IJEPEM

International Journal of Environmental Pollution and Environmental Modelling,
Vol. 5(1): 1-7 (2022)
(Original Paper)

Effects of Cadmium (Cd) on the Seed Germination and Growth of some selective Ethiopian Soybean (*Glycine max* L.) Genotypes

Zerihun Jida [1*]

[1] Department of Biology, College of Natural and Computational Sciences, Wolkite University, Ethiopia

E-Mail: *zelifejida@gmail.com*

Received 18.06.2021; Accepted 11.10.2021

Abstract: The objective of this work was to evaluate the effects of cadmium (Cd) exposure on Soybean (*Glycine max* L.) plant germination and growth. This experiment was conducted at Biology Department laboratory and Biotechnology Department Green house, Wolkite University, Ethiopia, during the period of June to August 2019. The Petri dishes were treated with an equal volume of the different concentrations of $CdCl_2$ solutions (0, 10,20,30,40 and 50 ppm). The seeds were allowed to germinate in the dark in an incubator at 25°C for 5 days and percentage of germination were recorded when the radicle reached 2 mm in length. In the pot culture experiment, Soybean were also analyzed on three different sampling (15, 30 and 45) days in soil added with various levels of cadmium similar with Petri dishes. The inner surfaces of the pot were lined with a polythene sheet and each pot contained 3kg of air-dried soil. In each pot, six seeds of Soybean were sown and watered to field capacity. A maximum of three plants were thinned per each pot, after a week of germination and the effect of cadmium were tested at different levels of concentrations that decreased the germination and growth parameters such as root and shoot length compared with untreated plants.
Keywords: Cadmium, Genotype, Growth, Seed germination and Soybean.

INTRODUCTION

All living organisms are mainly affected directly or indirectly because of the environment pollution or contamination. The pollution problem has become a worldwide and is an undesirable change in the biological, physical or chemical characteristics of air, water and land or soil that will harmful to human and other life (Meiyu et al., 2017; Ibrahim et al., 2013; Prasad, 1995). These pollutions of the Environmental are the result of rapid industrialization, technological advancement and geometrically increase in human population. From these the cadmium (cd) Chromium, Mercury, and zinc (zn) have great position of heavy metals those are affect the plant seedling germination, photosynthesis and yield related problems. Cadmium is one of the most toxic heavy metals causing serious problems in crops (Moradi et al., 2015; Thamayanthi et al., 2011).

Now a day one of the bioenvironmental problems of world is water and soil pollution with heavy metals that have the effect on agricultural yields and endanger the human health. The accumulations of heavy metals in soil were due to industrial pollution, the use of some commercial fertilizers, or contamination from bedrock by volcanic eruption is a great problem on the plant growth (Kabata-Pendias, 2001; Momchil et al., 2018; Szopi et al., 2019; Farid et al., 2015; Larsson et al., 1998) and they may reduce plant growth through inhibition of different biochemical synthesis. The increment of the levels of heavy metals in the human body can be due to consumption of plants grown in areas contaminated with these metals or irrigation with waters contaminated with them (Alexander et al., 2006).

Cadmium affects the plants morphological, biochemical, physiological, and structural processes (Mishra et al., 2006). Usually the activities like absorption and transportation of elements such as calcium, phosphorus, potassium, and water in plants, and also the main plant processes such as photosynthesis, cell proliferation, and water absorption by plant roots are mainly affected by cadmium and cause abnormalities in general growth in plant species (Rascio and Navari- Izzo, 2011; Das et al., 2000). Roots are likely to be firstly affected by heavy metals since much more metal ions are accumulated in roots than shoots. Cadmium toxicity obviously inhibits plant root growth and affects root morphology (Daud et al., 2009; Liu et al., 2003).

[*] *Corresponding E-mail: zelifejida@gmail.com*

MATERIALS AND METHODS

Seed materials

The seeds of Soybean (*Glycine max* L.) were collected from Awash Melkasa Agricultural Research center and seeds with uniform size, colour and weight were chosen for the experimental purpose. The experiment was conducted at Biology laboratory and Biotechnology green house, Wolkite University, Ethiopia, located at 165 km southwest of Addis Ababa, 08º12.856' N and 37º48.119' E, during the period of June to August, 2019.

Seed Germination

The Soybean (*Glycine max* L.) seeds were collected from Awash Melkasa Agricultural Research center. Twenty healthy seeds were surface sterilized with O.1% mercuric chloride solution (Ramasubramanian, et al.,1993), and were spread uniformly in Petri dishes lined with filter paper. The Petri dishes were treated with an equal volume of the different concentrations of $CdCl_2$ solutions (0, 10,20,30,40 and 50 ppm). The seeds were allowed to germinate in the dark in an incubator at 25°C for 5 days. Percentage (%) germination was recorded when the radicle reached 2 mm in length. The germinated seeds were counted and removed every day until the end of the test period. Five replicates were used for each treatment.

