Response of *Lantana camara* Plants to Foliar Applied Citric Acid for Decreasing the Harmful Effect of Heavy Metals Pollution in the Irrigation Water (A) Effect of Cadmium

Nader A. El-Shanhorey[1] and Omar N. Emam[2]

ABSTRACT

The present study was carried-out at Antoniades Research Branch, Horticultural Research Institute, Agriculture Research Center (ARC), Alexandria, Egypt during two successive seasons of 2018 and 2019. The aim of this study was to evaluate the effects of irrigation water contaminated with cadmium on the growth of *Lantana camara* plants and the possibility of using citric acid spray treatments to overcome the effects of cadmium pollution. Seedlings of *Lantana camara* were planted individually in plastic pots (20 cm diameter) filled with 5 kg of sandy soil. The Cadmium contaminated irrigation water treatments were 0,100, 200 and 300 mg/L were applied. The plants were also monthly sprayed by citric acid at concentrations of 0, 250 and 500 mg/L.

The results showed that for vegetative growth parameters there was no significant difference in the interaction between cadmium concentrations in water of irrigation and foliar spray by citric acid, while a significant reduction was observed in all parameters after irrigation with cadmium contaminated water and a significant increase in vegetative growth parameters was observed after 250 mg/L citric acid application. For chlorophyll and carbohydrate content, the highest significant value was obtained in plants irrigated with tap water and sprayed with 500 mg/L citric acid while the highest significant level of cadmium content in leaves, stem and roots was obtained due treatment by 300 mg/L cadmium without application of citric acid.

Key wards: *Lantana camara*, cadmium, citric acid.

INTRODUCTION

Phytoremediation has become an effective and affordable technological solution used to extract or remove toxic metals from contaminated soil. Phytoremediation is the use of plants to clean up a contamination from soils, sediments and water. This technology is environment friendly and potentially cost effective. Plants with exceptional metal-accumulating capacity are known as hyperaccumulator plants (Choruk *et al.*, 2006). Plants need trace amount of heavy metal but their excessive availability may cause plant toxicity (Sharma *et al.*, 2006). Phytotoxic concentration of heavy metals referred in the literature does not always specify the levels (Wua *et al.*, 2010). Cadmium is a toxic metal that has an environmental concern (Mahler *et al.*, 1981). There are many sources of environmental pollution by cadmium, including fuel combustion, industrial sludges, phosphate fertilizers, and mine tailings (Unhalekhana and Kositanont, 2008). Cadmium can be absorbed by human body through respiration and consumption, and cadmium then accumulates in the liver and kidney, causing acute and chronic symptoms such as nausea, abdominal pain, diarrhea, kidney dysfunction, and osteomalacia (Simmons *et al.*, 2005).

Endogenous organic acids are the source of both carbon skeleton and energy for cells and are used in the respiratory cycle and other biochemical pathways (Da Silva, 2003). Citric acid is a six carbon organic acid, having a central role in citric acid cycle in mitochondria that creates cellular energy by phosphorylative oxidation reactions. It is created by addition of acetyl-CoA to oxaloacetic acid that is converted to succinate and malate in next steps (Wills *et al.*, 1981).

Lantana camara plant is found mostly in the South India, in sub-tropical and tropical America and in Africa. The plant named *Lantana camara* linn. Family: Verbenaceae is commonly known as wild sage or red sage and lantana weed. It is a large scrambling evergreen, strong smelling shrub with stout prickles, its leaves were opposite on both sides. Lantana flowers were small, generally orange but often vary in colors from white to dark red, which are prominently capitates in heads; bracts conspicuous and persistent. Lantana fruits were small, 5 mm diameter, drupaceous and shining, blue, greenish, blackish, with two nutlets in it. Its seeds were germinated easily throughout central and south India in most dry stony hills and black *Lantana camara* is a small perennial shrub which can grow to around 2m in height and forms dense thickets in a variety of habitats. Due to extensive selective breeding throughout the 17th and 18th Century for use as an ornamental plant there are now many forms of *Lantana*

DOI: 10.21608/asejaiqjsae.2020.71079

[1]Botanical Gardens Research Department, Horticultural Research Institute, ARC, Alexandria, Egypt.

[2] Horticultural Department, Faculty of Agriculture, Beni-Suif University, Egypt.

Received January 6, 2020, Accepted February 10, 2020

camara present throughout the world (Ashwini *et al.*, 2014).

In this study *Lantana camara* was selected due to its characteristics as non-edible plant which can grow in tropical areas and it has many uses in landscaping. Therefore the objective of this study was to determine the potential of *Lantana camara* in removing cadmium from soil affected by Cadmium contaminated irrigation water and to investigate on the ability of *Lantana camara* in removing heavy metals.

MATERIALS AND METHODS

The present study was carried-out at Antoniades Research Branch, Horticultural Research Institute, Agriculture Research Center (ARC), Alexandria, Egypt during two successive seasons of 2018 and 2019.

On the 15th of February, 2018 and 2019 in the first and second seasons, respectively, similar seedlings of *Lantana camara* (15-20 cm height and 10-15 number of leaves per plant) were planted individually in plastic pots (20 cm diameter) filled with 5 kg sandy soil. The chemical constituents of the soil were measured as described by Jackson (1958) and the results obtained are shown in Table (1).

On the 1st of March (in both seasons), the contaminated irrigation water treatments were initiated. Four concentrations of cadmium acetate [$Cd.(CH_3COO)_2\ 2H_2O$]: 0,100, 200 and 300 mg/L were prepared dissolved in the irrigation water. The plants were irrigated three times per week. At the end of the experiment every pot had received about 127 liters of Cadmium contaminated water (Table 2). In both seasons, the plants received monthly sprayed by citric acid from 15th May till 15th August in both seasons at concentrations of 0, 250 and 500 mg/L. The control plants were sprayed with tap water. On 30th of September in the both seasons, the plants were harvested.

In the two seasons, the plants have been received N, P and K chemical fertilizers in the form of soluble fertilizer (Kristalon 19-19-19) at rate of 1.5 g/ pot. Fertilization was repeated every 30 days throughout the growing season (from the 1th of March till the 30th of September). In addition, weeds were removed manually upon emergence.

Data recorded:

(1) Vegetative growth parameters:

Plant height (cm), number of leaves per plant, leaves dry weight per plant (g), leaves area (cm^2) according to Koller (1972), branches number per plant, stem diameter (cm), stem dry weight (g), root length (cm), root dry weight (g), flowers number per plant and flower dry weight (g) were also measured.

