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IMPACT OF ELECTROMAGNETIC FIELD AND HEAVY METAL ON GROWTH OF *VIGNA RADIATA*

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Abstract

The present study deals with the individual and combined effect of heavy metals and EMF. The treatments include different concentrations of lead and cadmium (250mm, 500mm and 750mm) which are selected as higher than permissible limits and other is an electromagnetic field (EMF). The effect of these stresses studied on the length of plant, the leaves number, biomass of plant and accumulation of lead and cadmium contents in mung bean seedlings (*Vigna radiata*). The results showed 500 and 750mm of lead and cadmium significantly decline plant height, the number of leaves and whole plant fresh and dry weight as in order (Cd 750mm> Cd 500mm>Pb750mm>Pb500mm), but a slight suppressed in all developing parameters and weight when exposed by EMF. Whereas, the combined treatment of lead+EMF and cadmium+EMF *i.e* 750mmCd +EMF>750mmPb + EMF cause a considerable decline in growth parameter and biomass of mung bean. In mung bean sequence of accumulation of lead and cadmium functioning as Cd 750mm> Cd 750mm EMF> Cd 500mm> Pb 750mm EMF> Pb 750mm. This significant building up of lead and cadmium content under single and combined treatment affected the growth factors of mung bean seedlings.

Key words: Electromagnetic field, Lead (Pb), Cadmium (Cd), Milimolal (mm), BDL (below detectable limits).

Introduction

Heavy metals are the metals, which have a higher density than water (Appenroth, 2010). Heavy metals like lead and cadmium have toxicity level for living beings also have the ability to disturb essential biochemical process of living cells. Lead and cadmium contamination in soil withdraw deep impact on agricultural land (Sharma & Dubey, 2005). Municipal waste, sludge, industrial waste and anthropogenic activities withdraw heavy metals in soil (Ghosh & Singh, 2005). In rice plant, lead decrease pH of the soil and absorb by the root and affect the rhizosphere processes (Lin *et al*., 2004) Lead and cadmium adversely affected germination, root and shoot growth of mustard seedling (Heideri & Sarani, 2011). Chevas *et al.*, 2011, observed that high level of cadmium concentration in soil of sunflower field significantly decreases the plant height, leaf area and fresh weight of seedlings. In high amount, lead and cadmium lowered the phenotypic and biochemical parameters by accumulation in *Tagetes erecta* L. (Shah *et al.*, 2017a and b). In mung bean and soybean seedlings building up and diffusion of lead and cadmium in plant through the absorption decrease the growth and physiological processes (Mao *et al.*, 2018).

Combination of the electric and magnetic field produce electromagnetic field, which create due to flow of current and wireless devices. Naturally, Electromagnetic Field formed due to a thunderstorms (Fraser-Smith & Kjono, 2014). In the recent era, proficient use of wireless devices like cell phones, radio frequencies and high-tension wires around vicinity sites are the main sources of Electromagnetic Field exposure in our environment (Anon., 2005; Kundi, 2009). Exposure of Electromagnetic Field may damage the endodermis tissues of plant (Goldworthy, 2006). When *Helianthus annus* exposed to Electromagnetic Field, the biomass of seedling has significantly increased (Fischer *et al*., 2004). Epicotyl of *Pisum sativum* elongated significantly due to the exposure of low electrometric field (Yamashita *et al.*, 2004). Low-frequency Electromagnetic Field induces the enzyme activities in wheat and sunflower seedling (Aksenov *et al.*, 2000; Vashisth & Nagarajan, 2010). Chlorophyll content also induced due to the electromagnetic field (Turker *et al*., 2007 and Radhakrishnan & Kumari, 2013). Electromagnetic Field created due to high tension wires causes an increase in the meiotic abnormalities at each level of meiosis and an increase in the number of sterile pollen grains (Zaidi & Khatoon, 2003, 2012; Zaidi *et al*., 2012, 2013a and b and Zaidi *et al.*, 2018).

