

Consequences of Mercury and Cadmium-Induced Stress on Morphological Changes in Indian Mustard

Bala Abhinav Sai Mentada, Rohan Chakraborty and Anaytullah Siddique*
Department of Agronomy, Lovely Professional University, Punjab (Punjab), India.

(Corresponding author: Anaytullah Siddique*)

(Received: 23 April 2023; Revised: 25 May 2023; Accepted: 02 June 2023; Published: 05 July 2023)

(Published by Research Trend)

ABSTRACT: Heavy metals are creating big challenges for the scientific community because it creates many problems in which some of them are the absorption and translocation of water and minerals which is a basic need of any plant for normal growth and development. Hence to understand its severity a pot-based heavy metal study was carried out to investigate the deteriorative impact of HgCl_2 and CdCl_2 on morphological and yield-attributing traits in the Indian mustard variety T-59. To evaluate the impact of HgCl_2 and CdCl_2 , plant height (cm), fresh and dry weight plant⁻¹ (g), total leaf area Plant⁻¹, LAI, CGR, and SPAD reading, the average length of siliqua, the number of siliqua plant⁻¹ and seeds siliqua⁻¹ were considered. The results of the current study indicated the gradual reduction in the growth of entire traits studies concerning the elevation of concentrations of both heavy metals ranging from 1.5 to 5.0 mM. Among the treatments, the highest reduction was detected in T₄ of both heavy metals. The maximum % reduction was recorded at 30 DAS compared to 60 and 90 DAS in the entire set of traits while the comparative analysis among the heavy metal (HgCl_2 and CdCl_2) indicated that HgCl_2 is more toxic compared to CdCl_2 for the morphological traits of Indian mustard.

Keywords: Cadmium chloride, LAI, mercury chloride, morphological trait, Indian mustard.

INTRODUCTION

Indian mustard (*Brassica juncea* L.) is a well-known oilseed crop that is grown extensively in India and other parts of the Asian continent for thousands of years. Rapeseed-mustard accounts for 28.6% of total oilseed production in India, placing second only to groundnut, and is responsible for 27.8% of the total Indian market in oilseeds (Shekhawat *et al.*, 2012). Mustard, like other crops, is susceptible to a variety of stresses that can impair growth and productivity consequently reduction in oil production. The stresses include drought, high and low temperatures, salinity, nutrient deficiencies, pest attacks, etc. (Gan *et al.*, 2004). Apart from these stress factors, cadmium and mercury are heavy metals that can be harmful to all crops. Some of the potential consequences of cadmium and mercury on plants were chlorosis, inhibition of photosynthesis, reduced nutrient uptake, DNA damage, reduced plant growth, and increased oxidative stresses (Azevedo and Rodriguez 2012). Mercury contamination in soil can have detrimental effects on entire growth phases of crop plants while in the presence of high concentrations, mercury can reduce the germination ability of the seed and plant growth, inhibit photosynthesis, and interfere with nutrient uptake (Bose *et al.*, 2008; Baig *et al.*, 2020). Heavy metals in water sources poses significant environmental and public health risks (Manzoor and Kaware 2022). However, the presence of cadmium in the soil is almost

equally harmful to the crop plant concerning the morphological growth, and metabolic events. It can accumulate in the plant tissues and reduce plant growth, crop yields, and quality. Cadmium can also interfere with the plant's nutrient uptake, leading to nutrient deficiencies and impaired plant growth thereby leaf chlorosis, reduced photosynthesis, and stunted growth (Suhani *et al.*, 2021; Siddique and Dubey 2017). Indian mustard is a plant that has been demonstrated to be useful in the phytoremediation of heavy metal-polluted soils, such as cadmium and mercury. Because the roots of Indian mustard can heavy metals accumulate and tolerate high quantities, they are an excellent candidate for phytoremediation, which involves plants absorbing heavy metals, which are subsequently stored in plant tissues or transformed into less dangerous forms (Rathore *et al.*, 2019). Therefore, India mustard can also help extract heavy metals from the contaminated soil which can augment the phytoremediation through good irrigation practices and the use of chelates like EDTA (Farid *et al.*, 2013).

