Annals of Plant and Soil Research 22(1): 75-79 (2020)

Biochemical and physiological response of maize (*Zea mays*) to chromium and lead induced stress

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Received: September, 2019; Revised accepted: November, 2019

ABSTRACT

A greenhouse experiment was carried out to study the effect of lead and chromium on biochemical and physiological parameters of maize (Zea mays L.) at Dr. B.R.A.University Agra (U.P) during Kharib season of 2015. The plants were treated with three concentrations each of Pb and Cr along with a control. The observations on shoot and root length, leaf area, root development and biomass production were recorded. The physiological parameters like shoot and root length, biomass production tended to decrease with increasing concentration of Pb and Cr over control. Stress induced by Pb and Cr declined the pigment compositions viz. chl 'a' ' b' as well as the total chlorophyll content over control. But the amount of proline content was increased with Pb and Cr concentrations. The effect of lead was more severe as compared to chromium at all concentrations (50,100 and 150 µM). Application of a considerable amount of nitrogen may be useful to alleviate the stress problem of these two elements.

Keywords: Zea mays, biochemical parameters, heavy metals, Maize

INTRODUCTION

Maize(Zea mays L.) or corn belongs to the family *Poaceae*. In India, it is mainly grown in several states viz. Uttar Pradesh, Andhra Pradesh, Madhya Pradesh, Bihar, Jammu and Kashmir and Punjab. Whole plant of maize is widely used for animal feed, industrial raw material, staple food and preparation of popcorns. Maize is the richest sources of carbohydrates and vitamins and is used in the manufacture of syrup, oil, dextrose, gelatin and lactic acid etc. Lead (Pb) is a silvery-white toxic heavy metal rarely found in native form in nature but it combines with other elements to form a variety of minerals. It is highly destructive to plants and most difficult to control. Lead is harmful to plants and affects germination of seeds and exerts deleterious effects on growth and metabolism of plants. Chromium (Cr) is the seventh most abundant transition element considered as a strong toxic element. A high concentration of Cr has been found to be harmful to microorganism and plants. It adversely affects several biological parameters; ultimately there is loss of vegetation. The pollution through heavy metal is a major problem of our environmental because the maximal contamination of heavy metal is very harmful to human, agriculture and wild life. These elements play a role as cofactors of key metabolic enzymes, but when their concentration is high in soil, they become the toxic to the plants (Bhatti *et al.* 2013)**.** Therefore, present investigation was undertaken to study the effect of Pb and Cr on maize crop.

MATERIALS AND METHODS

A laboratory experiment was conducted at Department of Botany, Dr. B. R. Ambedkar University Agra using seeds of maize. The seeds of maize were first washed with distilled H_2O and then immerged in 5% bavisten. They were again washed with distilled water for 5-10 minutes and soaked in 0.1% mercuric chloride ($HgCl_2$) and further washed with distilled water for 4-5 times. Five ml solution of calcium nitrate (5mM) in treatments having different concentrations of Cr and Pb (control, 50, 100 and 150M) were applied. Ten surface sterilized seeds were kept in each sterilized petridish. Distilled H_2O was used as control. Minimum three replication for each treatment were maintained. After 5 days the germination percentages were recorded (Kabir *et al.* 2008). For green house experiment, sand was washed with distilled H_2O and then with 2% solurion of sodium hypo chlorite. The surface sterilized seeds of maize were sown in earthen pots containing 2kg of acid washed sand. The sand was then treated with Evans and Nason nutrient solution (1953).

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Chromium and lead (control, 50, 100 and 150µm) concentrations were given along with the nutrient solution with and without nitrogen. Heavy metal treatment was given twice in a week followed by irrigation with distilled water. Prepared nutrient solution was stored in a refrigerator and given twice a week. Samples were taken separately from each treatment and divided into root and shoot. These were used for the determination of physiological and biochemical parameters.Root and shoot length was recorded both from treated as well as control plants.Leaf area was measured using standard graph paper method.The fresh weights of root and shoot were recorded after drying in a oven at 60^0C for 48 hours.Chlorophyll content of each plant was estimated as per the methodology of Arnon (1949). Proline content in the leaves of plants was determined using the methodology of Bates *et al.* (1973).

RESULTS AND DISCUSSION

Physiological parameters

Germination percentage: The reduction in seed germination was higher in Pb as compared to Cr. As compared with control (98%), seeds exhibited 85, 70 and 64% germination in 50, 100 and 150 µM solution of Pb and 88, 72 and 68% in 50, 100 and 150 µM of Cr (Table 1). However, with the application of nitrogen the deleterious effect of Cr and Pb was reduced to some extent and germination percentage increased as compared to plants where nitrogen was not provided (Table 2). Decrease in the germination of seed can be attributed to the accelerated breakdown of stored nutrients in seeds and changing of permeability properties of cell membrane, due to negative effect of heavy metals (Heidari and Sarani 2011).

