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RESPONSE OF *Lantana camara var.* Nana PLANTS TO FOLIAR APPLIED MALIC ACID FOR DECREASING THE HARMFUL EFFECT OF LEAD POLLUTION IN THE IRRIGATION WATER

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By

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ABSTRACT

The present study was carried-out at Antoniades Research Branch, Horticultural Research Institute, A.R.C. Alexandria, Egypt during the two successive seasons of 2017 and 2018. The aim of the study was to evaluate the effects of irrigation water contaminated with lead on *Lantana camara* var. Nana plants and the possibility of using malic acid spray treatments to alleviate the effects of lead pollution. Seedlings of *Lantana camara* var. Nana were planted individually in plastic pots (20 cm diameter) filled with 6 kg of mixture soil (sand and clay (1:1)). The leadcontaminated irrigation water treatments were 0,100, 200 and 300 ppm. The plants were monthly sprayed with malic acid at concentrations of 0, 250 and 500 ppm. The results showed that for vegetative growth parameters there, was no significant difference in the interaction between lead concentrations and foliar spray by malic acid. While a significant reduction was observed in all parameters after irrigation with lead contaminated water, and a significant increase in vegetative growth parameters was observed after 250 ppm malic acid application. For chlorophyll and carbohydrate content, the highest significant value were obtained from plants irrigated with tap water and sprayed with 500 ppm malic acid. While the highest significant amount of lead content in leaves, stem and roots were obtained from the treatment 300 ppm lead without application of malic acid.

Key wards: *Lantana camara var.Nana, lead, malic acid.*

1. INTRODUCTION

Lantana camara shrub is found mostly in South India, sub-tropical and tropical America and 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 are opposite on both sides. Lantana flowers are small, generally orange but often vary in colors from white to dark red, which are prominently capitates in heads; bracts are conspicuous and persistent. Lantana fruits are small, 5 mm diameter, drupaceous and shining, blue, greenish, blackish, with two nutlets within. Lantana seeds are 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 2 m in height and forms a variety of habitats. Due to extensive selective breeding throughout the 17^{th} and 18^{th} century for use as an ornamental plant, there are now many forms of *Lantana camara* present throughout the world (Ashwini *et al.*, 2014).

Plants need trace amount of heavy metal but their excessive availability may cause plant toxicity (Sharma *et al*., 2006). Phytotoxic concentration of the heavy metals referred in the literature does not always specify the levels (Wua *et al*., 2010). Lead is a toxic heavy metal that has an environmental concern (Mahler *et al.*, 1981). There are many sources of environmental lead pollution including fuel combustion, industrial sludges, phosphate fertilizers, and mine tailings (Unhalekhana and Kositanont, 2008).

Malic acid is one of the most common low molecular weight organic acids in root exudates. Root-exuded organic acids are important mechanism in response to environment stress (Jones, 1998). Recently, many studies revealed that the amount of root-exuded organic acids increase under nutrient stress to increased nutrient availability (Dakora and Phillips, 2002). Malic acid is metabolized in plant mitochondria by reaction of malic enzymes, (Talebi *et al*., 2014). Malate is a common reserve anion playing a role in the plant vacuole as counter ion for K and Ca (Darandeh and Hadavi, 2012).

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

2. MATERIALS AND METHODS

The present study was carried-out at Antoniades Research Branch, Horticultural Research Institute, A.R.C. Alexandria, Egypt, during the two successive seasons of 2017 and 2018. The aim of this study was to evaluate the effects of irrigation water contaminated with lead on *Lantana camara* var. Nana plants grown in a mixture of sand and clay1:1(v/v), as well as, the possibility of using malic acid spray treatments to overcome the effects of lead pollution.

On the 15th of February, in both seasons of 2017 and 2018, identical seedlings of *Lantana camara* var. Nana (15-20 cm height with about 10-15 leaves) were individually planted in plastic pots (20 cm diameter) filled with 6 kg of soil mixture (sand and clay1:1(v/v)). The chemical composition of the mixture was measured as described by Jackson (1958) and presented in Table (A).

On the 1st of March (in both seasons), the contaminated irrigation water treatments were initiated, using concentrations of lead (II) acetate ($Pb(CH_3COO)_2$) 0,100, 200 and 300 ppm. The plants were irrigated three times a week; at the end of the experiment every plant received about 85 liters cumulative amount per pot of contaminated water in Table (B). In both seasons, the plants received monthly spraying from 15th May till 15th August. The plants were also sprayed with malic acid at concentrations of 0, 250 and 500 ppm. Control plants were sprayed with tap water. The plants were harvested on 30th of September in the both seasons,.

