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Research Article

Performance of Wheat Genotypes under Cadmium Contamination of Soil

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Abstract

In order to evaluate different wheat genotypes against cadmium contamination of soil, an experiment was carried out in the department of Plant Breeding and Genetics, Pir Mehr Ali Shah-Arid Agriculture University Rawalpindi. The experiment was carried out under the control conditions. The experiment was laid out by using two factorial Completely Randomized Design (CRD) with six treatments and four replications. The treatments included six cadmium concentrations of cadmium in soil i.e., (control treatment, 5 ppm, 10 ppm, 15 ppm, 20 ppm and 25 ppm). Parameters studied were germination % age, plant height (cm), fresh shoot weight (g), dry shoot weight (g) and cadmium contents in shoot. The results showed the accumulation of cadmium in shoot of different wheat genotypes as compared to control treatment. Cadmium depicted the great variation as compared to control in different parameters studied.

Keywords: Accumulation; Cadmium concentration; Shoot; Uptake; Variation; Wheat genotypes

Introduction

Wheat (*Triticumaestivum* L.) is an important cereal crop of Pakistan. Wheat is the main crop produced in the country. It is used as the staple food and also used more as compared to any crop such as rice and maize [1]. Cadmium (Cd) is considered as the most toxic heavy metal as compared to other metals in soil which will ultimately reduce the plant growth and also affect some important characters of plants [2]. As its amount increases inside the soil, it will affect the overall crop production. Its addition in soil is due to water which is coming from our industries, metal mining, supply of fertilizer, and exploitation of pest control chemicals, seepage and dirt [3]. Cadmium pollutes the environment as well as it accumulates in grain of different crops and when man eats that food it causes different health problems more obvious are kidney, lungs and stomach problems. Cd has no significance for the functioning of crop plant but is much harmful to all the organisms in soil [4]. Maximum uptake of cadmium in wheat might be related to potash deficiency [5,6]. High mobility of this metal in soil-plant system allows its easy entry into the food chain where it may provoke both human diseases [7] and known toxic effects on animals, microorganisms and plants. Increasing international concern about the risks associated with long-term consumption of crops contaminated with Cd has led the international food standards organization, Codex Alimentarius commission, to propose a 0.1mg Cd.kg^{-1} dry weight limit for cereals, pulses and legumes [8]. As this criterion may put under pressure the market of some agricultural products, several strategies have been proposed for the successful management of the Cd-contaminated agricultural soils. One approach is aiming to screen and use low Cd-accumulating genotypes of crops, known to accumulate unacceptable high Cd levels in grain [9]. The second approach recommends profitable use of both non-food crops and cereals for seed production [10,11]. The third option is metal phytoextraction, based on the natural or "induced" ability of plants Cd phytoextraction 70 to uptake metals (and organics) from soil and to concentrate them in the harvestable parts [12,13]. Movement of Cd from roots to shoots is a critical point for Cd phytoextraction. To be able to reach xylem vessels, metal uptake is taking place at the younger parts of the root, where Casparian strips are not well developed [14]. The absorbed metals are unloaded from the xylem parenchyma into mature xylem vessels, but this process is not well understood [15]. There is some evidence for elevated loading rates for some metals in hyper accumulator plants: Zn in *Thlaspi caerulescens* [16] and Ni in *Alyssum lesbiacum* [15], but no information is available for Cd. Regarding the significance of cadmium on plant fate and its crucial effect on the health of humans, the present study was designed with the objective to sort out different wheat genotypes which can be utilized to reduce cadmium contamination of soil.

Materials and Methods

The experimental material consisted of 20 wheat genotypes. These genotypes were obtained from Plant Genetic Resources Institute (PGRI), National Agricultural Research Centre (NARC), and Islamabad. Sowing was done in the research area of Pir Mehr Ali Shah- Arid Agriculture University Rawalpindi, during October, 2011. These genotypes were sown in small pots, each pot having 375g of soil using the electric balance. Completely Randomized Design (CRD) was used with four replications at different levels of cadmium concentrations (control, 5 ppm, 10 ppm, 15 ppm, 20 ppm, and 25 ppm). Parameters recorded in this study were germination percentage, plant height, fresh shoot weight, and dry shoot weight and cadmium contents in shoot. Germination percentage was taken after 30 days of sowing by dividing total number of seedling emerged over the

