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The Effect of Ca-Bentonite Application on Cadmium Uptake and Shoot Dry Matter of Bread Wheat

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Abstract: Cadmium (Cd) is a non-essential heavy metal that is highly toxic even at very low concentrations. Although Cd is a non-essential trace metal, when reached to high levels in agricultural soils, it can be easily absorbed by plants. Cadmium accumulation in wheat (*Triticum aestivum* L.) and its subsequent transfer to food chain is an important problem worldwide. Bentonite is a material essentially composed by montmorillonite and related clay minerals of the smectite group. The purpose of this study was to investigate the effects of bentonite (0, 3, 6 and 12%) application on Cd uptake of bread wheat growing in high Cd (0, 5 and 10 mg kg^{-1} soil) application. The experiment was conducted randomized block design with three replicates. The results revealed that shoot dry weight of bread was significantly increased with increasing doses of bentonite applications. While the dry weight of shoot without bentonite application was 480 mg/plant, it increased approximately 2 fold with 12% bentonite application. Cadmium concentration with the bentonite of control application decreased 4 times from 20.74 mg kg^{-1} to 5.07 mg kg^{-1} with application of 12% bentonite. The results show that Cd toxicity in the shoot was alleviated by bentonite treatment.

Ca-Bentonit Uygulamasının Ekmeklik Buğdayın Kadmiyum Alımına ve Yeşil Aksam Kuru Madde Verimi Üzerine Etkisi

Anahtar Kelimeler
Ekmeklik buğday,
Bentonit,
Kadmiyum

Öz: Kadmiyum (Cd), çok düşük konsantrasyonlarda bile oldukça toksik olan, mutlak gerekli olmayan bir ağır metaldir. Kadmiyum gerekli olmayan ağır metal olmasına rağmen, tarım topraklarında yüksek seviyelere ulaştığında bitkiler tarafından kolaylıkla alınabilir. Buğday 'da (*Triticum aestivum* L.) Cd birikiminin olması ve ardından besin zinciri vasıtasıyla insanlara geçişi global bir sorundur. Bentonit, esas olarak montmorillonit ve smektit grubuna ait kil minerallerinden oluşmaktadır. Bu çalışmanın amacı, bentonit (0, %3, %6 ve %12) ve Cd (0, 5 ve 10 mg kg^{-1} toprak) uygulaması altında yetiştirilen ekmeklik buğdayın Cd alımı üzerine etkilerini araştırmaktır. Deneme tesadüf blokları deneme deseninde üç tekerrürlü olarak yürütülmüştür. Sonuçlar, artan dozlarda bentonit uygulamaları ile ekmeğin yeşil aksam kuru madde verimini önemli ölçüde arttığını ortaya koymuştur. Bentonit uygulanmayan kontrol grubunda yeşil aksam kuru madde miktarı 480 mg/bitki iken, %12 bentonit uygulaması ile kuru madde verimi yaklaşık 2 kat artmıştır. Kontrol uygulamasında Cd konsantrasyonu 20.74 mg kg^{-1} iken %12 bentonit uygulamasında 4 kat azalarak 5.07 mg kg^{-1} olarak belirlenmiştir. Sonuçlar, bentonit uygulaması ile yeşil aksam Cd toksititesinin hafifletildiğini göstermektedir.

