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EFFECTS OF SALINITY ON CADMIUM AVAILABILITY IN SOIL AND FRUITS OF TOMATO (*LYCOPERSICON ESCULENTUM* MILLER)

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Abstract

Soil and water salinity are important problems in the coastal region of Bangladesh. Heavy metal also entering in the soil through various ways such as sewage sludge, fertilizers and pesticides. A pot experiment was conducted to study the variability of cadmium (Cd) availability in soil and tomato (*Lycopersicon esculentum* Miller) grown on to Cd-contaminated saline soil. The experiment was outlined in a completely randomized block design (RCBD) with a factorial layout which include 5 levels (0, 2, 4, 6 and 8 ds/m) of salinity and 4 levels (0, 10, 20 and 30 µg/g) of Cd. Result of soil analysis showed that the availability of Cd's increased in soil with the increase of salinity level. Fruit analysis also showed that the concentration of Cd in tomato fruit increased with the increase of salinity, but the yield of tomato fruit decreased with the increase of salinity of the soil.

Introduction

Salinity is one of the most crucial abiotic stresses restraining crop growth and development as well as reduction yield. About 20% area of the country is covered by the coastal region that 53% is affected by different degrees of salinity (Haque 2006), where environmental stress has increased in an alarming during the last couple of decades. In those areas, the ranges of salinity are categorized on the basis of electrical conductivity (EC) between 2 dS/m and 16 ds/m. Salinity is still increasing, imposing a great threat to agricultural production. Salinity presents several challenges to plant growth, including nutrient deficiencies and disorders (Santos *et al.* 2002). According to (Hu and Schmidhalter 2005) the mineral nutrition of plants has frequently been associated with their ability to tolerate salinity that the imbalance of minerals caused by salinity treatment can be seen as an indication of a broader metabolic disorder.

Conversely, heavy metals enter the soil in various ways, such as atmospheric precipitation, use of organic manure and chemical fertilizers, sewage, agricultural and industrial waste, and pesticides. The Cadmium is one of the most toxic heavy metals which has a negative impact on mammals and plants (Kabata Pendias 2010). The most critical entry pathway of Cd to agricultural lands is phosphorous fertilizers, and for the lead, this way is sewage waste and agricultural and industrial waste and other industrial pollutants. The inhibition of Cd stress on plant growth is related to its effect on nutrient uptake and distribution. The uptake and translocation of mineral nutrients like Fe, Zn, Cu and Mn under Cd stress have been reported in soybean (Drazic *et al.* 2004), rice (Liu *et al.* 2003), wheat (Zhang *et al.* 2002) and barley (Wu *et al.* 2003). However, plants grown in salt-affected soil encounter both salinity and Cd stresses.

Tomato (*L. esculentum* Miller.) belonging to Solanaceae, is one of the most important, popular, nutritious and palatable vegetables grown in Bangladesh. It plays a vital role in providing a remarkable quantity of vitamin A and vitamin C in the human diet. It can be eaten raw, ripe, and

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after cooking. It is cultivated all over Bangladesh due to its adaptability to a wide range of soil and climate. Previously many investigations were carried out to find out the role of salty water linked to the yield of tomatoes. However, little is known about the role of salty water in the accumulation of heavy metal in tomato fruit. Thus, the present investigation was carried out to find out the role of elevated levels of salt concentration on the accumulation of Cd in soil and tomato fruit as well as on the yield of tomato.

Materials and Methods

The present research work was conducted in a shade house at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of soil salinity on Cd availability in soil and tomato grown on contaminated soil. Five levels of salinity (S_1= 0, S_2 = 2, S_3= 4, S_4= 6 and S_5 = 8 ds/m) and four levels of Cadmium (C_1= 0, C_2 = 10, C_3 = 20 and C_4 = 30 μg/g) were tested with three replications. The experiment was conducted in a RCBD with a factorial layout.

To set the experiment 14 l volumetric plastic pots were filled with natural soil containing inherently low Cd concentration (0.04 μg/g). The soil was mixed-up with a treatment combination following the experimental design and kept incubated for 15 days. Subsequently, tomato seedlings were grown in plastic trays filled with coco dust which were irrigated four times a day. After 29 days, seedlings were transplanted to a plastic pot. Standard doses of fertilizer and pesticides were applied to all plants for management.