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total number of seeds sown. Plant height was calculated in centimeters from base to top where spike emergence took place. For fresh shoot weight, plants were separated from the soil washed with water and shoot was cleaned with the help of tissue to avoid moisture and then shoot was weighed by using digital balancer to avoid the dryness of shoots. Dry shoot weight was taken by placing the shoots in oven for three days at 70ºC, after that shoots were taken off from oven and placed into desiccator to avoid moisture for further analysis. Cadmium in shoots was recorded by using the atomic absorption spectrophotometer (Model GBC-932 Plus). About 0.5 g of plant ground material was taken into digestion tube and 4.4 ml of digestion blend was added to each tube. Digestion was done at 350°C for 2 hours. After this, all solution became color less and remaining solid turned into white color. First, there was no color change, so solution was further heated for 1 hour to change the color. Based on the data recorded, three promising wheat genotypes were selected which were further used in the second experiment.

Statistical analysis

Data were subjected to ANOVA (Analysis of Variance) technique and means were compared by LSD test following [17].

Results and Discussion

Germination percentage

The results of germination percentage are shown in table 1. The maximum germination was found at treatment $T_{3,}$ 98% followed by 97% at treatment T_4. Minimum germination was found in treatment T_5 which was 87%. Our findings depicted the variable amount of germination percentage at different cadmium levels. This might be due to genotypic or geographic differences such as control showing more germination as compared to treatment T_5 but the control showing less germination as compared to T_2, T_3 and T_4, respectively. Variation in seed germination of different cultivars against Cd stress might have been due to presence of genetic diversity in the cultivars used in the study. Such kind of response has also been reported by Zhang et al., [18]. The findings of present study revealed that 20 ppm must be the maximum limit for Cd but treatment T_4 (97%) showed that there was less effect of Cd due to variation in genotypes. Due to genetic and environmental variations some genotypes performed best and others performed not well as compared to control $T_{0.}$

T_0 (Control)	T_1 (5 ppm)	T_2 (10 ppm)	T_3 (15 ppm)	T_4 (20 ppm)	T_5 (25 ppm)
90%	96%	94%	98%	97%	87%

Table 1: Germination percentage at different cadmium amounts.

Effect of cadmium on plant height (cm)

The results of plant height (cm) are shown in table 2. Data showed that, there was a difference present among the Means of all the wheat genotypes. Maximum plant height (cm) was observed in genotype (018674) 15.767 cm followed by genotypes (018679), 15.608 cm, (018680) 15.412 cm and (018685) 15.275 cm, respectively. Minimum plant height (cm) was seen in genotype (018688) 11.350 cm, (018692) 11.375 cm and (018683) 11.387 cm, respectively. Maximum plant height was observed at treatment T_1 (16.76). Minimum plant height was recorded at treatment T_0 (10.6) Treatment means are shown in figure 1. Plant height has a considerable effect on ultimate yield of the wheat crop. Short statured plants are more desirable from high yielding point of view. Our findings showed different cadmium levels do not affect plant height significantly. This means that at a certain level of, Cd "toxicity the plant height trait is not affected. In the present study, interesting results are obtained regarding effect of 5 ppm and 10 ppm of Cd on plant height than rest of the treatments". The variable results might be due to different genetic nature of wheat genotypes. Zhou and Qiu [19] reported that with an increase in Cadmium concentration plant height is also increased.

