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ORIGINAL RESEARCH ARTICLE

Effect of contaminated water on seed germination traits of crops

Hana Souahi[1,*], Assia Abdelmalek[3,4], Khaoula Akrout[2], Rania Gacem[2], Abderrezzeq Chebout[2]

[1] *Laboratory of Water and Environment, Echahid Cheikh Larbi Tebessi University, 12002 Tebessa, Algeria*

[2] *Biomolecules and Application Laboratory, Faculty of Exact Sciences and Natural and Life Sciences, Larbi Tebessi University, 12002 Tebessa, Algeria*

[3] *Department of molecular and cellular biology, Faculty of Life and Natural Sciences, University of Abbes Laghrour, 40004 Khenchela, Algeria*

[4] *Laboratory of Biotechnology, Water, Environment and health, University of Abbes Laghrour, 40004 Khenchela, Algeria*

*** Corresponding author:** Hana Souahi, hana.souahi@univ-tebessa.dz

ABSTRACT

Lead (Pb) is one of the noxious trace metal element (TME) contaminants in the environment. In this work, we conducted a comparative physiological response study through some germination parameters between four cereals (*Triticum durum*, *Triticum aestivum*, *Hordeum vulgare*, and *Zea mays*) grown on a nutrient solution for 10 days and treated with three increasing levels of lead acetate (0.15, 0.3, and 0.6 g/L) in order to evaluate the impact of different lead concentrations on the germination capacity of these species. The results showed that lead has an abiotic stress effect on the four varieties examined at 0.3 g/L and 0.6 g/L. We recorded a significant to very highly significant effect in all the parameters studied. In the underground parts, in particular, a highly significant reduction in precocity of germination was recorded in *Triticum durum*, *Triticum aestivum*, *Hordeum vulgare*, and *Zea mays*. There was also a highly significant to very highly significant decrease in germination percentage in durum wheat, soft wheat, and maize. Under the most severe stress conditions (0.6 g/L), the barley variety showed stress tolerance with a germination rate of 92%. According to the findings of this study, the varieties examined can be grouped into two categories: variants that are susceptible to metal stress (*Triticum durum*, *Triticum aestivum*, and *Zea mays*) and varieties that are tolerant to lead exposure (*Hordeum vulgare*).

Keywords: cereals; lead; metal stress; growth

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1. Introduction

Cereals are the main source of food in many countries[1]. They are essential to a healthy diet, and it is now suggested that we consume between 4 and 6 pieces of grain products daily because of their content of fibre, oligoelements, and vitamins, which are thought to prevent various diseases. All grain products are rich in carbohydrates, which makes them the basis of a balanced and healthy diet. This is why this particular food group is so important[2].

At present, the accumulation of heavy metals is one of the most serious environmental problems. Many of them are toxic to crops, and because of the potential damage that they could cause to humans and animals[3,4]. The use of sewage sludge in agriculture, metal extraction, and the extensive use of pesticides and chemical fertilizers are the principal causes of environmental pollution by heavy metals[5–7].

Specifically, metals are non-degradable and, therefore, in aquatic and terrestrial environments, they can persist for long periods[8].

Contamination by trace metals (TME) has become a significant environmental issue that limits plant production and poses health risks to humans[9]. Although Northeastern Algeria's heavy metal contamination was generally at a low-risk level, we must continue to pay attention to the dangers of heavy metals to human health and their introduction into the soil, particularly cadmium (Cd)[10]. Currently, lead exposure and lead poisoning remain a growing public health problem in both developing and developed countries. Its capacity for bioaccumulation means that even low-level, long-term exposure can result in significant kidney damage[11].

Physiological and biochemical analyses showed Pb-induced growth inhibition and oxidative damage in a concentration-dependent manner[12]. Lead had significant adverse effects on plant fresh weight, shoot growth, root growth, root morphology, chlorophyll content, browning, stomatal growth, photosynthetic capacity, and fluorescence decline ratio[13].

Such stress conditions revealed that by increasing the concentration of lead, the germination rate (%), the tolerance index (TI), and the seedling vigor index (SVI) decreased significantly, suggesting their toxic effect on water spinach[14].

The seed germination test under lead (Pb) stress could be a quick test to understand plant tolerance to this heavy metal[15].

The concentration of pollutants in crops determines the quality of agricultural products, so it's important to study the phytotoxicity of heavy metals in polluted waters. Our objective is to study the responses of four cereals to metal stress (lead acetate) during germination and to determine the cultivars with optimum tolerance.

The result of this study will be the basis for determining the maximum lead concentration threshold, which still allows the crops to grow until it can be harvested.

2. Material and methods

Four species of cereals (*Triticum durum*, *Triticum aestivum*, *Hordeum vulgare*, and *Zea mays*) were used in the experiment to investigate the effects of lead (Pb) on seed development during the germination period. After rinsing three times in distilled water, seeds were soaked for 10 minutes in a 10% (v/v) solution of sodium hypochlorite (NaOCl). Next, 10 seeds were placed in petri dihes (90 mm diameter) on filter paper and treated separately with solutions containing 0.15, 0.3, and 0.6 g Pb L^{-1}, provided as lead acetate Pb $(CH_3COO)_2$.

