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

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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 T_4 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). 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 ($HgCl_2$ and $CdCl_2$) 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 cm^2 day^{-1}) were carried out by adopting the formula given by (Watson, 947 and 1952).

LAI = Total leaf area (cm^2) / Total ground area (cm^2)

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.* $HgCl_2$ and $CdCl_2$ 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 $HgCl_2$ and $CdCl_2$ increased from 0.5 mM to 3.0 mM. The maximum deteriorative impact in the entire morphological traits was detected in T_4 (3mM) of $HgCl_2$ and $CdCl_2$ compared to the control set. The minimum value of plant height in the $HgCl_2$-treated set was 16, 62, and 147 cm, and 17, 68, and 149 cm were recorded in the $CdCl_2$-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 $HgCl_2$ and $CdCl_2$-induced stress in terms of % reduction over control showing that the maximum % reduction in $HgCl_2$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 $CdCl_2$ 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 $HgCl_2$ compared to $CdCl_2$.

LAI and CGR were also analyzed with externally imposed heavy metals *i.e.* $HgCl_2$ and $CdCl_2$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 $HgCl_2$ and $CdCl_2$ was noticed in T_4 (0.9, 3.6, and 3.8) at the intervals of 30 and 60 DAS while the minimum CGR g cm^2 day^{-1} was also recorded in T_4 (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, $CdCl_2$ was detected least LAI (17%) compared to $HgCl_2$ (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 T_4 (23, 33, 42 and 26, 35, 44) compared to the rest of the treatments including control in both the sets of heavy metals ($HgCl_2$ and $CdCl_2$). However, the data furnished (Table 3) regarding the % reduction over control, revealed that $HgCl_2$ is more toxic (29, 27, and 23%) compared to $CdCl_2$ (20, 21, and 19%).

The influence of $HgCl_2$ and $CdCl_2$-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 T_4 of $HgCl_2$ (29, 33, and 20) and $CdCl_2$ (25, 21, and 15) while the difference in the % reduction among the heavy metals indicated that $HgCl_2$ is more harmful than $CdCl_2$ (Table 3).

The present piece of work indicated that $HgCl_2$ and $CdCl_2$ 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 $HgCl_2$ is often more toxic rather than $CdCl_2$. The detrimental effect of heavy metals on plant growth and development is well-known while out of all the heavy metals, $HgCl_2$ and $CdCl_2$ 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: T_0 = control, T_1= 1.5mM concentration, T_2= 2.0 mM concentration, T_3= 2.5 mM concentration, T_4= 3.0 mM concentration

Table 2: Influence of $HgCl_2$ and $CdCl_2$-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 $HgCl_2$ and $CdCl_2$-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		

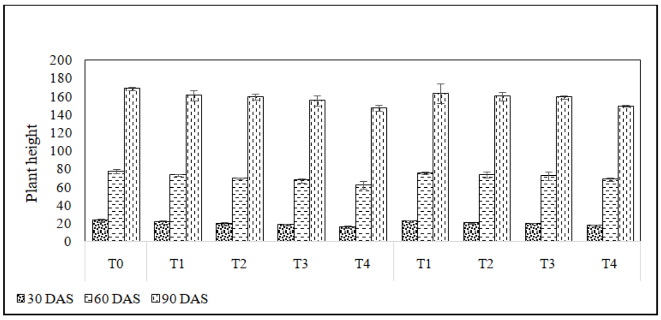

Fig. 1. Influence of $HgCl_2$ and $CdCl_2$ induced stress on plant height (cm) in Indian mustard.

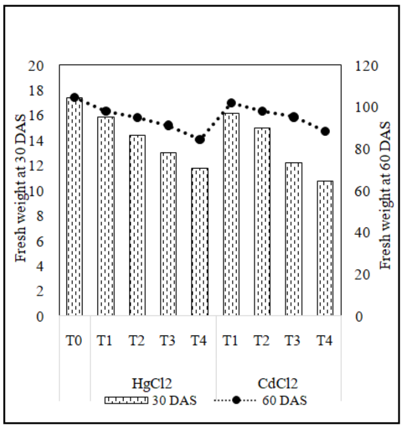

Fig. 2. Influence of $HgCl_2$ and $CdCl_2$ induced stress on fresh weight plant^{-1} (g).

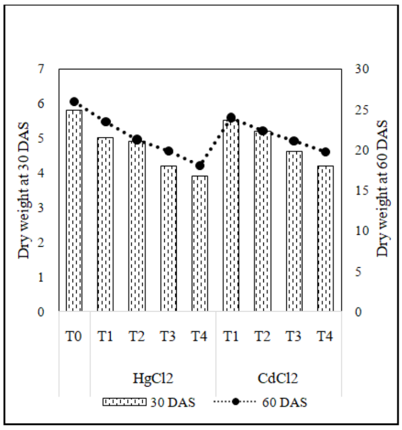

Fig. 3. Influence of $HgCl_2$ and $CdCl_2$ induced stress on dry weight plant^{-1} (g).

Note: T_0 = control, T_1= 1.5mM concentration, T_2= 2.0 mM concentration, T_3= 2.5 mM concentration, T_4= 3.0 mM concentration

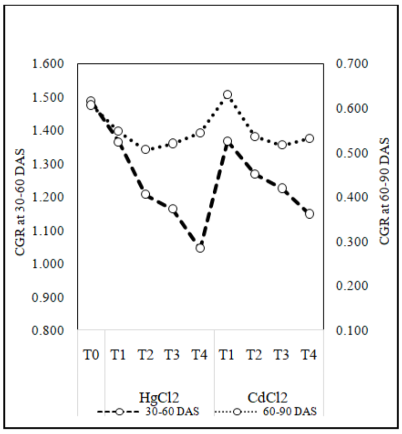

Fig. 4. Influence of $HgCl_2$ and $CdCl_2$ induced stress on CGR (g cm^2 day^{-1}).

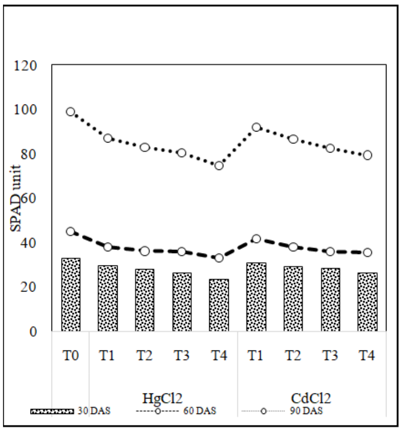

Fig. 5. Influence of $HgCl_2$ and $CdCl_2$ induced stress on SPAD unit.

CONCLUSIONS

The findings of the present investigation are based on $HgCl_2$ and $CdCl_2$-inducedstress 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 $HgCl_2$ was found to be more harmful than cadmium ($CdCl_2$) 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 $CdCl_2$ and $HgCl_2$ in Indian mustard. Hence, the scientific community will work on a possible solution to take care ultimate loss in the yield of Indian mustard.

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Conflict of Interest. None.

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