The soil and tomato samples were collected at the maturity of fruit and data on yield of tomato were recorded. Collected soil samples were air-dried for three days at room temperature and crushed and passed through a 2 mm mesh sieve and stored at ambient temperature prior to analysis. Tomato samples were washed with tap water and distilled water in the laboratory to remove adsorbed dust and particulate matter and then cut and chopped into small pieces. Afterwards, the samples were air-dried for five days and further dried in a hot air oven at 50-60˚C for 24 hrs. The dried samples were grounded into powder using acid-washed laboratory mortar and pestle and then sieved using a 2 mm mesh sieve and stored in polyethylene bags to keep in desiccators until digestion. Cadmium from soil and tomato samples were extracted by the method of Jackson (1973) using a di-acid digestion mixture (HNO_3:$HClO_4$, 3 : 1) and analyzed by atomic absorption spectrophotometer (AAS).

Analysis of variance (ANOVA) was used for analyzing data, where the General Linear Models (GLM) of Statistical Analysis Software (SPSS) was used (Sawyer *et al.* 2007). Duncan's Multiple Range Test for values and Least Significant Difference (LSD) at a 5% level of confidence were used for separating treatment means. Wherever a significant difference was found the means obtained were compared at $P = 0.05$ level of probability.

Results and Discussion

Cadmium accumulation in soil and tomato fruit due to salinity and its effects on the yield of tomato fruit showed significant variation (Table 1). The concentration of Cd in soil and tomato due to salinity revealed that Cd concentration increased with the increase of salinity level, but the yield of tomato fruits decreased with the increase of salinity (Fig. 1).

The highest concentrations of Cd (14.27 μg/g) were found in soil and tomato fruit (11.18 μg/g) due to the highest level of salinity. On the other hand, the lowest concentrations of Cd (2.65 μg/g) were found in soil and tomato fruit (1.42 μg/g) when the level was lowest i e., 0 level of salinity. Kadkhodaie *et al.* (2012) reported that the availability amount of heavy metals (Cd, Pb, Ni) was increased in soil with the increase of salinity. That the concentration of Cd and Pb increased in soil with increase of NaCl was reported by Bingham *et al.* (1984). Kadkhodaie *et al.* (2012) also showed that there was a corresponding increase in the concentration of absorbed Cd in all parts (root, stem, leaf) of sunflower and Sudan grass with increase of salinity. Cd concentration in crops shoots and roots increased by 52% as compared with control with increase in salinity (Fathi *et al.* 2017). Cadmium absorption increased in saline affected soils and directly hampered the crops (Norvell *et al.* 2000). Khoshgoftar *et al.* (2004) verified that soil salinity is one of the key factor in controlling Cd uptake by wheat.

Table 1. Effect of salinity level on the Cd concentration in soil and tomato fruit as well as on the yield of tomato.

Salinity levels	Cd level in the soil (µg/g)	Cd concentration in tomato (µg/g)	The yield of tomato plant (kg/plant)
S_0	2.65e	1.42e	0.89a
S_1	6.15d	3.59d	0.48b
S_2	9.39c	6.81c	0.34c
S_3	11.45b	8.52b	0.15d
S_4	14.27a	11.18a	0.14d
LSD	0.5185	0.8047	0.0364

*Values with the same letters in a column do not differ significantly.

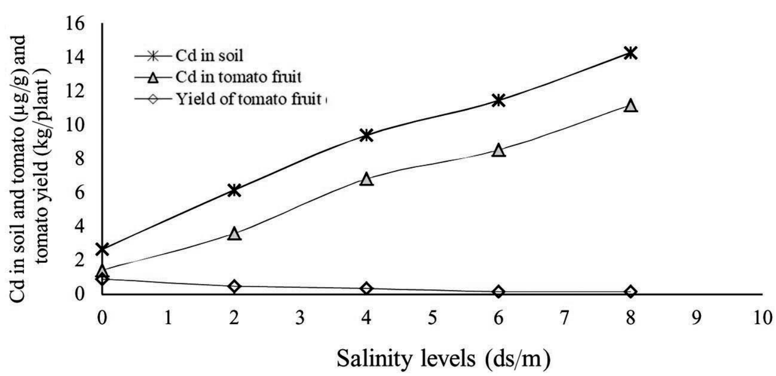

Fig. 1. Change of Cd in soil and tomato µg/g and yield of tomato (kg/plant) with different salinity levels.