(2) Chemical analysis:

- Total chlorophyll index was measured as a SPAD for the fresh leaves of plants, for the different treatments under the experiment at the end of the season using Minolta (chlorophyll meter) SPAD 502 according to Yadava (1986).
- Total carbohydrate percentage in the leaves was determined according to Dubios *et al.*(1956).
- Proline content (mg/g) in the leaves was determined according to Bates *et al.* (1973).
- Determination of cadmium content. Plant samples were divided into leaves stem and roots, oven dried at 72°C for 2 hrs in an oven until. The dried plant samples were ground to powder. The oven dried samples were digested for extraction of cadmium, using the method described by Piper (1947) and the concentration of heavy metal was the assured using an atomic absorption spectrophotometer.
- Available heavy metal, i.e. (Cadmium) in soil sample was extracted by DPTA-Solution according to Lindsay and Norvell (1978) and measured by Inductively Coupled Plasma Spectrometry.
- Transfer factor (TF) is given by the relation the ratio of the concentration of metal in the shoots to the concentration of metal in the soil (Chen *et al*., 2004). Indicates to the efficiency of any plant to transfer any metal from soil to the aerial parts.

The pot experimental design was split plot with three replicates. Each replicate contained three plants. The main plot was cadmium contaminated water concentration, while the subplot was citric acid treatments.

Table 1. The chemical properties of the used sandy soil for the two seasons 2018 and 2019.

Season	pH	EC dS/m	Water soluble cations (meq/l)				Water soluble anions (meq/l)		
			Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{--}
2018	7.93	1.55	3.4	3.4	6.5	1.3	3.6	6.7	2.4
2019	7.91	1.52	3.2	3.0	6.3	1.2	3.3	6.5	2.2

Table 2. Total amount of used irrigation water for each plant (l/pot) in each treatment during the two growing seasons of 2018 and 2019.

Field Capacity (%)	Months of first and second seasons							
	March	April	May	June	July	August	September	Total
100 %	14.00	15.00	16.00	17.00	20.00	23.00	22.00	127.00

The obtained data were subjected to analysis of variance (ANOVA) using the SAS program, SAS Institute (SAS Institute, 2002). The Means of the individual factors and their interactions were compared by L.S.D test at 5% level of probability according to Snedecor and Cochran (1989).

RESULTS

1. Vegetative growth:

Leaves parameters

Table (3) showed that, in both seasons, irrigation water contaminated with cadmium decreased the tested leaves parameters of *Lantana camara* plants. While plants irrigated with tap water (control) had the highest mean values of number of leaves per plant (96.83 and 98.66), leaves dry weight (1.94 and 2.29 g) and leaves area (462.59 and 317.26 cm^2) in the first and second seasons, respectively. Increasing the cadmium concentration caused significant reductions in the tested leaves parameters. The highest cadmium concentration (300 mg/L) produced significantly the lowest plants mean values of number of leaves per plant (86.22 and 88.05), leaves dry weight (1.73 and 2.08 g) and leaves area (282.63 and 241.93 cm^2) in the first and second seasons, respectively, compared with the other concentrations.

Table 3. Means of number of leaves per plant, leaves dry weight (g) and leaves area (cm^2) of *Lantana camara* plants as influenced by cadmium (Cd), citric acid (CA) and their combinations (Cd× CA) in the two seasons of 2018 and 2019.

Treatments		Number of leaves per plant		Leaves dry weight/plant (g)		Leaves area per plant (cm^2)	
Cd (mg/L)	CA (mg/L)	2018	2019	2018	2019	2018	2019
	0	94.83	96.66	1.90	2.24	410.40	301.91
0	250	98.83	100.66	1.99	2.34	536.32	327.38
	500	96.83	98.66	1.94	2.29	441.05	322.49
Mean (Cd)		96.83	98.66	1.94	2.29	462.59	317.26
	0	91.83	93.66	1.85	2.23	382.18	276.07
100	250	96.83	98.66	1.95	2.28	400.29	286.52
	500	92.83	94.66	1.86	2.20	399.98	281.91
Mean (Cd)		93.83	95.66	1.88	2.23	394.15	281.50
	0	87.33	89.16	1.76	2.14	351.77	256.66
200	250	91.16	93.00	1.83	2.18	359.19	286.48
	500	90.16	92.00	1.80	2.15	357.20	264.6
Mean (Cd)		89.55	91.38	1.79	2.15	356.05	269.24
	0	84.83	86.66	1.70	2.05	259.51	230.94
300	250	87.50	89.33	1.76	2.12	314.77	255.49
	500	86.33	88.16	1.73	2.08	273.63	239.36
Mean (Cd)		86.22	88.05	1.73	2.08	282.63	241.93
	0	89.70	91.53	1.80	2.16	350.96	266.39
Mean (CA)	250	93.58	95.41	1.88	2.23	402.64	288.96
	500	91.53	93.37	1.83	2.18	367.96	277.09
	Cd	1.68	1.50	0.03	0.03	49.37	38.85
L.S.D. at 0.05	CA	1.95	1.90	0.04	0.04	26.80	25.96
	Cd * CA	2.25	2.19	0.04	0.04	30.80	29.84

Leaves parameters were also significantly affected by spraying the plants with citric acid. In both seasons, the tested leaves parameters were increased gradually when the citric acid concentration was increased from 0 mg/L (control) to 250 mg/L. Accordingly, Table (3) showed that *Lantana camara* plants sprayed with 250 mg/L citric acid showed significantly higher mean values of number of leaves per plant (93.58 and 95.41), leaves dry weight (1.88 and 2.23 g) and leaves area (402.64 and 288.96 cm^2) in the first and second seasons, respectively, compared with the other concentrations.

Regarding the interaction between the effects of irrigation with Cadmium contaminated water and citric acid treatments on the tested leaves parameter of *Lantana camara* plants, the recorded results in the two seasons showed that, the highest values were obtained for plants irrigated with tap water (control) and sprayed with citric acid at 250 mg/L with mean values of number of leaves per plant (98.83 and 100.66), leaves dry weight (1.99 and 2.34 g) and leaves area (536.32 and 327.38 cm^2) in the first and second seasons, respectively, compared with the other concentrations. On the other hand, the least values with mean values of number of leaves per plant (84.83 and 86.66), leaves dry weight (1.70 and 2.05 g) and leaves area (259.51 and 230.94 cm^2) in the first and second seasons, respectively, were resulted when the plants were irrigated using the highest cadmium concentration (300 mg/L) without citric acid treatment. It can be also showed that in many cases, spraying plants with citric acid had reduced the adverse effect of contaminated water with cadmium (Table 3).

