Article

Effect of cadmium on the germinative parameters of bread wheat

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Abstract

The wheat is being a plant largely cultivated for its seeds and its straw wherefore the research of tolerant varieties to this dangerous element for the plant or the human health is necessary. Its concentrations increase day after day in the ground considering the development of the farming which involves the intensive contributions of this polling metal element. Objectives of this study is to test the effect of a range of cadmium concentration from 0 to 200 mg L^{-1} Cd^{+2}on the parameters of germination of two varieties of bread wheat Anza and Hiddab. The results show that the phytotoxicity increases, according to the increase in the Cd amount on the rate of germination, root and shoot length, root and shoot dry weight and tolerant index compared with the control for both varieties studied, nevertheless, Hiddab variety shows more sensitivity when compared to Anza variety. The inhibiting effect of cadmium on the germination stage can be continued in the advanced stages of plant cycle and disturb its physiological aspects.

Key words: *Triticum aestivum* L., cadmium, phytotoxicity, tolerance index.

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Introduction

Metallic tracks elements are natural constituents of all the ecosystems (the atmosphere, the hydrosphere, the lithosphere and the biosphere). Their distribution proceeds from two origins: the one, natural is the result of geogeniques process as the erosion, the geochemical precipitation of rocks and some source water, the volcanic and bacterial activity (Baize and Sterckeman, 2013), Other one, reveals anthropogeniques activities. Indeed, these last years, the development of the industrial activities caused a considerable increase of their content in the environment where they can reach of various ways. In gas form, dissolved or bound particles, transport pollutants can penetrate into the ground by air means (dry accumulation), by using the water as vector (haste, surface water, wet accumulation). Or still via organic solids as such purification mud, compost, fertilizers especially phosphated fertilizers and pesticides, etc.

In vegetables, certain ETM are essential to the major physiological processes, in particular the breath, the photosynthesis or the assimilation of the nourishing elements (Cu, Zn, Nor, Fe, Co) (Kabata-Pendias and Pendias, 2001). Some of them are also involved in the molecular processes such as the control of the expression of the genes, the biosynthesis of proteins, nucleic acids, substances of growth, some chlorophyll and the secondary metabolites, the lipid metabolism or the stress tolerance (Rengel, 1999). They therefore, play a very important role in the multiple enzymatic systems involving reactions of oxydoreduction **(**Chaignon, 2001). However, the ETM don’t have all function known this day in the metabolism of the plant and some are considered as toxic elements (Kabata-Pendias and Pendias, 2001).

All the heavy metals can, from a concentration threshold, lead to toxicity in plants. Several studies showed that the presence of metallic elements tracks and more particularly Cd in the environment of culture can express itself, beyond a limit threshold, by the appearance of symptoms of poisoning, accompanied with an inhibition of the weight growth of plants, with a reduction of the photosynthesis and with a decrease of the nourishing elements (Verbruggen *et al*., 2009; DalCorso *et al*., 2013). Resulting from its physical and chemical properties, close to those some zinc and to some calcium, allow it to cross the biological barriers and to accumulate in tissues; we identify it as being an extremely toxic pollutant (Godt *et al*., 2006). Whatever is its origin, the present cadmium in the ground does not decompose either by chemical way, or by biological way. It is accumulated in superficial from of in the grounds and can be pulled by runoff water to affect the deep ground waters. In this case, it can be absorbed by plants, which represents a major problem for the human health. An exhibition in the cadmium lead to large number of harmful effects, the renal hurts and the cancer appearing among the gravest (Godt *et al*., 2006).

As for the wheat, it constitutes the basic food of a third party of the humanity, supplying it calories and proteins, more than quite different cultivated plant, of which it needs contributions in fertilizing elements as regards the nitrogen, the phosphor and the potassium to complete the lack of the part supplied by the ground which is always insufficient for an optimal production. As many plants the phase of germination is sensitive to the environmental factors; a range of concentrations of cadmium is going to be studied to determine their phytotoxicity on two varieties of common wheat *Triticum aestivum* L.

Materials and methods

The germination trial was done in the laboratory of the biotechnology in department of agronomy of the University of Blida1. Two varieties of bread wheat (*Triticum aestivum* L.) Anza and Hiddab widely used by our farmers are used in this study.