MATERIALS AND METHODS

A pot-based experiment was carried out on the Research Farm of Lovely Professional University during the Rabi season. Experimental seeds of Indian mustard (*Brassica juncea* L.) variety T-59 were procured from the Punjab Agricultural University which is used to analyze the detrimental impact of heavy metals (HgCl_2 and CdCl_2). The experiment was

arranged in a completely randomized design in five replications while four different concentrations of both the heavy metals (HgCl₂ and CdCl₂) ranging from 1.5 to 3.0 mM were applied in each set of pots along with the chelating agents EDTA before the seed sowing. Standard agronomic practices were adopted from the pot filling to the end of crop harvest.

The morphological traits were recorded at 30, 60, and 90 Days after transplantation wherein tagged plants from each pot were selected to measure the morphological traits, growth analysis, like the height of the plant (cm), fresh and dry weight plant⁻¹ (g). The leaf area plant⁻¹ was measured by the use of a leaf area meter (Model No-211) while the calculation of leaf area index (LAI), and crop growth rate (CGR, g cm² day⁻¹) were carried out by adopting the formula given by (Watson, 1947 and 1952).

$LAI = \text{Total leaf area (cm}^2\text{)} / \text{Total ground area (cm}^2\text{)}$

$CGR = (W_2 - W_1) / (T_2 - T_1) * 1/A$

Traits that contribute to yield include the average number of siliquae plant⁻¹, the average length of siliqua, and seeds siliqua⁻¹ were measured after the harvest while the data generated in the present research work were statistically analyzed using OPSTAT online software developed by HAU, India.

RESULTS AND DISCUSSION

Externally imposed heavy metals *i.e.* HgCl₂ and CdCl₂ were analyzed concerning morphological traits like plant height (cm), fresh and dry weight plant⁻¹ (g) of Indian mustard and found that gradual reduction in the morphological traits as the concentrations of both heavy metals HgCl₂ and CdCl₂ increased from 0.5 mM to 3.0 mM. The maximum deteriorative impact in the entire morphological traits was detected in T₄ (3mM) of HgCl₂ and CdCl₂ compared to the control set. The minimum value of plant height in the HgCl₂-treated set was 16, 62, and 147 cm, and 17, 68, and 149 cm were recorded in the CdCl₂-treated set (Fig. 1). A similar trend for the fresh and dry weight of the plant was recorded in both heavy metals *i.e.* 11.8, 10.8, 84.4, 88.4, and 3.9, 4.2, 18.04, 19.71 mg plant⁻¹ at 30 and 60 DAS (Fig. 2). The data furnished in (Table 3) represents the effect of HgCl₂ and CdCl₂-induced stress in terms of % reduction over control showing that the maximum % reduction in HgCl₂ for the plant height was (28, 20, 12), fresh weight (32 and 19), dry weight (33 and 30), and leaves area (31 and 22) while in case of CdCl₂ for the plant height was (26, 13 and 10), fresh weight (38 and 15), dry weight (28 and 24), and leaves area (26 and 18). Thus, a close analysis of the most negative impact of heavy metals on morphological traits is reflected in HgCl₂ compared to CdCl₂.

LAI and CGR were also analyzed with externally imposed heavy metals *i.e.* HgCl₂ and CdCl₂ and found a gradual reduction in both parameters with an elevation of concentrations of both heavy metals (Table 1 and Fig. 4). The minimum LAI due to HgCl₂ and CdCl₂

was noticed in T₄ (0.9, 3.6, and 3.8) at the intervals of 30 and 60 DAS while the minimum CGR g cm² day⁻¹ was also recorded in T₄ (1.04 and 1.15) at 30-60 DAS intervals even though a bit of variation was recorded at 60-90 DAS intervals. Percent reduction of LAI over control presented (Table 3) reveals that both the heavy are equally harmful at 30 DAS (31%) while at the latter growth stage *i.e.* 60 DAS, CdCl₂ was detected least LAI (17%) compared to HgCl₂ (22%).

