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RESPONSE OF *Amaranthus tricolor*, L. PLANTS TO NITROGENOUS NUTRITION AND THEIR ROLE IN REMEDIATING SOME POLLUTED SOILS WITH HEAVY METALS

[17]

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ABSTRACTS

This study was carried out in pots at the Experimental Nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, during the two successive seasons of 2005 and 2006, with the aim of investigating the response of *Amaranthus tricolor*, L. plants grown in different soils including soil from Faculty of Agriculture, Cairo University as an un-polluted soil, and four different soils polluted with Ni and Zn from Al-Gabal Al-Asfar, Abou Rawash, El-Tebbin or Shobra El-Kheima to nitrogenous nutrition [7.5 or 15 gm ammonium sulphate (20.5% N)/ pot/season], and their role in remediating the polluted soils.

Both nitrogenous fertilization treatments significantly increased vegetative growth characteristics, compared to the control (in most cases). In general, raising the N level resulted in steady significant increases in these parameters and increased the leaf contents of total chlorophylls, carotenoids, anthocyanin, total carbohydrates, N, P and K, as well as Ni and Zn uptake, while steadily decreased the extractable Ni and Zn of the used soils.

In most cases, Al-Gabal Al-Asfar soil was clearly the most effective soil in promoting the growth of plants and increasing their chemical constituents (total chlorophylls, carotenoids contents, total carbohydrates, N, P and K percentages), followed by the soil of the Faculty of Agriculture. On the other hand, plants grown in Shobra El-Kheima soil gave significantly lower values for vegetative growth characteristics than the plants grown in other soils (in most cases) and the lowest concentrations of the previous chemical constituents, but gave the highest anthocyanin, Ni and Zn concentrations.

In general, the plants grown in Al-Gabal Al-Asfar soil and supplied with the highest nitrogen rate gave the highest values for most of the studied vegetative growth characteristics and chemical constituents of the plant, whereas the plants grown in Shobra El-Kheima soil and receiving no nitrogenous fertilization gave the lowest values.

It can be recommended that for the best vegetative growth of *Amaranthus tricolor*, L. plants in different tested soils, the plants should be supplied with 15 gm ammonium sulphate (20.5% N) /pot/season. This treatment gave better results for most of the studied vegetative growth parameters, as well as for most of the plant chemical constituents, and increased the ability of plants to remediate Ni polluted soils. It is worth mentioning that

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Amaranthus tricolor plants cannot remediate Zn polluted soils.

INTRODUCTION

The pollution of soils with metals is a major environmental problem throughout the world. Soils polluted with metals may threaten ecosystems and human health. So, the remediation of such soils is a challenging task because metals do not degrade and persist indefinitely in the environment. Disposal of polluted soil in landfills accounts for a large proportion of the traditional remediation techniques at present, but it is not probably economically feasible. Therefore, new technologies based on environmentally friendly and low-cost processes are urgently required (**Lombi *et al* 2001**). When categorizing plants that can grow in the presence of toxic elements, the terms "tolerant and hyperaccumulator" are used. A tolerant species is one that can grow on soil with concentrations of particular elements that are toxic to most other plants, also it is not necessarily an indicator or hyperaccumulator. Hyperaccumulators take up particularly high amounts of a toxic metal. In this respect, **Revees and Baker (2000)** stated that the thresholds for plant hyperaccumulation (shoot dry weight) were set at 1000 mg kg^{-1} Zn, 100 mg kg^{-1} Cd, 1000 mg kg^{-1} Pb. As of to date, about 400 plants that hyperaccumulate metals are reported. Plant species that hyperaccumulate high amount of toxic metal introduce a new, low-cost, and environmentally friendly technique for soil remediation; this technique is phytoremediation. The United States Environmental Protection Agency (**U.S. EPA, 1998**) described phytoremediation as the use of certain plants to clean up soil, sediment and water contaminated with metal and/or organic contaminants and defined six types of phytoremediation. It includes phytoextraction, phytodegradation, phytostabilization, phytovolatilization, rhizodegradation and rhizofiltration **Salt *et al* (1998)** defined two basic strategies of phytoextraction. The first is chelate-assisted phytoextraction, which consists of two processes: release of bound metals into soil solution combined with transport of metal to the harvestable shoot. The role of chelate is to increase the metal concentration in soil solution. The second is the continuous phytoextraction, which relies on the specialized physiological processes that allow plants to accumulate metals over the complete growth cycle. This type of metal uptake is epitomized by hyperaccumulator plants.

Amaranthus tricolor, L. is a tropical plant (summer annual plant in Egypt), which belongs to family Amaranthaceae (**Brickell, 1999**). It is used in planting back borders in different types of gardens for its coloured leaves. In addition to its landscape use as a source of colour, it is also one of the main sources of the natural pigments anthocyanin, used in several industries such as foods, beverages and bread products (**Paredes-Lopez, 1994**). Moreover, it is used internally as a folk medicine to improve vision and to strengthen the liver. Its ash is mixed with rapeseed oil, and used externally as an ointment for dressing boils and itch (**Carbajal *et al* 1991**).

Nitrogenous nutrition is necessary for the various biochemical processes that occur within the plant, and that are essential for normal plant growth and development (**Devlin, 1979**). Nitrogenous fertilization treatments have favourably influenced the growth of several *Amaranthus* species [**Das and Ghosh (1999)** on *A. tricolor*, **Genc and Acar (1999)** on *A. mantegazzianus* and *A. cruentus*, **Agele *et al* (2004)** on *A. cruentus*, **Nie *et al* (2004)** on *A. tricolor* and **Rathore *et al* (2004)** on *A. hypocondriacus*.].

This study was conducted with the aim of investigating the response of *Amaranthus tricolor*, L. plants to nitrogenous nutrition, and their role in remediating different polluted soils with heavy metals.