In the two seasons, all plants received NPK chemical fertilization using (Kristalon 19-19-19) at the rate of 1.5 g/ pot, and it 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)**, stem diameter (cm), stem dry weight (g), root length (cm) and root dry weight (g).

(2) Chemical analysis determination:

- Total chlorophylls contents were determined as a SPAD from 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 carbohydrates percentage in the leaves was determined according to Dubios *et al*.(1956).
- Determination of lead content: Plant parts were individually sperated into leaves, stem and roots, then dried at 72°C in an oven until

Table (A): The chemical properties of the used soil mixture for the two seasons 2017 and 2018.

Season	pH	EC ds/m	Cations (meq/l)				Anions (meq/l)		
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
2017	**8.08**	**2.53**	18.20	14.20	23.91	4.49	7.20	21.00	27.10
2018	**8.17**	**2.35**	18.09	14.11	23.53	4.38	7.11	20.75	25.87

Table (B): The total and cumulative amount of the water used for each plant (l/pot) in each treatment during the two growing seasons of 2017 and 2018, under F.C. of 90%.

Field capacity (%)	Months of growing seasons							
	March	April	May	June	July	August	September	Total
90 %	9.50	10.00	10.50	11.50	13.50	15.50	14.50	**85.00**

constant weight. The dried plant samples were grounded. The dried samples were then digested for extraction of lead, using the method described by Piper (1947) and the concentration of lead in the samples was determined using an atomic absorption spectrophotometer.

- Available heavy metal (Lead) contents in soil samples were extracted by DPTA solution according to Lindsay and Norvell (1978) and determined by Inductively Coupled Plasma Spectrometry.
- Transfer factor (TF) is given calculated as: the ratio of the concentration lead the shoots to the concentration of lead in the soil (Chen *et al*., 2004). The transfer factor is a value used in evaluation studies on the impact of routine or accidental releases of pollutant into the environment.

The experimental design was split plot with three replicates, each replicate contained three plants. The main plot was lead treatments, while the subplot was malic acid treatments. Data were subjected to analysis of variance (ANOVA) using the SAS program, **(**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).

3. RESULTS

3.1. Vegetative growth:

3.1.1. Plant height and leaf parameters

Data presented in Table (1) showed that in both seasons, irrigating *Lantana camara* var. Nana plants with water contaminated with lead decreased the leaf parameters. Plants irrigated with the lowest lead concentration (100 ppm) had the highest mean values of plant height (32.66 and 38.58 cm), number of leaves per plant (98.83 and 98.88), leaves dry weight (1.91 and 2.26 g) and leaf area (472.62 and 327.29 cm^2) in the first and the second seasons, respectively. Moreover, raising lead concentration caused steady significant reductions in leaf parameters, as the highest concentration (300 ppm) resulted significantly in the shortest plants (29.13 and 35.00 cm), the least number of leaves per plant (88.22 and 88.38), leaves dry weight (1.70 and 2.05 g) and the smallest leaves area (292.66 and 251.97 cm^2) in the first and the second seasons, respectively.

Leaf parameters were significantly affected by spraying the plants with malic acid. In both seasons, plant height of *Lantana camara* var. Nana increased with the treatment of malic acid it 250 ppm. Accordingly, it can be seen from the data in Table (1) that *Lantana camara* var. Nana plants sprayed with 250 ppm malic acid were significantly the tallest (31.58 and 37.58 cm), with the highest number of leaves per plant (95.58 and 95.99), the heaviest leaves dry weight (1.85 and 2.20 g) and with the largest leaves area (412.67 and 298.99 cm^2) in the first and the second seasons, respectively.

Regarding the interaction between the effects of irrigation with lead-contaminated water and malic acid treatments on plant height and leaves parameters of *Lantana camara* var. Nana plants, the results recorded in the two seasons show that, the highest values were obtained in the plants irrigated with lead at 100 ppm and sprayed with malic acid at 250 ppm with mean values of plant height (33.33 and 39.33 cm), number of leaves per plant (100.83 and 101.16), leaves dry weight per plant (1.95 and 2.31 g) and leaves area per plant (546.35 and 337.41 cm^2) in the first and second seasons, respectively. On the other hand, the shortest plants with (28.66 and 34.50 cm), the lowest number of leaves per plant (86.83 and 86.66), the lowest leaves dry weight (1.67 and 2.02 g) and the smallest leaves area (269.54 and 240.98 cm^2) in the first and second seasons, respectively, were recorded when *Lantana camara* var. Nana plants were irrigated with lead at (300 ppm) alone, without malic acid treatment, but in many cases, spraying the plants with malic acid reduced the undesirable effect of contaminated water with lead on these traits or parameters.