In contrast, the yield of tomato fruits increased with decrease of salinity (Fig. 1). The highest yield (0.89 kg/plant) was obtained from salinity dose S_0 (Control) and the lowest yield (0.14 kg/plant) was obtained from salinity dose S_4 (8ds/m). Salinity is a limiting factor in crop growth (Hajer *et al.* 2006). The tomato yield has been reported to be negatively affected by the increasing salinity (Hou *et al.* 2014). Ahmed *et al.* (2017) found that the highest total fruit yield (36.57 t/ha) was produced by irrigation with fresh water and the lowest fruit yield (21.87 t/ha) was found for the irrigation of saline water (10 ds/m).

Cadmium concentration on soil and tomato fruit as well as the yield of tomato fruit varied significantly with different levels of Cd (Table 2). The highest amount of Cd (12.00 µg/g) and 9.08 µg/g, respectively) in soil and tomato was present due to C_4 (30 µg/g), whereas, the lowest concentration of Cd (5.40 and 3.32 µg/g, respectively) existed for C_1 (Control). A general trend was observed that the application of a higher dose of Cd is the cause of higher concentrations of Cd in soil and tomato fruits (Fig. 2).

Table 2. Effect of Cd dose on the Cd concentration in soil and tomato fruit as well as on the yield of tomato.

Cd dose	Cd level in the soil (µg/g)	Cd concentration in tomato (µg/g)	The yield of tomato plant (kg/ plant)
C_1	5.40d	3.52d	0.54a
C_2	7.39c	5.19c	0.42b
C_3	10.30b	7.42b	0.33c
C_4	12.00a	9.08a	0.31c
LSD	0.467	0.719	0.032

*Values with the same letters in a column do not differ significantly.

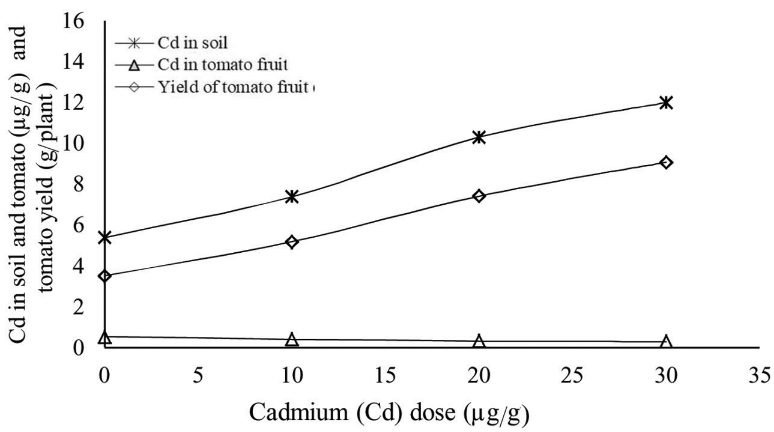

Fig. 2. Change of Cadmium (Cd) in soil and tomato (µg/g) and yield of tomato (kg plant^{-1}) with different doses of Cd.