Stem parameter

Table (4) showed that irrigation with contaminated cadmium water decreased stem parameter, compared to that of plants irrigated with tap water (control). In both seasons, plants irrigated with tap water had the thickest stem, with mean plant height (34.16 and 39.99 cm), number of branches per plant (7.33 and 12.33), stem diameter (0.54 and 0.72 cm) and stem dry weight (3.24 and 5.25 g) in the first and second seasons, respectively.

Table 4. Means of plant height (cm), branches number per plant, stem diameter (cm) and stem dry weight (g) of *Lantana camara* plants as influenced by cadmium (Cd), citric acid (CA) and their combinations (Cd × CA) in the two seasons of 2018 and 2019.

Treatments		Plant height (cm)		Branches number per plant		Stem diameter (cm)		Stem dry weight (g)	
Cd (mg/L)	CA (mg/L)	2018	2019	2018	2019	2018	2019	2018	2019
000	0	33.50	39.33	7.00	11.83	0.53	0.70	2.96	4.98
	250	34.83	40.66	7.83	12.83	0.54	0.71	3.69	5.69
	500	34.16	40.00	7.16	12.33	0.56	0.75	3.07	5.09
Mean (Cd)		34.16	39.99	7.33	12.33	0.54	0.72	3.24	5.25
100	0	32.50	38.33	6.66	10.66	0.51	0.68	2.66	4.17
	250	34.16	40.00	7.00	11.66	0.50	0.67	2.84	4.62
	500	32.83	38.66	6.83	10.83	0.49	0.66	2.69	4.25
Mean (Cd)		33.16	38.99	6.83	11.05	0.50	0.67	2.73	4.34
200	0	31.00	36.83	6.33	10.16	0.49	0.67	2.48	3.84
	250	32.25	38.08	6.66	10.50	0.48	0.65	2.76	4.48
	500	31.91	37.75	6.66	10.16	0.47	0.66	2.61	4.02
Mean (Cd)		31.72	37.55	6.55	10.27	0.48	0.66	2.61	4.11
300	0	30.16	36.00	6.16	8.83	0.46	0.59	2.27	3.81
	250	31.08	36.91	6.33	10.00	0.41	0.60	2.76	4.47
	500	30.66	36.50	6.16	9.66	0.44	0.61	2.64	3.90
Mean (Cd)		30.63	36.47	6.21	9.49	0.43	0.60	2.55	4.06
Mean (CA)	0	31.79	37.62	6.53	10.37	0.49	0.66	2.59	4.20
	250	33.08	38.91	6.95	11.24	0.48	0.65	3.01	4.81
	500	32.39	38.22	6.70	10.74	0.49	0.67	2.75	4.31
L.S.D. at 0.05	Cd	0.54	0.57	0.38	1.85	0.04	0.05	0.22	0.78
	CA	0.64	0.61	0.25	0.80	0.02	0.02	0.12	0.44
	Cd * CA	0.74	0.70	0.29	0.92	0.02	0.02	0.14	0.50

Increasing the cadmium concentration in irrigation water caused a steady reduction in stem parameters. This reduction in stem parameter was significant (compared to the control), even at the highest cadmium concentration (300 mg/L), which gave plant height (30.63 and 36.47 cm), number of branches per plant (6.21 and 9.49), stem diameter (0.43 and 0.60 cm), and stem dry weight (2.55 and 4.06 g) in the first and second seasons, respectively, compared with the other concentrations.

In contrast to the effect of cadmium treatments, citric acid treatments improved stem parameter of *Lantana camara* plants, compared to the control. Moreover, plants sprayed with 250 mg/L citric acid had significantly mean plant height (33.08 and 38.91 cm), number of branches per plant (6.95 and 11.24) and stem dry weight (3.01 and 4.81 g) in the first and second seasons, respectively, compared with the other concentrations. Plants sprayed with 500 mg/L citric acid had significantly mean stem diameter (0.49 and 0.67 cm), compared to those of control plants.

Regarding the interaction between the effects of irrigation with water contaminated by cadmium and spraying by citric acid on stem parameter of *Lantana camara* plants, the recorded results for the two seasons Table (4) showed that significant differences were detected between the values obtained from plants receiving the different treatment combinations. The highest values mean plant height (34.16 and 40.00 cm), number of branches per plant (7.83 and 12.83) and stem dry weight (3.69 and 5.69 g) in the first and second seasons, respectively, were obtained in the plants irrigated with tap water and sprayed with citric acid at 250 mg/L. While, stem diameter (0.56 and 0.75 cm), were obtained in the plants irrigated with tap water and sprayed with citric acid at 500 mg/L. On the other hand, the thinnest values mean plant height (30.16 and 36.00 cm), number of branches per plant (6.16 and 8.83) and stem dry weight (2.27 and 3.81 g) in the first and second seasons, respectively, were obtained in plants irrigated by the highest cadmium concentration (300 mg/L) without citric acid treatment, while, stem diameter (0.41 and 0.60 cm), were obtained in plants irrigated using the highest cadmium concentration (300 mg/L) and sprayed with citric acid (250 mg/L). Table (4) showed that, in many cases, spraying the plants with citric acid reduced the adverse effect of Cadmium contaminated water.

Root parameter

Table (5) showed that irrigation with Cadmium contaminated water decreased root parameter, compared to that of plants irrigated with tap water (control). In both seasons, plants irrigated with tap water had the highest values of mean root length (16.87 and 20.20 cm) and root dry weight (2.21 and 3.57 g) in the first and second seasons, respectively. Increasing cadmium concentration in irrigation water caused a steady reduction in root parameter. These reductions in root parameters were significant as compared to the control even at the highest cadmium concentration (300 mg/L), which gave root length (15.02 and 18.34 cm) and root dry weight (1.74 and 2.76 g) in the first and second seasons, respectively.

In contrast to the effect of cadmium treatments, citric acid treatments improved root parameter of *Lantana camara* plants, compared to the control. Moreover, plants sprayed with 250 mg/L citric acid had significantly mean root length (16.32 and 19.62 cm) and root dry weight (2.05 and 3.27 g) in the first and second seasons, respectively, compared to the those of control plants, or plants sprayed with any other citric acid concentration.