3.1.2. Stem and root parameter

The data recorded for the stem and root parameters of *Lantana camara* var. Nana plants in the two seasons (Table 2) showed that irrigation with lead-contaminated water decreased stem and root parameters, compared to that of plants irrigated with tap water (control). In both seasons, plants irrigated with tap water had the thickest stem (0.53 and 0.71 cm), with the heaviest stem dry weight (3.19 and 5.20 g), the longest roots (16.82 and 20.15 cm) as well as the heaviest root dry weight (2.16 and 3.52 g), respectively. On the other hand, raising lead concentration in irrigation water caused a steady reduction in stem and root parameters. This reduction was significant (compared to the

Table (1): Means of plant height (cm), number of leaves per plant, leaves dry weight (g) and leaves area (cm^2) of *Lantana camara* var. Nana plants as influenced by lead (Pb), Malic acid (MA) and their combinations (Pb× MA) in the two seasons of 2017 and 2018.

Treatments		**Plant height (cm)**		**Number of leaves per plant**		**Leaves dry weight (g)**		**Leaves area (cm^2)**	
Lead (ppm)	**Malic acid (ppm)**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
0	0	31.00	36.83	93.83	93.33	1.81	2.20	392.21	286.10
	250	32.66	38.66	98.83	99.16	1.92	2.25	410.32	296.55
	500	31.33	37.25	94.83	94.66	1.83	2.17	410.01	291.94
Mean (Pb)		**31.66**	**37.58**	**95.83**	**95.71**	**1.85**	**2.20**	**404.18**	**291.53**
100	0	32.00	37.83	96.83	96.50	1.87	2.21	420.43	311.94
	250	33.33	39.33	100.83	101.16	1.95	2.31	546.35	337.41
	500	32.66	38.58	98.83	99.00	1.91	2.26	451.08	332.53
Mean (Pb)		**32.66**	**38.58**	**98.83**	**98.88**	**1.91**	**2.26**	**472.62**	**327.29**
200	0	29.50	35.33	89.33	89.33	1.73	2.11	361.80	266.69
	250	30.75	36.83	93.16	93.66	1.80	2.15	369.22	296.51
	500	30.41	36.25	92.16	92.33	1.77	2.12	367.23	274.64
Mean (Pb)		**30.22**	**36.13**	**91.55**	**91.77**	**1.76**	**2.12**	**366.08**	**279.28**
300	0	28.66	34.50	86.83	86.66	1.67	2.02	269.54	240.98
	250	29.58	35.50	89.50	90.00	1.73	2.09	324.80	265.52
	500	29.16	35.00	88.33	88.50	1.70	2.05	283.66	249.42
Mean (Pb)		**29.13**	**35.00**	**88.22**	**88.38**	**1.70**	**2.05**	**292.66**	**251.97**
Mean (MA)	0	30.29	36.12	91.70	91.45	1.77	2.13	360.99	276.42
	250	31.58	37.58	95.58	95.99	1.85	2.20	412.67	298.99
	500	30.89	36.77	93.53	93.62	1.80	2.15	377.99	287.13
L.S.D. at 0.05	**Pb**	**0.54**	**0.53**	**1.68**	**1.65**	**0.03**	**0.02**	**49.37**	**38.85**
	MA	**0.64**	**0.65**	**1.95**	**1.88**	**0.04**	**0.04**	**26.80**	**25.96**
	Pb × MA	**0.74**	**0.74**	**2.25**	**2.16**	**0.04**	**0.05**	**30.80**	**29.84**

control), even at the highest lead concentration (300 ppm), which gave stem diameter (0.42 and 0.57 cm), stem dry weight (2.50 and 4.01 g), root length (15.00 and 18.29 cm) and root dry weight (1.69 and 2.71 g) in the first and the second seasons, respectively.

In contrast to the effect of lead treatments, malic acid treatments improved stem and root parameters of *Lantana camara* var. Nana plants, compared to the control. Moreover, plants sprayed with 250 ppm malic acid had significantly higher means of stem diameter (0.48 and 0.66 cm), stem dry weight (2.96 and 4.76 g), root length (16.27 and 19.57 cm) and root dry weight (2.00 and 3.22 g) in the first and second seasons, respectively, compared to those of control plants, or plants sprayed with any other malic acid concentration.