1. INTRODUCTION

Contamination of agricultural soils with heavy metals is an important problem worldwide, but also poses a serious threat to crop yields [1, 2, 3, 4, 5]. Cadmium (Cd), one of the heavy metals, is a toxic metal found almost everywhere, negatively affecting both plant and human health, and is very harmful even at very low levels [5, 6]. In the last 50 years, it has been announced that 22.000 tons of Cd has been released into the environment and 82%-94% of this is mixed into the soil [7]. It is also an important source of phosphorus fertilizers for the introduction of Cd into agroecosystems [8, 9]. Therefore, balanced fertilization of phosphorus is rather important in agricultural production [10]. While normal Cd levels in the soil range from 0 to 1 mg kg^{-1}, today the soils are at 1 to 3 mg kg^{-1} Cd levels and show a light pollution level. It has been explained that cadmium can accumulate in the plant tissue very easily even at very low concentrations in the soil and inhibit plant growth [11, 12, 13, 14, 15, 16]. It is possible for herbal products to be contaminated with Cd and to enter and accumulate in the human body by the food chain [17, 18]. Cadmium can be easily transported to grain products grown all over the world, especially in wheat grains [19]. When high Cd accumulates in wheat grains, serious health problems may occur as a result of people's consumption of these grains. For this reason, research on reducing Cd in cereal-based foods has been accelerated in recent years. There is a need to identify and apply the factors that reduce the transport of Cd, especially in agricultural soils. Clay minerals, which are an integral part of the soil system, are non-toxic, inexpensive, have a large specific area, and are widely used as soil conditioners [20, 21, 22]. The high metal adsorption capacity and low cost of clay minerals make them one of the most common treatment options for heavy metal adsorption [23, 24]. Bentonite is a natural soil conditioner that is mainly composed of clay minerals of the montmorillonite and smectite group, which can reduce water loss in the soil and increase crop yield [25]. Bentonite has a strong adsorption capacity for Cd in the soil, it can immobilize this metal and reduce the uptake of these metals by agricultural products [26, 27]. Wheat is the most important grain in the world after rice and corn, and approximately 60% is consumed as food [28]. As the human population grows, demand for wheat is expected to increase by an estimated 70% over the next few decades (2020-2050) [29]. Compared to other grains, wheat can accumulate more Cd in the root and grain [30, 31]. Therefore, with the intake of wheat-derived food products with the food chain, it also causes a small amount of Cd to be taken into the human body. Wheat, which meets the daily nutritional needs of people, should be of high quality and harmful metals should be reduced. The aim of this study is to investigate the effect of bentonite application to soils on cadmium uptake of bread wheat.

2. MATERIAL AND METHOD

2.1. Some Physical and Chemical Properties of Soil Used In The Experiment

The soil used for the pot experiment was loamy in texture with organic matter content of 1.52%. The soil used properties were determined soil pH 4.81, lime 0.8%, salinity 652 µs/cm, available P 3.74 mg/kg, available K 222 mg/kg, availability Mg 166 mg/kg and total Cd concentrations 0.51 mg Cd/kg. The analysis of all chemical and physical properties of the soils was carried out using standard methods given by [32].

2.2. Growth Conditions

Plants were grown under greenhouse conditions in plastic pots containing 1.7 kg soil. Seeds of bread wheat (*Triticum aestivum* L. cv. Bayraktar) were sown in plastic pots. The soil used was obtained from Ordu Province in Black Sea Region. About 12 seeds were sown in each pot and after emergence the seedlings were thinned to 6 per pot at the two leaf stage. For the Cd treatment, Cd were applied at a rate of 0, 5.0 and 10 mg kg^{-1} soil in the form of $3CdSO_4.8H_2O$ and Bentonite treatments consisted of four doses of (0%, 3%, 6% and 12%) bentonite, together with a basal treatment of 200 mg N kg^{-1} soil as $Ca(NO_3)_2$ and 100 mg P kg^{-1} soil as KH_2PO_4. After 45 day of growth in the greenhouse, the shoots were harvested and dried at 65 ºC for determination of dry matter weight and Cd concentration in the shoot. The shoot of Cd concentration was determined with Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-OES; Varian Vista-pro) instrument.

In order to determine whether there is a relationship between the analysis results determined in the leaf samples, analysis of variance using SPSS and lettering with LSD test were made according to Tukey.

3. RESULTS AND DISCUSSION

3.1. Shoot Dry Matter Weight, Mg $Plant^{-1}$

This research was carried out to determine the effects of different doses and application times of Cd and bentonite on bread wheat. The experiment was carried out in greenhouse conditions in the design of randomized plots with 3 replications. Plants were grown in strongly acid soil treated with increasing Cd (0, 5 and 10 mg kg^{-1}) and Bentonite (0%, 3%, 6% and 12%) and harvested after 45 days of growth under greenhouse conditions. Although shoot dry matter weight decreased with increasing Cd application, dry matter weight increased with increasing bentonite application. Increasing bentonite application tended to decrease Cd concentrations in shoot. Increasing bentonite doses significantly affected the reduction of Cd concentration ($P< 0.05$) in shoot.

Increasing soil Cd application without bentonite showed a negative effect on the shoot dry weight. The shoot dry weight in the plants not treated with bentonite was found as 485 mg/plant, but it decreased significantly to 430 mg/plant, with the soil application of 10 mg/kg Cd (Table 1). Dry matter yield increased with increasing bentonite applications. In the control, dry matter yield was determined mean 480 as mg/plant and increased with increasing bentonite doses.

