.175 ± 0.1087	1.110 ± 0.0555	1.011 ± 0.0505	5.328 ± 0.2664	3.715 ± 0.1857	3.400 ± 0.1700
10	2.072 ± 0.1036	0.865 ± 0.0432	0.735 ± 0.0367	4.672 ± 0.2336	2.635 ± 0.1317	2.550 ± 0.1275
25	1.953 ± 0.0976	0.732 ± 0.0366	0.660 ± 0.0330	4.155 ± 0.2077	2.143 ± 0.1071	2.000 ± 0.1000
50	1.494 ± 0.0747	0.516 ± 0.0258	0.500 ± 0.0250	3.556 ± 0.1778	2.106 ± 0.1053	1.916 ± 0.0956

**Table 9.** Effect of different concentrations of chromium on non-reducing sugar content (mg/g fr. wt) of *A. esculentus* at two stages of its growth.

Chromium concentrations (mg/l)	25 DAS			75 DAS		
	Leaf	Stem	Root	Leaf	Stem	Root
Control	2.841 ± 0.1420	2.015 ± 0.1007	1.965 ± 0.0982	7.146 ± 0.3573	6.215 ± 0.3107	5.000 ± 0.2500

2.5	2.678 ± 0.1339	1.812 ± 0.0906	1.732 ± 0.0866	6.785 ± 0.3392	5.880 ± 0.2940	4.810 ± 0.2405
5	2.442 ± 0.1121	1.432 ± 0.0716	1.106 ± 0.0553	5.886 ± 0.2943	5.410 ± 0.2705	4.312 ± 0.2156
10	2.220 ± 0.1110	0.916 ± 0.0458	0.985 ± 0.0492	5.102 ± 0.2551	4.762 ± 0.2381	3.615 ± 0.1807
25	2.072 ± 0.1036	0.815 ± 0.0407	0.876 ± 0.0438	4.660 ± 0.2330	4.312 ± 0.2156	3.288 ± 0.1644
50	1.598 ± 0.0799	0.726 ± 0.0362	0.785 ± 0.0392	4.215 ± 0.2107	3.816 ± 0.1908	2.432 ± 0.1216

**Table 10.** Effect of different concentrations of chromium on total sugar content (mg/g fr. wt) of *A. esculentus* at two stages of its growth.

Chromium concentrations (mg/l)	25 DAS			75 DAS		
	Leaf	Stem	Root	Leaf	Stem	Root
Control	5.505 ± 0.2750	3.515 ± 0.1757	3.377 ± 0.1688	13.258 ± 0.6629	10.877 ± 0.5438	9.102 ± 0.4551
2.5	5.060 ± 0.2530	3.138 ± 0.1569	2.944 ± 0.1472	12.800 ± 0.6400	9.986 ± 0.4993	8.587 ± 0.4273
5	4.617 ± 0.2308	2.542 ± 0.1271	2.117 ± 0.1058	11.214 ± 0.5607	9.125 ± 0.4562	7.712 ± 0.3856
10	4.292 ± 0.2146	1.781 ± 0.0890	1.721 ± 0.0860	9.774 ± 0.4887	7.397 ± 0.3698	6.165 ± 0.3082
25	4.025	1.547	1.536	8.815	6.455	5.288

	± 0.2012	± 0.0773	± 0.7680	± 0.4407	± 0.3227	± 0.2644
50	3.092 ± 0.1546	1.242 ± 0.0621	1.285 ± 0.0642	7.771 ± 0.3885	5.922 ± 0.2961	4.348 ± 0.2174

The lowest total sugar content (leaf 3.092, stem 1.242, root 1.285 mg/g fr. wt.) were observed at 75<sup>th</sup> days of its growth in 50 mg/l concentration of chromium irrigation (Table 10). Loss of sugar formation may also be due to the conversion of sugar into energy when the plants were stressed (Outridge and Noler, 1991). It may be also due to the imbalance which might eventually lead to depletion of carbohydrate reserve (Mahadeswaraswamy and Theresa, 1992).

### 3. 9. Analysis of chromium polluted soil

Physico-chemical properties of different concentrations of chromium polluted soil are given in Table 11. The bhendi crop grown chromium polluted soil revealed that they are having the values of pH (0.18), EC (7.8), nitrogen (50 g/kg), phosphorus (8.0 g/kg), potassium (87 g/kg), copper (14.15 ppm), zinc (11.00 ppm), iron (18.0 ppm), manganese (3.00 ppm) and chromium (1107 mg/g) were observed at 50 mg/l concentration of chromium polluted soil.

The control soil are having pH (7.6 ppm), EC (0.39 ppm), nitrogen (46 g/kg), phosphorus (9 g/kg), potassium (500 g/kg), copper (21.15 ppm), zinc (15.20 ppm), iron (22.95 ppm), manganese (5.15 ppm) with nil chromium.

**Table 11.** Physicochemical analyses of different concentrations of chromium polluted soil.

Chromium concentrations (mg/l)	Soil Properties									
	pH	EC (Mm hos/cm)	N (g/kg)	P (g/kg)	K (g/kg)	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cr (mg/kg)
Control	7.6	0.39	46	9	500	21.15	15.20	22.95	5.15	-
2.5	7.7	0.32	70	11.5	82	20.10	13.80	20.00	5.00	57.0
5	8.7	0.14	46	8.5	100	18.00	13.05	19.15	5.00	114.0
10	7.9	0.22	59	8.5	92	16.00	12.12	19.00	4.10	217.0
25	0.19	8.4	49	10	92	15.30	11.10	18.25	3.85	598.0
50	0.18	7.8	50	8.0	87	14.15	11.00	18.00	3.00	110.7

#### 4. CONCLUSION

Present study concluded that the phytotoxicity effect of hexavalent Cr severely affected the growth and biomass of *A. esculentus*. The harmful effects of Cr on plant's growth and development by extensively investigating the physiological and biochemical parameters. It was known that adverse effects of Cr were due to the negative impacts on physiological and biochemical parameters. High concentrations of Cr is highly contaminated soil. The study suggest that the chromium is highly toxic to the growth and development of *A.esculentus*

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