Regarding the interaction between the effects of irrigation with lead contaminated water and malic acid treatments on stem and root parameters of *Lantana camara* var. Nana plants, the results recorded in the two seasons (Table 2) showed significant differences among the values obtained from the different treatment combinations. The highest values of stem diameter (0.58 and 0.76 cm), stem dry weight (3.64 and 5.64 g), root length (17.17 and 20.50 cm) and root dry weight (2.47 and 3.82 g) in the first and second seasons, respectively, were obtained in the plants irrigated with tap water and sprayed with malic acid at 250 ppm. On the other hand, the lowest values of stem diameter (0.38 and 0.56 cm), stem dry weight (2.22 and 3.76 g), root length (14.76 and 18.05 cm) and root dry weight (1.51 and 2.54 g) in the first and second seasons, respectively, were obtained with lead at 300 ppm without malic acid treatment. It can also been seen from the data presented in Table (2) that in many cases, spraying the plants with malic acid alleviated the undesirable effects of lead, in irrigation water.

3.1.3. Flowers number per plant

Data presented in (Table 3) showed that, in both seasons, decreased with irrigation water contaminated with lead the flowers number of *Lantana camara* var. Nana plants. Plants irrigated with the lowest lead concentration (100 ppm) produced the highest number of flowers (19.44 and 27.05) in the first and the second seasons, respectively, but, raising lead concentration, in irrigation water caused steady significant reduction in flowers number per plant as the highest lead concentration (300ppm)

Table (2): Means of stem diameter (cm), stem dry weight (g), root length (cm) and root dry weight (g) of *Lantana camara* var. Nana plants as influenced by lead (Pb), Malic acid (MA) and their combinations (Pb × MA) in the two seasons of 2017 and 2018.

Treatments		Stem diameter (cm)		Stem dry weight (g)		Root length (cm)		Root dry weight (g)	
Lead (ppm)	**Malic acid (ppm)**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
000	0	0.50	0.68	2.91	4.93	16.48	19.80	1.97	3.34
	250	0.58	0.76	3.64	5.64	17.17	20.50	2.47	3.82
	500	0.51	0.70	3.02	5.04	16.83	20.15	2.04	3.41
Mean (Pb)		**0.53**	**0.71**	**3.19**	**5.20**	**16.82**	**20.15**	**2.16**	**3.52**
100	0	0.46	0.65	2.61	4.11	15.97	19.27	1.77	2.79
	250	0.48	0.66	2.79	4.57	16.83	20.14	1.89	3.10
	500	0.48	0.66	2.64	4.20	16.14	19.45	1.79	2.84
Mean (Pb)		**0.47**	**0.65**	**2.68**	**4.29**	**16.31**	**19.62**	**1.81**	**2.91**
200	0	0.45	0.63	2.43	3.79	15.20	18.49	1.65	2.57
	250	0.46	0.65	2.71	4.42	15.84	19.14	1.84	3.00
	500	0.46	0.65	2.56	3.97	15.67	18.97	1.74	2.69
Mean (Pb)		**0.45**	**0.64**	**2.56**	**4.06**	**15.57**	**18.86**	**1.74**	**2.75**
300	0	0.38	0.56	2.22	3.76	14.76	18.05	1.51	2.54
	250	0.43	0.58	2.71	4.42	15.24	18.53	1.83	2.99
	500	0.45	0.58	2.58	3.85	15.02	18.31	1.75	2.61
Mean (Pb)		**0.42**	**0.57**	**2.50**	**4.01**	**15.00**	**18.29**	**1.69**	**2.71**
Mean (MA)	0	0.44	0.63	2.54	4.14	15.60	18.90	1.72	2.81
	250	0.48	0.66	2.96	4.76	16.27	19.57	2.00	3.22
	500	0.47	0.64	2.70	4.26	15.91	19.22	1.83	2.88
L.S.D. at 0.05	**Pb**	**0.04**	**0.04**	**0.22**	**0.79**	**0.27**	**0.28**	**0.15**	**0.53**
	MA	**0.03**	**0.02**	**0.12**	**0.44**	**0.33**	**0.34**	**0.08**	**0.29**
	Pb × MA	**0.03**	**0.02**	**0.14**	**0.50**	**0.38**	**0.38**	**0.09**	**0.34**

Table (3): Means of flower number per plant of *Lantana camara var.* Nana plants as influenced by lead (Pb), Malic acid (MA) and their combinations (Pb × MA) in the two seasons of 2017 and 2018.