MATERIALS AND METHODS

This study was carried out at the Experimental Nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, during the two successive seasons of 2005 and 2006, with the aim of investigating the response of *Amaranthus tricolor*, L. plants to nitrogenous nutrition, and their role in remediating different polluted soils with heavy metals.

Seeds of of *Amaranthus tricolor* were obtained from the nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, and were sown on 15th March 2005 and 2006 (in the first and second seasons, respectively), in 8-cm plastic pots filled with a 1:1 (v/v) mixture of sand and clay. On 1st May 2005 and 2006 (in the first and second seasons, respectively), the seedlings, with a height of 8 cm diameter, were transplanted individually into perforated polyethylene bags (30-cm diameter) filled with 5 kg of: (1) clay loam soil from the nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza (as an un-polluted soil), or one of four different polluted soils including: (2) sandy loam soil from Al-Gabal Al-Asfar, Cairo, (3) sandy loam soil from Abou Rawash, Giza, (4) clay soil from El-Tebbin, Cairo or (5) clay soil from Shobra El-Kheima, Kalyoubeya. The source of pollutants, general characteristics, available macronutrients and DTPA extractable nickel and zinc were determined in surface samples (0-30 cm) of the five studied soils, and are shown in **Table (1)**. The pots were kept outdoors throughout the experiment.

Nitrogenous fertilizer was applied to the plants at the rates of 7.5 or 15 gm ammonium sulphate (20.5 % N) /pot/season, divided into 3 equal doses applied at 4 weeks intervals, starting two weeks after transplanting the seedlings. An unfertilized control was also included in the experiment. All pots received phosphorus fertilizer in the form of calcium superphosphate (15.5% P_2O_5), which was mixed into the soil two weeks before transplanting the seedlings, at the rate of 5 gm/pot. Potassium fertilizer was added in the form of potassium sulphate (48% K_2O) at the rate of 3 gm/pot, divided into two equal doses, which were applied after 2 and 6 weeks from transplanting.

The plants were irrigated every 3 days using a tap water (with a total salts concentration of 270 ppm). At each irrigation, the plants were watered till 90% of soil field capacity (F.C.). The soil moisture tension was measured before each irrigation using microtensiometers, and the quantity of water needed to reach 90% F.C. was calculated, as described by **Richards (1949)**.

The layout of the experiment was a split-plot design, with the main plots arranged in a randomized complete blocks design, with three blocks (replicates). The main plots were assigned to the different soils, while the sub-plots were assigned to the nitrogenous nutrition treatments. The study included 15 treatments [5 different soils × 3 nitrogenous fertilization rates (including the control)], with each block consisting of 45 plants (3 plants/ treatment).

At the termination of each season (on 30th September 2005 and 2006 in the first and second seasons, respectively), plants were cut 1 cm above the soil surface, rinsed once with diluted HCl and twice with H_2O. Data were recorded on some plant vegetative growth characteristics, including plant height (cm), stem diameter (mm) at a height of 5 cm from the soil surface, number of branches/plant, as well as the fresh and dry weights of stems, leaves and roots/plant. The data on the vegetative growth characteristics were subjected to statistical analysis of variance, and the means were compared using the "Least Significant Difference (L.S.D.)" test at the 5% level, as described by **Little and Hills (1978)**.

Table 1. Location, source of pollutants, general characteristics, available macronutrients and DTPA extractable nickel and zinc of the studied soils.

No.	Location	Source of pollutant*	PH (1 : 2.5)	E.C. (dS m), (1 : 2.5)	Organic matter (%)	CEC (meq/100g)	$CaCO_3$ %	Particle size distribution				Texture class	Field capacity (%)	Available macronutrients (ppm)			DTPA extractable (µg/ g)	
								Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)			N	P	K	Ni	Zn
1	Fac. Agric , Giza	Nil	7.9	0.47	1.4	31	0.9	6.96	18.45	40.37	34.22	Clay loam	33	18	17	239	0.2	7.0
2	Al-Gabal Al-Asfar	D & I	6.8	1.07	3.8	43	1.0	32.44	37.89	11.74	17.93	Sandy loam	25	80	31	442	8.6	86.0
3	Abou Rawash	D & I	7.1	0.91	2.5	12	2.8	32.02	39.45	12.69	15.84	Sandy loam	23	57	25	330	7.9	91.0
4	El-Tebbin	I	7.8	0.62	0.7	42	4.9	10.23	19.88	25.75	44.14	Clay	38	50	16	323	8.4	96.0
5	Shobra El-Kheima	I	7.9	0.21	0.6	44	3.1	5.30	20.77	29.81	44.12	Clay	37	48	17	230	9.2	102.0

* D: Domestic wastes I: Industrial wastes

Chemical analysis of fresh leaf samples was also conducted to determine their contents of total chlorophylls (a+b) and carotenoids (using the method described by **Nornai, 1982**) and anthocyanin (as described by **Fuleki and Francis, 1968**). In addition, samples of leaves were oven-dried at a temperature of 70°C for 24 hours, and their contents of nutrients were extracted using the method described by **Piper (1947)**. The nutrients extract was chemically analyzed to determine the contents of nitrogen (using the modified Micro-Kjeldahl apparatus, as described by **Pregl, 1945**), phosphorus (using the method described by **Jackson, 1967**), potassium (estimated photometrically using a Jenway flamephotometer), nickel and zinc using an atomic absorption spectrophotometer, model GBC, 932AA). Also the content of total carbohydrates in dried leaf samples was determined using the method described by **Dubois *et al* (1956)**. The uptake of Ni and Zn was calculated by multiplying the dry weight of above-ground parts of the plant by the concentration of the two minerals in the plant tissues.

At the end of the experiment, the soils were analyzed for DTPA- extractable Ni and Zn, as recommended by **Lindsay and Norvell (1978)**.