S. No.	Wheat Genotypes	Plant Height (cm)	Fresh Shoot Weight (g)	Dry Shoot Weight(g)	Cadmium (ppm)
1	18674	15.767 A	0.2113 A	0.2113 A	5.6667 A
2	18679	15.608 AB	0.2104 AB	0.2104 AB	5.5208 B
3	18680	15.412 AB	0.1979 ABC	0.1979 ABC	5.4833 BC
4	18685	15.275 ABC	0.1906 ABCD	0.1906 ABCD	5.5042 BC
5	18678	15.267 ABC	0.1882 ABCDE	0.1882 ABCDE	5.4833 BC
6	18684	15.160 ABC	0.1827 ABCDEF	0.1827 ABCDEF	5.4792 BC
7	18686	15.129 ABCD	0.1816 ABCDEF	0.1816 ABCDEF	5.4750 BC
8	18675	15.087 ABCD	0.1775 ABCDEF	0.1775 ABCDEF	5.4708 BC
9	18682	14.921 ABCD	0.1716 ABCDEF	0.1716 ABCDEF	5.4708 BC
10	18702	14.892 ABCD	0.1715 ABCDEF	0.1715 ABCDEF	5.4708 BC
11	18677	14.825 ABCD	0.1710 BCDEF	0.1710 BCDEF	5.4708 BC
12	18691	14.742 ABCD	0.1707 BCDEF	0.1707 BCDEF	5.4667 BC
13	18703	14.329 ABCD	0.1697 CDEF	0.1697 CDEF	5.4625 BC
14	18681	14.050 BCD	0.1644 CDEF	0.1644 CDEF	5.4500 BC
15	18676	13.642 CD	0.1585 CDEF	0.1585 CDEF	5.4500 BC
16	18687	13.442 D	0.1516 DEF	0.1516 DEF	5.4458 BC
17	18689	11.675 E	0.1495 EF	0.1495 EF	5.4333 BC
18	18683	11.387 E	0.1475 F	0.1475 F	4.7333 C*
19	18692	11.375 E	0.1472 F	0.1472 F	4.2417 D*
20	18688	11.350 E	0.1449 F	0.1449 F	4.1458 E*

Table 2: Treatment Mean of different parameters of 20 wheat genotypes used in the study.

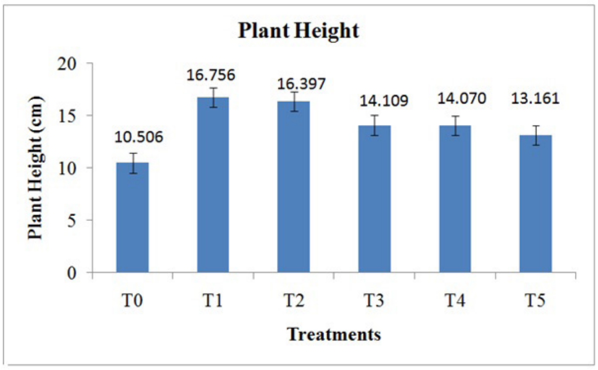

Figure 1: Bars graph showing the treatment mean for plant height.

Effect of cadmium on fresh, shoot weight

Shoot fresh weight data is shown in table 2. There was a difference among the genotypes and treatment means studied. Among different genotypes, maximum fresh shoot weight was found in genotype (018702) 0.2113 followed by (018702) 0.21g, (018691) 0.197g and 018681 (0.197), respectively. Minimum fresh shoot weight was observed in genotype (018683) 0.145 g, (018688) 0.1472 and (018675) 0.1475 g, respectively. Maximum fresh shoot weight was found at treatment T_1 (0.193). Minimum fresh shoot weight was recorded in T_5 (0.156). Mean fresh shoot weight in genotypes under Cd treatment decreased 44.7% in comparison with control. Treatment means are shown in figure 2. Bhardwaj et al., [20] in their study on beans found that if Cadmium content is increased 1.5, 2.0, 2.5, 3.0 g kg^{-1} it resulted in a decrease in total weight and shoot fresh weight of young seedlings. Khadijeh et al., [21] also reported that if we increase the cadmium level it would ultimately reduce the fresh shoot weight of seedlings. Presence of cadmium activity can lead to reduction in yield ultimately.

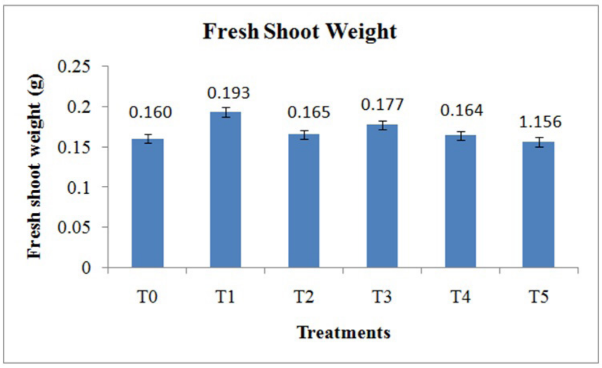

Figure 2: Bars graph showing the treatment mean for fresh shoot weight.