Treatments		Flower number per plant	
Lead (ppm)	**Malic acid (ppm)**	**2017**	**2018**
000	0	19.00	25.83
	250	20.00	27.16
	500	19.16	26.00
Mean (Pb)		**19.38**	**26.33**
100	0	19.50	26.33
	250	20.33	27.83
	500	20.00	27.00
Mean (Pb)		**19.94**	**27.05**
200	0	18.00	24.66
	250	18.83	25.50
	500	18.66	25.33
Mean (Pb)		**18.49**	**25.16**
300	0	17.33	24.16
	250	18.16	24.66
	500	17.83	24.50
Mean (Pb)		**17.77**	**24.44**
Mean (MA)	0	18.45	25.24
	250	19.33	26.28
	500	18.91	25.70
L.S.D. at 0.05	**Pb**	**0.24**	**0.40**
	MA	**0.47**	**0.51**
	Pb × MA	**0.54**	**0.58**

significantly produced the lowest number of flowers per plant (17.77 and 24.44) in the first and second seasons, respectively.

Flowers number per plant was also significantly affected by spraying the plants with malic acid. In both seasons, flower number increased gradually when the malic acid concentration was raised from 0 ppm (control) to 250 ppm, in (Table 3) as *Lantana camara* var. Nana plants sprayed with 250 ppm malic acid significantly formed the highest number of flowers per plant (19.33 and 26.28) in the first and second seasons, respectively.

Regarding the interaction between the effects of irrigation with contaminated lead water and malic acid treatments on flowers number of *Lantana camara* var. Nana plants, the results in both seasons, showed that, the highest values were (20.00 and 27.16), obtained in the plants irrigated with tap water and sprayed with malic acid at 250 ppm, respectively. On the other hand, the minimum number of flowers (17.33 and 24.16) in the first and second seasons, respectively, was obtained with highest lead concentration (300 ppm) without malic acid treatment, it can also revealed that in many cases, spraying the plants with malic acid reduced the undesirable effect of contaminated water with lead.

3.2. Chemical constituents

3.2.1. Total chlorophylls (SPAD) and Carbohydrates content (% D.W)

The results presented in Table (4) showed that the highest content of total chlorophylls was obtained in plants irrigated with tap water (54.84 and 55.32 SPAD) and carbohydrates (18.64 and 18.81% D.W) in the first and the second seasons, respectively. Raising lead concentration in irrigation water resulted in steady sign

ificant reductions in the total chlorophylls and carbohydrates content, which reached its lowest values (49.43 and 50.14 SPAD) and (16.80 and 17.05 % D.W) in the first and the second seasons, respectively, in plants receiving the highest lead concentration 300 ppm.

The results of leaf chemical analysis (Table 4) also showed that malic acid treatments had clear effect on the total chlorophyll and carbohydrates content. The highest contents of total chlorophyll (54.51 and 54.97 SPAD) and carbohydrates (18.53 and 18.69 % D.W) in the first and the second seasons, respectively, in plants sprayed with malic acid at 500 ppm.

Regarding the interaction between the effects of irrigation using water contaminated with lead and malic acid treatments, the data presented in Table (4) showed that the highest total chlorophylls contents (56.50 and 56.87 SPAD) and carbohydrates (19.21 and 19.34 % D.W) in the first and the second seasons, respectively, were found in leaves of plants irrigated with tap water and sprayed with malic acid at 500 ppm and the corresponding lowest values (46.70 and 47.73 SPAD) and (15.88 and 16.23 % D.W) were obtained with lead at 300 ppm without malic acid treatment.

3.2.2. Lead content in leaves, stems and roots (ppm)

Data in Table (4) showed that lead content in the dried leaves of *Lantana camara* var. Nana plants increased steadily with increasing lead concentration in irrigation water. The lowest lead content in leaves (0.536 and 1.035 ppm), in stem (1.525 and 2.024 ppm) and in root (0.785 and 1.054 ppm) in the first and second seasons, respectively, were found in control plants, whereas the corresponding highest values in leaves (3.088 and 3.613 ppm), in stem (4.103 and 4.625 ppm) and in root (2.114 and 2.383

Table (4): Means of chemical constituents characteristics of *Lantana camara* var. Nana plants as influenced by lead (Pb), Malic acid (MA) and their combinations (Pb×MA) in the two seasons of 2017 and 2018.