Materials and Methods

Investigating trial was designed for obtain the individual and combined response of Electromagnetic Field, lead & cadmium concentrations in mung bean seedlings. The sterilized and imbibed seeds exposed for half an hour to Electromagnetic Field under Electromagnetic Field stand which created up to 199.9 mG (milligauss) of Electromagnetic Field. The seeds then sown in pots. In the individual treatment of lead and cadmium, all concentrations were prepared in the millimolal (mm) unit. All respective pots received 250mm; 500mm and 750mm concentrations with 500gm of soil then sterilized imbibed seeds were sown. Similarly, for combined treatments, each pot received 250mm, 500mm, and 750mm lead and cadmium concentrations in 500gm of soil and Electromagnetic Field exposed seeds were sown. Control pots were also established. All the treated and control plants watering regularly & Electromagnetic Field treated plants exposed to Electromagnetic Field in alternate days. Lenth of each plant and leaves count in each plant noted ones in a week, the trail was terminated after 30days, after which whole plants fresh and dry weight also taken (Table 1).

For the analysis the contents of lead and cadmium in plants, dry plant material were digested in nitric acid, later the prepared samples were examined by Atomic Absorption Spectrophotometer (García & Báez, 2012) (Table 2).

Mean and standard error of all aspects which noted during experiment and content of lead & cadmium calculated by computer data analysis program at M/S excel program, also statistical analysis was performed by SPSS 20 program by mean of the general linear model test (univariate method).

The results showed (Table 1) that, in individual treatments of EMF, mean values of length of plants, leaves number and biomass of mung bean seedling were decreased as compared to control. Similarly, the gradual pronounced decrease observed in growth and biomass in higher concentration of cadmium and lead (750mm) ($p<0.001$) (Table 3) in comparison to control & Electromagnetic Field also. On the other hand, in combined treatment, mean value of length, leaves number & fresh & dry biomass were significantly decreased as compared to control and individual treatments ($p<0.05$) as shown in Table 3. In higher concentration of lead and cadmium with Electromagnetic Field exposure lowering mean value in all growth parameters hence combined treatment of Electromagnetic Field and Cd750mm highly significant decline more as compared to combined treatment of Electromagnetic Field and Pb750mm (Figs. 1, 2 & 3). Our results collaborate to others like Kumar *et al*., (2016) concluded that a considerable decrease in coleoptile growth of *Zea mays*. Also our results similar with the results of Sharma *et al.*, (2009) and Halgamuge and Eberhardt (2015) who observed a reduction in germination rate in seeds of soya bean and mung bean respectively. A decline in growth activities and disturbed growth process in mung bean seedling and *Zea mays* seedling due to exposure of Electromagnetic Field noticed by Kouzmanova *et al.*, (2009) and Zar *et al*., (2015). In previous findings Ibrahim *et al*., (2017), Chaves *et al*., (2011) and Bavi *et al*., (2011) observed a significant reduction in growth and biomass of *Gynura procumbens, Helianthus annus and Pisum sativum* due to the high amount of cadmium concentration. Similarly, plants like wheat, spinach, lentil, cabbage and tomato exposed with high concentration of lead, plant growth fresh and dry weight remarkably reduced (Mesmar and Jabbar (1991), Akinci *et al*., (2010), Lamhamdi *et al.*, (2011) and (2013). The reductions in growth and biomass of mung bean is related to translocation and building up of lead and cadmium in plant cells which alter the metabolic path way, metal ion compete with important micro nutrients which ultimately responsible for stunted growth, it can confirmed with Thamayanthi *et al*., (2013), Nouri *et al*., 2001, Arduini *et al*., 1996.

Results and Discussion

Table 1. Following table showing the individual and combined effect of Electromagnetic Field and heavy metals (lead and cadmium) concentrations on growth aspects of mung bean seedling.