Control treatments were supplied with a nutrient solution. Each germination test is carried out in ten repetitions (R1, R2, R3, R4, R5, R6, R7, R8, R9, and R10) for each concentration.

Seeds were considered germinated when their radical length was 2 mm[16]. After 10 days of treatment, the following parameters were measured:

2.1. Precocity of germination (%)

The precocity of seeding corresponds to the rate at which seeds germinated on the 1st day. In this case, the precocity of germination is expressed by the rate of the first germinated seeds[17].

2.2. Germination percentage (%)

Seed germination of cereals was registered every 24 h according to the technique for evaluating seedlings for ten days. The following formula was used to compute the germination percentage (GP)[16] for each replication of the treatment.

2.3. Kinetics of germination

To better understand the physiological process of sprouted grain, the number of sprouting grains was counted daily until the 7th day of the experiment of the germ behaviour of the studied varieties[18].

3. Results and discussion

The analysis of variance is shown in **Table 1**. Heavy metal concentration and interaction between cereal species had a significant effect on all characteristics at 0.1% probability.

Table 1. Analysis of variance of the measured traits.

S. O. V	df	Precocity of germination	Germination percentage
Cereals species (A)	3	29.89***	124.04***
Concentration (B)	3	197.51***	75.35***
A × B	9	8.26***	6.27***

*** significant at 0.1% probability.

The evaluation of the interaction between species of crops and concentrations of lead (**Figure 1**) showed lead acetate with 0.3 and 0.6 g Pb L^{-1} concentrations had the highest inhibitory effect on germination precocity as compared to control.

In 0.3 g Pb L^{-1} treatment, the precocity of seed germination was 50% in *Triticum durum*, 42% in *Triticum aestivum*, 42% in *Hordeum vulgare*, and 26% in *Zea mays*.

In 0.6 g Pb L^{-1} treatment, the precocity of seed germination was 22% in *Triticum durum*, 15% in *Triticum aestivum*, 13% in *Hordeum vulgare*, and 16% in *Zea mays*.

These results show that with increasing lead acetate concentration, the mentioned characteristics decreased. But this decrease in *Triticum aestivum* was very small in comparison with other species.

Figure 2 illustrates the impact of lead (Pb) on the total germination percentage of various crops. In the absence of lead (0 g/L), all seeds showed very good germination. The rate of seed germination was respectively 99% in *Triticum durum*, 100% in *Triticum aestivum*, 100% in *Hordeum vulgare*, and 82% in *Zea mays*.

However, as lead concentration increased, there was a significant decrease ($p < 0.001$) in total germination of *Triticum durum*, *Triticum aestivum*, and *Zea mays* seeds. In fact, at the highest concentration (0.6 g/L), the germination rate was the lowest, with *Triticum durum* and *Zea mays* seeds showing rates of 67% and 51%, respectively. On the other hand, *Hordeum vulgare* seeds consistently showed higher total germination percentages than other varieties, regardless of lead concentration.

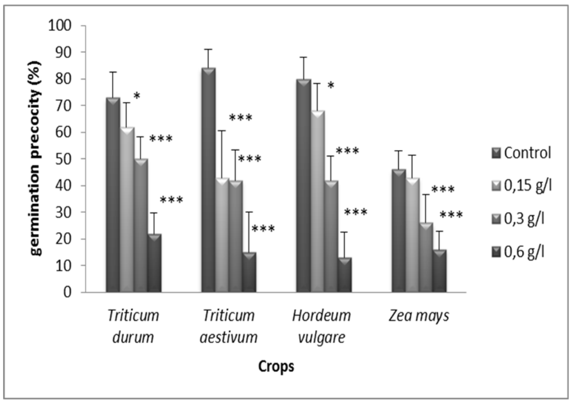

Figure 1. Impact of different lead concentration on germination precocity of cereals.

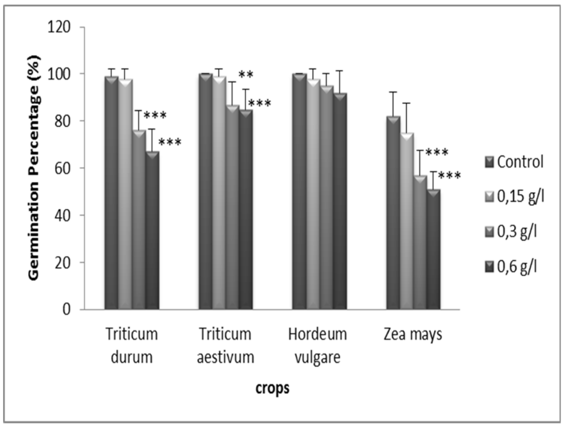

Figure 2. Effect of different doses of lead on on germination percentage of cereals species.