RESULTS AND DISCUSSION

I. Vegetative growth

1. Effect of nitrogenous nutrition

The results recorded in the two seasons **(Tables 2-4)** showed that the different vegetative growth characteristics of *Amaranthus tricolor* plants i.e. plant height, stem diameter, number of branches/plant and fresh and dry weights of stems, leaves and roots/plant were favourably affected by the different N fertilization treatments. In most cases, plants receiving any of the tested fertilization levels gave significantly higher values for the different growth parameters, compared to unfertilized (control) plants. The only exception to these results was obtained in the second season, with fertilization using 7.5 gm ammonium sulphate/pot/season giving insignificantly taller plants than the unfertilized control plants, whereas the higher fertilization rate (15 gm ammonium sulphate/pot/season) gave significantly taller plants than the control plants **(Table 2)**. The promotion of vegetative growth as a result of nitrogenous nutrition is in agreement with the results reported by **Nawawi *et al* (1985) and Hilman & Abidin (1987)** on *Amaranthus tricolor*, **Hirano *et al* (1991)** on *A. cruentus*, **Makus (1992)** on *A. tricolor*, **Elbehri *et al* (1993)** on *A. hypochondriacus* X *A. hybridus* cv. Plainsman, **Zerfus and Shchitov (1995)** on *A. cruentus*, **Auwalu and Tenebe (1997)** on *A. cruentus*, **Saini and Shekhar (1998)** on *A. hypochondriacus*, **Das and Ghosh (1999)** on *A. tricolor*, **Genc and Acar (1999)** on *A. mantegazzianus* and *A. cruentus*, **Agele *et al* (2004)** on *A. cruentus*, **Nie *et al* (2004)** on *A. tricolor* and **Rathore *et al* (2004)** on *A. hypocondriacus*. The favourable effect of the different N fertilization treatments on the vegetative growth characteristics (compared to the control) can be attributed to the important role played by N in the physiological processes within the plant, which in turn affect the growth of the vegetative and root systems. Also, nitrogen is present in the structure of protein molecules **[Devlin (1979); Taiz and Zeiger (2002)]**.

In both seasons, all the studied characteristics showed steady increases in the recorded values as the nitrogen level was raised. In general, plants that received 15 gm ammonium sulphate /pot/season gave significantly higher values for vegetative growth characteristics than plants that received 7.5 gm ammonium sulphate/pot/season. Two exceptions to this general trend were recorded in both seasons, with plants fertilized with 15 gm ammonium sulphate /pot/season giving insignificantly thicker stems and heavier fresh weight of leaves than plants receiving 7.5 gm ammonium sulphate /pot/season. Accordingly, the most vigorous vegetative growth (in terms of the studied growth characteristics) was obtained in plants supplied with 15 gm ammonium sulphate /pot/season. This confirms the conclusion that nitrogen plays an important role in promoting vegetative growth of *Amaranthus tricolor* plants.

2- Effect of different soils

The results recorded in the two seasons **(Tables 2-4)** showed that among the different soils used, the sandy loam soil obtained from Al-Gabal Al-Asfar was clearly the most effective one for promoting the growth of *Amaranthus tricolor* plants, giving the highest values for most of the studied characteristics (plant height, stem diameter, number of branches / plant, fresh and dry weights of stems and leaves / plant), followed by plants grown in Faculty of Agriculture (clay loam) soil. Only one exception to this general trend was recorded in both seasons, with plants grown in the soil of Faculty of Agriculture having significantly heavier fresh and dry weights of roots than the

Table 2. Effect of N fertilization levels and different soils on plant height, stem diameter and number of branches of *Amaranthus tricolor*, L. plants during the 2005 and 2006 seasons.

Fertilization treatments (F)	First season (2005)						Second season (2006)					
	Soils (S)						Soils (S)					
	S1	S2	S3	S4	S5	**Mean**	S1	S2	S3	S4	S5	**Mean**
Plant height (cm)												
Control	90.3	98.4	70.9	82.6	55.8	**79.6**	110.8	121.6	86.3	90.5	52.5	**92.3**
N1	115.7	132.6	80.5	85.0	58.5	**94.5**	118.5	130.0	90.5	98.1	63.7	**100.2**
N2	136.1	145.5	96.2	110.8	65.1	**110.7**	145.1	152.7	100.1	108.4	72.0	**115.7**
Mean	**114.0**	**125.5**	**82.5**	**92.8**	**59.8**	----	**124.8**	**134.8**	**92.3**	**99.0**	**62.7**	----
L.S.D.$_{(0.05)}$												
F	12.8						9.5					
S	18.1						12.8					
FXS	23.5						19.6					
Stem diameter (mm)												
Control	25.1	30.1	22.1	23.6	15.6	**23.3**	23.4	30.7	24.1	24.4	17.5	**24.0**
N1	29.7	35.6	26.7	25.6	18.0	**27.1**	30.6	33.4	26.0	27.6	21.0	**27.7**
N2	32.6	37.7	28.6	29.1	19.1	**29.4**	34.0	36.7	27.1	28.7	21.6	**29.6**
Mean	**29.1**	**34.5**	**25.8**	**26.1**	**17.6**	----	**29.3**	**33.6**	**25.7**	**26.9**	**20.0**	----
L.S.D.$_{(0.05)}$												
F	2.5						2.3					
S	3.8						4.2					
FXS	4.4						5.9					
Number of branches / plant												
Control	10.2	9.3	7.5	7.1	6.0	**8.0**	9.5	10.7	8.5	8.7	8.3	**9.1**
N1	11.7	12.5	8.5	8.7	8.2	**9.9**	13.0	12.2	10.0	10.5	8.7	**10.9**
N2	13.0	14.3	11.0	9.5	8.4	**11.2**	13.5	16.4	11.7	11.5	9.3	**12.5**
Mean	**11.6**	**12.0**	**9.0**	**8.4**	**7.5**	----	**12.0**	**13.1**	**10.1**	**10.2**	**8.8**	----
L.S.D.$_{(0.05)}$												
F	1.3						1.2					
S	2.1						1.8					
FXS	2.5						2.6					

S1: Fac. Agric., Giza. S2: Al Gabal Al- Asfar. S3 : Abou -Rawash.
S4 : El - Tebbin. S5 : Shobra El- Kheima.
N1 and N2 = N at 7.5 or 15 gm ammonium sulphate (20.5 % N) /pot/season

Table 3. Effect of N fertilization levels and different soils on fresh weights of stems, leaves and roots of *Amaranthus tricolor*, L. plants during the 2005 and 2006 seasons.