Treatment		Length (cm)	Leaves count	Fresh mass weight (g)	Dry mass weight (g)
Control	Mean	16.73	6.78	3.21	0.69
	Std. Error	0.6	0.264	0.156	0.06056
Electromagnetic field	Mean	13.8	5.66	3.04	0.38
	Std. Error	0.39	0.33	1.009	0.274
250mm Pb	Mean	8.93	4.6	1.20	0.020
	Std. Error	0.42	0.3	0.472	0.0003
500mm Pb	Mean	6.80	3.3	1.66	0.02
	Std. Error	0.208	0.303	0.669	0.006
750mm Pb	Mean	4.18	2.6	0.65	0.01
	Std. Error	0.67	0.33	0.301	0.006
250mm Pb +Electromagnetic field	Mean	7.42	4.0	2.06	0.07
	Std. Error	0.36	0.57	0.033	0.005
500mm Pb + Electromagnetic field	Mean	6.8	3.6	1.13	0.03
	Std. Error	0.321	0.30	0.578	0.016
750mm Pb + Electromagnetic field	Mean	2.83	2.33	2.50	0.050
	Std. Error	0.376	0.3	0.305	0.023
250mm Cd	Mean	7.64	5.3	1.66	0.073
	Std. Error	0.723	0.33	0.284	0.008
500mm Cd	Mean	5.76	3.66	1.33	0.083
	Std. Error	0.38	0.33	0.33	0.006
750mm Cd	Mean	1.80	2.33	0.720	0.022
	Std. Error	0.15	0.03	0.331	0.18
250mm Cd + Electromagnetic field	Mean	9.57	4.67	1.76	0.013
	Std. Error	1.35	0.033	0.433	0.003
500mm Cd + Electromagnetic field	Mean	5.07	2.33	1.16	0.01
	Std. Error	0.489	0.66	0.176	0.02
750mm Cd + Electromagnetic field	Mean	1.87	1.6	0.80	0.010
	Std. Error	0.578	0.03	0.054	0.01

Table 2. Following table showing the individual and combined effect of Electromagnetic Field exposure, lead and cadmium concentrations on content of lead and cadmium in mung bean seedlings.

Treatment		Soil sample (mg/l)	Plant sample (mg/l)
Control	Mean	0.342	BDL
	Std. Error	1.88	
Electromagnetic field	Mean	BDL	0.831
	Std. Error		0.083
250mm Pb	Mean	3.614	BDL
	Std. Error	0.006	
500mm Pb	Mean	1.249	BDL
	Std. Error	0.345	
750mm Pb	Mean	3.912	20.802
	Std. Error	0.005	0.055
250mm Pb +Electromagnetic field	Mean	3.36	BDL
	Std. Error	0.23	
500mm Pb + Electromagnetic field	Mean	3.935	BDL
	Std. Error	0.001	
750mm Pb + Electromagnetic field	Mean	3.894	30.396
	Std. Error	0.001	0.745
250mm Cd	Mean	0.68	28.56
	Std. Error	0.11	0.864
500mm Cd	Mean	BDL	38.78
	Std. Error		3.96
750mm Cd	Mean	3.56	59.57
	Std. Error	0.034	1.38
250mm Cd + Electromagnetic field	Mean	0.911	22.04
	Std. Error	0.041	2.12
500mm Cd + Electromagnetic field	Mean	0.966	11.89
	Std. Error	0.021	0.603
750mm Cd + Electromagnetic field	Mean	0.841	47.89
	Std. Error	0.019	1.193

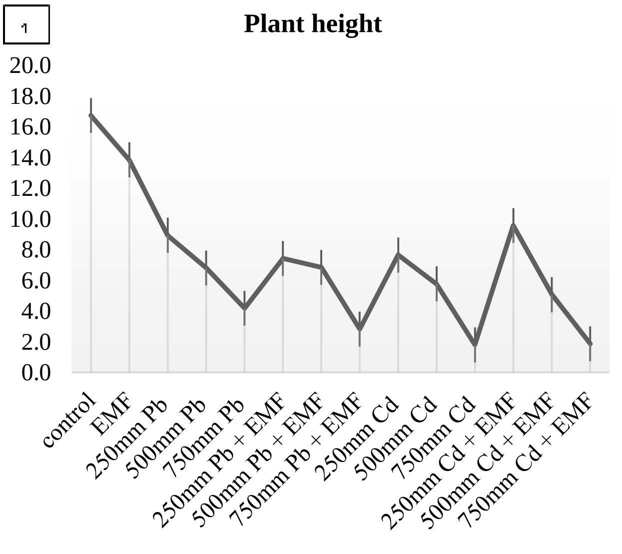

Fig.1. Effect of electromagnetic field, $PbCl_2$ and $CdCl_2$ on mung bean seedling height.