Treatments		**Chlorophyll content (SPAD)**		**Carbohydrates content (%)**		**Lead content in leaves (ppm)**		**Lead content in stem (ppm)**		**Lead content in roots (ppm)**	
Lead (ppm)	Milk acid (ppm)	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
000	0	53.18	53.89	18.08	18.32	0.783	1.309	1.797	2.253	0.926	1.195
	250	54.85	55.21	18.65	18.77	0.517	1.041	1.532	2.053	0.789	1.058
	500	56.50	56.87	19.21	19.34	0.309	0.756	1.247	1.768	0.642	0.911
Mean (Pb)		**54.84**	**55.32**	**18.64**	**18.81**	**0.536**	**1.035**	**1.525**	**2.024**	**0.785**	**1.054**
100	0	49.34	49.72	16.78	16.90	1.590	2.114	2.605	3.026	1.342	1.610
	250	54.31	55.04	18.47	18.72	1.528	2.052	2.543	2.997	1.310	1.579
	500	56.08	56.45	19.07	19.19	1.383	1.908	2.398	2.885	1.235	1.504
Mean (Pb)		**53.24**	**53.73**	**18.10**	**18.27**	**1.500**	**2.024**	**2.515**	**2.969**	**1.295**	**1.054**
200	0	47.74	48.75	16.23	16.58	2.830	2.821	3.845	3.833	1.981	1.975
	250	52.75	53.12	17.94	18.06	2.721	2.712	3.736	3.724	1.925	1.919
	500	53.66	54.05	18.24	18.38	2.656	2.677	3.668	3.689	1.890	1.901
Mean (Pb)		**51.38**	**51.97**	**17.47**	**17.67**	**2.735**	**2.736**	**3.749**	**3.748**	**1.932**	**1.931**
300	0	46.70	47.73	15.88	16.23	3.192	3.717	4.207	4.728	2.167	2.437
	250	49.78	50.16	16.92	17.06	3.042	3.566	4.057	4.578	2.090	2.359
	500	51.83	52.53	17.62	17.86	3.032	3.557	4.047	4.569	2.086	2.354
Mean (Pb)		**49.43**	**50.14**	**16.80**	**17.05**	**3.088**	**3.613**	**4.103**	**4.625**	**2.114**	**2.383**
Mean (MA)	0	49.24	50.02	16.74	17.00	2.098	2.490	3.113	3.460	1.604	1.804
	250	52.92	53.38	17.99	18.15	1.952	2.342	2.967	3.338	1.528	1.728
	500	54.51	54.97	18.53	18.69	1.845	2.224	2.840	3.227	1.463	1.667
L.S.D. at 0.05	**Pb**	**0.51**	**0.49**	**0.17**	**0.17**	**0.310**	**0.292**	**0.286**	**0.253**	**0.147**	**0.150**
	MA	**0.38**	**0.37**	**0.13**	**0.12**	**0.313**	**0.287**	**0.330**	**0.260**	**0.170**	**0.148**
	Pb× MA	**0.44**	**0.43**	**0.15**	**0.14**	**0.360**	**0.329**	**0.378**	**0.308**	**0.195**	**0.169**

ppm) were recorded in the plants irrigated with the highest lead concentration 300 ppm.

Concerning the effect of malic acid treatments on lead content in leaves, the data recorded in the two seasons (Table 4) showed the high level of malic acid (500 ppm) was the only treatment that caused a significant decrease in lead content in leaves (1.845 and 2.224 ppm), in stems (2.840 and 3.227 ppm) and in roots (1.463 and 1.667 ppm) in the first and the second seasons, respectively, compared to that of control plants with the highest lead content in leaves (2.098 and 2.490 ppm), in stems (3.113 and 3.460 ppm) and in root (1.604 and 1.804 ppm) in the first and the second seasons, respectively.

Concerning the interaction between the effects of irrigation using water contaminated with lead and malic acid treatments on lead content in different plant parts, the results in (Table 4) showed that the lowest values of lead content in leaves (0.309 and 0.756 ppm), in stems (1.247 and 1.768 ppm) and in root (0.642 and 0.911 ppm) in the first and the second seasons, respectively, were obtained in the plants irrigated with tap water and sprayed with malic acid at 500 ppm. On the other hand, the highest lead content in the plant parts were obtained with the treatment of lead at 300 ppm without malic acid application giving (3.192 and 3.717 ppm), in stems (4.207 and 4.728 ppm) and in roots (2.167 and 2.437 ppm).

Table (5): Average of lead content in soil samples as influenced by lead concentration in water irrigation and foliar application of malic acid on *Lantana camara* var. Nana in the two seasons of 2017 and 2018.