Experimental soil

The soil used in the experiment was sandy loam in nature and the pH of the soil was 7.15. It contains 72 kg available P and 93 kg available K/ha, 122 kg available N, and micro nutrients of 16.25mg available Cu, 185.3mg Fe, 168 mg Mn and 19.35 mg Zn/kg and cadmium was not available in this experimental soil. The cadmium chloride ($CdCl_2$ ½ H_2O) was used as cadmium source.

Pot culture experiment

The pot culture experiment was conducted at Biotechnology green house, Wolkite University, Ethiopia, during the period of June to August, 2019. Surface sterilized soybean seeds were sown in pots (15 cm in diameter) containing mixture of sandy loam soil in nature, soybean (*Glycine max* L.) plants were grown in pots containing untreated soil (Control) and soil mixed with various levels of cadmium (10, 20, 30, 40 and 50 mg kg^{-1}). The inner surfaces of pots were lined with a polythene sheet. Each pot contained 3kg of air dried soil. Six seeds were sown in each pot. All pots were watered daily. Plants were thinned to a maximum of three per pots, after a week of germination. Each treatment including the control was replicated five times. Data points in the tables and figures represent the means, with all deviation bars shown (±1 standard deviations of mean). Both the mean and standard deviation were performed where appropriate using the statistical package on Microsoft-Excel Version-2010.

Sampling

The plant samples were collected on 15th 30th and 45th days after sowing. Three plants from each replicates of a pot were analyzed for the shoot and root were measured using standardized procedures derived from the method of Kalra and Dhiman, (1977).

EXPERIMENTAL RESULTS

Germination

Germination percentage values of Soybean (*Glycine max* L.) cultivars under cadmium treatments of different concentrations were presented in (Figure-1). The highest percentage of germination Soybean was recorded at control and the lowest germination percentage of Soybean due to cadmium treatment at 50 mg/l concentration. These observations are due to the inhibitory effects of some heavy metals like ($CdCl_2$, $HgCl_2$, $PbCl_2$, and $CuS0_4$). The similar result patterns of response were recorded in the case of the species of *Raphanus sativus* L. due to cadmium treatment by (Vijayaragavan et al., 2007). During this study, the decrease in the germination percentage of Soybean seeds may be related to the negative effects of cadmium on water uptake and water movement. Barcelo, et al., (1986) also reported that the cadmium affected lowering water stress tolerance and decreasing water absorption and transport. Hence, the highest concentration of cadmium in the germination medium of Soybean seeds seems may be to reduce the availability of water in the embryo axis, and this may be the reason for the low seedling establishment.