The seeds were supplied by the ITGC (technical Institute of the field crops) are disinfected in the sodium hydrochlorite at 2% during 10 minutes then rinsed with some distilled water to eliminate the fungal contaminations. They are placed in Petri boxes having 10 cm of diameter and moistened with 10 ml of distilled water concerning the witness or the solution of cadmium. The test is done with 100 graines/variety then 10 graines/box exposed to increasing concentrations of chloride of cadmium respectively as 0, 50, 100, 150 and 200 mg L^{-1}. The Petri boxes are kept in the darkness in 25 °C during 7 days. After seven days of germination, 10 seedlings of every Petri box were taken to measure the length of stem and rootlets as well as the fresh weight and the dry weight after drying in the steam room for 72 h at 70 °C. The percentage of germination is the cumulated number of germinated seeds computed the seventh day including those which have a moderate rootlet superior than 2 mm (Soltani *et al*., 2006).

To estimate the influence of the increasing concentrations of cadmium on the germination of the varieties of bread wheat Anza and Hiddab, we calculated the rate of germination, the length of coleoptiles, the length of root, dry weight of coleoptiles and roots.

Tolerance index (TI) = $\frac{\text{Mean root length in metal solution}}{\text{Mean root length in distilled water}}$ x100 (Iqbal and Rahmati, 1992).

Stem phytotoxicity (%).

$$\frac{\text{Stem length of control - Stem length of treatment}}{\text{Stem length of control}} \text{x100}$$

Root phytotoxicity (%).

$$\frac{\text{Root length of control-root length of treatment}}{\text{Root length of control}} \text{x100}$$

Statistical analyses

The statistical analysis of the obtained results was calculated by the software SPSS© version 2000 for Windows™. The comparison between the averages of the various treatments also has been, established by an Anova followed by the test of Tukey for the comparison of the averages. This to be able to select the concentrations having a significant impact on the germination. In addition, the correlation of Pearson between the parameters in the various concentrations in cadmium was also studied.

Results and discussion

The results of our study are summered in the table1 where it contains the means obtained from the parameters studied under the combined effect of variety studied and concentration of cadmium, and this by computing the rate of germination, the length of coleoptiles and roots, the dry weight of coleoptiles and roots, phytotoxicity coleoptiles and roots and the tolerance index, which are illustrated in graphs (Figures 1-8).

Table 1. Means of germination rate, length of stem and roots, dry weight of stem and roots, index of tolerance and phytotoxicity of the coléoptiles and roots under the combined effect of variety-concentration studied Cd of the varieties.

Varieties	Cd dose ($mg\ L^{-1}$)	GR (%)	SL (cm)	RL (cm)	SDW (g)	RDW (g)	TI	Phyto_S (%)	Phyto_R (%)
Anza	Témoin	100^{a}	11.093^{a}	11.773^{b}	0.042^{a}	0.038^{a}	100^{a}	$2.176E-14^{e}$	$1.776E-15^{f}$
	50	100^{a}	7.333^{b}	6.287^{c}	0.03^{b}	0.023	53.417^{bc}	33.867^{d}	46.573^{d}
	100	100^{a}	3.873^{c}	2.4^{f}	0.025^{c}	0.023^{c}	20.353^{de}	65.073^{b}	79.637^{b}
	150	93.33^{ab}	3.373	2.26^{f}	0.023^{c}	0.021^{c}	19.24^{de}	69.587^{b}	80.75^{b}
	200	83.33^{b}	2.267^{d}	1.68^{j}	0.019^{d}	0.02^{cd}	14.287^{e}	79.57^{a}	85.703^{ab}
Hiddab	Témoin	95^{a}	12.447^{a}	13.327^{a}	0.05^{a}	0.032^{b}	100^{a}	$1.421E-14^{e}$	$1.421E-14^{f}$
	50	93.33^{a}	8.68^{ab}	7.88^{bc}	0.036^{ab}	0.028^{b}	59.13^{b}	30.233^{d}	40.86^{e}
	100	81.66^{b}	5.453^{c}	4.173^{d}	0.029^{b}	0.023^{c}	31.313^{c}	56.12^{c}	68.677^{c}
	150	80^{b}	3.487^{c}	3.407^{e}	0.021^{bc}	0.021^{c}	25.613^{d}	71.973^{b}	74.377^{bc}
	200	70^{c}	2.707^{d}	1.25^{j}	0.015^{d}	0.015^{d}	9.383^{f}	78.247^{a}	90.607^{a}

Date of germination

According to the test Anova which reveals a significant difference of the interaction variety-concentration, we note a significant difference (p 0.01) between both studied varieties Anza and Hiddab for the concentrations 100, 150 and 200 mg which inhibit the germination of the variety Hiddab compared to variety Anza (Figure 1).