Treatments		Lead content in soil (ppm)	
Lead (ppm)	Malic acid (ppm)	2017	2018
0	0	0.435	0.492
	250	0.361	0.419
	500	0.280	0.341
100	0	0.935	0.994
	250	0.887	0.956
	500	0.868	0.927
200	0	1.695	1.754
	250	1.545	1.624
	500	1.446	1.505
300	0	2.194	2.253
	250	2.123	2.192
	500	2.064	2.123

3.3. Transfer factor (TF) of lead

Transfer factor (TF) indicates the efficiency of plants to transfer metals from root to the aerial parts, which is calculated as the ratio between metal concentration in different plant parts to the metal concentration in the soil **(Chen *et al.*, 2004)**.

3.3.1. Lead content in soil samples (ppm)

Data in Table (5) showed that the lowest average of lead content was observed in the soil cultured by untreated plants, while the highest average of lead content was observed in the soil after the treatment 300 ppm lead and 0 ppm malic acid.

3.3.2. Transfer factors

From the data presented in Table (6), it can be seen that the transfer factor in the different dried plant parts of *Lantana camara* var. Nana was decreased steadily with raising lead concentration in irrigation water. Accordingly, the lowest lead value in the leaves (1.445 and 1.655 ppm), in stem (1.929 and 2.119 ppm) and in root (0.993 and 1.091 ppm) was found in plants irrigated with water containing lead concentration 300 ppm, whereas the highest value in leaves (1.755 and 2.453 ppm), in stem (4.275 and 4.887 ppm) and in root (2.201 and 2.541 ppm) was found in plants irrigated with tap water (control). So, the transfer factor in the dried plant parts (Table 6) was reduced steadily with raising malic acid concentration. Accordingly, the highest lead value in the leaves (1.665 and 2.010 ppm), in stems (2.775 and 2.976 ppm) and in roots (1.429 and 1.563 ppm) was recorded in the leaves of control plants, whereas plants sprayed with the highest malic acid concentration 500 ppm had the lowest lead value in the leaves (1.500 and 1.932 ppm), in stems (2.927 and 3.224 ppm) and in roots (1.507 and 1.666 ppm).

4.DISCUSSION

This study revealed that at high heavy-metal concentrations, the plant height was significantly reduced, and the biomass was decreased. The root growth was more sensitive than other parameters, as roots rapidly absorbed water and had higher accumulations of heavy metal elements. The results presented in this study were in agreement with earlier reports on other plants, such as aquatic plant *wolffia arrhiza* (Piotrowska *et al.*, 2010), barley *Hordeum vulgare* (Tiryakioglu *et al.*, 2006) and *Typha*

Table (6): Means of transfer factor to leaves, stem and roots of *Lantana camara* var. Nana plants as influenced by lead (Pb), Malic acid (MA) and their combinations (Pb ×MA) in the two seasons of 2017 and 2018.

Treatments		Transfer factor to leaves (TFL)		Transfer factor to stem (TFS)		Transfer factor to root (TFR)	
Lead (ppm)	Malic acid (ppm)	2017	2018	2017	2018	2017	2018
000	0	1.669	2.660	4.131	4.579	2.128	2.428
	250	1.761	2.484	4.243	4.899	2.185	2.525
	500	1.836	2.217	4.453	5.184	2.292	2.671
Mean (Pb)		**1.755**	**2.453**	**4.275**	**4.887**	**2.201**	**2.541**
100	0	1.700	2.126	2.786	3.044	1.435	1.619
	250	1.722	2.169	2.866	3.168	1.476	1.669
	500	1.593	2.058	2.762	3.112	1.422	1.622
Mean (Pb)		**1.671**	**2.117**	**2.804**	**3.108**	**1.444**	**1.636**
200	0	1.454	1.608	2.268	2.185	1.168	1.125
	250	1.432	1.690	2.418	2.321	1.245	1.196
	500	1.468	1.778	2.536	2.451	1.307	1.263
Mean (Pb)		**1.451**	**1.692**	**2.407**	**2.319**	**1.240**	**1.194**
300	0	1.800	1.649	1.917	2.098	0.987	1.081
	250	1.432	1.641	1.910	2.107	0.984	1.086
	500	1.103	1.675	1.9607	2.152	1.010	1.108
Mean (Pb)		**1.445**	**1.655**	**1.929**	**2.119**	**0.993**	**1.091**
Mean (MA)	0	1.655	2.010	2.775	2.976	1.429	1.563
	250	1.586	1.996	2.859	3.123	1.472	1.619
	500	1.500	1.932	2.927	3.224	1.507	1.666

angustifolia (Bah *et al.*, 2011). Other studies with woody plant reported a high 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 and Jamil *et al*., 2009). Additionally, the plant seedlings exhibited a high root/shoot ratio. 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 and Lux, 2010 and Li *et al.*, 2010).