Regarding the interaction between the effects of irrigation with Cadmium contaminated cadmium water and citric acid treatments on root parameter of *Lantana camara* plants, the results in Table (5) showed that significant differences between the values obtained for plants receiving the different treatment combinations. The highest values mean root length (17.22 and 20.55 cm) and root dry weight (2.52 and 3.87 g) in the first and second seasons, respectively, were obtained in the plants irrigated with tap water and sprayed with citric acid at 250 mg/L. On the other hand, the lowest values of mean root length (14.81 and 18.10 cm) and root dry weight (1.56 and 2.59 g) in the first and second seasons, respectively, were obtained in the plants irrigated using the highest cadmium concentration 300 mg/L without citric acid treatment. It can be seen from Table (5) that in many cases, spraying the plants with citric acid reduced the undesirable effect of contaminated water with cadmium.

Flowers parameter

Table (6) showed that, in both seasons, irrigation water contaminated with cadmium decreased the flowers parameters of *Lantana camara* plants. Plants irrigated with tap water (control) had the highest mean values of number of flowers per plant (21.94 and 28.94) and flower dry weight (2.08 and 3.44 g) in the first and second seasons, respectively. Increasing cadmium concentration caused significant reductions in flowers parameters, with the highest cadmium concentration (300 mg/L) giving significantly the smallest flowers mean values of number of flowers per plant (19.77 and 26.44)

Table 5. Means of root length (cm) and root dry weight (g) of *Lantana camara* plants as influenced by cadmium (Cd), citric acid (CA) and their combinations (Cd × CA) in the two seasons of 2018 and 2019.

Treatments		Root length (cm)		Root dry weight/plant(g)	
Cd (mg/L)	**CA (mg/L)**	**2018**	**2019**	**2018**	**2019**
	0	16.53	19.85	2.02	3.39
000	250	17.22	20.55	2.52	3.87
	500	16.88	20.20	2.09	3.47
Mean (Cd)		16.87	20.20	2.21	3.57
	0	16.02	19.32	1.81	2.84
100	250	16.88	20.19	1.94	3.15
	500	16.19	19.50	1.83	2.89
Mean (Cd)		16.36	19.67	1.86	2.96
	0	15.25	18.54	1.70	2.62
200	250	15.89	19.19	1.89	3.05
	500	15.72	19.02	1.78	2.74
Mean (Cd)		15.62	18.91	1.79	2.80
	0	14.81	18.10	1.56	2.59
300	250	15.29	18.58	1.88	3.04
	500	15.07	18.36	1.80	2.66
Mean (Cd)		15.05	18.34	1.74	2.76
	0	15.65	18.95	1.77	2.86
Mean (CA)	250	16.32	19.62	2.05	3.27
	500	15.96	19.27	1.87	2.94
	Cd	0.27	0.28	0.15	0.53
L.S.D. at 0.05	CA	0.33	0.33	0.08	0.29
	Cd * CA	0.38	0.38	0.09	0.34

and flower dry weight (1.62 and 2.63 g) in the first and second seasons, respectively, compared with the other concentrations.

Flowers parameters were also significantly affected by spraying the plants with citric acid. In both seasons, increased gradually as citric acid concentration was increased from 0 mg/L (control) to 250 mg/L. Accordingly, Table (6) showed that *Lantana camara* plants sprayed with 250 mg/L citric acid were significantly mean values of number of flowers per plant (21.33 and 28.16) and flower dry weight (1.93 and 3.14 g) in the first and second seasons, respectively, compared with the other concentrations.

Regarding the interaction between the effects of irrigation with Cadmium contaminated water and citric acid treatments on flowers parameters of *Lantana camara* plants, the recorded results in the two seasons showed that, the highest values were obtained in the plants irrigated with tap water and sprayed with citric acid at 250 mg/L with mean values of number of flowers per plant (22.33 and 29.50) and flower dry weight (2.40 and 3.74 g) in the first and second seasons, respectively. On the other hand, the plants with mean values of number of flowers per plant (19.33 and 26.16) and flower dry weight (1.43 and 2.46 g) in the first and second seasons, respectively, were found when the plants were irrigated using the highest cadmium concentration (300 mg/L) without citric acid treatment. It can also been seen from Table (6) that in many cases, spraying the plants with citric acid reduced the undesirable effect of contaminated water with cadmium.

2. Chemical composition

Leaf chemical analysis

Table (7) showed that the highest value of total chlorophyll was obtained in plant irrigation with tap water (56.26 and 56.74 SPAD) and of total carbohydrates (19.79 and 19.95%) in the first and second seasons, respectively, while the maximum proline content (2.54 and 2.50 mg/g) was obtained in the plants irrigated with cadmium water at 300 mg/L. Increasing the cadmium concentration in irrigation water resulted in steady significant reductions in the chlorophyll and carbohydrates content, which reached its lowest mean value for chlorophyll (50.85 and 51.56 SPAD) and total carbohydrates (17.94 and 18.18 %) in the first and second seasons, respectively, in plants receiving the highest cadmium concentration 300 mg/L, while, proline content (2.54 and 2.50 mg/g) were obtained in the plants irrigated with tap water.

Table (7) also showed that citric acid treatments had possible effect on leaf chlorophyll (55.93 and 56.39 SPAD) and total carbohydrates (19.68 and 19.83 %) in the first and second seasons, respectively, in plants sprayed with citric acid at 500 mg/L, while, proline contents (2.04 and 2.07 mg/g) were obtained in plants sprayed without citric acid.

Regarding to the interaction between the effects of irrigation using water Cadmium contaminated water and citric acid treatments, Table (7) showed that the highest total chlorophyll contents (57.92 and 56.74) and total carbohydrates (20.36 and 20.48 %) in the first and second seasons, respectively, were found in leaves of plants irrigated with tap water and sprayed with citric acid at 500 mg/L, while, proline content (2.55 and 2.53 mg/g) were resulted in when the plants were irrigated by the highest cadmium concentration (300 mg/L) without citric acid treatment.

Cadmium content in leaves, stem and root (mg/L)

Table (8) showed that, the cadmium content (mg/L) in the dried plant parts of *Lantana camara* plants was increased with increasing the cadmium concentration in the irrigation water. Generally, the lowest mean cadmium content of leaves (0.301 and 0.439 mg/L), cadmium content in stem (0.508 and 0.681 mg/L) and cadmium content in root (0.392 and 0.526 mg/L) in the first and second seasons, respectively, were found in leaves of plants irrigated with tap water, whereas the highest mean values of cadmium content in leaves (1.543 and 1.806 mg/L), cadmium content in stem (1.367 and 1.541 mg/L) and cadmium content in root (1.056 and 1.191 mg/L) in the first and second seasons, respectively, were found in plants irrigated with water containing the highest cadmium concentration 300 mg/L.