Fertilization treatments (F)	First season (2005)						Second season (2006)					
	Soils (S)						Soils (S)					
	S1	S2	S3	S4	S5	**Mean**	S1	S2	S3	S4	S5	**Mean**
Fresh weight of stems (g/plant)												
Control	255.3	330.5	186.0	121.9	85.5	**195.8**	280.5	264.1	195.8	150.3	100.6	**198.3**
N1	271.6	380.8	222.7	162.6	115.3	**230.6**	310.8	330.6	240.6	171.2	136.5	**237.9**
N2	369.2	486.1	270.4	185.1	130.8	**288.3**	350.1	364.7	252.3	201.4	152.9	**264.3**
Mean	**298.7**	**399.1**	**226.4**	**156.5**	**110.5**	----	**313.8**	**319.8**	**229.6**	**174.3**	**130.0**	----
L.S.D $_{(0.05)}$												
F	20.5						19.5					
S	26.9						31.5					
FXS	34.7						40.7					
Fresh weight of leaves (g/plant)												
Control	140.3	168.6	130.2	126.4	73.8	**127.9**	152.1	176.2	149.7	95.3	91.6	**133.0**
N1	152.4	200.8	146.7	139.0	89.3	**145.6**	173.8	212.5	153.1	115.5	100.2	**151.0**
N2	161.9	205.5	160.1	150.3	103.6	**156.3**	201.6	237.0	160.4	136.9	105.6	**168.3**
Mean	**151.5**	**191.6**	**145.7**	**138.6**	**88.9**	----	**175.8**	**208.6**	**154.4**	**115.9**	**99.1**	----
L.S.D $_{(0.05)}$												
F	13.6						17.5					
S	18.2						21.8					
FXS	25.9						32.6					
Fresh weight of roots (g/plant)												
Control	86.5	74.0	60.3	66.5	49.5	**67.4**	100.1	82.6	79.0	70.5	40.3	**74.5**
N1	120.1	102.1	66.5	70.8	62.7	**84.4**	112.1	91.8	82.5	75.8	51.5	**82.7**
N2	125.8	112.5	96.1	81.9	64.1	**96.1**	136.8	119.6	114.6	95.8	70.6	**107.5**
Mean	**110.8**	**96.2**	**74.3**	**73.1**	**58.8**	----	**116.3**	**98.0**	**92.0**	**80.7**	**54.1**	----
L.S.D $_{(0.05)}$												
F	6.5						7.8					
S	8.7						10.9					
FXS	9.6						12.5					

S1 Fac. Agric., Giza. S2: Al Gabal Al-Asfar. S3 Abou -Rawash.
S4 : El Tebbin. S5 Shobra El- Kheima.
N1 and N2 = N at 7.5 or 15 gm ammonium sulphate (20.5 % N) /pot/season.

Table 4. Effect of N fertilization levels and different soils on dry weights of stems, leaves and roots of *Amaranthus tricolor*, L. plants during the 2005 and 2006 seasons.

Fertilization treatments (F)	First season (2005)						Second season (2006)					
	Soils (S)						Soils (S)					
	S1	S2	S3	S4	S5	**Mean**	S1	S2	S3	S4	S5	**Mean**
Dry weight of stems (g/plant)												
Control	31.5	40.4	23.3	19.0	17.1	**26.3**	40.9	35.6	33.5	20.6	14.8	**29.1**
N1	37.4	46.9	32.8	20.9	20.0	**31.6**	47.3	53.5	36.9	28.0	17.5	**36.6**
N2	43.9	55.8	34.7	28.5	21.9	**37.0**	59.1	63.3	45.4	37.3	27.7	**46.6**
Mean	**37.6**	**47.7**	**30.3**	**22.8**	**19.7**	----	**49.1**	**50.8**	**38.6**	**28.6**	**20.0**	----
L.S.D.$_{(0.05)}$												
F	4.5						3.1					
S	5.8						4.9					
FXS	8.5						6.7					
Dry weight of leaves (g/plant)												
Control	15.8	16.9	14.0	12.1	11.5	**14.1**	18.5	19.1	14.7	12.5	8.8	**14.7**
N1	16.1	24.6	14.6	14.5	13.4	**16.6**	19.9	21.5	17.1	13.9	12.9	**17.1**
N2	22.5	29.8	15.6	14.8	13.9	**19.3**	25.6	27.9	17.5	16.1	14.5	**20.3**
Mean	**18.1**	**23.8**	**14.7**	**13.8**	**12.9**	----	**21.3**	**22.8**	**16.4**	**14.2**	**12.1**	----
L.S.D.$_{(0.05)}$												
F	1.4						1.6					
S	2.0						2.5					
FXS	3.1						3.7					
Dry weight of roots (g/plant)												
Control	18.5	15.5	11.0	14.6	9.0	**13.7**	22.9	17.5	18.5	12.8	7.6	**15.9**
N1	22.3	19.8	13.1	16.7	9.6	**16.3**	23.5	20.5	20.1	13.5	10.5	**17.6**
N2	24.7	21.1	19.5	17.3	11.5	**18.8**	30.3	24.8	22.6	17.5	13.1	**21.7**
Mean	**21.8**	**18.8**	**14.5**	**16.2**	**10.0**	----	**25.6**	**20.9**	**20.4**	**14.5**	**10.4**	----
L.S.D.$_{(0.05)}$												
F	1.4						1.6					
S	1.8						1.8					
FXS	2.1						2.4					

S1: Fac. Agric., Giza. S2: Al - Gabal Al- Asfar. S3 : Abou -Rawash.
S4 : El - Tebbin. S5 : Shobra El- Kheima.
N1 and N2 = N at 7.5 or 15 gm ammonium sulphate (20.5 %N) /pot/season

plants grown in any of the other tested soils, including Al-Gabal Al-Asfar soil. In most cases, plants grown in Al-Gabal Al-Asfar soil gave significantly higher values for vegetative growth characteristics than those grown in other soils. The increase in vegetative growth of plants grown in Al-Gabal Al-Asfar soil may be attributed to its high content of organic matter (compared to other soils used) which has favourable effects on the soil, such as improving some of its physiochemical properties, preventing salt injury to plants that sometimes results from concentration of chemical fertilizers through the buffering properties of organic matter, and providing soil with the essential macro and micronutrients **(Wallace, 1994 a and b)**.