The impact of lead (Pb) on the germination kinetics of crop seeds was also examined (**Figure 3**). In *Triticum aestivum*, *Hordeum vulgare*, and *Zea mays* seeds, germination started the second day of imbibition for concentrations 0 and 0.15, 0.3 and 0.6 gL^{-1} of Pb $(CH_3COO)_2$, but with the presence of high concentrations of Pb $(CH_3COO)_2$ (0.6 gL^{-1}), radicles of the *Triticum durum* seeds appeared on the 3rd day. With the presence of higher concentrations of this heavy metal, the germination is delayed, and the period of the delay increases with the concentration. Heavy metals not only decreased germination but also delayed it.

Heavy metal concentrations at high concentrations are more likely to harm plants that are stressed. Lead toxicity has become important due to its constant increase in the environment.

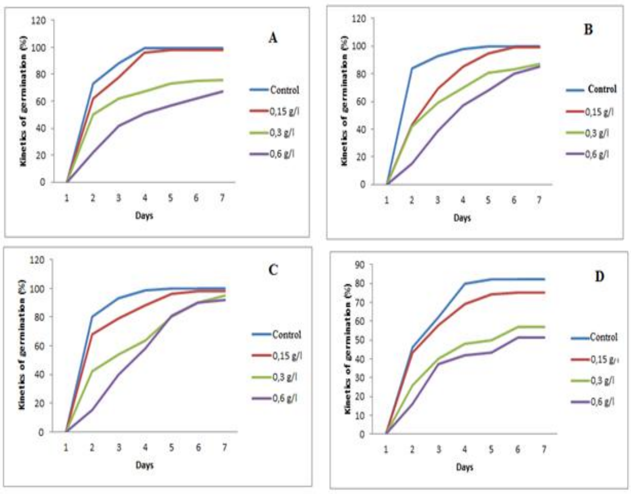

Figure 3. Impact of different lead concentration on Kinetics of germination of **(A)** *Triticum durum*; **(B)** *Triticum aestivum*; **(C)** *Hordeum vulgare*; **(D)** *Zea mays*.

According to the results of the study, germination characteristics were significantly decreased with the level of lead acetate concentration.

Many researchers have extensively described the toxic effects of cereals[19–22]. Different heavy metal concentrations have different phytotoxic effects on seed germination and seedling growth in diverse crops. *Daucus carrota* (L.), *Raphanus sativus* (L.), *Beta vulgaris* (L.), *Lycopersium esculentum* (L.), *Solanum melongena* (L.), *Vigna radiata* (L.), *Lablab purpureus* (L.), *Lathyrus ordoratus* (L.), *Lycopersium esculentum* (L.), *Triticum aestivum* (L.), and *Triticum durum* (Desf.) were reported[23–25]. The lead inhibited seed germination in ten-day-old seedlings of cereals species[26] study inhibited seed germination in ten-day-old seedlings of the plant species studied. Lead (Pb) exhibited greater toxicity toward *Zea mays* seed germination[27].

In species with lead-permeable seed coats, lead slowed germination and decreased seed germination capacity in a dose-dependent manner[28]. The impact of lead varies depending on the duration of exposure, the level of stress experienced by the plant, and the specific organs affected. Additionally, the uptake of lead differs across various plant tissues, with a decreasing order of uptake observed in roots, stems, and leaves[29]. Interfering with metabolic processes by lead (Pb), resulting in a loss of viability and diminished energy production capacity in the embryo, might be responsible for the decreased germination.

Energy production plays an important role in seed germination, and its blocking has an impact on the synthesis of proteins and nucleic acids, as well as the process of mitosis[30]. Accelerated degradation of food materials stored in seeds by lead application is attributed to reduced seed germination. Alterations in the permeability properties of the cell membrane may also cause a decrease in the germination of seeds[31]. Wheat was treated with lead at concentrations of 1, 2, 5, 10, and 20 mm, and the germination process was reduced with each increase in concentration[32]. In addition, lead inhibits and delays germination, slowing its speed. This delay may result from changes in certain enzymes and hormones present in the seed[33]. It has been mentioned that delayed germination can result from seed hydration problems caused by a high osmotic potential, which then provokes certain mechanisms essential for radicle emergence[34].

4. Conclusion

According to the obtained results, it is suggested that the heavy metal Pb has toxic effects on plant germination characteristics. It was hypothesized that the concentration of Pb used in this research inhibited seed germination in 10-day-old seedlings of the studied plant species. However, the response of the tested plants to Pb varied. Some plant species exhibited a milder response under stress conditions. Additionally, it should be noted that barley showed the highest resistance to lead acetate-induced stress.

Author contributions

Conceptualization, HS and AA; methodology, AA; software, HS; validation, HA, AA, KA, RG and AC; formal analysis, HS; investigation, AA; resources, KA, RG and AC; data curation, HS and AA; writing—original draft preparation, HA, AA, KA, RG and AC; writing—review and editing, HS; visualization, HS; supervision, HS and AA; project administration, HS and AA; funding acquisition, HS and AA. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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