Concerning the effect of citric acid treatments on the cadmium content in plant parts, Table (8) showed that citric acid treatment by 500 mg/L caused a significant decrease the mean values of cadmium content in leaves (0.922 and 1.111 mg/L), cadmium content in stem (0.946 and 1.078 mg/L) and cadmium content in root (0.731 and 0.833 mg/L) in the first and second seasons,

Table 6. Means of Flowers number per plant and flower dry weight (g) of *Lantana camara* plants as influenced by cadmium (Cd), citric acid (CA) and their combinations (Cd × CA) in the two seasons of 2018 and 2019.

Treatments		Flowers number per plant		Flower dry weight (g)	
Cd (mg/L)	**CA (mg/L)**	**2018**	**2019**	**2018**	**2019**
	0	21.50	28.33	1.89	3.26
000	250	22.33	29.50	2.40	3.74
	500	22.00	29.00	1.96	3.33
Mean (Cd)		21.94	28.94	2.08	3.44
	0	21.00	27.83	1.68	2.71
100	250	22.00	29.00	1.81	3.01
	500	21.16	28.00	1.71	2.77
Mean (Cd)		21.38	28.27	1.73	2.83
	0	20.00	26.66	1.57	2.49
200	250	20.83	27.50	1.76	2.92
	500	20.66	27.33	1.66	2.61
Mean (Cd)		20.49	27.16	1.66	2.67
	0	19.33	26.16	1.43	2.46
300	250	20.16	26.66	1.75	2.92
	500	19.83	26.50	1.68	2.53
Mean (Cd)		19.77	26.44	1.62	2.63
	0	20.45	27.24	1.64	2.73
Mean (CA)	250	21.33	28.16	1.93	3.14
	500	20.91	27.70	1.75	2.81
	Cd	0.29	0.37	0.15	0.53
L.S.D. at 0.05	CA	0.47	0.47	0.08	0.29
	Cd * CA	0.54	0.54	0.09	0.34

Table 7. Means of some chemical constituents characteristics of *Lantana camara* plants as influenced by cadmium (Cd), citric acid (CA) and their combinations (Cd×CA) in the two seasons of 2018 and 2019.

Treatments		Chlorophyll content (SPAD)		Carbohydrates content (%)		Proline content (mg/g D.W)	
Cd (mg/L)	CA (mg/L)	2018	2019	2018	2019	2018	2019
000	0	54.59	55.31	19.22	19.46	1.43	1.46
	250	56.27	56.63	19.79	19.91	1.41	1.44
	500	57.92	58.29	20.36	20.48	1.30	1.35
Mean (Cd)		56.26	56.74	19.79	19.95	1.38	1.41
100	0	50.76	51.14	17.92	18.04	1.89	1.94
	250	55.72	56.46	19.60	19.86	1.85	1.88
	500	57.50	57.87	20.21	20.33	1.85	1.88
Mean (Cd)		54.66	55.15	19.24	19.41	1.86	1.90
200	0	49.16	50.17	17.37	17.72	2.31	2.36
	250	54.17	54.54	19.08	19.20	2.26	2.32
	500	55.08	55.47	19.39	19.52	2.29	2.33
Mean (Cd)		52.80	53.39	18.61	18.81	2.28	2.33
300	0	48.12	49.15	17.01	17.37	2.55	2.53
	250	51.19	51.58	18.06	18.19	2.53	2.50
	500	53.25	53.95	18.76	19.00	2.54	2.49
Mean (Cd)		50.85	51.56	17.94	18.18	2.54	2.50
Mean (CA)	0	50.65	51.44	17.88	18.14	2.04	2.07
	250	54.33	54.80	19.13	19.29	2.01	2.03
	500	55.93	56.39	19.68	19.83	1.99	2.01
L.S.D. at 0.05	Cd	0.51	0.49	0.17	0.16	0.05	0.04
	CA	0.38	0.37	0.13	0.12	0.02	0.02
	Cd * CA	0.44	0.43	0.15	0.14	0.02	0.02

respectively, compared to that of control plants had the highest cadmium content in leaves (1.073 and 1.186 mg/L), cadmium content in stem (1.037 and 1.166 mg/L) and cadmium content in root (0.801 and 0.901 mg/L) in the first and second seasons, respectively.

Concerning the interaction effects between irrigation using Cadmium contaminated water with cadmium and citric acid treatments on the cadmium content in plant parts, Table (8) showed that the lowest mean values of cadmium content in leaves (0.154 and 0.377 mg/L), cadmium content in stem (0.416 and 0.589 mg/L) and cadmium content in root (0.320 and 0.455 mg/L) in the first and second seasons, respectively, were of found in plants irrigated with tap water and sprayed with citric acid at 500 mg/L. On the other hand, the highest cadmium content was obtained in the plant parts of irrigated with cadmium water at 300 mg/L and receiving no citric acid treatment cadmium content in leaves (1.595 and 1.858 mg/L), cadmium content in stem (1.402 and 1.575 mg/L) and cadmium content in root (1.083 and 1.218 mg/L).

3. Transfer factor (TF) of heavy metals

Cadmium content in soil samples (mg/kg)

Table (9) showed that the lowest average value of cadmium content was in untreated soil, while the highest average of cadmium content was observed in soil after the treatment by 300 mg/L cadmium and 0 mg/L citric acid.

Transfer factor to leaves, stem and root

Table (10), showed that the transfer factor (TF) in the dried plant parts of *Lantana camara* plants was decreased steadily with increasing cadmium concentration in irrigation water. Accordingly, the lowest cadmium values in leaves (1.347 and 1.494 mg/L), stem (1.193 and 1.275 mg/L) and root (0.922 and 0.985 mg/L) were found in plants irrigated with water containing cadmium concentration 300 mg/L, whereas the highest values of transfer factor in leaves (2.540 and 3.247 mg/L), stem (4.073 and 5.087 mg/L) and root (3.141 and 3.931 mg/L) were found in plants irrigated with tap water (control).

Table 8. Means of cadmium content in leaves, stem and root characteristics of *Lantana camara* plants as influenced by cadmium (Cd), citric acid (CA) and their combinations (Cd×CA) in the two seasons of 2018 and 2019.