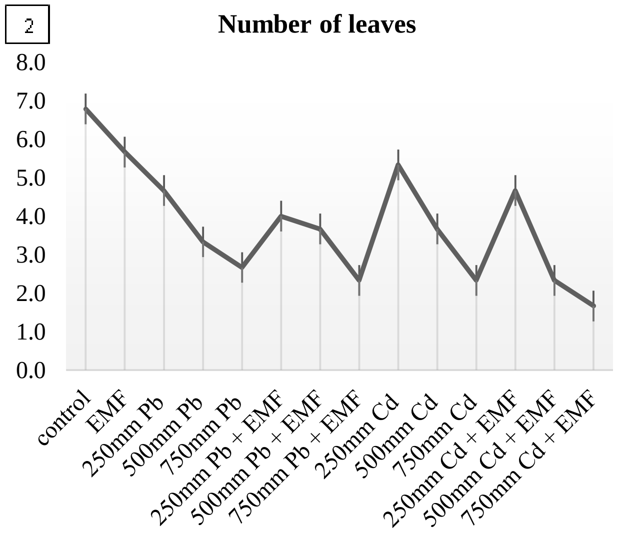

Fig. 2. Effect of electromagnetic field, $PbCl_2$ and $CdCl_2$ on number of leaves of mung bean seedling.

The results of Table 2 showed that the mean value of lead content in treated soil ranges between 1.249 mg/L to 3.921 mg/L. whereas, Electromagnetic Field treated soil contains 0.494 mg/L and untreated soil or control soil contained 0.738 mg/L (Table 2). The highest content of lead observed in Electromagnetic Field+Pb500mm treated soil 3.935 mg/L. The content of lead increased in the following order in treated soil: Pb 500mm < Electromagnetic Field + Pb 250mm < Pb 250mm < Electromagnetic Field + Pb 750mm < Pb 750mm< Electromagnetic Field + Pb500mm, which were higher than limiting values which are established by world health organization in2007 and Anon., (2010) (Fig. 4).

Table 3. Effect of electromagnetic field and heavy metals (lead and cadmium) on mung bean seedlings.

Length of plant

Treatments	Type III SS	Degree of freedom	M. S	F-value	Significance
Corrected model	1469.059[a]	17	86.415	90.818	0.000
Intercept	30.557	1	30.557	32.114	0.000
Control	5.019	2	2.510	2.638	0.085
Electromagnetic field	3.206	3	1.069	1.123	0.353
Lead	743.986	3	247.995	260.632	0.000
Cadmium	877.213	3	292.404	307.303	0.000
Electromagnetic field * lead	10.422	3	3.474	3.651	0.021
Electromagnetic field * cadmium	25.851	3	8.617	9.056	0.000
Error	34.255	36	0.952		
Total	5931.118	54			

Leaves count

Treatments	Type III SS	Degree of freedom	M. S	F-value	Significance
Corrected model	282.954[a]	17	16.644	39.019	0.000
Intercept	31.940	1	31.940	74.876	0.000
Control	.843	2	.421	.988	0.382
Electromagnetic field	1.308	3	.436	1.022	0.394
Lead	125.373	3	41.791	97.969	0.000
Cadmium	147.093	3	49.031	114.942	0.000
Electromagnetic field * lead	8.973	3	2.991	7.011	0.001
Electromagnetic field * cadmium	6.659	3	2.220	5.204	0.004
Error	15.357	36	0.427		
Total	1543.047	54			

Fresh mass weight

Treatment	Type III SS	Degree of freedom	M.S	F-value	Significance
Corrected Model	101.087[a]	17	5.946	6.245	0.000
Intercept	1.491	1	1.491	1.566	0.219
Control	0.637	2	.319	0.335	0.718
Electromagnetic Field	5.182	3	1.727	1.814	0.162
Lead	34.584	3	11.528	12.108	0.000
Cadmium	51.749	3	17.250	18.117	0.000
Electromagnetic field * lead	15.477	3	5.159	5.418	0.004
Electromagnetic field * cadmium	5.708	3	1.903	1.998	0.132
Error	34.277	36	0.952		
Total	407.615	54			

Table 3. (Cont'd.).