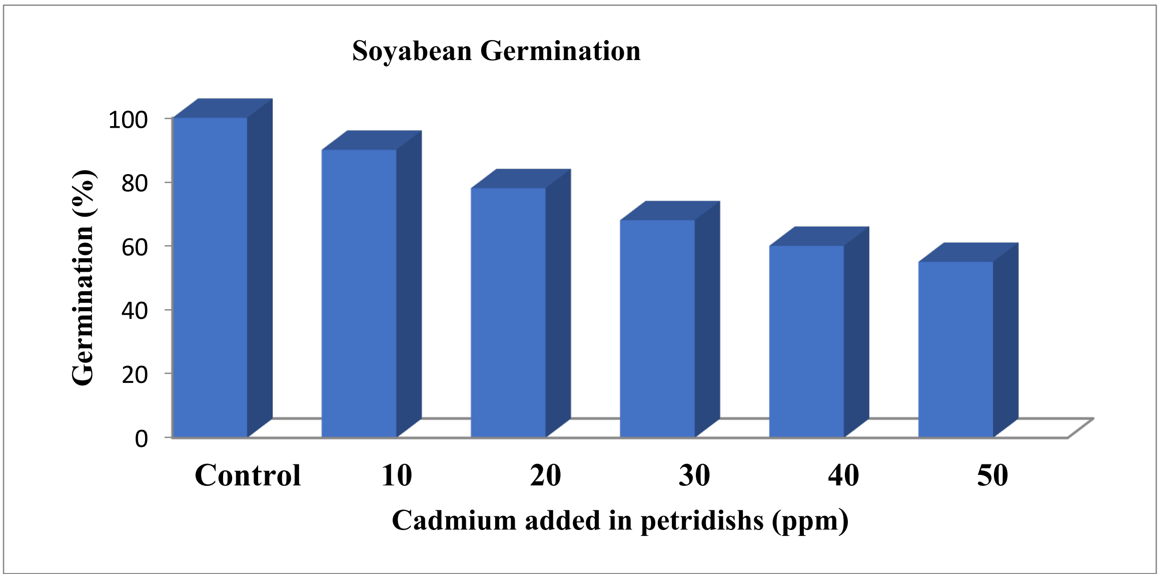

Figure 1. Effects of Cadmium on Soybean seed germination on 15th days

Growth

The elongation rate of root and shoot lengths are essential for plants movement for water and mineral nutrients. The length, fresh and dry weight of root and shoot of Soybean plants has been adversely affected due to cadmium treatment, when compared to the control (Table 1, 2, 3). There was a gradual decrease in the root and shoot length with an increase in cadmium level 10, 30 and 50 mg kg^{-1} in the soil in all the sampling days. These results were agreed with the findings of Chen, et al., (2003) in soybean, Thamayanthi et al., (2011) in Zinnia plants, Xu, et al., (2008) in garlic Rai, et al., (2005) in *Phyllanthus amarus,* Wahid et al., 2008, Song et al., 2019 and Sun et al., 2016.

The excess amount of cadmium inhibitory in root and shoot length might be it cause the reduction in cell division due to the toxic effect of heavy metals on protein synthesis and may be these contributed to the retardation of normal growth of the plants (Thamayanthi et al., 2011). Also the other results suggested by Hagemeyer et al., (2002.), Thamayanthi et al., (2011) and Marcnano et al., (2002) also reported the similar results on the morphological and structural effects caused by heavy toxic metals in plants was due to decrease in root elongation, root tip damage, decrease in root formation, suppression of elongation growth rate of cells, affecting the structure of meristematic cells and inhibition of the size of plant (Guo et al., 2016 and Bahmani et al., 2012). When the plants are taken up the excess amount of these non-essential elements, it inhibits physiological processes such as plant water relationships, photosynthesis and respiration, inhibiting the activity of the cell and its enlargement and mineral nutrition, that resulting poor growth (Thamayanthi et al., 2011; Sanita di Toppi and Gabbrielli, 1999).

No	Cadmium treatment (mgkg-1)	Root length (cm)	Shoot length (cm)
1	Control	12.05	20.06
2	10	11.95 ±0.032	29.40 ±0.051
3	20	10.85 ±0.03	18.65 ±0.05
4	30	10.02 ±0.025	15.82 ±0.04
5	40	9.64 ±0.3	14.36 ±0.041
6	50	8.45 ±0.3	12.65 ±0.032

Table 1. The Effect of cadmium on Shoots and Roots of Soybean on 15 days

No	Cadmium treatment ($mgkg^{-1}$)	Root length (cm)	Shoot length (cm)
1	Control	16.45	25.10
2	10	15.82 ±0.03	24.06 ±0.06
3	20	14.50 ±0.05	23.05 ±0.055
4	30	12.72 ±0.03	21.75 ±0.06
5	40	9.93 ±0.03	19.65 ±0.05
6	50	8.83 ±0.25	17.30 ±0.052

Table 2. The Effect of cadmium on Shoots and Roots of Soybean on 30 days

Table 3. The Effect of cadmium on Shoots and Roots of Soybean on 45 days

Generally, our result showed that decreasing shoot and root parts of the Soybean with progressive increase in cadmium level in all the sampling days in the soil and the similar results were observed by Zhou and Qiu, (2005) in *Sedum alfredii*, Schutzendubel and Polle, (2002) in the species of *Populus canescens,* (Ling et al., 2015; Zhou et al., 2017; Dias et al., 2013).

CONCLUSION

The present study results have shown that cadmium treatments were inhibited the seed germination and plant growth of Soybean plants when compared with control plants. The decreased of these germination and growth may be due to directly or indirectly inhibits of cadmium on physiological processes such as respiration, plant water relationships, loss of cellular turgor, inhibiting the activity of the cell and its enlargement, resulting in poor growth. So there were a consequents reduction in the growth of root and shoot length of plants of soybean plants. The shoot lengths of cadmium treated were higher than the root lengths soybean plants.