On the other hand, the soil obtained from Shobra El-Kheima was the least suitable for growing *Amaranthus tricolor* plants. In both seasons, plants grown in this soil gave the lowest values for all the recorded growth characteristics, compared to plants grown in other soils. In most cases, plants grown in this soil gave significantly lower values for vegetative growth characteristics than the plants grown in the other soils. These results may be attributed to its high content of Ni and Zn (compared to the other soils used) which have negative effects on plant growth, as mentioned by **Kabata-Pendias and Pendias (2001)**, who reported that the absorption of nutrients, root development and metabolism are strongly retarded in plants under Ni and Zn stress. These results are in agreement with the findings of **Azpiazu (1989)** on *Lolium multiflorum*, **Aidid and Okamoto (1993)** on *Impatiens balsamina*, **Chen *et al* (2000)** on mung bean (*Vigna radiata*) and lucerene (*Medicago sativa*), **Ahmed (2001)** on *Tagetes minuta*, *T. patula* and *T. erecta*, **Abbaas (2002)** on *Casuarina glauca*, *Taxodium distichum* and *Populus nigra*, **Bazaraa (2005)** on *Pelargonium zonale*, *Gazania splendens* and *Vinca rosea* and **El-Kady (2005)** on *Brassaia arboricola* var. *variegata* and *Ficus microcarpa* var. *Hawaii*.

The results presented in **Tables (2-4)** also show that, in most cases, the plants grown in Abou Rawash and El-Tebbin soils gave values that were intermediate between those grown in Faculty of Agriculture and Shobra El-Kheima soils. However, the relative effectiveness of these two soils, compared to each other, differed from one growth characteristic to the other.

3- Interaction between the effects of nitrogenous nutrition and different soils

From the data in **Tables (2-4)**, it can be concluded that the vegetative growth characteristics of *Amaranthus tricolor* plants showed considerable differences between the values recorded as a result of using the different treatment combinations (for all the recorded characteristics). In general, plants grown in Al-Gabal Al-Asfar soil and fertilized with 15 gm ammonium sulphate/pot/season had the most vigorous vegetative growth. In both seasons, this treatment combination gave the highest values for the plant height, stem diameter, number of branches/plant, fresh and dry weights of stems and leaves/plant, whereas the heaviest fresh and dry weights of roots /plant were recorded with plants grown in Faculty of Agriculture soil and fertilized with 15 gm ammonium sulphate/ pot/ season.

On the other hand, the lowest values recorded for all the vegetative growth characteristics were obtained from plants grown in Shobra El-Kheima soil and receiving no fertilization (control).

II. Effect on the chemical composition of the plant

1. Leaf pigments content

a- Total chlorophylls (a+b) and carotenoids

The data presented in **Table (5)** show that N fertilization had a favourable effect on total chlorophylls (a+b) and carotenoids synthesis and accumulation in the leaves of *Amaranthus tricolor* plants. In both seasons, plants receiving the different N fertilization treatments had higher contents of total chlorophylls (a+b) and carotenoids than unfertilized (control) plants. Moreover, the total chlorophylls and carotenoids contents were steadily increased with raising the nitrogen level in the applied fertilizer. Accordingly, ammonium sulphate at 15 gm/pot/season gave the highest total chlorophylls and carotenoids contents in both seasons. The increase in total chlorophylls content can be attributed to the role played by nitrogen as an essential component in the structure of porphyrines, which are found in many metabolically active compounds, including chlorophylls. Chlorophylls are bound to, and perhaps even embedded within protein molecules **(Devlin, 1979)**. These results are in agreement with the findings of **El-Saeid *et al* (1996)** on *Tagetes patula* and **Gouda (2002)** on *Tagetes erecta* and *Amaranthus tricolor*.

Table 5. Effect of N fertilization levels and different soils on total chlorophylls (a+b), carotenoids, anthocyanin and total carbohydrates contents of *Amaranthus tricolor*, L. plants during the 2005 and 2006 seasons.