Dry mass weight					
Treatments	**Type III SS**	**Degree of freedom**	**MS**	**F-value**	**Signifucance**
Corrected model	2.795[a]	17	0.164	3.511	0.001
Intercept	0.272	1	0.272	5.803	0.021
Control	0.001	2	0.000	0.007	0.993
Electromagnetic field	0.061	3	0.020	0.433	0.730
Lead	1.895	3	0.632	13.488	0.000
Cadmium	1.821	3	0.607	12.965	0.000
Electromagnetic field * lead	0.069	3	0.023	0.490	0.691
Electromagnetic field * cadmium	0.191	3	0.064	1.356	0.272
Error	1.686	36	0.047		
Total	6.692	54			
Soil sample					
Treatments	**Type III SS**	**Degree of freedom**	**M. S**	**F-value**	**Significance**
Corrected Model	107.789[a]	17	6.341	14.148	0.000
Intercept	157.983	1	157.983	352.510	0.000
Control	0.105	2	0.053	0.117	0.890
Electromagnetic field	16.169	3	5.390	12.026	0.000
Lead	70.333	3	23.444	52.312	0.000
Cadmium	14.871	3	4.957	11.060	0.000
Electromagnetic field * lead	5.904	3	1.968	4.391	0.010
Electromagnetic field * cadmium	8.102	3	2.701	6.026	0.002
Error	16.134	36	0.448		
Total	282.800	54			
Plant sample					
Treaments	**Type III SS**	**Degree of freedom**	**M .S**	**F-value**	**Significance**
Corrected model	18526.356[a]	17	1089.786	835.040	0.000
Intercept	157.983	1	157.983	352.510	0.000
Control	0.000	2	7.778	0.121	1.000
Electromagnetic field	533.769	3	177.923	136.332	0.000
Lead	392.213	3	130.738	100.177	0.000
Cadmium	10118.728	3	3372.909	2584.467	0.000
Electromagnetic field * lead	309.826	3	103.275	79.134	0.000
Electromagnetic field * cadmium	583.192	3	194.397	148.956	0.000
Error	46.982	36	1.305		
Total	27524.451	54			

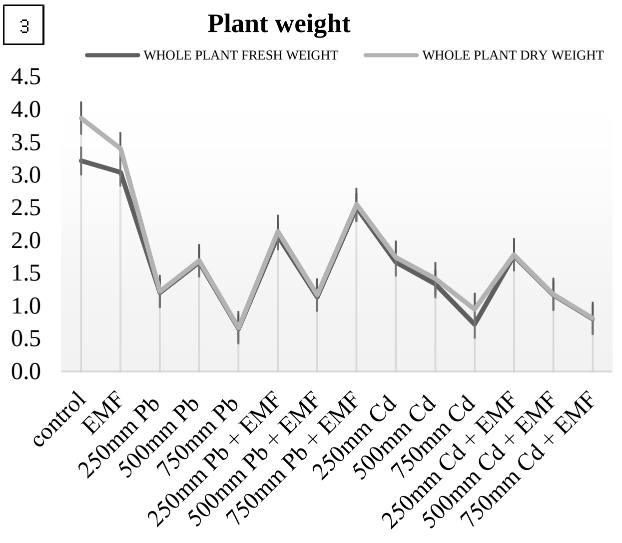

Fig. 3. Effect of electromagnetic field, $PbCl_2$ and $CdCl_2$ on whole plant fresh and dry weight of mung bean seedling.

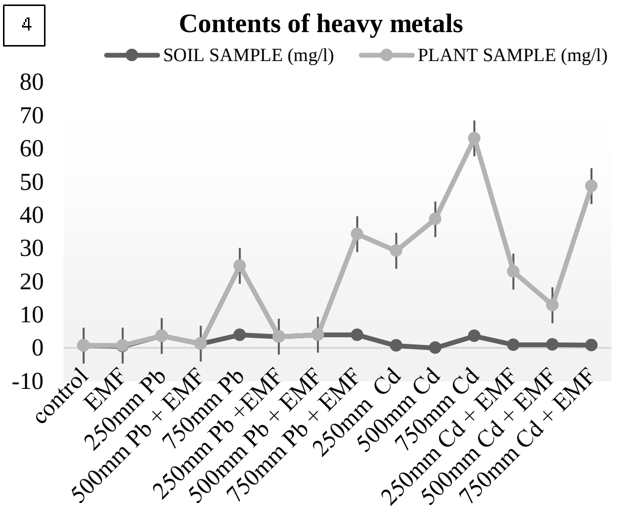

Fig. 4. Effect of electromagnetic field, $PbCl_2$ and $CdCl_2$ on lead and cadmium contents in mung bean seedling.

