# Evaluating the growth capacity and heavy metal absorption of sweet sorghum and grain sorghum at the seedling stage

**Tra T. T. Dinh**

Department of Environment and Biology, Quang Binh University, Quang Binh, Vietnam

**ARTICLE INFO**

**Research paper**

Received: April 09, 2018
Revised: May 17, 2018
Accepted: May 28, 2018

**Keywords**

Cadmium
Grain sorghum
Heavy metal
Phytoremediation
Sweet sorghum

**Corresponding author**

Dinh Thi Thanh Tra
Email: dinhthanhtra83@gmail.com

## ABSTRACT

In recent years, the use of plants for clean-up and recovery (phytoremediation) has been studied and used in many countries of the world. In this study, E-Tian sweet sorghum (ET) and BT x 623 (BT) sorghum were treated with heavy metal cadmium at 5 concentrations (0, 5, 10, 25, 50 mg/kg). The growth of plant; absorption, accumulation of cadmium (Cd) heavy metals in plant parts at the seedling stage have been identified and assessed. The results showed that Cd affected the height and number of leaves of the plant. Especially, Cd accumulation in the plant decreased in sequence: root, stem, leaf. When comparing the heavy metals accumulation in the two cultivars, the results showed that the BT cultivar had higher Cd uptake and accumulation potential than ET. Therefore, BT can be used for phytoremediation of heavy metals in soil but not for providing food and feed.

**Cited as:** Dinh, T. T. T. (2018). Evaluating the growth capacity and heavy metal absorption of sweet sorghum and grain sorghum at the seedling stage. *The Journal of Agriculture and Development* 17(3), 44-48.

## 1. Introduction

Nowadays, heavy metal contamination in soil has become a great concern for global and every country due to human's mining and using fertilizer and pesticide application, and fuel production... (Garbisu & Alkorta, 2003). Excessive heavy metals, for example, lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), copper (Cu), and nickel (Ni), in agricultural areas seriously threaten food safety and public health. Elimination or remediation of heavy metal contamination in soil is urgently in request to prevent human and animals from toxicity. The treatment for these heavy metals meets many difficulties and costs much. In current years, phytoremediation is a cost-effective and eco-friendly technique to clean up heavy metal pollution in soil (Li et al., 2004).

Sorghum (*Sorghum bicolor* L.) consists of natural variant cultivars of sorghum with abundant sucrose storage in culm and great biomass, and is thereby considered an ideal feedstock for biofuel production (Murray et al., 2008). Sweet sorghum will be a competitive candidate species for soil remediation due to its great biomass and strong resistance to adverse environmental conditions. To preliminarily evaluate its potential for phytoremediation, a number of morphological and physiological characteristics of sorghum were investigated under heavy metal stresses (Cd, Pb, Zn, Cu) in previous studies (Zhuang et al., 2009; Liu et al., 2011; Soudek et al., 2013). The results indicate that sweet sorghum can grow well, absorb heavy metals, and clean up contaminated soil (Zhuang et al., 2009).

Grain sorghum is an important cereal in temperate semi-arid countries with high yield and rapid growth (Rawy et al., 2013). However, no research has been done on the absorption and accumulation of heavy metals in this important food crop.

In this paper's scope, we study the accumulation of Cd heavy metals in plant parts, then, compare the capacity of Cd heavy metal accumulation of two sorghum kinds. The research results contribute to providing the scientific basis for the application of sorghum for the purpose of restoring agricultural land contaminated with heavy metals.

## 2. Material and Methods

### 2.1. Plant material and experimental design

The elite line of sweet sorghum E-Tian (ET) and grain sorghum BT x 623 (BT) were used for experiments. The ET originated from China, which was introduced in 1970s possesses rich sugar storage in stem. The BT x 623 (BT) originated from America with high yield and good quality (Zheng et al., 2011).