Table 1: Physiological changes in maize without nitrogen under different concentrations of Pb and Cr

Treatments	Germination %	Shoot length (cm)	Root length (cm)	Shoot fresh wt. (g)	Root fresh wt. (g)	Shoot dry wt. (g)	Root dry wt. (g)	Leaf area (c)	Root devlp. (no. of adv. root)
Control	98	38.4 ±2.48	14.98 ±10.1	7.0 ±0.27	3.06 ±0.20	2.78 ±0.13	0.35 ±0.03	37.77 ±0.02	7.0 ±1.0
50µM ($CrCl_2$)	88	37.8 ±4.74	13.94 ±4.12	6.1 ±0.25	2.16 ±0.42	2.66 ±0.15	0.31 ±0.03	29.76 ±0.01	6.8 ±2.28
100µM ($CrCl_2$)	72	37.0 ±5.08	12.58 ±3.21	5.11 ±0.18	2.04 ±0.37	2.08 ±0.45	0.27 ±0.04	24.66 ±0.03	6.2 ±1.3
150µM ($CrCl_2$)	68	33.8 ±4.60	10.50 ±4.39	3.92 ±0.17	1.77 ±0.18	1.84 ±.54	0.25 ±0.01	21.15 ±0.10	4.6 ±1.14
50µM ($PbCl_2$)	85	36.2 ±4.60	13.54 ±2.92	5.81 ±0.15	2.04 ±0.41	2.28 ±0.40	0.30 ±0.02	24.56 ±0.12	6.0 ±1.22
100µM ($PbCl_2$)	70	33.08 ±5.89	11.20 ±2.41	5.31 ±0.23	1.96 ±0.44	1.98 ±0.13	0.25 ±0.02	22.82 ±0.17	4.6 ±0.89
150µM ($PbCl_2$)	64	31.44 ±1.97	11.12 ±0.89	3.86 ±0.51	1.16 ±0.57	1.62 ±0.24	0.14 ±0.16	18.69 ±0.12	4.4 ±0.89

Mean ± standard deviation, data are average of three replicates

Seedling growth: The root length of 14.98 cm under control was reduced up to 13.94 cm and 13.54 cm under 50 µM concentration of Cr and Pb, respectively. At 150 µM concentration, plants showed a root length of 10.50 cm and 11.12 cm, respectively. Plant showed 37.8 cm and 36.2 cm shoot length at 50 µM concentration as compared to control (38.42 cm) whereas at 150 µM concentrations it was 33.8 cm and 31.4 cm, respectively. Additional nitrogen innutrient medium resulted in an increase in the length of root and shoot (Table 2). Abdussalam *et al.* (2015) and Vijayarenjan (2013) reported similar results in *Boerhavia diffusa* and cluster bean, respectively.

Leaf Area: The leaf area decreased up to 29.76 cm^2 and 24.56 cm^2 respectively in plants treated with 50 µM Cr and Pb solution.At 100 µM concentration, 24.66 cm^2 and 22.82 cm^2, leaf area was recorded respectively as compared to control (37.77 cm^2) and minimum values of 21.15 cm^2 and 18.69 cm^2 were recorded at 150 µM respectively. The data (Table 2) showed a slight increase in the leaf area of maize with N solution. The exposure of maize seedlings to Cr stress resulted in change in morphology and damage in maize leaves (Wang *et al.* 2013).