Keller and Schulin (2003) reported that the removal of heavy metals through leaching or uptake by the plants is much lower than the rate of their entry into the soil which leads to the gradual accumulation of these elements in the soil. Plants take up heavy metals by absorbing them from the polluted environments as well as from contaminated soils and water through root systems (Deribachew *et al.* 2015). On the other hand, increase of Cd concentration was found in all tissues of the plants (roots, stem, young, mature and old leaves) by increasing the Cd contamination in the soil (De Maria *et al.* 2013). Marga 2016 reported that the tomatoes grown on contaminated soils may lead to the uptake of elevated metals producing adverse effects. In contrary, excess use of Cd in soil reduced the yield of tomatoes compared to lower doses. The highest yield (0.54 kg/plant) of tomato fruit was observed in case of the lowest concentration (C_1) of Cd (Control) and the lowest yield (0.31 kg/plant) of tomato fruit was observed in the case of the highest concentration of Cd (0.30 µg/g). Fathi *et al.* (2017) indicated that soil treated with Cd and sewage sludge decreased the dry and fresh wet weight of the plant. The inhibition of Cd stress on plant growth is related to its effect on nutrient uptake and distribution. The uptake of Cd triggers the degradation of chlorophyll content resulting in restricted photosynthetic rate in addition to affecting nitrogen metabolism, enzymatic and non-enzymatic activity (Khan *et al.* 2015).

Table 3. Interaction effect of Cd dose and salinity level on Cd concentration in soil and tomato fruit as well as the yield of tomato fruit.

Cd dose × Salinity levels	Cd level in the soil (µg/g)	Cd concentration in tomato (µg/g)	The yield of tomato plant (kg/plant)
C_1S_0	0.06m	0.03l	1.23a
C_1S_1	3.83k	1.74jk	0.67c
C_1S_2	5.35j	3.56i	0.42de
C_1S_3	7.10i	5.95g	0.22hi
C_1S_4	10.66fg	6.33fg	0.14jk
C_2S_0	1.69l	0.87kl	0.94b
C_2S_1	5.28j	2.87ij	0.48d
C_2S_2	7.60hi	5.19gh	0.36ef
C_2S_3	10.20g	7.86ef	0.16ij
C_2S_4	12.18de	9.18de	0.17ij
C_3S_0	3.64k	1.95jk	0.73c
C_3S_1	7.34hi	4.16hi	0.39e
C_3S_2	11.41ef	8.24e	0.31fg
C_3S_3	13.28c	9.04de	0.12jk
C_3S_4	16.05b	13.71b	0.13jk
C_4S_0	5.23j	2.84ij	0.66c
C_4S_1	8.17h	5.60gh	0.38e
C_4S_2	13.20cd	10.23cd	0.27gh
C_4S_3	15.23b	11.23c	0.08k
C_4S_4	18.18a	15.51a	0.13jk
LSD	1.037	1.6094	0.0729

*Values with the same letters are not significantly different.

The salinity levels (0, 2, 4, 6 and 8 ds/m) and Cd doses (0, 10, 20 and 30 µg/g) on Cd accumulation in soil and tomato and the yield of tomato showed significant variation (Table 3). Low level of salinity with Cd dose showed lower Cd concentration both in soil and tomato. Besides, the combined effect of higher doses of salinity and Cd was responsible for the higher Cd concentration in soil and tomato fruits. The combination with the highest dose of Cd and salinity levels (C_4S_4) showed a higher amount of Cd in soil (18.18 µg/g) and tomato (15.51µg/g), while minimum Cd in soil (0.06 µg/g) and tomato (0.031 µg/g) was found for the combination with the lowest concentration of Cd and salinity levels (C_1S_0). Conversely, the yield of tomatoes decreased significantly with the increment of salinity level and Cd concentration. The lowest level of salinity with Cd dose (C_1S_0) showed the highest return of tomato fruit (1.23 kg/plant), whereas the lowest yield (0.08 kg/plant) was found for treatment combination of the highest salinity and Cd level (C_4S_3). It has been well documented that combined NaCl and Cd stress resulted in more severe growth inhibition of barley plants than Cd or NaCl stress alone (Smýkalova and Zamecnikova 2003). DalCorso *et al.* (2010) and Chen *et al.* (2015) reported that the environmental stress including Cd accumulation can be detrimental to plant morpho-physiological development. Sepehr and Ghorbanli (2006) also found that the interaction between Cd and NaCl at higher doses decreased plant biomass, growth, and chlorophyll content in maize.

Finally, the accumulation of Cd concentration in tomato fruit exhibited an upward trend with the rising levels of salinity and Cd dose, both individually and when combined. However, the increase in salinity level and Cd dose, whether separately or in combination, led to a decline in tomato yield.

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