The soil was fertilized with base fertilizers (urea, diammonium phosphate and potassium sulfate), contained 2.0 g nitrogen, 0.26 g phosphorus ($P_2O_5$) and 0.35 g potassium ($K_2O$) for high-yield land application. Soil is crushed, put into the pots (2 kg/pot, pot sizes are 30 cm in diameter, 25 cm in height). Soil was amended with $CdCl_2$ at final concentrations of 0, 5, 10, 25, 50 mg/kg. The group not treated with $CdCl_2$ was the control group.

Seeds were soaked in warm water at $28^0$C, then placed on a moist filter paper tray in a warm place for germination. After 3 days, the seedlings were transferred to the potted soil, 2 seedlings/pot. The pots were placed in the greenhouse of the Institute of Environmental Resources, Southwestern University, China at a temperature of 28-$32^0$C during lighting time of 14-16 h; and at 22-$26^0$C in the dark for 8-10 h. Water content was adjusted daily. The water-holding capacity of the soil was never exceeded, therefore no leaching occurred. The same care conditions and procedures were used for all experimental and control plants. Each experiment formula and control formula consisted of 12 plants with 3 replications. On day 35 after planting, roots, stems, and leaves were collected and analyzed in the laboratory.

### 2.2. Analysis of Cd heavy metal content

The plant samples were dried in a ventilated oven at $105^0$C for 30 mins and $70^0$C for 48 h and subsequently grinded into powders. Approximately 0.1 g of the grinded sample was soaked in a mixture of $HNO_3$ and $HClO_4$ (3:1; v/v) according Sun et al. (2008). Cd concentration was determined using a flame atomic absorption spectrometry HITACHI Z5000 (Tokyo, Japan).

### 2.3. Data analysis

The data were calculated using Statistix (version 9.0). Significant differences were determined by least significant differences (LSD) at 5% level of probability.

## 3. Results

### 3.1. Effect of Cd on plant height

Although there was no significant difference between the results, low Cd concentrations had a slight effect on the growth of the plant height in the sweet sorghum ET (average height at 5 mg Cd/kg was 66.67 $\pm$ 3.05 cm, Table 1). While high Cd levels inhibited the growth of plant height (at 25 and 50 mg/kg Cd, the mean plant heights were 57 $\pm$ 7.21 cm and 48 $\pm$ 3.06 cm, respectively).

The plant height of BT was inhibited by Cd very clearly, the higher the Cd level was, the lower the plant height was (from 64.00 $\pm$ 10.54 cm in the control, down to 46.5 $\pm$ 3,04 cm in the experimental formula Cd 5 mg/kg and reached the minimum value 40.33 $\pm$ 9.87 cm at Cd 50 mg/kg). The results showed that Cd significantly affected the growth of both sorghum experimental varieties.

Comparison between the two varieties, it can be seen that ET can be better tolerated than BT when it was treated with low concentrations (5 mg/kg Cd), expressed by higher of plant height than the control group.

### 3.2. Effect of Cd on number of leaves

At the seedling stage, the response of sorghum to Cd was similar in both experimental varieties. The number of leaves of both varieties decreased in comparison with the control group. However, for ET varieties, as well as the plant height index, the number of leaves increased at Cd 5 mg/kg, and decreased gradually as the Cd concentration increased (Table 1). The results show that Cd affects the number of leaf, which can affect other growth characteristics such as photosynthesis, sugar content and starch content of plants.

In previous studies also showed that the higher the Cd level was, the lower the gowth rate. Liu et al. (2011) reported that low Cd concentrations could promote plant growth and height of sweet sorghum and experimental sudan grass variety, plant height reached high values at Cd 25 mg/kg while at high concentrations (50 and 100 mg/kg), Cd inhibits the growth of plant height. In other studies in rice, high concentrations of Cd (50 and 100 mg/kg) strongly inhibited the height of the plant (Herath et al., 2014). A study by Liu et al. (2014) showed that, after 3 to 7 days of treatment with Cd (25, 50 and 100 mg/kg), the growth of young cotton plants were significantly inhibited, reflecting a sharp drop in height, biomass and leaf area.