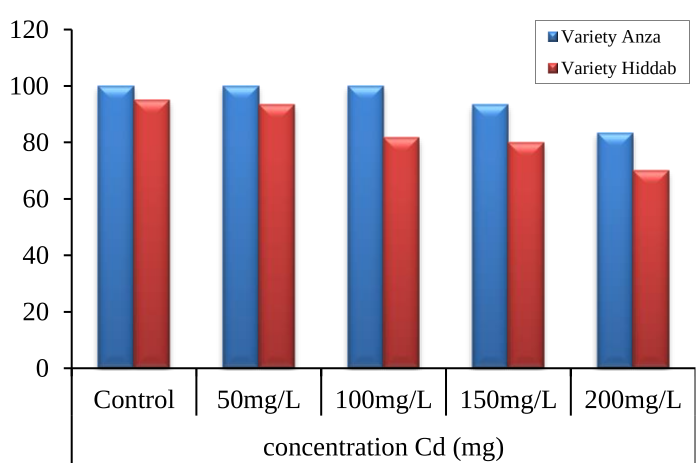
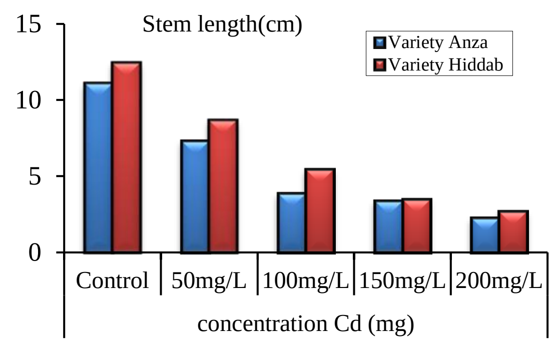


Figure 1. Averages of germination rate under the effect combined of variety-concentration Cd.

Length of stem and roots

According to the statistical analysis, the length of stem is significantly (*p* 0.001) influenced by the increasing concentrations of cadmium of which it varies from 12.44 and 11.09 cm registered by the varieties Hiddab and Anza respectively for the control. 2.7 and 2.26 cm for the varieties Hiddab and Anza and this for the treatment 200 mg (Figure 2) with a rate of 77.29% reduction. The same effect of cadmium on the length of roots, its means vary between 11.71-13.32 cm for the varieties Anza and Hiddab for the control and 1.25-1.68 cm for the varieties Hiddab and Anza with the concentration of 200 mg of cadmium (Figure 2) with a rate of 86.67% inhibition.



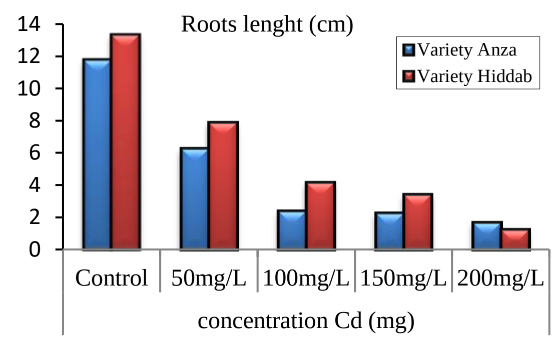
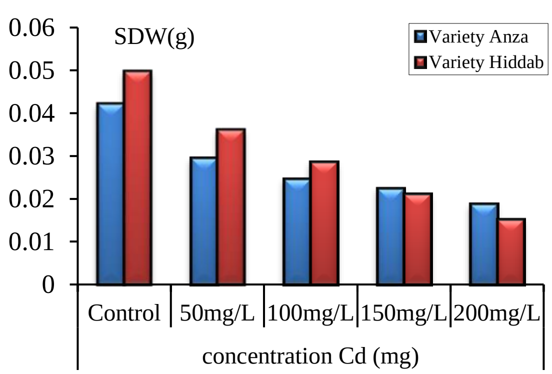


Figure 2. The combined effect variety-concentration Cd on the stem length and roots. Old seedlings 7 days were exposed to various concentrations of CdCl2. The takings were made seedling by seedling. The values are averages of 10 repetitions. The bars of error correspond to the standard errors.

Dry weight of stem and roots

The effect of the interaction variety x concentration reveals a very highly significant effect (*p* 0.001) on the dry weight of stem, of which one register a reduction of dry weight of 56.93% (Figure 3). About roots, they are strongly influenced where we register the smalest weight for the variety Hiddab with a value of 0.015 g under the concentration of 200 mg compared with the the highest weight obtained by Anza 0.038 g with the control, with a rate of 48.11% reduction (Figure 3).