SPAD unit data presented (Fig. 5) showed a similar trend as morphological and growth analysis parameters wherein the significantly minimum SPAD reading was detected in T₄ (23, 33, 42 and 26, 35, 44) compared to the rest of the treatments including control in both the sets of heavy metals (HgCl₂ and CdCl₂). However, the data furnished (Table 3) regarding the % reduction over control, revealed that HgCl₂ is more toxic (29, 27, and 23%) compared to CdCl₂ (20, 21, and 19%).

The influence of HgCl₂ and CdCl₂-induced stress was also analyzed with an average length of siliqua plant⁻¹, seeds siliqua⁻¹ and siliqua plant⁻¹ in Indian mustard wherein a gradual reduction in all the yield attributing traits along with elevation of heavy metals (Table 2). The highest % reduction in yield attributing traits was recorded in T₄ of HgCl₂ (29, 33, and 20) and CdCl₂ (25, 21, and 15) while the difference in the % reduction among the heavy metals indicated that HgCl₂ is more harmful than CdCl₂ (Table 3).

The present piece of work indicated that HgCl₂ and CdCl₂ both have a phytotoxic effect not only on morphological traits (plant height, fresh and dry weight, and leaf area) but also on growth analysis (LAI and CGR), yield attributes (average length of siliqua plant⁻¹, seeds siliqua⁻¹ and siliqua plant⁻¹) and SPAD unit whereas HgCl₂ is often more toxic rather than CdCl₂. The detrimental effect of heavy metals on plant growth and development is well-known while out of all the heavy metals, HgCl₂ and CdCl₂ are the most popular concerning phytotoxicity (Bose *et al.*, 2008; Naik *et al.*, 2022). The mustard crop can absorb and store the heavy metals in the tissues of the plant compared to other popular crops. Thus, it acts negatively on the plant cell consequently altering the basic structure of the cell, suppressing the cell division, and under hyper accumulation causing the death of the cell (Balali-Mood *et al.*, 2021; Ahmad *et al.*, 2011a and 2012). Parallel it causes a kind of stress known as heavy metal stress that alters the absorption of water and minerals (Ali and Gill 2022). Reduction in SPAD reading along with elevation of heavy metals (Table 3) indicated that the degradation of chlorophyll content in the plant can cause chlorosis consequently inhibiting in rate of photosynthesis and other interlink metabolic process (Tiwari and Lata 2018). Thus, the reduction in photosynthate is followed by the alteration in morphological structure, growth, and yield attributes (Muhammad *et al.*, 2021).

Table 1: Influence of Mercuric chloride and Cadmium chloride-induced stress on total leaf area plant⁻¹ and LAI in Indian Mustard.

Treatments		Total leaf area plant ⁻¹		LAI	
		30 DAS	60 DAS	30 DAS	60 DAS
	T0	596.6	2070.0	1.3	4.6
HgCl ₂	T1	530.5	1904.8	1.2	4.2
	T2	484.2	1779.1	1.1	4.0
	T3	438.1	1685.2	1.0	3.7
	T4	413.2	1622.2	0.9	3.6
CdCl ₂	T1	559.4	1996.9	1.2	4.4
	T2	509.0	1841.8	1.1	4.1
	T3	461.4	1771.5	1.0	3.9
	T4	440.1	1704.2	0.9	3.8
CD		57.84	132.63	0.04	0.29
SE (m)		19.13	43.86	0.01	0.10
C.V.		6.72	4.17	2.01	4.16

Note: T₀ = control, T₁ = 1.5mM concentration, T₂ = 2.0 mM concentration, T₃ = 2.5 mM concentration, T₄ = 3.0 mM concentration

Table 2: Influence of HgCl₂ and CdCl₂-induced stress on average length of siliqua plant⁻¹, seeds siliqua⁻¹ and siliqua plant⁻¹ in Indian mustard.