### 3.3. Ability to absorb heavy metals in plants

The experimental results showed that, at the seedling stage, both ET and BT showed strong Cd absorption from contaminated soil (Figure 1a and b). In the control treatments of both cultivars, there was not Cd. However, in the experimental formulation, the Cd concentrations in the leaves, stems and roots of both varieties also increased when Cd levels were treated accordingly. There was a significant difference in Cd concentration accumulated in the plants between the Cd treatments. In both varieties, roots absorbed and accumulated the highest Cd, followed by stems and leaves. This suggests that the plant has the mechanism to prevent the transfer of Cd from the roots to the shoots.

In ET, the lowest Cd concentration accumulated was recorded in leaf of plant. Cd concentrations increased from 0.005 $\mu$g/g DW to 0.453 $\mu$g/g DW when the Cd level increased from 5 to 50 mg/kg (Figure 1a). Cd concentration in roots is 6 times as high as Cd accumulated in stems. The highest Cd concentration in roots was recorded in the experimental Cd concentration 50 mg/kg (4.51 $\mu$g/g DW).

Comparison between the two types, the results showed that BT varieties can absorb and accumulate Cd content is nearly 5 times as high as than ET can (Figure 1b). Cadmium content in leaves of BT was so high, increasing 2.559 $\mu$g/g DW to 6.788 $\mu$g/g DW when Cd treatment increased from 5 to 50 mg/kg. Cd content accumulation in the stem was also much higher than ET, reaching the highest value of 10.332 $\mu$g/g DW at Cd 50 mg/kg, 3 times as high as ET's. Cadmium was absorbed and accumulated at the highest level in roots, the highest accumulated Cd value was 14.719 $\mu$g/g DW.

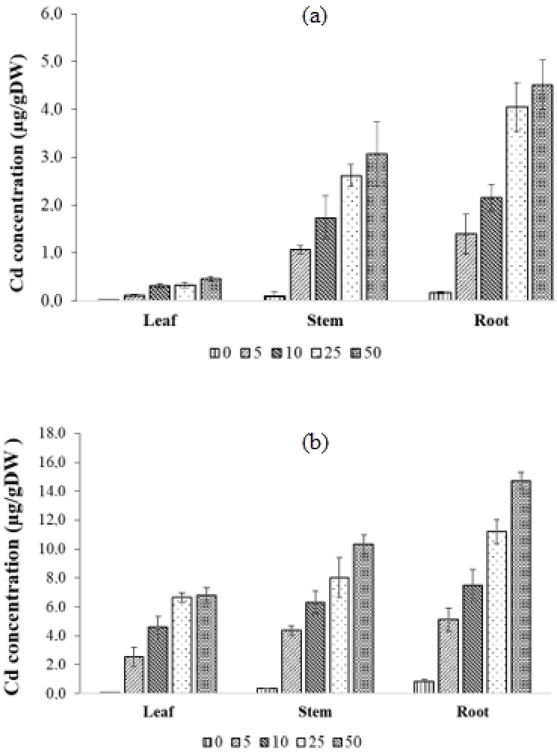


**Figure 1.** Cd concentration accumulated in parts of ETian sweet sorghum (1a) and BT grain sorghum (1b) (*DW: dry weight*).

## 4. Discussion

The distribution of Cd in different parts of vegetation plays an important role in minimizing the harms of heavy metals to plant. At the seedling stage of the study, both sorghum varieties showed their Cd absorption ability was high. The results of this study are consistent with previous studies on different vegetation species (Barros et al., 2009; Zhuang et al., 2009; Angelova et al., 2011). Tu et al. (2013) investigated the concentration