Fertilization treatments (F)	First season (2005) Soils (S) S1	S2	S3	S4	S5	Mean	Second season (2006) Soils (S) S1	S2	S3	S4	S5	Mean
Total chlorophylls content (mg /g f. w.)												
Control	1.35	1.66	1.30	1.12	1.06	**1.30**	1.30	2.01	1.43	1.31	1.16	**1.44**
N1	1.41	1.78	1.51	1.29	1.18	**1.43**	1.56	2.17	1.48	1.56	1.29	**1.61**
N2	1.43	1.81	1.59	1.39	1.21	**1.49**	1.66	2.23	1.69	1.58	1.29	**1.69**
Mean	**1.40**	**1.75**	**1.47**	**1.27**	**1.15**	----	**1.51**	**2.14**	**1.53**	**1.48**	**1.25**	----
Carotenoids content (mg /g f. w.)												
Control	0.44	0.59	0.40	0.41	0.36	**0.44**	0.45	0.76	0.56	0.48	0.38	**0.53**
N1	0.58	0.69	0.63	0.52	0.45	**0.57**	0.66	0.87	0.75	0.61	0.49	**0.68**
N2	0.63	0.72	0.70	0.59	0.48	**0.62**	0.71	1.05	0.82	0.65	0.54	**0.75**
Mean	**0.55**	**0.67**	**0.58**	**0.51**	**0.43**	----	**0.61**	**0.89**	**0.71**	**0.58**	**0.47**	----
anthocyanins content (mg /g f. w.)												
Control	1.52	1.67	1.62	1.82	2.10	**1.75**	1.73	1.59	1.85	1.97	2.03	**1.83**
N1	1.83	1.94	1.67	2.00	2.19	**1.93**	1.97	2.22	1.95	2.31	2.22	**2.13**
N2	2.15	1.95	1.74	2.09	2.45	**2.08**	2.09	2.27	1.98	2.45	2.57	**2.27**
Mean	**1.83**	**1.85**	**1.68**	**1.97**	**2.25**	----	**1.93**	**2.03**	**1.93**	**2.24**	**2.27**	----
Total carbohydrates content (% of dry matter)												
Control	16.9	17.7	14.4	14.9	12.5	**15.3**	17.5	17.9	16.9	14.0	13.8	**16.0**
N1	18.9	19.5	18.2	15.3	13.6	**17.1**	20.1	21.6	18.9	17.6	13.9	**18.4**
N2	22.0	22.6	20.9	16.8	13.8	**19.2**	21.5	22.8	19.5	17.9	14.1	**19.2**
Mean	**19.3**	**19.9**	**17.8**	**15.7**	**13.3**	----	**19.7**	**20.8**	**18.4**	**16.5**	**13.9**	----

S1: Fac. Agric., Giza. S2: Al – Gabal Al- Asfar. S3: Abou -Rawash.
S4: El – Tebbin. S5: Shobra El- Kheima
N1 and N2 = N at 7.5 or 15 gm ammonium sulphate (20.5 % N) /pot/season.

Among the different soils used, Al-Gabal Al-Asfar soil was the most effective for increasing total chlorophylls and carotenoids in the leaves, followed by Abou Rawash, Faculty of Agriculture and El-Tebbin soils. On the other hand, the lowest total chlorophylls and carotenoids contents (in both seasons) were found in the leaves of plants grown in Shobra El-Kheima soil, which contained the highest Ni and Zn concentrations. Similar results were found by **Ahmed (2001)** on *Tagetes minuta*, *T. patula* and *T. erecta*, **Bazaraa (2005)** on *Gazania splendens* and *Vinca rosea* and **El-Kady (2005)** on *Brassaia arboricola* var. *variegata* and *Ficus microcarpa* var. *Hawaii*.

Regarding the interaction between the effects of N fertilizer rates and different soils on the total chlorophylls and carotenoids contents, the data presented in **Table (5)** show that the best treatment combination in this respect was growing the plants in Al-Gabal Al-Asfar soil, and supplying them with 15 gm ammonium sulphate /pot/season. This treatment combination gave higher total chlorophylls and carotenoids contents (in both seasons), compared to those obtained from any other treatment combination. On the other hand, the lowest values recorded in both seasons were found in plants grown in Shobra El-Kheima soil and supplied with no fertilization.

b- Anthocyanin

Data presented in **Table (5)** show that N fertilization had a favourable effect on anthocyanin synthesis and accumulation in the leaves of *Amaranthus tricolor* plants. In both seasons, plants receiving the different N fertilization treatments had higher content of anthocyanin, compared to unfertilized (control) plants. Moreover, the anthocyanin content was steadily increased with raising the nitrogen rate applied. Accordingly, supplying the plants with ammonium sulphate at 15 gm/pot/season gave the highest anthocyanin content in both seasons. These results are in agreement with the findings of **Farid *et al* (1994)** on *Hibiscus sabdariffa* and **Gouda (2002)** on *Amaranthus tricolor*.

Among the different soils used, Shobra El-Kheima soil was the most effective soil in increasing the anthocyanin content in leaves of *Amaranthus tricolor* plants, followed by El-Tebbin, Al-Gabal Al-Asfar, Faculty of Agriculture and Abou Rawash soils, in this order (in both seasons). In the second season, plants grown in the Faculty of Agriculture and Abou Rawash soils gave the same content of anthocyanin in the leaves.

Regarding the interaction between the effects of N fertilizer rates and different soils on the anthocyanin content, the data presented in **Table (5)** show that the best treatment combination in this respect was growing the plants in the Shobra El-Kheima soil, and supplying them with 15 gm ammonium sulphate /pot/season. This treatment combination gave higher anthocyanin contents (in both seasons) than those obtained from any other treatment combination. On the other hand, the lowest value recorded in the first season was found in plants grown in the Faculty of Agriculture soil and supplied with no fertilization, whereas the lowest anthocyanin content recorded in the second season was found in plants grown in Al-Gabal Al-Asfar soil and supplied with no fertilization.

2- Total carbohydrates content

The effect of N fertilizer rate on the total carbohydrates content in the leaves of *Amaranthus tricolor* plants **(Table 5)** was generally similar to their effect on the total chlorophylls and carotenoids contents. In both seasons, plants receiving the different N fertilization levels had higher total carbohydrates contents than the unfertilized control plants. Moreover, raising the rate of nitrogen applied resulted in a steady increase in the carbohydrates content, with ammonium sulphate at 15 gm/pot/season giving the highest values in the two seasons. These results can be easily explained by the indirect effect of nitrogenous fertilization on carbohydrate synthesis. As previously mentioned, the nitrogen supplied by fertilization is essential in the structure of porphyrines and, consequently, leads to an increase in the content of chlorophylls. Also, the porphyrine molecules are found in the cytochrome enzymes essential in photosynthesis. This increase in the contents of chlorophylls and cytochrome enzymes results in an increase in the rate of photosynthesis, and a promotion in carbohydrate synthesis and accumulation **(Devlin, 1979)**. Similar increases in the carbohydrates content as a result of fertilization treatments have been reported by **Gouda (2002)** on *Tagetes erecta* and *Amaranthus tricolor*. Also, carbohydrates not used in nitrogen metabolism may be used in anthocyanin synthesis, leading to accumulation of this pigment **(Taiz and Zeiger, 2002)**, and this may explain the increase in anthocyanin as a result of increasing N nutrition rate (as previously mentioned).