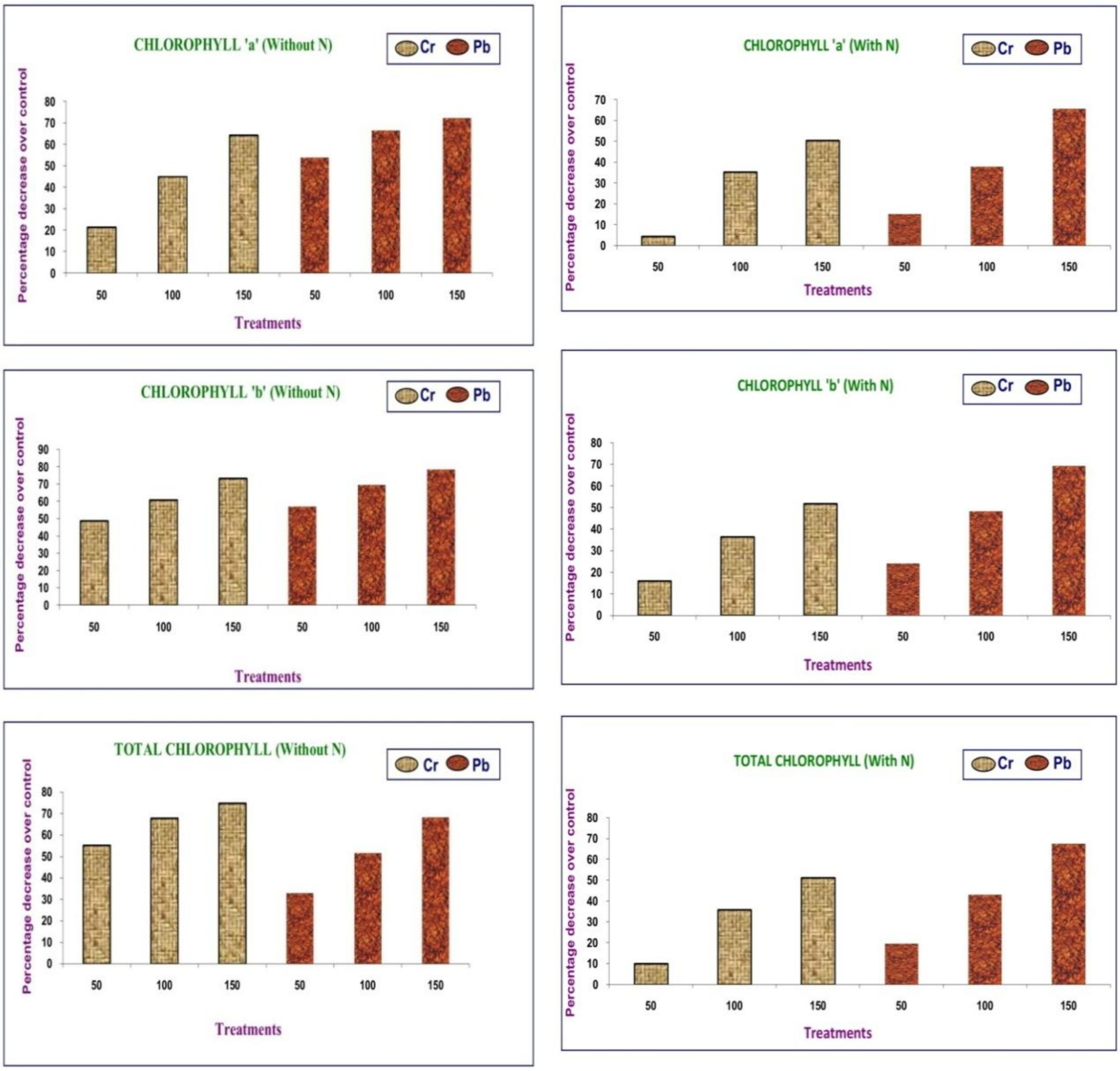

Fig. 1: Effect of Cr and Pb on pigment composition in maize grown without and with nitrogen

Root Development: The numbers of adventitious roots were not affected much by lower concentration of chromium and lead, but at higher concentration these roots were adversely affected. The inhibitory effect was more pronounced due to the lead than chromium interestingly. Lower concentration of these heavy metals proved beneficial for the development of these roots. Higher concentrations (100 and 150 µM) proved deleterious for these roots. Nitrogen application proved beneficial only upto some extent (Table 2).

Biomass production: The chromium and lead caused a substantial decrease in fresh and dry weight of both root and shoot of maize. When the plants were treated with nitrogen, the results were positive in root as well as in shoot weight (Table 2). Maize plant recorded significantly reduction in biomass production under Cr treatment. Maiti *et al.* (2012), Vijayarengan (2013), Nagaranjan and Ganesh (2014) also noted a reduction in biomass production with chromium.

Biochemical parameters

Pigment Composition: The effect of Pb on pigments was more pronounced than Cr at all the concentrations. The extent of increase in chlorophyll 'a' content was more as compared to chlorophyll 'b'. At 50, 100 and 150 µM concentrations of Pb, chlorophyll 'a' content was reduced by 54, 66 and 72% whereas chlorophyll 'b' decreased by 57, 69 and 78% with 50, 100

Table 2: Physiological changes in maize with nitrogen under different concentrations of Pb and Cr