**Table 1.** Effect of Cd on plant height and leaf number

| Cd treatment | | Plant height (cm) | Number of leaf |
|---|---|---|---|
| ET | 0 | 63,67 ± 9,07$^{a}$ | 7,00 ± 0,00$^{ab}$ |
| | 5 | 66,67 ± 3,05$^{a}$ | 7,30 ± 0,57$^{a}$ |
| | 10 | 57,33 ± 8,08$^{ab}$ | 6,00 ± 0,00$^{c}$ |
| | 25 | 57,00 ± 7,21$^{ab}$ | 6,30 ± 0,57$^{bc}$ |
| | 50 | 48,00 ± 3,06$^{b}$ | 6,67 ± 0,57$^{abc}$ |
| BT | 0 | 64,00 ± 10,54$^{a}$ | 6,67 ± 0,57$^{a}$ |
| | 5 | 46,50 ± 3,04$^{b}$ | 6,00 ± 0,00$^{ab}$ |
| | 10 | 48,67 ± 5,51$^{ab}$ | 5,67 ± 0,57$^{b}$ |
| | 25 | 44,33 ± 11,01$^{b}$ | 5,33 ± 0,57$^{c}$ |
| | 50 | 40,33 ± 9,87$^{b}$ | 4,67 ± 0,57$^{bc}$ |

$^{a\text{-}c}$The different letters in the same column of a variety show a significant difference at $P < 0.05$.

of Cd in leaves, roots and stems of two sweet sorghum varieties which increased with prolonged treatment time with Cd. Both varieties exhibited high Cd accumulation in roots, followed by stems and leaves. However, the results of studies by Izadiyar and Yargholi (2010) on Cd absorption and accumulation in sorghum are the highest in roots and lowest in stems. The results show that the response to heavy metals is different depending on each type of sorghum.

Cadmium is absorbed and accumulated firstly in the roots, then transported to the stems and leaves. The BT sorghum has a lower average plant height than the ET sweet sorghum, BT also has strongly ability of growth, thus, the Cd can be transported from the roots to the stem and to leaves with more strength. It is possible that the defense mechanism of ET against Cd is better than that of BT. As a result, the Cd content accumulated in parts of the plant is lower. Therefore, further research is needed on the molecular and biochemical mechanisms and physiology of these two sorghum varieties. In a study by Pinto et al. (2006), increasing Cd pollution caused the rise of phytochelat content in plants.

Phytochelatins are an important layer of proteins, which are produced by the plants to increase their response to heavy metal ions such as Hg and Cd, in order to reduce the damage of these metals in the plant (Pinto et al., 2006). The results of Soudek et al. (2013) showed that the roots have a mechanism to prevent Cd transport to shoots. Cadmium accumulation in plants is limited by several factors, such as: 1) biological activity of roots; 2) the speed of transportation to the roots through apoplastic and symplastic pathways; 3) Cd fixation in roots such as Cd-phytochelatin complex formation and accumulation in vacuoles; 4) Transport speed in xylem and Cd distribution to plant parts (Rahat et al., 2012).

## 5. Conclusions

The experiment helped to determine, compare the absorption and accumulation of Cd heavy metals in parts of sweet sorghum and grain sorghum. It can be concluded that, Cd affects the growth of both sorghum varieties, through reduction of plant height and number of leaves. Each plant has different levels of Cd accumulation in order: root, stem, leaf. Comparison between the two sorghum varieties, BT has higher ability of Cd absorbtion and accumulation than ET. Therefore, BT can be used for phytoremediation of heavy metal in soil but could not use for providing food and feed. If combined with the purpose of treating heavy metal pollution and biofuel production, ET sweet sorghum could be used.

## Acknowledgements

The author would like to thank Research Center of Bioenergy and Bioremediation, College of Resources and Environment, Southwest University (Chongqing, China) for providing the laboratory facilities and equipment support.

## References

Angelova, V. R., Ivanova, R. V., Delibaltova, V. A., & Ivanov, K. I. (2011). Use of Sorghum crop for insitu phytoremediation of polluted soils. *Journal of Agricultural Science and Technology A* 1(5), 693-702.

Barros, A. B., Floccob, C. G., & Donati, E. R. (2009).

Study of the heavy metal phytoextraction capacity of two forage species growing in an hydroponic environment. *Journal of Hazardous Materials* 165(3), 366-371.