The results in Table 2, shows the mean value of lead content in treated Mung Bean plant sample which ranges between 0.396 mg/L to 20.802 mg/L. Whereas, Electromagnetic Field treated plant sample contains 0.230 mg/L of lead and control plant samples or untreated plant sample contain below the detection range of lead. The highest value observed in Electromagnetic Field + Pb750mm treated plant sample (30.39mg/L) (Table 2), also Pb 750mm showed 20.802 mg/L of lead content. Whereas, in the previous finding, Weaver and Schoenbach (2003) and Novac *et al*., (2009), observed that Electromagnetic Field creates non-thermal biological damage in a plant cell by breaking phospholipid bilayer of roots. Similarly, Hadi & Aziz (2015), observed that lead is one known heavy metal, which is not essential in any cell physiology and metabolism, and it can be regulated through cation exchange capacity of the soil. On the other hand, in Pb 250mm, 500mm and Electromagnetic Field+250mm & 500mm treated plants lead was not found or below the detection range (Table 2). Since, lead accumulation in a different plant like tomato and wheat varies with the exposure interval and availability of lead in medium (Akinci *et al*., (2010) and Lamhandi *et al*., (2011). Haussling *et al.*, (1998), Javis & Leung (2002) and Pandey and Sharma (2002) observed that accumulation of lead ultimately reduced the uptake of mineral nutrient which directly affects the growth of *Picea abies, Pinus radiata,* and cabbage. This accumulation of lead may leads with reduced plant growth and physiological and biochemical dysfunction in plants (Seregin & Kosenvikova (2008) and Lamhamdi *et al*., (2011). The observation (Table 2) represented that the means of cadmium content in treated soil ranges between 0.68 mg/L to 3.56 mg/L. whereas, Electromagnetic Field treated soil not contained cadmium and untreated soil or control soil contained 0.342 mg/L. The highest content of cadmium observed in Cd 750mm treated soil 3.56 mg/L (Table 2). The content of cadmium increased in the following manner in treated soil: Cd 250mm < Electromagnetic Field + 750mm < Electromagnetic Field + Cd 250mm < Electromagnetic Field + Cd 500mm < Cd 750mm (Fig. 4). In the results, data revealed the means of cadmium content in plant sample, which ranges between 11.89 mg/L to 59.57 mg/L (Table 2). Whereas, Electromagnetic Field treated plant sample contains 0.831 mg/L of cadmium and control plant samples or untreated plant sample contain the negligible value of cadmium. The highest value 59.57 mg/L observed in Cd 750mm treated plant sample, also Cd 500mm showed 38.74 mg/L of cadmium content and in Electromagnetic Field + Cd 750mm 47.89mg/L cadmium content were observed, which were higher than limiting ranges which buildup by Anon., (2007) and Anon., (2010) (Table 2). Since Liu *et al.*, (2007) observed that cadmium accumulation remoting by plant age and different plant parts efficiency. Also, Goldworthy (1999) observed that Exposure of Electromagnetic Field caused damage of endodermis tissues due to which leakage of cells and nutrient uptake disturbed. Hence, the cadmium content increases in the following order: Electromagnetic Field + Cd 500mm < Cd 250mm < Electromagnetic Field + Cd 250mm < Electromagnetic Field + Cd 750mm < Cd 500mm < Cd 750mm (Fig. 4). Like, Tudoreanu and Phillips (2004) observed that cadmium have no known physiological function in plant, but it is transmitted to plant by a dominant source which if found in soil as cadmium soil solution. Although they can easily enter the plant from the soil through several micronutrient transporters (Lux *et al*., 2011). The accumulation of cadmium in *Gynura procumbense* reduced the efficiency of its herbal nutrients (Ibrahim *et al*., 2017). The results also contribute literature, high accumulation of lead and cadmium in mung bean seedling play a part in reduction of growth and biomass, also EMF exposure be a factor to lose cell membrane which promote the passage for heavy metals ions that pullout more suppression of growth in mung bean.

Conclusion

Individual treatments of Electromagnetic Field exposure and higher concentrations of lead and cadmium reduce length, leaves count and fresh and dry biomass of mung bean plants rather than control. Also it can concluded that plants that accumulate the higher amount of lead chloride and cadmium chloride reduced more developing aspects of mung bean plants. On the other hand, combined treatment of Electromagnetic Field exposure and lead concentrations and Electromagnetic Field exposure and cadmium concentrations cause an adverse response to phenotypic characters and weight. High concentrations of cadmium + Electromagnetic Field declined length, leaves number and weight of mung beans plant in comparison to combined treatment of lead concentrations + Electromagnetic Field. It is concluded that Electromagnetic Field exposure may lead the more building of heavy metals in plants which also leads to reduced growth and whole plant biomass of mung bean seedling.

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