Treatments		Average length of siliqua (cm)	Seeds siliqua ⁻¹	Siliqua plant ⁻¹
	T0	8.00	13.00	115.67
HgCl ₂	T1	7.63	13.00	112.33
	T2	6.33	11.67	102.33
	T3	6.00	10.33	98.00
	T4	5.63	8.67	92.33
CdCl ₂	T1	7.17	12.33	109.00
	T2	6.67	12.67	105.00
	T3	6.50	12.00	100.00
	T4	6.00	10.33	98.67
CD at 5%		1.04	2.13	9.10
SE (m)		0.35	0.70	3.01
C.V.		8.96	10.55	5.12

Table 3: Influence of HgCl₂ and CdCl₂-induced stress on % reduction on morphological traits and yield attributes in Indian mustard.

Percent reduction over control	30 DAS		60 DAS		90 DAS	
	Max. % reduction due to HgCl ₂	Max. % reduction due to CdCl ₂	Max. % reduction due to HgCl ₂	Max. % reduction due to CdCl ₂	Max. % reduction due to HgCl ₂	Max. % reduction due to CdCl ₂
Plant height (cm)	-28	-26	-20	-13	-12	-11
Fresh weight plant ⁻¹ (g)	-32	-38	-19	-15	NA	NA
Dry weight plant ⁻¹ (g)	-33	-28	-30	-24	NA	NA
Leaf area plant ⁻¹ (cm ²)	-31	-26	-22	-18	NA	NA
LAI	-31	-31	-22	-17	NA	NA
SPAD Unit	-29	-20	-27	-21	-23	-19
	Max. % reduction due to HgCl ₂			Max. % reduction due to HgCl ₂		
Average length of Siliqua (cm)	-29			-25		
Seeds Siliqua ⁻¹	-33			-21		
Siliqua plant ⁻¹	-20			-15		

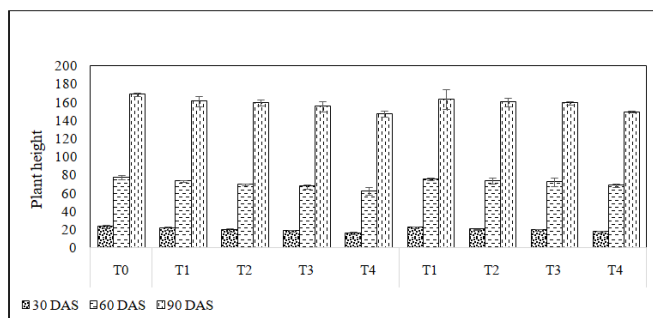


Fig. 1. Influence of HgCl₂ and CdCl₂ induced stress on plant height (cm) in Indian mustard.

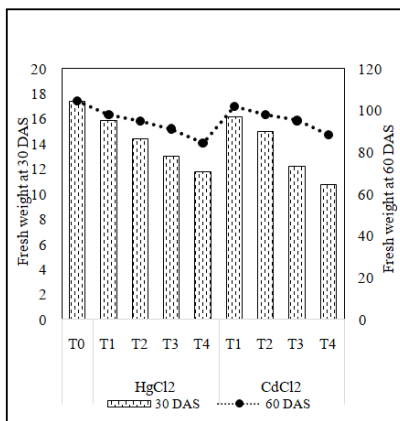


Fig. 2. Influence of HgCl₂ and CdCl₂ induced stress on fresh weight plant⁻¹ (g).