Garbisu, C., & Alkorta, I. (2003). Basic concepts on heavy metal soil bioremediation. *The European Journal of Mineral Processing and Environmental Protection* 3(1), 58-66

Herath, H., Bandara, D. C., Weerasinghe, P. A., Iqbal, M. C. M., & Wijayawardhana, H. C. (2014). Effect of Cadmium on Growth Parameters and Plant Accumulation in Different Rice (Oryza sativa L.) Varieties in Sri Lanka. *Tropical Agricultural Research* 25(4), 532 - 542.

Izadiyar, M. H. (2010). Study of Cadmium Absorption and Accumulation in Different Parts of Four Forages. *American-Eurasian Journal of Agricultural & Environmental Sciences* 9(3), 231-238.

Liu, D. L., Kai, Q. H., Jing, M., Qiu, W. W., Wang, X. P., & Zhang, S. P. (2011). Effects of cadmium on the growth and physiological characteristics of sorghum plants. *African Journal of Biotechnology* 10(70), 15770-15776.

Liu, L. T., Sun, H. C., Chen, J., Zhang, Y. J., Li, D. X., & Li, C. D. (2014). Effects of cadmium (Cd) on seedling growth traits and photosynthesis parameters in cotton (Gossypium hirsutum L.). *Plant Omics Journal* 7(4), 284-291.

Murray, S. C., Sharma, A., Rooney, W. L., Klein, P. E., Mullet, J. E., & Mitchell, S. E. (2008). Genetic improvement of sorghum as a biofuel feedstock I: QTL for stem sugar and grain nonstructural carbohydrates. *Crop Science* 48(6), 2165-2179.

Pinto, A., Goncalves, M. S., & Mota, A. (2006). Sorghum detoxi cation mechanisms. *Journal Plant Nutrition* 29(7), 1229-1242.

Soudek, P., Jakub, N., Lukas, P., and Sarka, P. (2013). The Sorghum Plants Utilization For Accumulation of Heavy Metals. *3rd International Conference on Energy and Environmental Science IPCBEE 2013*. Retrieved March 05, 2018, from http://www.ipcbee.com/vol54/002-ICEES2013-ES015.pdf

Tu, E. X., Tu, E. H., Zai, T. N. L., Ku, E. B., & Ye, K. (2013). Study on the Accumulation Properties of Sweet Sorghum Seedling to Cd and Pb. *Chinese Agricultural Science Bulletin* 29(3), 80-85.

Rahat, N., Noushina, I., Asim, M. M., Iqbal, R., Khan, Shabina S., & Khan, N. A. (2012). Cadmium Toxicity in Plants and Role of Mineral Nutrients in Its Alleviation. *American Journal of Plant Sciences* 3(10), 1476-1489.

Rawy E., Mourad, A. E. A., & Kady, A. M. (2013). Evaluation of some grain sorghum lines for resistance to Sesamia cretica Led. and yield potential. *Egyptian Journal of Agricultural Research* 91(3), 977-988.

Zheng, L., Guo, X., He, B., Sun, L., Peng, Y., & Dong, S. (2011). Genome-wide patterns of genetic variation in sweet and grain sorghum (Sorghum bicolor). *Genome Biology* 12(11), R114.

Zhou, C., Zhang, K., Lin, J., Li, Y., Chen, N., Zou, X., Hou, X., & Ma, X. (2015). Physiological Responses and Tolerance Mechanisms to Cadmium in Conyza canadensis. *International Journal of Phytoremediation* 17(3), 280-289.

Zhuang, P., Shu, W. S., Li, Z., Liao, B., Li, J. T., & Shao, J. S. (2009). Removal of metals by sorghum plants from contaminated land. *Journal of Environmental Sciences* 21(10), 1432-1437.

Ziarati, P., Nazeri, S., & Germi, M. S., (2015). Phytoextraction of Heavy Metals by Two Sorghum pices in Treated Soil Using Black Tea Residue for Cleaninguo the Contaminated Soil. *Oriental Journal of chemistry* 31(1), 317-326.

Sun, Y. B., Zhou, Q. X., & Diao, C. Y. (2008). Effects of cadmium and arsenic on growth and metal accumulation of Cd-hyperaccumulator Solanum nigrum L. *Bioresource Technology* 99(5), 1103-1110.