Plants can tolerate lead either by external exclusion or internal tolerance. By the external exclusion, lead ions are excluded from entering the plant cells and thus lead cannot accumulate in the organelles and excess lead ions are removed out of the plant cell (Sharma and Dubey 2005). The internal tolerance of lead is mainly due to the synthesis of organic lead compounds (cysteine, glutathione, phytochelatin, etc) and eventually lead ions are transformed in the cell into chemically bound structures with lower toxicity, alleviating the Pb toxic effect on the plants tissues (Pourrut *et al.*, 2011). Lead can damage the ultrastructures of the organs, tissues, chloroplast, mitochondria, nucleus, cell wall, and cell membrane in the plants. This damage can cause a loss of organelle function, and can eventually affect the normal physiological functions that include photosynthesis, respiration, protein synthesis, cell division within the plant species **(**Salazar and Pignata, 2014).

Concerning the treatments and the control samples, at a preliminary stage, one should note that the transfer factor of most treatments is lower than one for lead; which means that the physiological need of the plant for these elements is rather limited.

In malic acid, while there were no significant differences between the applied concentrations, but in the root, fresh weight, and root dry weight, we see that only the higher concentration is considered significantly different from the control. When comparing with earlier reports, here we observe more similarity between responses of selected traits to organic acids. In some traits, the lower concentration gave good results that give us the idea of possible distinct patterns of response to concentration of applied organic acids. Therefore, we suggest testing both lower and higher concentrations of these organic acids to reach a better understanding in this regard (Talebi *et al.,* 2014). Malic acid spray increased chlorophyll content significantly. Chlorophyll content was the highest in plants treated with malic acid alone with SPAD reading compared with the control. All factor-levels containing malic acid had significantly higher chlorophyll content compared with the control (Darandeh and Hadavi, 2012).

Conclusions

The concentrations of heavy metals increase in the environment from year to year**.** Therefore decontamination of heavy metal-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 the contaminated areas. This green technology can be applied to remediate the polluted soils without creating any destructive effect of soil structure or parameters. 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 heavy metals using non-edible plant like *Lantana camara* var. Nana offers an environmental friendly and cost-effective method for remediating the polluted soil. *Lantana camara* var. Nana was found to be able to efficiently remove the heavy metals such as lead.

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إستجابة نباتات اللانتانا للرش بحمض الماليك لتقليل الأثر الضار للتلوث بالرصاص فى ماء الرى

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ملخص

أجريت هذه الدراسة في فرع البحوث بأنطونيادس، معهد بحوث البساتين، مركز البحوث الزراعية - الإسكندرية، مصر خلال الموسمين المتتاليين 2017 و 2018. كان الهدف من هذه الدراسة تقييم آثار مياه الري الملوثة بالرصاص على نباتات اللانتانا المزروعة في تربة خليط (رمل و طمى 1:1) ، كذلك إمكانية استخدام الرش بحمض الماليك للتغلب على الآثار الضارة للرصاص. زرعت شتلات اللانتانا بشكل فردي في أوعية بلاستيكية (قطرها 20 سم) مملوءة بـ 6 كجم من التربة الخليط. وكانت معاملات مياه الري الملوثة بأربعة تراكيزات من الرصاص وهى صفر ، 100، 200 ، 300 جزء فى المليون. تم رش النباتات شهريا بحامض الماليك في ثلاث تركيزات هى صفر، 250 و 500 جزء فى المليون في كلا الموسمين. أظهرت النتائج أن هناك اختلاف كبير في التفاعل بين تركيزات الرصاص ورش النباتات بحامض الماليك. وقد لوحظ انخفاض كبير في كافة معاملات الري بالماء الملوث بالرصاص وكذلك لوجظت زيادة كبيرة فى معدلات النموالخضرى عند معاملة النباتات بـ 250 جزء فى المليون حمض الماليك. تم الحصول على أعلى قيمة من محتوى الكلوروفيل والكربوهيدرات من النباتات المروية بماء الصنبور والرش بتركيز 500 جزء فى المليون حامض الماليك في حين أن أعلى كمية كبيرة من محتوى الرصاص في الأوراق و الساق و الجذور كانت من خلال رى النباتات بماء ملوث بتركيز 300 جزء فى المليون من الرصاص بدون الرش بحمض الماليك.

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