International Journal of Scientific Research in Science, Engineering and Technology

Print ISSN - 2395-1990
Online ISSN : 2394-4099

OPEN ACCESS

Available Online at : www.ijsrset.com
doi : https://doi.org/10.32628/IJSRSET

Effects of Chromium and Cadmium on Germination of Seed

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ARTICLEINFO

Article History :

Accepted: 05 Oct 2023
Published: 30 Oct 2023

Publication Issue :
Volume 10, Issue 5
September-October-2023
Page Number :
294-299

ABSTRACT

This study investigates the impact of heavy metals, specifically chromium (Cr) and cadmium (Cd), on the germination process of seeds. Heavy metal pollution is a growing environmental concern with detrimental effects on ecosystems, including soil and water contamination. In this experiment, seeds from a selected plant species were subjected to varying concentrations of chromium and cadmium in controlled laboratory conditions. The germination process was monitored, and key parameters such as germination percentage, germination rate, and seedling vigor were assessed. The results revealed a dose-dependent inhibition of seed germination in the presence of both chromium and cadmium. Higher concentrations of these heavy metals led to a significant reduction in germination percentage, delayed germination, and compromised seedling vigor. The adverse effects were attributed to the toxic nature of chromium and cadmium, which interfere with essential physiological processes in plant cells. Furthermore, the study explored potential mechanisms of heavy metal-induced stress on seeds, such as oxidative damage and disruption of cellular structures. Understanding the impact of chromium and cadmium on seed germination is crucial for predicting the long-term effects on plant populations and ecosystem health. The findings contribute valuable insights to the field of environmental science and could aid in the development of strategies for mitigating the negative effects of heavy metal pollution on plant life. This research underscores the importance of addressing heavy metal contamination to safeguard the sustainability of ecosystems and promote environmental conservation efforts.

Keywords : Environment, Seed germinations, High Concentration, Heavy Metals.

I. INTRODUCTION

The ecological situation of the biosphere is becoming unbalanced day by day due to technological and industrial progress as well as population explosion. The accumulation of external material or energy in higher than normal concentrations in a particular environment makes the environment partially or completely unfavourable to humans. These modifications may have an impact on man directly or indirectly through his access to water, agricultural, as well as other "biological products", his material possessions or property, or his possibilities for outdoor enjoyment and environment appreciation. Environmental pollution can cause health issues by affecting I human health and life, (ii) economic issues by lowering the value of human materials and property, (iii) ecological issues by upsetting a stable ecosystem, endangering the very existence of some species, and (iv) general aesthetic issues by impairing human senses.

They are not acted upon by microbes, but are oxidized and dissociated spontaneously. Heavy metal pollution has created a major ecological crisis. Heavy metals except rubidium, strontium etc., metal ions with density greater than 5 and atomic number greater than 23 (vanadium) are non-degradable and accumulate in considerable quantities and their material is biomagnified through the food chain into the living system. At toxic levels, they are harmful to both plant and animal systems, usually by suppressing protein molecules and blocking enzymatic reactions. Some heavy metals are not required for plant nutrition and therefore their excessive release into the environment is dangerous. Other heavy metals, such as iron or zinc that are otherwise essential, also become dangerous when their levels reach abnormal amounts. Both chromium and cadmium are well-established heavy metal pollutants.

Concentrations of chromium may range from up to 400 ppm in the earth's crust, 0.04 ppm in river water to 0.00005 ppm in seawater. The chromium concentration in drinking water supply samples from 60 cities in India ranged between 0.002 – 0.005 ppm (Soman et al.). USEPA Suggests a total chromium limit approx 0.05 in domestic water etc. Trivalent chromium enters the human population primarily through food. The average daily consumption of chromium per capita in India is 150 micrograms (Soman et al.), 152 in Canada and 60-280 grams in the USA.