Treatments		Cadmium content in leaves (mg/L)		Cadmium content in stem (mg/L)		Cadmium content in root (mg/L)	
Cd (mg/L)	CA (mg/L)	2018	2019	2018	2019	2018	2019
000	0	0.491	0.421	0.599	0.772	0.462	0.597
	250	0.258	0.520	0.510	0.684	0.394	0.528
	500	0.154	0.377	0.416	0.589	0.320	0.455
Mean (Cd)		0.301	0.439	0.508	0.681	0.392	0.526
100	0	0.794	1.056	0.868	1.041	0.671	0.805
	250	0.764	1.026	0.847	1.021	0.654	0.789
	500	0.691	0.953	0.798	0.972	0.617	0.751
Mean (Cd)		0.749	1.011	0.837	1.011	0.647	0.781
200	0	1.415	1.410	1.281	1.277	0.990	0.987
	250	1.360	1.355	1.245	1.241	0.962	0.959
	500	1.328	1.338	1.222	1.229	0.945	0.950
Mean (Cd)		1.367	1.367	1.249	1.249	0.965	0.965
300	0	1.595	1.858	1.402	1.575	1.083	1.218
	250	1.520	1.783	1.352	1.526	1.045	1.179
	500	1.516	1.778	1.349	1.523	1.042	1.177
Mean (Cd)		1.543	1.806	1.367	1.541	1.056	1.191
Mean (CA)	0	1.073	1.186	1.037	1.166	0.801	0.901
	250	0.975	1.171	0.988	1.118	0.763	0.863
	500	0.922	1.111	0.946	1.078	0.731	0.833
L.S.D. at 0.05	Cd	0.121	0.115	0.095	0.097	0.073	0.075
	CA	0.136	0.079	0.110	0.095	0.085	0.074
	Cd * CA	0.157	0.088	0.125	0.108	0.097	0.084

Table 9. Averages value of cadmium content in soil samples as influenced by cadmium concentrations in irrigation water and foliar application of citric acid on *Lantana camara* in the two seasons of 2018 and 2019.

Treatments		Cadmium content in soil (mg/kg)			
Cadmium (mg/L)	Citric acid (mg/L)	2018		2019	
		Before	After	Before	After
0	0	0.020	0.107	0.021	0.112
	250	0.022	0.119	0.024	0.131
	500	0.033	0.178	0.035	0.187
100	0	0.098	0.520	0.013	0.549
	250	0.094	0.501	0.099	0.528
	500	0.091	0.485	0.096	0.512
200	0	0.073	0.918	0.082	0.969
	250	0.060	0.850	0.069	0.897
	500	0.048	0.787	0.056	0.831
300	0	0.022	1.179	0.034	1.244
	250	0.016	1.147	0.028	1.211
	500	0.019	1.111	0.021	1.172

Table 10. Mean values of transfer factor to leaves, stem and roots of *Lantana camara* plants as influenced by cadmium (Cd), citric acid (CA) and their combinations (Cd ×CA) in the two seasons of 2018 and 2019.

Treatments		Transfer factor to leaves (TFL)		Transfer factor to stem (TFS)		Transfer factor to root (TFR)	
Cadmium (mg/L)	citric acid (mg/L)	2018	2019	2018	2019	2018	2019
000	0	4.588	3.758	5.598	6.892	4.317	5.330
	250	2.168	3.969	4.285	5.221	3.310	4.030
	500	0.865	2.016	2.337	3.149	1.797	2.433
Mean (Cd)		2.540	3.247	4.073	5.087	3.141	3.931
100	0	1.526	1.923	1.669	1.896	1.290	1.466
	250	1.524	1.943	1.690	1.933	1.305	1.494
	500	1.424	1.861	1.645	1.898	1.272	1.466
Mean (Cd)		1.491	1.909	1.668	1.909	1.289	1.475
200	0	1.541	1.455	1.395	1.317	1.078	1.018
	250	1.600	1.510	1.464	1.383	1.131	1.069
	500	1.6871	1.610	1.552	1.478	1.200	1.143
Mean (Cd)		1.609	1.525	1.470	1.392	1.136	1.076
300	0	1.352	1.493	1.189	1.266	0.918	0.979
	250	1.325	1.472	1.178	1.260	0.911	0.973
	500	1.364	1.517	1.214	1.299	0.937	1.004
Mean (Cd)		1.347	1.494	1.193	1.275	0.922	0.985
Mean (MA)	0	2.251	2.157	2.462	2.842	1.900	2.198
	250	1.654	2.223	2.154	2.449	1.664	1.891
	500	1.335	1.751	1.687	1.956	1.301	1.511

Table (10) also showed that the transfer factor (TF) in the dried plant parts was reduced steadily with increasing citric acid concentration. Accordingly, the highest cadmium values in leaves (2.251 and 2.157 mg/L), stem (2.462 and 2.842 mg/L) and root (1.900 and 2.198 mg/L) were found in the leaves of control plants, whereas plants sprayed with the highest citric acid concentration (500 mg/L) had the lowest cadmium values in leaves (1.335 and 1.751 mg/L), stem (1.687 and 1.956 mg/L) and root (1.301 and 1.511 mg/L) of the two seasons, respectively.

DISCUSSION

This study revealed that at high cadmium concentrations, the plant height was significantly reduced, and the biomass was decreased. The root growth was more sensitive than other plant parameters, as roots rapidly absorbed water and had higher accumulations of cadmium elements. The results presented by this study in agree with earlier reported on other plants, such as aquatic plant *Wolffia arrhiza* (Piotrowska *et al.*, 2010), barley *Hordeum vulgare* (Tiryakioglu *et al.*, 2006), *Typha angustifolia* (Bah *et al.*, 2011) and *Jatropha curcas* (El-Shanhorey and Emam, 2016). Other studies with woody plant reported a higher inhibition of root elongation (Dominguez *et al.*, 2009). In particular, Jatropha plants could bioaccumulate and bioconcentrate toxic heavy metals from an aqueous solution (Mohammad *et al.*, 2010) and could be used as phytoremediation candidates in some countries (Juwarkar *et al.*, 2008; Kumar *et al.*, 2008; Jamil *et al.*, 2009). Additionally, the plant seedling exhibited a high root/shoot ratio throughout the experiment. An alternative explanation might relate to a strong root system with many roots spread out over the entire soil for survival because root/shoot ratio could reflect plant's response to various environment factors (Otieno *et al.*, 2005; Lukacova Kulikova and Lux, 2010; Li *et al.*, 2010).