Table 1. The effect of bentonite application on the shoot dry matter in bread wheat

Applications		Shoot dry matter weight, mg $plant^{-1}$			
		0 Cd ppm	5 Cd ppm	10 Cd ppm	Ortalama
Ca Bentonite	0%	485g	526e-g	430g	**481D**
	3%	700cd	669d-f	516fg	**628C**
	6%	845a-c	700cd	673de	**739B**
	12%	1060a	815b-d	946ab	**940A**
Ortalama		**773A**	**678AB**	**641B**	

The highest dry matter yield was determined as 940 mg/plant in 12% bentonite application. These increases and decreases in dry matter yield were found to be statistically significant at the $p<0.05$ level. The present study finding was consistent with, Wafaa and Wagida [33], El-Nagar et al.[34], they explored that the application of bentonite could considerably improved the plant growth and wheat yield.

3.2. Shoot Cadmium Concentration, (mg kg^{-1})

It was determined that there was a decrease in the average Cd concentrations of shoot with the increase of bentonite dose applications. With the increase in Cd doses, the average shoot Cd concentrations increased. These increases and decreases in shoot Cd concentration found to be statistically significant at the $p<0.05$ level. While the shoot Cd concentration in control (Cd0 and bentonite 0%) pots was 2.51 mg kg^{-1}, it became 0.56 mg kg^{-1} with 12% bentonite application and decreased approximately 4.5 fold. It was determined that shoot Cd concentrations decreased as the bentonite doses increased in all applications of Cd (0, 5, 10 mg kg^{-1}) (Table 2).

Table 2. The effect of bentonite application on the shoot cd concantration in bread wheat

Applications		Shoot Cd Concentration, mg kg^{-1}			
		0 ppm	5 ppm	10 ppm	Ortalama
Ca Bentonite	0%	2.51g	18.56c	41.15a	**20.77A**
	3%	1.56g	16.14d	31.16b	**16.28B**
	6%	0.86g	10.53e	14.89d	**8.76C**
	12%	0.56g	5.31f	9.35e	**5.07D**
Ortalama		**1.37C**	**12.63B**	**24.13A**	

Average Cd concentrations decreased with increasing bentonite applications. While the average Cd concentration was 20.74 mg/kg in the control, it was determined as 5.07 in the 12% bentonite application. The present study finding was consistent with, Shirvani et al. [35]. Sirait [36], Yu [37], they stated that bentonite application significantly reduced Cd uptake by plants.
Decrease in Cd uptake by wheat plants might be due to the higher surface area, with high cation exchange and ion adsorption capacity of Cd with Ca-bentonite. Bentonite minerals as one of the inorganic amendments can immobilize Cd by adsorption and precipitation process [26]. Bentonite has strong sorption capacity for soil Cd, which effectively immobilize metals to reduce metal uptake by crops [27]. Our study also showed that bentonite can significantly decreased shoot of Cd uptake. This result showed that Ca-bentonite can effectively decrease the mobility and bio availability of soil Cd. The results indicated that application of Ca-bentonite improved the plant growth by adsorbing the cadmium in the soil and alleviating the cadmium stress to the wheat. This is probably application of Ca-bentonite reduced the bioavailability of Cd and this might be due to the larger surface area as well as the stronger sorptive capacity of bentonite, which decreases the concentration of cations in the soil solution and thereby reduced the uptake by wheat.

4. CONCLUSION

Cadmium is a non-essential heavy metal that is highly toxic even at very low concentrations. Cadmium is pollutants that their discharge to the environment transported from different sources as agricultural and mining waste disposal, manure and phosphate fertilizer application to agricultural soils continuously. Cadmium contamination of agricultural soils is a growing concern which causes uptake by food crops. Wheat is a vital food crop cultivated in the world. Due to its high mobility, Cd can easily reach root uptake in wheat, shoot and grain by displacement. Uptake and accumulation of Cd by wheat may pose a risk to human life. Therefore, various agronomic approaches to reduce Cd uptake by wheat have been increasing rapidly in recent years. Various organic materials are used to reduce Cd uptake by wheat such as biochar, silicon, gyttja and bentonite. One of the most effective when compared to other organic materials is the use of bentonite. Application of bentonite to soils improves pH, CEC, nutrient availability and consequently increases agricultural productivity. According to the results of this research, addition of bentonite increases the chemical sorption of Cd and reduces the mobility of Cd as a consequence of complex formation. So, application of bentonite 12% demonstrated that wheat shoots reduced Cd uptake 4 fold. These results showed that bentonite can be used to reduce heavy metals in plants.

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