The results recorded in the two seasons **(Table 5)** showed also that, in both seasons, Al-Gabal Al-Asfar soil was the most effective soil in increasing carbohydrates content in the leaves of *Amaranthus tricolor* plants, followed by the Faculty of Agriculture soil, then the Abou Rawash, El-Tebbin and Shobra El-Kheima soils, in this order. The favourable effect of Al-Gabal Al-Asfar soil on carbohydrate synthesis and accumulation may be attributed to its high cation exchange capacity which allows the plant roots to take up the macro and micronutrients including the potassium needed for activation of the enzymes necessary for photosynthesis and, consequently, the synthesis of carbohydrates. On the other hand, the unfavourable effect of the Shobra El-Kheima soil on the total carbohydrates content in the leaves (in both seasons) can be easily explained since, as previously mentioned, the Shobra El-Kheima soil has high concentrations of Ni and Zn, which lead to a reduction in the content of chlorophylls. This reduction in the contents of chlorophylls results in a reduction in the rate of photosynthesis, and a reduction in carbohydrate synthesis and accumulation **(Devlin, 1979)**.

Considerable differences in the total carbohydrates content were recorded as a result of the interaction between the effects of N fertilizer rates and different soils. In both seasons, the highest values were obtained when plants grown in Al-Gabal Al-Asfar soil were fertilized with 15 gm ammonium sulphate /pot/season. On the other hand, the lowest values were obtained from plants grown in Shobra El-Kheima soil, and supplied with no fertilization.

3- N, P and K % in leaves

Chemical analysis of leaf samples showed that the N, P and K% were increased (in both seasons) as a result of the different N nutrition treatments, compared to the control **(Table 6)**. Also, raising the applied nitrogen level caused a steady increase in the N, P and K%, with the highest values being found in the leaves of plants supplied with 15 gm ammonium sulphate /pot/season. The increase in the percentage of nutrients (including N) was explained by **Jain (1983)**, who stated that raising the level of N in the root medium leads to an increase in vegetative growth, and this may be accompanied by an increase in the absorption of this essential element. These results are in agreement with the findings of **El-Leithy (1987)** on *Tagetes patula*, **Hirano *et al* (1991)** on *Amaranthus cruentus*, **Panchal *et al* (1991)** on *A. hypochondriacus* cvs. Rajogara and Rajagari, **Naadasy-Iharosi (1999)** on *A. hybridus* and **Gouda (2002)** on *Tagetes erecta* and *Amaranthus tricolor*.

In both seasons, *A. tricolor* plants grown in Al-Gabal Al-Asfar soil had the highest N, P, and K%, followed by those grown in the Faculty of Agriculture, Abou Rawash and El-Tebbin soils, in this order, whereas plants grown in Shobra El-Kheima soil gave the lowest values. These lowest N, P and K% that were recorded in plants grown in Shobra El-Kheima soil are associated with the highest content of heavy metals (Ni and Zn) in this soil **(Table 1)**. Such results are in agreement with the findings of **Abbaas (2002)** on *Casuarina glauca, Taxodium distichum* and *Populus nigra*. Also, the highest anthocyanin content in leaves of *Amaranthus tricolor* plants grown in Shobra El-Kheima soil **(Table 5)** may be attributed to the lowest N% in the leaves **(Table 6)** as mentioned by **Taiz and Zeiger (2002).**

Data in **Table (6)** also showed that the use of the different combinations of fertilizer rates and soils resulted in considerable variation in the N, P and K%. In both seasons, the highest N, P and K% were found in the leaves of plants grown in Al-Gabal Al-Asfar soil, and supplied with 15 gm ammonium sulphate /pot/season. On the other hand, the lowest values were generally obtained from plants grown in Shobra El-Kheima soil, and receiving no fertilization. The only exception to this trend was recorded in the first season, with

Table 6. Effect of N fertilization levels and different soils on nitrogen, phosphorus and potassium% in the leaves of *Amaranthus tricolor*, L. plants during the 2005 and 2006 seasons.

Fertilization treatments (F)	First season (2005) Soils (S)						Second season (2006) Soils (S)					
	S1	S2	S3	S4	S5	**Mean**	S1	S2	S3	S4	S5	**Mean**
						N (% of dry matter)						
Control	1.75	1.81	1.50	1.32	1.19	**1.51**	1.70	1.90	1.63	1.15	1.12	**1.50**
N1	2.08	2.25	1.93	1.69	1.40	**1.87**	2.31	2.26	2.11	1.46	1.50	**1.93**
N2	2.20	2.31	2.01	1.86	1.55	**1.99**	2.40	2.46	2.15	1.90	1.62	**2.11**
Mean	**2.01**	**2.12**	**1.81**	**1.62**	**1.38**	----	**2.14**	**2.21**	**1.96**	**1.50**	**1.41**	----
						P (% of dry matter)						
Control	0.17	0.19	0.16	0.10	0.09	**0.14**	0.21	0.23	0.15	0.08	0.06	**0.15**
N1	0.25	0.21	0.19	0.16	0.11	**0.18**	0.24	0.27	0.23	0.21	0.15	**0.22**
N2	0.25	0.28	0.22	0.26	0.18	**0.24**	0.29	0.31	0.28	0.20	0.16	**0.25**
Mean	**0.22**	**0.23**	**0.19**	**0.17**	**0.13**	----	**0.25**	**0.27**	**0.22**	**0.16**	**0.12**	----
						K (% of dry matter)						
Control	1.36	1.39	1.22	1.06	1.11	**1.23**	1.24	1.40	1.16	1.12	0.86	**1.16**
N1	1.46	1.58	1.35	1.30	1.21	**1.38**	1.43	1.56	1.39	1.23	1.15	**1.35**
N2	1.61	1.63	1.50	1.39	1.25	**1.48**	1.51	1.58	1.52	1.30	1.18	**1.42**
Mean	**1.48**	**1.53**	**1.36**	**1.25**	**1.19**	----	**1.39**	**1.51**	**1.36**	**1.22**	**1.06**	----

S1: Fac. Agric., Giza. S2: Al – Gabal Al- Asfar. S3: Abou -Rawash.
S4 : El – Tebbin. S5 : Shobra El- Kheima
N1 and N2 = N at 7.5 or 15 gm ammonium sulphate (20.5 % N) /pot/season.

plants grown in El-Tebbin soil and receiving no fertilization gave the lowest K% in the leaves of *Amaranthus tricolor* plants.