The physiological responses, such as the gas exchange rate and photosynthetic function, can be ascribed to the cadmium on the integrity and function of the photochemical apparatus of plant seedling, as well as the impact on chlorophyll concentrations in plant leaves. The photosynthesis rate, CO_2 and assimilation rate, in response to cadmium have been well documented (Chen *et al.*, 2012). In this study, cadmium resulted in a significant reduction in the chlorophyll contents, possibly due to the inhibition of chlorophyll biosynthesis or a breakdown of pigments and their precursors (Agrawal and Mishra, 2009) and (El-Shanhorey and EL-Sayed, 2017). Cadmium might replace the central Mg from chlorophyll molecules and thereby reduce the photosynthetic light-harvesting ability of plant (Agrawal and Mishra, 2009). In contrast, Carotein were less sensitive than chlorophyll a and chlorophyll b in response to both cadmium, which probably facilitated the maintenance of photosynthetic apparatus against heavy metal stress (Piotrowska *et al.*, 2010).

For the effect of citric acid it is observed that there is a significant increase in all vegetative parameters, chlorophyll content, carbohydrate percentage, significant decrease in cadmium content in leaves and roots and decrease in lead content. This may be due to that application of citric acid with any of the concentrations of cadmium led to a statistically decrease in the uptake of cadmium. This decrease in uptake of cadmium in the presence of citric acid resulted in the formation of citric acid–cadmium complexes that inhibited the uptake (Chen *et al.*, 2003).

Concerning treatments, at a preliminary stage, one should note that the transfer factor (TF) of most treatments is lower than one for cadmium; which means that the physiological need of the plant for this element is rather limited.

Translocation from roots to shoots via a number of physiological processes, including metal unloading into root xylem cells, long-distance carrying from the xylem to the shoots and metal reabsorption, by leaf mesophyll cells, from the xylem stream. Once the cadmium has been unloaded into the xylem vessels, the metals are carried to the shoots by the transpiration stream (Blaylock and Huang, 2000).

CONCLUSIONS

The concentrations of cadmium increases in the environment from year to year**.** Therefore decontamination of Cadmium contaminated water and soils is very important for maintenance of environmental health and ecological restoration. Phytoremediation is a new cleanup concept that involves the use of plants to clean or stabilize contaminated environments. Phytoremediation of metals is the most effective plant-based method to remove pollutants from contaminated areas. This green technology can be applied to remediate the polluted soils without creating any destructive effect of soil structure. Some specific plants, such as woody species, have been proven to have noticeable potential to absorb toxic heavy metals.

Phytoremediation of contaminated water and soil with cadmium using non-edible plant like *Lantana camara* offers an environmental friendly and cost-effective method for remediating the polluted soil. The *Lantana camara* was found to be able to efficiently remove the cadmium from soil.

REFERENCES

Agrawal S.B. and S. Mishra. 2009. Effects of supplemental ultraviolet-B and cadmium on growth, antioxidants and yield of *Pisum sativum* L. *Ecotoxicol. Environ. Saf.*, 72: 610-618.

Ashwini A., K. Swati and G. Sujata. 2014. Evaluation of Phytoremediation Potential of *Lantana camara* for Heavy Metals in an Industrially Polluted Area in Bhopal, India. International Journal of Engineering and Applied Sciences, 1 (2): 1-3.

Bah A.M., H. Dai, J. Zhao, H. Sun, F. Cao, G. Zhang and F. Wu. 2011. Effects of lead, chromium and lead on growth, metal uptake and antioxidative capacity in *Typha angustifolia*. *Biol. Trace Elem. Res.*, 142: 77-92.

Bates L.S., R.P. Waldern and L. D. Teare. 1973. Rapid determination of free proline under water stress studies. Plant and Soil, 39: 205-207.

Blaylock M. J. and J.W. Huang. 2000. Phytoextraction of metals. Phytoremediation of toxic metals: using plants to clean up the environment. Eds., Raskin, I. and B.D. Ensley. John Wiley and Sons, Inc, Toronto, p. 303.

Chen L., Y. Han, H. Jiang, H. Korpelainen and C. Li. 2012. Nitrogen nutrient status induces sexual differences in responses to cadmium in *Populus yunnanensis*. *J. Exp. Bot*., 62: 5037-5050.

Chen Y., Z. Shen, X. Li. 2004. The use of vetiver grass (*Vetiveria zizanioides*) in the phytoremediation of soils contaminated with heavy metals. Applied Geochemistry 19: 1553–1565.

Chen Y.X., Q. Lin, Y.M. Luo, Y.F. He, S.J. Zhen, Y.L. Yu, G.M. Tian and M.H. Wong. 2003. The role of citric acid on the phytoremediation of heavy metal contaminated soil. Chemosphere, 50:507–811.

Choruk K., J. Kurukote, P. Supprung, and S. Vetayasuporn .2006. Perennial plants in the phytoremediation of lead-contaminated soils. Biotechnology, 5 (1):1-4.

Da Silva J.A.T. 2003. The cut flower: postharvest considerations, J. Biol. Sci., 3(4): 406-442.

Dominguez M.T., F. Madrid, T. Maranon and J.M. Murillo .2009. Lead availability in soil and retention in oak roots: potential for phytostabilization. Chemosphere, 76: 480– 486.

Dubios M., K. Gilles, J. Hamlton, P. Rebers and F. Smith .1956. Colourimetric method for determination of sugars and related substances. Analytical Chemistry, 28(3): 350-356.

El-Shanhorey N.A. and K.A. Emam. 2016. Response of *Jatropha curcas* plants to foliar applied ascorbic acid for decreasing the harmful effect of cadmium pollution in the irrigation water. Alex. J. Agric. Sci. Alex.Univ., 61(3): 221-235.

El-Shanhorey N.A. and S.G. EL-Sayed. 2017. The Use of *Senecio cineraria* Plants Sprayed with Citric Acid for Cadmium Pollution Phytoremediation. Alexandria Science Exchange Journal, 38 (2): 343-355.

Jaafari N. and E. Hadavi. 2012. "Growth and essential oil yield of basil (*Ocimum basilicum* L.) as affected by foliar spray of citric acid and salicylic acid" Zeitschrift fur Arznei- und Gewurzpflanzen, 17 (2): 80–83.

Jackson N. L. 1958. Soil Chemical Analysis.Constable. Ltd. Co., London, 498 p.

Jamil S., P.C. Abhilash, N. Singh and P.N. Sharma .2009. Jatropha curcas: a potential crop for phytoremediation of coal fly ash. *J. Hazard. Mater.,* 172: 269-275.

Juwarkar A.A., S.K. Yadav, P. Kumar and S.K. Singh. 2008. Effect of biosludge and biofertilizer amendment on growth of *Jatropha curcas* in heavy metal contaminated soils. *Environ. Monit. Assess.,* 145: 7-15.