Treatments	Germination %	Shoot length (cm)	Root length (cm)	Shoot fresh wt. (g)	Root fresh wt. (g)	Shoot dry wt. (g)	Root dry wt. (g)	Leaf area (cm)	Root devlp. (no. of adv. root)
Control	100	43.42 ±2.64	15.28 ±5.16	7.2 ±0.52	3.3 ±0.35	3.64 ±0.21	0.48 ±0.77	41.11 ±0.06	7.2 ±1.3
50µM ($CrCl_2$)	93	42.96 ±5.44	14.83 ±3.80	6.22 ±0.43	2.74 ±0.15	3.24 ±0.27	0.34 ±0.05	33.81 ±0.03	6.8 ±1.4
100µM ($CrCl_2$)	86	42.8 ±2.87	13.19 ±3.65	5.6 ±0.29	2.14 ±0.23	2.64 ±0.14	0.30 ±0.02	28.81 ±0.05	6.6 ±2.4
150µM ($CrCl_2$)	76	38.9 ±3.73	10.67 ±4.33	4.77 ±0.18	1.78 ±0.21	2.32 ±0.21	0.25 ±0.07	25.37 ±0.08	4.8 ±0.44
50µM ($PbCl_2$)	90	40.8 ±3.04	13.75 ±6.50	6.1 ±0.64	2.39 ±0.13	3.58 ±0.22	0.33 ±0.04	28.33 ±0.04	6.4 ±1.14
100µM ($PbCl_2$)	82	38.3 ±3.27	12.42 ±4.37	5.44 ±0.48	2.12 ±0.32	3.46 ±0.11	0.29 ±0.05	26.79 ±0.09	5.0 ±1.0
150µM ($PbCl_2$)	73	35.75 ±4.24	11.50 ±1.31	4.51 ±0.28	1.71 ±0.16	2.98 ±0.16	0.25 ±0.02	23.10 ±0.12	4.6 ±1.14

and 150 µM concentration of Cr over control. The reductions in total chlorophyll were 2.19, 1.58 and 1.04 mg g^{-1} at 50, 100 and 150 µM concentration of Cr as compared to control (3.26) It was 1.46, 1.05 and 0.82 mg g^{-1} at 50, 100 and 150 µM concentration of Pb (Fig. 1A). Chlorophyll 'a' content exceeded that of chlorophyll 'b' in all the treated plants, which has been reported by Singh *et al.* (2013), Abdussalam *et al.* (2015) and Auriefah (2015).

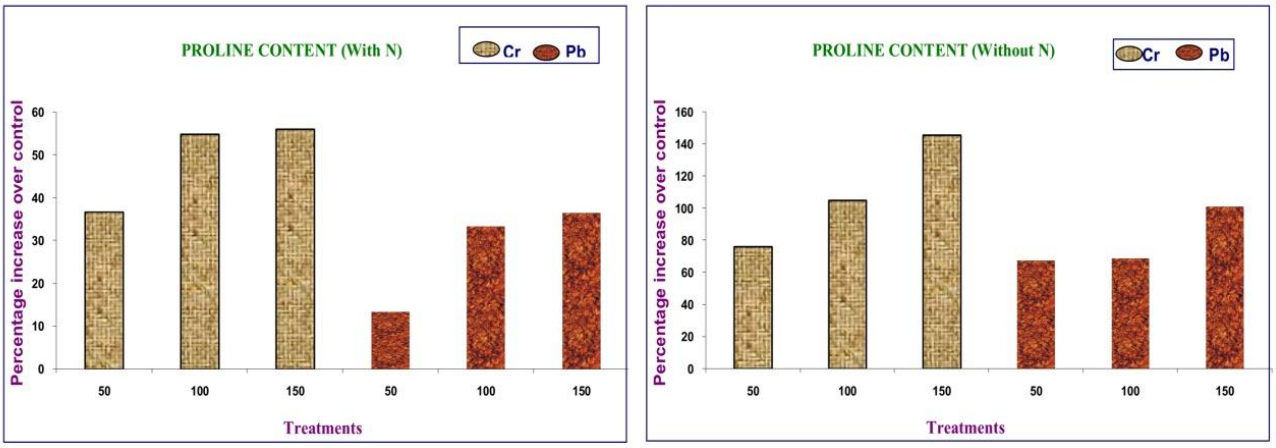

Fig. 2: Effect of Cr and Pb on proline content (mg g^{-1} FW) in maize grown with or without nitrogen

Praline content: Proline content increased significantly when the concentrations of Cr and Pb were increased (Fig. 2). Proline was accumulated in plants at various concentration of chromium and lead and maximum value was recorded at 150 µM (Fig. 2A). The proline content increased by 145% and 101%, respectively over control under chromium and lead treatment. However, the proline content decreased with application of nitrogen at maximum concentration of chromium and lead (150 µM). Proline was 56 and 36% over control under the application of nitrogen (Fig. 2 B). Similar results were reported by Singh *et al.* (2013).

On the basis of the results, it may be concluded that physiological parameters and chlorophyll decreased but proline increased with Pb and Cr. Where heavy metal deposition is a serious problem, the appropriate measures must to taken into consideration. However, the application of a considerable amount of nitrogen may be useful in alleviating the stress problem up to some extent.

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