Effect of cadmium on dry shoot weight

The calculated means regarding dry shoot weight observed are presented in table 2. The data revealed that there was a significant difference among the genotypic means studied. The maximum dry shoot weight was found by the genotype (018681) 0.0372g closely followed by (018683) 0.0366g, (018677) 0.0340g and (018680) 0.0339g, respectively. 0. Minimum dry shoot weight was observed in genotype V_{20} (018703) 0271g followed by genotype (018692) 0.0274g and (018688) 0.0276g, respectively. Treatment means are elaborated in figure 3. Maximum dry shoot weight was found at treatment T_1 (0.036). Minimum dry shoot weight was recorded at treatment T_4 (0.029). Khadijeh et al., [21] reported that dry shoot weight is decreased with the increase in cadmium concentrations.

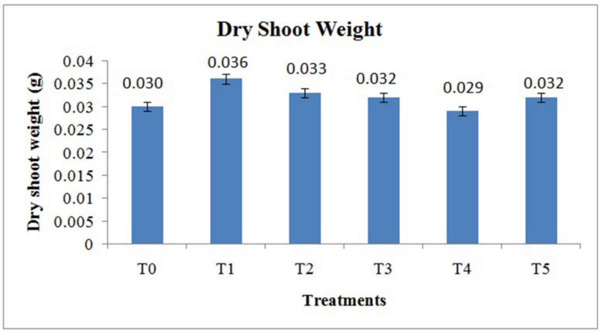

Figure 3: Bars graph showing the treatment mean for dry shoot weight.

Cadmium content in shoot

Data regarding cadmium content in shoot is presented in table 2. It revealed that interaction between the genotypes and treatment was highly significant. However, a difference was found in means of all the genotypes used in the study. Three genotypes were screened against the cadmium contamination of soil. Treatment means are shown in figure 4. Maximum cadmium uptake was found in wheat genotype (018675) 5.67 mg kg^{-1} and (018681) 5.52 mg kg^{-1}. Minimum cadmium uptake was recorded in genotype (018674) with the mean of (4.14 mg kg^{-1}) followed by genotype (018680) with the mean of 4.24 mg kg^{-1} and genotype (018676) with the mean of (4.73 mg kg^{-1}). Maximum cadmium uptake was recorded at treatment T_5 (10.7 mg kg^{-1}) followed by treatment T_4 (8.37 mg kg^{-1}). Minimum cadmium uptake was recorded at treatment T_1 control (0.00) followed by T_2 (2.27 mg kg^{-1}). Brookes PC [22] described that as we increase the amount of cadmium, plants showed more cadmium uptake.

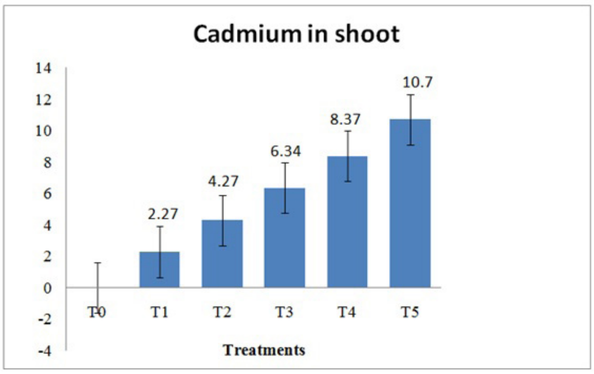

Figure 4: Bars graph showing the treatment mean for cadmium uptake.

Conclusion

The present study indicated that different plant traits performed different in different concentration of Cadmium content. Maximum cadmium uptake was found in wheat genotype (018675) 5.67 mg kg^{-1}

and (018681) 5.52 mg kg^{-1} and minimum cadmium uptake was recorded in genotype (018674) with the mean of (4.14 mg kg^{-1}). The maximum dry shoot weight was shown by the genotype (018681) 0.0372g and minimum dry shoot weight was observed in genotype (018703) 0.0271g. Maximum fresh shoot weight was found in genotype (018702) 0.2113 g and minimum fresh shoot weight was observed in genotype (018683) 0.145 g. Maximum plant height (cm) was observed in genotype (018674) 15.767 cm and minimum plant height (cm) was seen in genotype (018688) 11.350 cm. It is concluded that promising genotypes that performed best in the presence of cadmium content can be used for further breeding program.

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