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Assessment of Hazardous Effects of Lead on Growth Parameters of Soybean *(Glycine max* (L.) Merr.)

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Abstract: This study was designed to assessment the effects of different concentrations of heavy metal lead acetate (0, 200, 400, 600, 800, 1000 mg/kg) on growth attributes such as root shoot length, root shoot dry weight at pre, peak and post flowering stages of soybean (*Glycine max* (L.) Merr.) There was clear dose-response relationship between lead acetate concentration and the growth attributes of soybean plants. At 200 mg/kg there is no significant reduction but gradually with increased concentrations of lead acetate, there was a significant reduction in root and shoot length, as well as root and shoot dry weight, compared to the control group at all stages. The most pronounced effects were observed at 1000 mg/kg, indicating a dose-dependent toxicity of lead acetate on soybean plants. These findings highlight the importance of mitigating lead emissions and contamination to ensure agricultural productivity, environmental sustainability and public health.

Keywords: Heavy metal Pb, *Glycine max* (L.) Merr.), Soyabean, Growth parameter

Environmental contaminants due to speedup of anthropogenic activities affect nearly every aspect of the ecosystem. Among the contaminant, heavy metals (HMs) is the new emerging concern. Because the persistence bio-accumulative and harmfulness of its nature affect the plants and significantly diminish yield. (Hussain et al 2023). The noxious heavy metals in different valence states include zinc (Zn), arsenic (As), chromium (Cr), cadmium (Cd), mercury (Hg), copper (Cu), nickel (Ni) and lead (Pb), of these lead (Pb) is more pronounced at higher concentrations and durations. Exposure cause oxidative cell damage likes lipids, proteins and nucleic acids and their ultimate result is impaired host metabolism by generating reactive oxygen species (ROS). ROS such as superoxide radical (O_2^-), singlet oxygen ($_1O^2$), hydrogen peroxide (H_2O_2) and the hydroxyl radical (OH) (Qadir et al 2023). Visible symptoms include chlorotic spots, necrotic lesions etc. in leaf surface, senescence of leaf and stunted growth (Gupta et al 2016). Soybean is largest source of vegetable oil and protein in the worldwide but its yield and nutritional quality adversely affected by heavy metals. There is an urgent need to increase crop productivity for the increasing population (Gupta 2019). Hence, the present study was carried out with an objective to assessment of the hazardous effects of lead on growth of *Glycine max* (L.) Merr. (soybean).

MATERIAL AND METHODS

The experiments were conducted in the greenhouse at University of Rajasthan, Jaipur, during April under natural outdoor conditions with a photoperiod of 12 hours and an average temperature of 30°C. Pots filled with four kilograms of soil at 30 cm height and 25 cm diameter were used, with five lead concentrations (200, 400, 600, 800, 1000 mg/kg) applied as lead acetate. No other supplement nutrients were applied. Pots without added heavy metals constituted were taken as controls. Soybean seeds were surface sterilized with 0.1% mercuric chloride ($HgCl_2$) for two minutes and thoroughly washed with distilled water (DW). Ten sterilized seeds of soybean were sown equidistant at 2cm deep in each pot. Three replicates were used for each concentration. Watering was done on alternate days.

To assess plant height, plant root and shoot system was preserved while measuring the length from the soil surface to the highest leaf or flowering axis for shoot length, and from the root tip surface for root length, with measurements recorded in centimeters. Root and shoot dry weights were determined by carefully extracting plants from pots, washing roots to remove soil particles, separating roots and shoots, and subsequently drying them in an oven at 80°C for 48 hours until a constant dry weight was achieved. Statistical analysis employed SPSS ver. 25.0 and Microsoft Office Excel 2016.

RESULTS AND DISCUSSION

The plant vegetative growth indicators were affected by treatments at pre, peak and post-flowering stages (Table 1). In heavy metal lead treatment at highest concentration i.e. 1000 mg/kg resulted in the highest reduction of all the measure growth parameter at all mentioned stages. It indicates significant effect on vegetative growth parameters plant height, biomass which significantly decreased from the control plants. The highest reduction in root length (10.41cm), shoot length (21.27cm), root dry weight (0.218gm) and shoot dry weight (1.056gm) compared to untreated control plants root length (28.58cm), shoot length (47.46cm), root dry weight (0.462gm) and shoot dry weight (2.695gm) was at pre flowering stage. All studied parameters of soybean had much higher reduction due to lead treatments in comparison to control (Table 1) The reduction in root length varied from 12 to 63%, shoot length from 8 to 55%, RDW from 11 to 52 % and SDW from 19 to 68% in comparison to control (Table 2). The highest reduction at peak flowering stage in root length (15.80 cm), shoot length (28.02 cm), root dry weight (0.291 gm) and shoot dry weight (1.920 gm) was at 1000 mg/kg as compared to untreated control plants root length (36.02 cm), shoot length (55.94 cm), root dry weight (0.724 gm) and shoot dry weight (4.476 gm). The reduction in root length varied from 8 to 56%, shoot length varied from 7 to 50%, RDW varied from 8 to 59 % and SDW varied from 11 to 57% in comparison to control. At post-flowering stage result found that which highest reduction in root length (21.14 cm), shoot length (37.21 cm), root dry weight (0.375 gm) and shoot dry weight (2.345 gm) was at 1000 mg/kg compared to untreated control plants root length (48.18 cm), shoot length (67.02 cm), root dry weight (0.902 gm) and shoot dry weight (4.741 gm). The reduction in root length varied from 5 to 57%, shoot length varied from 9 to 44%, RDW varied from 21 to 58 % and SDW varied from 8 to 50% in comparison to control.