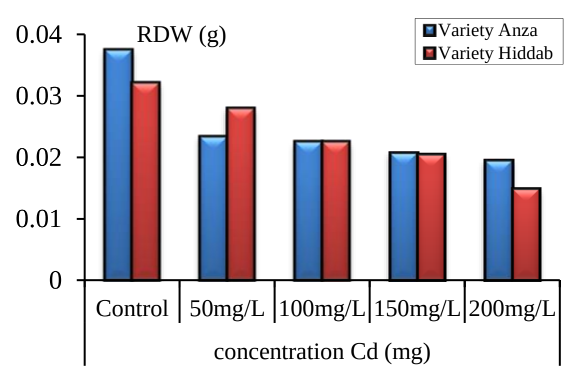


Figure 3. The Effect of the interaction variety-concentration Cd on the stem dry weight (SDW) and the roots dry weight (RDW). Old seedlings 7 days were exposed to various concentrations of CdCl2. The takings were made seedling by seedling. The values are averages of 10 repetitions. The bars of error correspond to the standard errors.

Phytotoxicity of stem

According to the means obtained from the effect of the interaction variety-concentration Cd on this parameter, which varied proportionally with the concentrations used for both varieties (Figure 4) 79.57 and 78.24% for the varieties Anza and Hiddab respectevely under the concentration of 200 mg (Table 1).

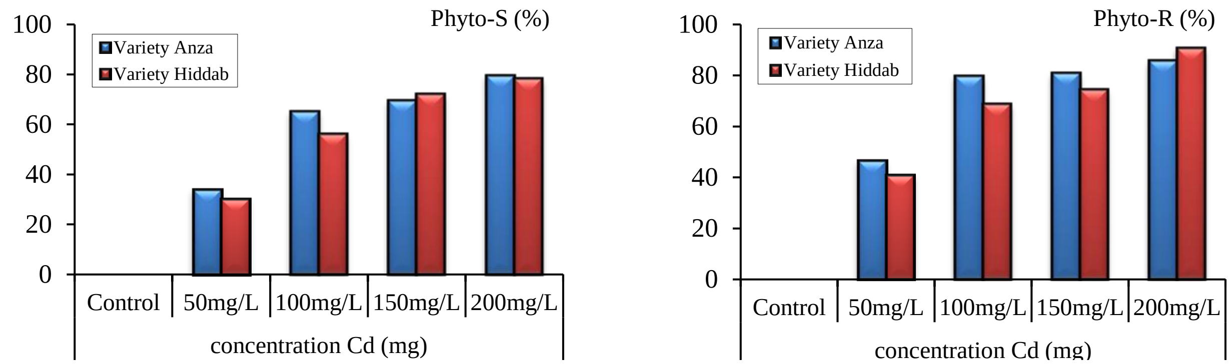


Figure 4. The combined effect by variety-concentration Cd on the stem and roots phytotoxicity. Old seedlings 7 days were exposed to various concentrations of CdCl2. The takings were made seedling by seedling. The values are averages of 10 repetitions. The bars of error correspond to the standard errors.

Phytotoxicity of roots

It increases according to the increase of the concentrations of cadmium for Anza and Hiddab with an average increase of 86.65% (Figure 5).

Tolerance index

The effect of the interaction variety-concentration reveals a very highly significant effect; it is inversely proportional with the concentration Cd (Table 1, Figure 5) the tolerance index decreases according to the increase of concentration Cd both varieties. The variety Hiddab is the least tolerant.

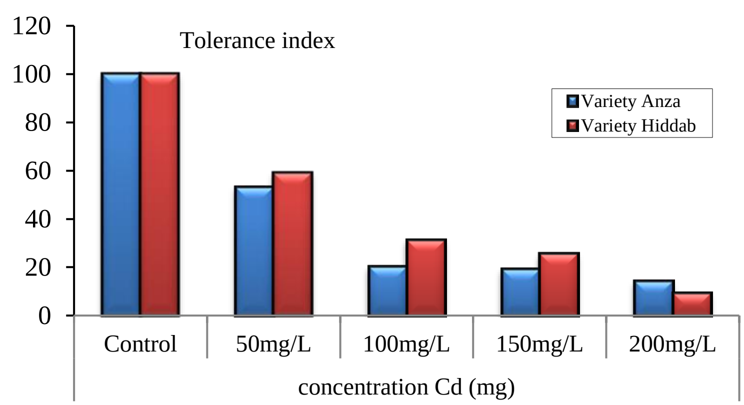


Figure 5. The tolerance index under the combine effect variety-concentration Cd. Old seedlings 7 days were exposed to various concentrations of CdCl2. The takings were made seedling by seedling. The values are averages of 10 repetitions. The bars of error correspond to the standard errors.

In order to complete the statistics analysis, a test of correlation is added to show the dependence between the various analyzed parameters (Table 2) whether, it is positive or negative in other words proportional or inversely proportional.