REFERENCES

Alexander P.D, Alloway B.J and Dourado A.M, (2006). 'Genotypic variations in the accumulation of cd, cu, pb, and zn exhibited by six commonly grown vegetables'. *Environmental pollution,* 144: 736-745

Bahmani R, Bihamta M. R, Habibi D, Forozesh P and Ahmadvand S, (2012). Effect of cadmium chloride on growth parameters of different bean genotypes (*Phaseolus vulgaris* L.). ARPN Journal of

No	Cadmium treatment (mgkg-1)	Root length (cm)	Shoot length (cm)
1	Control	21.65	36.85
2	10	20.11 ±0.06	35.06 ±0.12
3	20	17.56 ±0.05	33.03 ±0.07
4	30	15.05 ±0.04	31.63 ±0.09
5	40	13.71 ±0.05	29.05 ±0.075
6	50	12.47 ±0.04	27.10 ±0.065

Agricultural and Biological Science, VOL. 7, NO. 1

Barcelo J, Cabot C and Poschenrieder C, (1986). Cadmium induced decrease of water stress resistance in bush bean plants (*Phaseolus vulgaris* L.). II. Effects of Cd on endogenous abscisic acid levels. Plant Physiol. 125: 27-34

Chen T, Qiang W, and Wang X, (2003). Effects of cadmium combined with ultraviolet-B radiation on growth, gas exchange and stable carbon isotope value (13C) in soybean (*Glycine max* L.). In: Gao, W., J.R.Herman, G.Shi, K. Shibasaki, J.R. Slusser, (Eds.), Ultraviolet ground- and space-based measurements, models, and effects. II. Proceedings of the SPIE, vol. 4896: 210–218

Das, P., R. Rout and S. Samantaray. (2000). 'Studies on cadmium toxicity in plants: A review'. *Environmental Pollution,* 98: 22-36

Daud M.K, Sun Y, Dawood M, Hayat Y, Variath M.T, Wu Y, Raziuddin Mishkat, Salahuddin U, Najeeb U and Zhu S, (2009). Cadmium-induced functional and ultrastructural alterations in roots of two transgenic cotton cultivars. J. Hazard. Mater. 161: 463–473

Dias M.C, Monteiro C, Moutinho-Pereira J, Correia C, Gonçalves B and Santos C, (2013). 'Cadmium toxicity affects photosynthesis and plant growth at different levels'. *Acta physiologiae plantarum*, 35(4): 1281-1289

Farid M, Ali S, Ishaque W, Shakoor M.B, Niazi N.K, Bibi I, Dawood M, Gill R.A and Abbas F, (2015). Exogenous application of ethylene diamminetetraacetic acid enhanced phytoremediation of cadmium by Brassica napus L. Int. J. Environ. Sci. Technol. 12:3981–3992

Guo H, Hong C, Chen X, Xu Y, Liu Y, Jiang D, (2016). Different Growth and Physiological

Hagemeyer J and Breckle S.W, (2002). Trace element stress in roots. In: Y. Waisel, A. Eshel and U. Kafkafi (eds.), Plant roots: the hidden half, 3rd edn. Dekker, New York, pp. 763-785

Ibrahim Ilker Ozyigit , Filiz Vardar , Ulkuhan Yasar and Sener Akinci, (2013). Long-Term Effects of Aluminum and Cadmium on Growth, Leaf Anatomy, and Photosynthetic Pigments of Cotton, Communications in Soil Science and Plant Analysis, 44:21, 3076-3091

Kabata-Pendias A, (2001). Ttace elements in soils and plants. CRC press, Boca Rotan, Florida, USA

Kalra G.S and Dhiman S.D, (1977). Determination of leaf area of wheat plants by a rapid method. J. Ind. Bot. Soc. 56: 261-264

Larsson E, Bornman J, and Asp H, (1998). Influence of UV-B radiation and Cd2+ on chlorophyll fluorescence, growth and nutrient content. *Journal of Experimental Botany* 49 (323): 1031–1039

Ling Tao, Meiying Guo, Jun Ren, (2015). Effects of Cadmium on Seed Germination, Coleoptile Growth, and Root Elongation of Six Pulses. *Pol. J. Environ. Stud. Vol. 24, No. 1 (2015), 295-299*

Liu J, Li K, Xu J, Liang J, Lu X, Yang J and Zhu Q, (2003). Interaction of Cd and five mineral nutrients for uptake and accumulation in different rice cultivars and genotypes. Field Crop. Res. 83: 271–281

Marcnano L, Carruyo I, Del Campo A, and Monteil X, (2002). Effect of cadmium on the nucleoli of meristemetic cells of onion Allium cepa L.: An ultra structural study. Environ. Res. 88: 30–35