The growth parameters are important factors used to determine growth performance and crop productivity. This study revealed that under different lead concentrations, growth attributes such as root shoot length and root shoot dry weight were decreased with increasing concentrations of lead as compared to the control at pre, peak and post flowering stages of soybean (*Glycine max* (L.) Merr.) plants. Highest reduction found in these parameters at 1000mg/kg level. Similar finding presented by Li et al (2020) in the lead exposed *Lactuca sativa.* It was demonstrated that radicle growth of lettuce seed was easier inhibited by Pb at sever levels. Pb caused inhibition of cell division in plant's roots.

Table 1. Effect of lead on growth parameters of *Glycine max* (L.) Merr. at pre, peak and post-flowering stages

Parameter	Stage	Treatments (mg/kg)						Mean	CD (p=0.05)
		0	200	400	600	800	1000		
Root length (cm)	Pre-flowering	28.58	25.23	21.15	17.72	13.67	10.41	19.46	1.686
	Peak-flowering	36.02	33.05	28.39	24.31	19.29	15.80	26.14	
	Post-flowering	48.18	45.71	41.2	34.67	26.33	21.14	36.205	
	Mean	37.59	34.66	30.25	25.57	19.76	15.78	27.26	
	Mean difference between treatment	0	2.93	4.41	4.68	5.81	5.78	…	
Shoot length (cm)	Pre-flowering	47.46	43.24	36.36	31.21	26.18	21.27	34.29	0.865
	Peak-flowering	55.94	51.67	44.72	40.31	33.19	28.02	42.31	
	Post-flowering	67.02	61.04	58.16	51.32	44.17	37.21	53.15	
	Mean	56.81	51.98	46.41	40.94	34.51	28.83	43.24	
	Mean difference between treatment	0	4.83	5.57	5.47	6.43	5.68	…	
Root dry weight (gm)	Pre-flowering	0.462	0.410	0.359	0.290	0.258	0.218	0.333	0.0427
	Peak-flowering	0.724	0.662	0.59	0.454	0.373	0.291	0.516	
	Post-flowering	0.902	0.712	0.658	0.512	0.468	0.375	0.604	
	Mean	0.696	0.595	0.536	0.419	0.367	0.295	0.4843	
	Mean difference between treatment	0	0.101	0.059	0.117	0.052	0.072	…	
Shoot dry weight (gm)	Pre-flowering	2.695	2.179	1.938	1.705	1.331	1.056	1.817	0.1977
	Peak-flowering	4.476	3.987	3.612	3.343	2.204	1.920	3.257	
	Post-flowering	4.741	4.328	4.202	3.523	2.723	2.345	3.644	
	Mean	3.971	3.498	3.251	2.857	2.086	1.771	2.906	
	Mean difference between treatment	0	0.473	0.247	0.394	0.771	0.315	…	

Table 2. Effect of lead on growth parameters (Percent decrease over the control) of *Glycine max* (L.) Merr. var. JS 95-60 at pre, peak and post-flowering stages

Parameter	Stage	Treatments (mg/kg)				
		200	400	600	800	1000
Root length (%)	Pre-flowering	11.72	25.99	37.99	52.17	63.58
	Peak-flowering	8.02	21.11	32.51	46.45	56.14
	Post-flowering	5.13	14.87	28.04	45.35	56.12
Shoot length (%)	Pre-flowering	8.89	23.39	34.24	44.84	55.18
	Peak-flowering	7.63	20.05	27.94	40.67	49.91
	Post-flowering	8.92	13.22	23.42	34.09	44.48
Root dry weight (%)	Pre-flowering	11.25	22.29	37.23	44.15	52.81
	Peak-flowering	8.56	18.5	37.29	48.48	59.8
	Post-flowering	21.06	27.05	43.23	48.11	58.42
Shoot dry weight (%)	Pre-flowering	19.14	28.09	36.73	50.61	60.81
	Peak-flowering	10.92	19.3	25.31	50.76	57.1
	Post-flowering	8.71	11.37	25.69	42.56	50.53

Rapid inhibition of root growth occurs probably due to the inhibition of cell division in the root tip or decreased cell expansion in the elongation zone or both of them. Lead toxicity is reported to inhibit growth of several plant species, including *Triticum aestivum* (Kaur et al 2013), Cassia species (Khan MR, 2013), Oryza sativa (Srivastava et al 2014; Ashraf et al 2015) and *Carthamus tinctoriu* (Li et al 2015). It also seems that lead had a toxic effect on shoots elongation and overall development of shoots system as was shown in the current work and confirmed by Sedzik et al (2015), *Hordeum vulgare* (Al-Ghzawi et al 2019). The decrease in root shoot dry weights under Pb toxicity has been reported in sunflower (Saleem et al 2018), *Capsicum annum (*Kaya et al 2019), *Coriandrum sativum* (Fattahi et al 2021) and *Triticum aestivum* (Perveen et al 2022).

CONCLUSIONS

The study reveals that lead, significant heavy metal pollutant, exhibits acute toxicity to plants. Increasing lead concentrations adversely affect growth parameters like root length, shoot length, root and shoot dry weight in soybean seedlings. Particularly, the highest lead concentration of 1000 mg/kg demonstrates the most detrimental impact on these parameters. This underscores the importance of informing farmers about soil contamination by heavy metals.

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