Table 2. The Pearson correlation test of the parameters various studied.

		GR	SL	RL	SDW	RDW	TI	Phyto_S	Phyto_R
GR	Correlation of Pearson	1	0.62**	0.547**	0.638**	0.599**	0.585**	-0.65**	-0.586**
	Sig. (bilateral)		0	0	0	0	0	0	0
	N	60	60	60	60	60	60	60	60
LS	Correlation of Pearson	0.62**	1	0.947**	0.959**	0.84**	0.944**	-0.994**	-0.44**
	Sig. (bilateral)	0		0	0	0	0	0	0
	N	60	60	60	60	60	60	60	60
RL	Correlation of Pearson	0.547**	0.947**	1	0.905**	0.929**	0.982**	-0.952**	-0.982**
	Sig. (bilateral)	0	0		0	0	0	0	0
	N	60	60	60	60	60	60	60	60
SDW	Corrélation of Pearson	0.638**	0.959**	0.905**	1	0.823**	0.913**	-0.952**	-0.913**
	Sig. (bilateral)	0	0	0		0	0	0	0
	N	60	60	60	60	60	60	60	60
RDW	Correlation of Pearson	0.599**	0.84**	0.929**	0.823**	1	0.942**	-0.867**	-0.942**
	Sig. (bilateral)	0	0	0	0		0	0	0
	N	60	60	60	60	60	60	60	60
TI	Corrélation of Pearson	0.585**	0.944**	0.982**	0.913**	0.942**	1	-0.955**	-1**
	Sig. (bilateral)	0	0	0	0	0		0	0
	N	60	60	60	60	60	60	60	60
Phyto_S	Correlation of Pearson	-0.65**	-0.994**	-0.952**	-0.952**	-0.867**	-0.955**	1	0.955**
	Sig. (bilateral)	0	0	0	0	0	0		0
	N	60	60	60	60	60	60	60	60
Phyto_R	Correlation of Pearson	-0.586**	-0.944**	-0.982**	-0.913**	-0.942**	-1**	0.955**	1
	Sig. (bilateral)	0	0	0	0	0	0	0	
	N	60	60	60	60	60	60	60	60

**= the correlation is significative at 0.01 (bilateral).

The cadmium is classified as carcinogenic and genotoxic agent of group 1 by «international agency for research one cancer» or IARC, thus it is a not essential and very dangerous metal for the wing oufamiosms Indeed (Daud *et al*., 2008) 7. The germination or the late embryogenesis, is the first stage of the development of a plant. During the germination, the embryo increases in volume by the use of the energy resulting from the oxidation of the reserves under the influence of the action of the various hydrolasiques enzymes, which clears gradually the envelopes surrounding it and the exit of the coleoptiles and the rootlets. In whom the seed returns to the active life after a period of dormancy (Meyer *et al*., 2004).

In this phase the seed needs favorable external and internal conditions for a normal development. Several studies showed the negative impact and the toxicity of heavy metals on the process of seeding and the growth of seedlings (Ahsan *et al*., 2007; Datta *et al*., 2011).

The results indicate that the cadmium exerts a negative effect on all the germinative parameters (Rahul *et al*., 2008). It is important to mention that the germination rate is significantly influenced by the increase of the concentration of Cd. Dry weight of coleoptiles and roots, length of roots and stem (Ahmad *et al*., 2012). We notice an important reduction in length of roots compared to the other parameters.

The sensibility of roots is due for their localization in the first contact point with the external midium loaded with cadmium (Yang *et al*., 1998; Amirjani *et al*., 2012).

As far as the phytotoxicity of cadmium is concerned for both studied varieties; the means are variable from one to the other. The tolerance index for both varieties in the various concentrations of cadmium show that the variety Hiddab is more tolerant than the variety Anza. The resistance for the cadmium is reached by the production of the antioxidants which detoxifies the species free of oxygen (Liu and Zhang, 2007; Hartley-Whitaker *et al*., 2001).

The Pearson correlation test between the various studied parameters (Table 2), reveals a significantly proportional correlation between the rate of germination (RG), the length of the rootlet (LR), the length of stem (LS), the dry weight of rootlets and the stem (DWR and DWS). While the correlation with the phytotoxicity where there we consider rootlets or the stem is inversely proportional what confirms the inhibitive effect exercised by the cadmium on the parameters of germination (Lin *et al*., 2010).

Conclusion

Based on these results, the cadmium shows on one hand an inhibitive effect on the parameters of germination and On the other hand, the varieties behave differently, there are varieties tolerant and other sensitive. This leads us to the obligation of strategic choice of the varieties especially in the soils affected by cadmium and other metals.

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