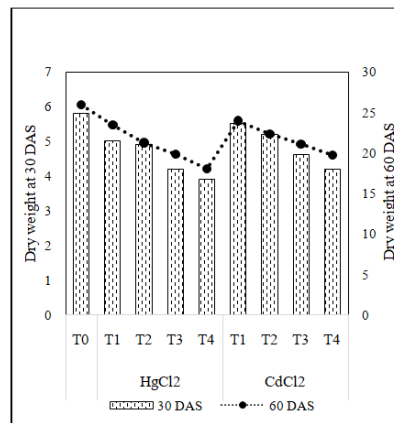


Fig. 3. Influence of HgCl₂ and CdCl₂ induced stress on dry weight plant⁻¹ (g).

Note: T₀= control, T₁= 1.5mM concentration, T₂= 2.0 mM concentration, T₃= 2.5 mM concentration, T₄= 3.0 mM concentration

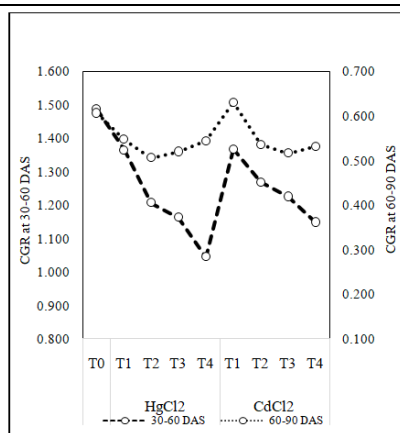


Fig. 4. Influence of HgCl₂ and CdCl₂ induced stress on CGR (g cm² day⁻¹).

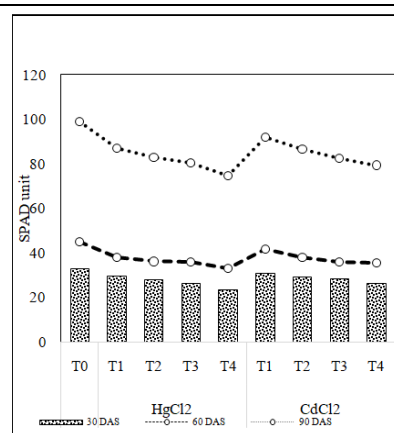


Fig. 5. Influence of HgCl₂ and CdCl₂ induced stress on SPAD unit.

CONCLUSIONS

The findings of the present investigation are based on HgCl₂ and CdCl₂-induced stress on morphological traits, growth analysis, and yield attributing characters in mustard. The findings of the results can be concluded as the concentrations of both the heavy metal increased, and a gradual reduction in the entire traits was detected. Thus, the growth was stunted and yield attributes were attempted limited growth. Additionally, it can also be concluded that the heavy metal HgCl₂ was found to be more harmful than cadmium (CdCl₂) in terms of its influence on growth

and development. Further studies could focus on developing strategies to reduce the influence of heavy metal stress on crop growth and yield.

FUTURE SCOPE

The present study will help to understand the level of severity, morphological impact, and yield loss due to the CdCl₂ and HgCl₂ in Indian mustard. Hence, the scientific community will work on a possible solution to take care ultimate loss in the yield of Indian mustard. **Acknowledgment.** The authors are grateful to the Lovely Professional University and supporting staff Mr. Robin Paul for proving and supporting the present research work.

Conflict of Interest. None.