Koller H.R. 1972. Leaf area, leaf weight relationship in the soybean canopy. Crop Sci., 12: 180-183.

Kumar G.P., S.K. Yadav, P.R. Thawale, S.K. Singh and A.A. Juwarkar. 2008. Growth of *Jatropha curcas* on heavy metal contaminated soil amended with industrial wastes and *Azotobacter*. A greenhouse study. Bioresour. Technol., 99: 2078-2082.

Li X., X. Shen, J. Li, A.E. Eneji, Z. Li, X. Tian and L. Duan. 2010. Coronatine alleviates water deficiency stress on winter wheat seedlings. J. Integr. Plant Biol., 52: 616-625.

Lindsay W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J., 42: 421-428.

Lukacova Kulikova Z. and A. Lux .2010. Silicon influence on maize, *Zea mays* L., hybrids exposed to lead treatm ent. Bull. Environ. Contam. Toxicol., 85: 243-250.

Mahler R.J., F.T. Bingham and A.C. Chang .1981. Effect of heavy metal pollution on plants. Applied Science, 1:72-109.

Mohammad M., S. Maitra, N. Ahmad, A. Bustam, T.K. Sen and B.K. Dutta .2010. Metal ion removal from aqueous solution using physic seed hull. *J. Hazard. Mater.,* 179: 363-372.

Otieno D.O., M.W. Schmidt, S. Adiku and J. Tenhunen .2005. Physiological and morphological responses to water stress in two *Acacia* species from contrasting habitats. *Tree Physiol.,* 25: 361-371.

Piotrowska A., A. Bajguz, B. Godlewska-Zylkiewicz and E. Zambrzycka .2010. Changes in growth, biochemical components, and antioxidant activity in aquatic plant *Wolffia arrhiza* (Lemnaceae) exposed to cadmium and lead. Arch. Environ. Contam.Toxicol., 58: 594-604.

Piper O.S. 1947. Soil and plant Analysis. Adelaite University, Adelaide , Australia , 258-275.

SAS Institute .2002. SAS User Guide and Program 20 Version 9.0.38. Cary, North Carolina, USA.

Sharma B.D., S.S. Mukhopadhyay and J.C. Katyal .2006. Distribution of total and DTPA- extractable zinc, copper, manganese and iron in vertisols of India. Commun Soil Sci Plant Anal., 37: 653-672.

Simmons R.W., P. Pongsakul and D. Saiyasitpanich .2005. Elevated levels of cadmium and zinc in paddy soils and elevated levels of cadmium in rice grain downstream of zinc mineralized area in Thailand: implications for public health. Environmental Geochemistry and Health, 27:501-511.

Snedecor, G. W. and W. Cochran .1989. Statistical Methods, 8^{th} ed. Edition, Iowa State University Press. Ames. Iowa. USA.

Talebi M., E. Hadavi and N. Jaafari. 2014. Foliar sprays of citric acid and malic acid modify growth, flowering, and root to shoot ratio of Gazania (*Gazania rigens* L.): A Comparative Analysis by ANOVA and Structural Equations Modeling. Adv. Agric. Article ID, 147278: 1-6.

Tiryakioglu M., S. Eker, F. Ozkutlu, S. Husted and I. Cakmak .2006. Antioxidant defense system and lead uptake in barley genotypes differing in lead tolerance. J. Trace Elem. Med. Biol., 20: 181-189.

Unhalekhana U., and C. Kositanont. 2008. Distribution of lead in soil around zinc mining area. Thai Journal of Toxicology, 23: 170-174.

Wills R., T. Lee, D. Graham, W. McGlasson and E. Hall .1981. Post-harvest: an introduction to the physiology and handling of fruit and vegetables. Kensington, NSW, New South Wales Univ. Press.

Wua G., H. Kanga, X. Zhangc, H. Shaob, L. Chuc and C. Ruand.2010. A critical review on the bio-removal of hazardous heavy metals from contaminated soils: Issues, progress, eco-environmental concerns and opportunities. J. Haz. Mat., 174: 1-8.

Yadava U. 1986. A rapid and nondestructive method to determine chlorophyll in intact leaves. Hort. Sci., 21(6): 1449-1450.

الملخص العربي

إستجابة نباتات اللانتانا للرش بحمض الستريك لتقليل الأثر الضار للتلوث بالعناصر الثقيلة فى ماء الرى (أ) تأثير الكادميوم

نادر أحمد الشنهورى، عمر نبيل إمام

أجريت هذه الدراسة في فرع البحوث بأنطونيادس، معهد بحوث البساتين، مركز البحوث الزراعية – الإسكندرية، مصر خلال الموسمين المتتاليين ٢٠١٨ و٢٠١٩. وتهدف الدراسة تقييم آثار الري بمياة ملوثة بالكادميوم على نمو نباتات اللانتانا المزروعة في تربة رملية، كذلك إمكانية استخدام الرش بحمض الستريك للتغلب على الآثار الضارة للكادميوم. ولتحقيق ذلك زرعت شتلات اللانتانا بشكل فردي في أوعية بلاستيكية (قطرها ٢٠ سم) مملوءة ٥ كجم من التربة الرملية. وكانت معاملات مياه الري الملوثة بأربعة تراكيزات من الكادميوم وهى صفر، ١٠٠، ٢٠٠، ٣٠٠ مليجرام/ لتر. تم رش النباتات شهريا أيضا بحامض الستريك بإستخدام ثلاث تركيزات هى صفر، ٢٥٠ و٥٠٠ مليجرام/ لتر في كلا الموسمين.

أظهرت نتائج الدراسة أن هناك اختلاف كبير في التفاعل بين تركيزات الكادميوم ورش النباتات بحامض الستريك. وقد وجد انخفاض كبير في كافة معاملات الري بالماء الملوث بالكادميوم وكذلك لوجظ زيادة كبيرة فى معدلات النموالخضرى بعد الرش٢٥٠ مليجرام/ لتر حمض الستريك. تم الحصول على أعلى قيمة من محتوى الكلوروفيل والكربوهيدرات من النباتات المروية بماء الصنبور والرش بتركيز ٥٠٠ مليجرام/ لتر حامض الستريك في حين أن أعلى تركيز من الكادميوم في الأوراق والساق والجذور من خلال الرى بماء ملوث بتركيز ٣٠٠ مليجرام/ لتر من الكادميوم بدون الرش بحمض الستريك.