Meiyu Huang, Huihui Zhu, Jing Zhang, Diyong Tang, Xiaole Han, Liang Chen, Dongyun Du, Jun Yao, Ke Chen and Jie Sun, (2017). Toxic effects of cadmium on tall fescue and different responses of the photosynthetic activities in the photosystem electron donor and acceptor sides. Scientific Reports 7: *14387*

Mishra S, Srivastava S, Tripathi R.D, Govindarajan R, Kuriakose S.V and Parasad M.N.V, (2006). 'Phytochelatin synthesis and response of antioxidant during cadmium stress in *Bacopa monnieri* L'. *Plant Physiology and Biochemestry*, 44(1):25-37

Momchil Paunov, Lyubka Koleva, Andon Vassilev, Jaco Vangronsveld and Vasilij Goltsev, (2018). Effects of Different Metals on Photosynthesis: Cadmium and Zinc Affect Chlorophyll Fluorescence in Durum Wheat. Int. J. Mol. Sci. 2018, 19, 787

Moradi L and Ehsanzadeh P, (2015). Effects of Cd on photosynthesis and growth of safflower (*Carthamus tinctorius* L.) genotypes. Photosynthetica 53 (4): 506-518

Prasad M.N.V, (1995). Cadmium toxicity and tolerance in vascular plants. Environ. Exp. Bot. 35: 525–545

Rai V, Khatoon S, Bisht S.S, and Mehrotra S, (2005). Effect of cadmium on growth, ultra morphology of leaf and secondary metabolites of *Phyllanthus amarus* Schum. and Thonn. Chemosphere. 61:1644–1650

Ramasubramanian V, Kannan N, and Ravichandran V, (1993). Analysis of industrial effluents and their impact on the growth and metabolism of *Phaseolus mungo* L. Commun. Soil. Sci. Plant Anal. 24 (17 & 18): 2241

Rascio N and Navari-Izzo F, (2011). 'Heavy metal hyper accumulating plants: How and why do Responses to Cadmium of the Three Miscanthus Species. PLoS ONE 11(4): e0153475

Sanita di Toppi, L. and Gabbrielli R, (1999). Response to cadmium in higher plants- A review. Env. Exp. Bot. 41: 105-130

Schutzendubel A and Polle A, (2002). Plant responses to a biotic stresses: Heavy metal induced oxidative stress and protection by mycorrhization. J. Exp. Bot. 53: 1351-1365

Song X, Yue X, Chen W, Jiang H, Han Y and Li X, (2019). Detection of Cadmium Risk to the Photosynthetic Performance of Hybrid Pennisetum. Front. Plant Sci. 10:798

Sun H.Y, Wang X.Y, Wang Y.N, Wei Y.Y and Wang G.H, (2016). Alleviation of cadmium toxicity in cucumber (*Cucumis sativus*) seedlings by the application of selenium. Spanish Journal of Agricultural Research, Volume 14, Issue 4, e1105

Szopi ´ nski M, Sitko K, Giero ´ n ˙Z, Rusinowski S, Corso M, Hermans C, Verbruggen N and Małkowski E, (2019). Toxic Effects of Cd and Zn on the Photosynthetic Apparatus of the Arabidopsis halleri and Arabidopsis arenosa Pseudo-Metallophytes. Front. Plant Sci. 10:748. Tech. 99 (14): 6372-6378

Thamayanthi D, Sharavanan P.S and Vijayaragavan M, (2011). Effect of cadmium on seed germination, growth and pigments content of Zinnia plant. Current Botany 2011, 2(8): 08-13

they do it? And what makes them so interesting? '*Plant Science*, 180(2):169-181

Vijayaragavan, M. and Vijayarengan P, (2007). Phytotoxicity of cadmium and its effects on growth and photosynthetic responses in *Raphanus sativus* (L.). Plant Archives, 07(11):555-55

Wahid A, Ghani A, Javed F, (2008). Effect of cadmium on photosynthesis, nutrition and growth of mungbean. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 28 (2), pp.273-280. hal-00886452

Xu P, Zou J, Meng Q, Zou J, Jiang W, and Liu D, (2008). Effects of Cd2+ on seedling growth of garlic (*Allium sativum* L.) and selected physiological and biochemical characters. Bioresource

Zhou J, Wan H, He J, Lyu D and Li H, (2017). Integration of Cadmium Accumulation, Subcellular Distribution, and Physiological Responses to Understand Cadmium Tolerance in Apple Rootstocks. Front. Plant Sci. 8:966

Zhou, W and Qiu B, (2005). Effects of cadmium hyper accumulation on physiological characteristics of *Sedum alfredii* Hance (Crassulaceae). Plant Sci. 169 (4): 737–745