REFERENCES

- Ahmad, P., Nabi, G. and Ashraf, M. (2011a). Cadmium-induced oxidative damage in mustard [*Brassica juncea* (L.) Czern. & Coss.] plants can be alleviated by salicylic acid. *South African Journal of Botany*, 77(1), 36-44.
- Ahmad, P., Ozturk, M. and Gucel, S. (2012). Oxidative damage and antioxidants induced by heavy metal stress in two cultivars of mustard (*Brassica juncea* L.) plants. *Fresenius Environ Bull.*, 21(10), 2953-2961.
- Ali, B. and Gill, R. A. (2022). Heavy metal toxicity in plants: Recent insights on physiological and molecular aspects, volume II. *Frontiers in Plant Science*, 13, 1016257.
- Azevedo, R. and Rodriguez, E. (2012). Phytotoxicity of mercury in plants: a review. *Journal of Botany*, 6(1), 20-26.
- Baig, M. A., Qamar, S., Ali, A.A., Ahmad, J. and Qureshi, M. I. (2020). Heavy metal toxicity and tolerance in crop plants. *Contaminants in Agriculture: Sources, Impacts and Management*, pp 201-216.
- Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M. R. and Sadeghi, M. (2021). Toxic mechanisms of five heavy metals: mercury, lead, chromium, cadmium, and arsenic. *Frontiers in pharmacology*, 227.
- Bose, B., Kumari, S., Anaytullah, Srivastava, A. K., Kuril, S. K. and Singh, P. K. (2008). Effect of mercuric chloride on seed germination, seedling growth and enzyme activity in maize (*Zea mays* L.). *Indian Journal of Plant Physiology*, 13(3), 284-290.
- Farid, M., Ali, S., Shakoor, M. B., Bharwana, S. A., Rizvi, H., Ehsan, S. and Hannan, F. (2013). EDTA assisted phytoremediation of cadmium, lead, and zinc. *International Journal of Agronomy and Plant Production*, 4(11), 2833-2846.
- Gan, Y., Angadi, S. V., Cutforth, H., Potts, D., Angadi, V. V. and McDonald, C. L. (2004). Canola and mustard response to short periods of temperature and water stress at different developmental stages. *Canadian Journal of Plant Science*, 84(3), 697-704.
- Manzoor, J. and Kaware, S. P. (2022). Impact of Heavy Metals on Water Quality and Human Health. *International Journal on Emerging Technologies*, 13(2), 12-17.
- Muhammad, I., Shalmani, A., Ali, M., Yang, Q. H., Ahmad, H. and Li, F. B. (2021). Mechanisms regulating the dynamics of photosynthesis under abiotic stresses. *Frontiers in Plant Science*, 11, 615942.
- Naik, M., Kumar, D., Akash, Sinam, V. and Siddique, A. (2022). Cadmium toxicity in plants: remedial strategy through seed priming. *Pollution Research*, 41(4), 1233-1238.
- Rathore, S. S., Shekhawat, K., Das, A., Kandpal, B. K. and Singh, V. K. (2019). Phytoremediation mechanism in Indian mustard (*Brassica juncea* L) and its enhancement through agronomic interventions. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, 89, 419-427.
- Shekhawat, K., Rathore, S. S., Premi, O. P., Kandpal, B. K. and Chauhan, J. S. (2012). Advances in agronomic management of Indian mustard (*Brassica juncea* L.) an overview. *International Journal of Agronomy*, 12 (3), 258-265.
- Siddique, A. and Dubey, A. (2017). Phyto-toxic Effect of Heavy Metal (CdCl₂) on Seed Germination, Seedling Growth and Antioxidant Defence Metabolism in Wheat (*Triticum aestivum* L.) Variety HUW-234. *International Journal of Bioresource and Stress Management*, 8(2), 261-267.
- Suhani, I., Sahab, S., Srivastava, V. and Singh, R. P. (2021). Impact of cadmium pollution on food safety and human health. *Current Opinion in Toxicology*, 27, 1-7.
- Tiwari, S. and Lata, C. (2018). Heavy metal stress, signaling, and tolerance due to plant-associated microbes: an overview. *Frontiers in Plant Science*, 9, 452.
- Watson, D. J. (1947). Comparative physiological studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. *Annals of Botany*, 11(41), 41-76.
- Watson, D. J. (1952). The physiological basis of variation in yield. *Advances in Agronomy*, 4, 101-145.

How to cite this article: Bala Abhinav Sai Mentada, Rohan Chakraborty and Anaytullah Siddique (2023). Consequences of Mercury and Cadmium-Induced Stress on Morphological Changes in Indian Mustard. *Biological Forum – An International Journal*, 15(7): 355-359.