Cadmium in the aquatic environment is mainly the result of effluents from the mining and metallurgical industries. The total amount of cadmium in the environment is estimated to be about 2,250 tonnes. The most important sources of exposure to cadmium in the environment are: coal combustion (32.39%), sewage sludge applications (12%) and the use of phosphatic fertilizers. The concentration of cadmium in the air (6.2%) ranged from 0.004 to 0.05 $\mu g/m^3$ in the city of Bombay (Khandekar et al.).

Both chromium and cadmium occupy major positions in heavy metal pollutants. Their effect in the form of chromium acetate and cadmium nitrate on seed germination percentage of some important genotypes of crop plants was studied initially. For this purpose, the seeds of plants were selected on the basis of their similarity in size, color and weight for various tests and sterilized with 0.1% mercuric chloride solution. These seeds are thoroughly washed with distilled water and then exposed to different concentrations of chromium and cadmium for specific periods of time, 12–36 hours (depending on the genotype) along with a control set. (Distilled water is used to digest the seeds, unique absorption step). Thereafter, the seeds were thoroughly washed with distilled water and placed on distilled water-wetted filter paper placed in Petri dishes for germination studies in the dark. Germination was allowed at room temperature under laboratory conditions. Seeds with 1 mm radicle length were considered as germinated seeds. The test plants selected for seed germination studies were *Hordeum vulgare* cvs. K-12 and NP-113, *Oryza sativa* cvs. Mussoorie & Sita & *Cajanas cajan* cvs. Bahar and NP-80. Interpolation period for *Hordeum vulgare* cvs. and *Cajanas cajan* cvs was 12 hours and for *Oryza sativa* cvs was 36 hours.

The percentage of germination was calculated from the number of seeds showing radicle emergence out of the total number of seeds placed in the petridish. Finally, an average of twenty readings were tabulated for analysis. Selected chromium and cadmium concentrations used for the study of the percentage of germination were 5 x 10^{-5} M, 1x10^{-4} M, 2.5x10^{-4} M, 5x 10^{-4} M, 1x 10^{-3} M and 2x $l0^{-3}$ M.

Table 1 and Table 2, show the 'germination percentages' of different genotypes, at different concentrations, of chromium and cadmium, respectively. Both tables indicate that the lowest concentrations of chromium and cadmium (5x $1o^{-5}$M) had either no effect or promotory effect on the percentage of seed germination. Higher concentrations of chromium and cadmium (2x$1Q^{-3}$M) had an inhibitory effect on seed germination percentage in all genotypes studied. In the chromium treated set, the germination percentage at lowest concentration (5x $l0^{-5}$ M) was Chromium 100%, 99%, 97%, 94%, 90% and 89%, in the genotype *H. vulgare* cv. K-12, *H. vulgare* cv. NP-113, *O. sativa* cv. Massoorie, *O. sativa* cv. Sita, *C. cajan* cv. Bahar and *C. cajan* cv. NP-80 respectively, which is higher than the germination percentage of their respective controls. At higher concentrations of chromium (2x $I0^{-3}$ M), The germination percentages of Chromium were 73%, 66%, 68%, 74%, 79% and 63%, in *H. vulgare* cv. K-12, *H. vulgare* cv. NP-113, *O. sativa* cv. Massoorie, *O. sativa* cv. Sita, *C. cajan* cv. Bahar and *C. cajan* cv. NP-80 respectively. The germination percentages in the cadmium treated set at low concentrations (5x10^{-5}M) were 97%, 95%, 95%, 90%, 87% and 85%, in *H. vulgare* cv. K-12, *H. vulgare* cv. NP-113, *O. sativa* cv. Massoorie, *O. sativa* cv. Sita, *C. cajan* cv. Bahar and *C. cajan* cv. NP-80 respectively, which is higher than germination percentage of their respective controls.

Table -1. Effect of "Chromium" on % of "Seed Germination"

Genotypes	Treatments						
	0	5 x 10^{-5}M	1 x 10^{-4}M	2.5 x 10^{-4}M	5 x 10^{-4}M	1 x 10^{-3}M	2 x 10^{-3}M
H. vulgare CV. K-12	95%	100%	93%	91%	85%	77%	73%
H. vulgare CV. NP-113	91%	99%	86%	82%	80%	72%	66%
O. sativa CV. Massoorie	86%	97%	82%	81%	79%	75%	68%
O. sativa CV. Sita	90%	94%	88%	85%	85%	80%	74%
C. cajan CV. Bahar	87%	90%	87%	85%	83%	81%	79%
C. cajan CV. NP-80	81%	89%	79%	75%	71%	68%	63%

Table -2. Effect of Cadmium on Percentage of Seed Germination

Genotypes	Treatments						
	0	5 x 10^{-5}M	1 x 10^{-4}M	2.5 x 10^{-4}M	5 x 10^{-4}M	1 x 10^{-3}M	2 x 10^{-3}M
H. vulgare CV. K-12	95%	97%	91%	88%	83%	75%	70%
H. vulgare CV. NP-113	91%	95%	84%	80%	76%	70%	64%
O. sativa CV. Massoorie	86%	95%	81%	80%	76%	70%	63%
O. sativa CV. Sita	90%	90%	86%	84%	81%	75%	70%
C. cajan CV. Bahar	87%	87%	85%	81%	79%	73%	70%
C. cajan CV. NP-80	81%	85%	78%	73%	69%	65%	61%

At the higher concentration (2x10^{-3}M Cd), the percentage of germination was ca 70%, 64%, 63%, 70%, 70% and 61% respectively in *H. vulgare* cv. K-12, *H. vulgare* cv. NP-113, *O. sativa* cv. Massoorie and *O. sativa* cv. Sita, *C. caian* cv. Bahar and *C. caian* cv. NP-80. But the figures of percentage germination at this concentration is misleading as in *H. vulgare* cv. NP-113, there was very little radicle emergence and in others the seedlings were very weak and mutilated, So, it was Inferred that this concentration was most inhibitory for seed germination.

Germination of seeds in control set in all cases was complete within three days of sowing but in different treatments germination was delayed by 1 to 3 days. Table 3 and table 4 show that in case of *H. vulgare* cv. NP-113 seed germination was complete in three days in control as well as in lower concentration i.e. 5x10^{-5}M. It was delayed in Chromium treated set by one day in 1x10^{-4}M Cr, 2.5x10^{-4M} Cr and 5x10^{-4}M Cr concentrations and by two days in 1x10^{-3} Cr concentration in 2x10^{-3} M Cr concentration even on 7th day the amount of radicle emergence was negligible. In Cadmium treated set, seed germination of *H. vulgare* cv. NP-113 was also delayed by one day in 1x10^{-4} M Cd and 2.5x10^{-4} M Cd concentrations, by two days in 5x10^{-4} M Cd concentration and by three days in 1x10^{-3} M Cd concentration. The amount of radicle emergence was negligible even on 8th day in 2x10^{-3}M Cd concentration.

Table - 3

Number of days taken for germination by seeds of *H. vulgare* cv. NP-113 (Chromium treated set)

Treatment	Number of days taken for germination
0	3
$5x10^{-5}M$	3
$1x10^{-4}M$	4
$2.5x10^{-4}M$	4
$5x10^{-4}M$	4
$1x10^{-3}M$	5
$2x10^{-3}M$	Radicle emergence negligible even on 7th day

Table – 4. Number of days taken for germination by seeds of *H. vulgare* cv. NP-113 (Cadmium treated set)

Treatment	Number of days taken for germination
0	3
$5x10^{-5}M$	3
$1x10^{-4}M$	4
$2.5x10^{-4}M$	4
$5x10^{-4}M$	5
$1x10^{-3}M$	6
$2x10^{-3}M$	Radicle emergence negligible even on 8th day

Summary

(1) All concentrations of chromium and cadmium except the lowest concentration are inhibited by seed germination. The highest concentration shows maximum inhibition and is almost fatal in some cases.

(2) Chromium and cadmium also cause delay in seed germination.

(3) Cadmium shows greater inhibitory effect on seed germination than chromium.

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