III- Dry weight of the above ground parts, their Ni and Zn concentration, and Ni and Zn uptake

The effect of N nutrition and different soils on dry weight of above ground parts (stems and leaves) of *Amaranthus tricolor* plants, Ni and Zn concentrations in the dry matter of above ground part tissues and their uptake are presented in **Table (7)**. In both seasons, the dry weights of above ground parts of plants grown in most of the polluted soils (viz., Abou Rawash, El-Tebbin and Shobra El-Kheima soils) were generally lower than that of plants grown in the un-polluted soil (Faculty of Agriculture soil). The only exception to this trend was recorded in both seasons with plants grown in the polluted soil of Al-Gabal Al-Asfar, which gave the heaviest dry weight of above ground parts, compared to plants grown in the other soils (in most cases). In each soil, in both seasons, raising the applied nitrogen level caused a steady increase in the dry weight of above ground parts, with the highest values being found in plants supplied with 15 gm ammonium sulphate/pot/ season.

Table 7. Effect of N fertilization levels and different soils on dry weight of above ground parts of *Amaranthus tricolor*, L. plants, their Ni and Zn concentrations and Ni and Zn uptake during the 2005 and 2006 seasons.

Soils	Fertilization treatments	First season (2005)			Second season (2006)		
		D.W. (g / pot)	Conc. (µg/ g D.W.)	Uptake (µg/ pot)	D.W. (g / pot)	Conc (µg/ g D.W.)	Uptake (µg/ pot)
				Nickel			
S1	Control	47.3	31	1466	59.4	29	1722
	N1	53.5	36	1926	67.2	27	1814
	N2	66.4	47	3121	84.7	23	1948
S2	Control	57.3	931	53346	54.7	827	45236
	N1	71.5	836	59774	75.0	711	53325
	N2	85.6	747	63943	91.2	699	63748
S3	Control	37.3	909	33906	48.2	846	40777
	N1	47.4	987	46784	54.0	801	43254
	N2	50.3	899	45220	62.9	782	49187
S4	Control	31.1	1002	31162	33.1	1086	35946
	N1	35.4	1296	45878	41.9	1091	45712
	N2	43.3	1198	51873	53.4	1021	54521
S5	Control	28.6	1342	38381	23.6	1071	25275
	N1	33.4	1498	50033	30.4	1114	33865
	N2	33.8	1286	46039	42.2	1009	42579
				Zinc			
S1	Control	47.3	19.9	941	59.4	15.8	938
	N1	53.5	18.6	995	67.2	14.7	987
	N2	66.4	17.8	1181	84.7	12.9	1092
S2	Control	57.3	40.4	2314	54.7	37.2	2034
	N1	71.5	41.0	2931	75.0	39.1	2932
	N2	85.6	35.2	3013	91.2	32.0	2918
S3	Control	37.3	45.8	1708	48.2	41.2	1985
	N1	47.4	43.2	2047	54.0	42.6	2300
	N2	50.3	41.9	2107	62.9	43.9	2761
S4	Control	31.1	55.8	1735	33.1	46.3	1532
	N1	35.4	51.2	1812	41.9	49.2	2061
	N2	43.3	47.8	2069	53.4	43.7	2333
S5	Control	28.6	65.2	1864	23.6	59.6	1406
	N1	33.4	59.1	1973	30.4	57.2	1738
	N2	35.8	57.2	2047	42.2	49.8	2101

S1: Fac. Agric., Giza S2: Al – Gabal Al- Asfar. S3: Abou -Rawash.
S4: El – Tebbin S5: Shobra El- Kheima.
N1 and N2 = N at 7.5 or 15 gm ammonium sulphate (20.5 % N) /pot/season.

In both seasons, the concentrations of Ni and Zn in dried above ground parts varied depending on the soil used. In general, plants grown in polluted soils had higher Ni and Zn concentrations than the un-polluted soil. In most cases, under the same N rate, plants grown in Shobra El-Kheima soil gave the highest Ni and Zn concentration followed by those grown in El-Tebbin, Abou Rawash and Al-Gabal Al-Asfar soils, whereas plants grown in Faculty of Agriculture soil had the lowest Ni and Zn concentrations. In general, the increase in Ni and Zn concentrations in dry matter of above ground parts of *Amaranthus tricolor* plants were associated with their concentrations in the soil. Such results are in agreement with the findings of **Fernandes and Henriques (1989)** on *Quercus rotundifolia*, **Vos (1989)** on poplar, **Abbaas (2002)** on *Casuarina glauca*, *Taxodium distichum* and *Populus nigra*, **Bazaraa (2005)** on *Pelargonium zonale*, *Gazania splendens* and *Vinca rosea*, **Chunilall *et al* (2005)** on *Amaranthus hybridus* and *A. dubius* and **El-Kady (2005)** on *Brassaia arboricola* var. *variegata* and *Ficus microcarpa* var. *Hawaii*.

The Ni concentrations in dried above ground parts of plants grown in polluted soils ranged from 747 to 1498 µg/g dry matter in the first season, and from 699 to 1114 µg/g dry matter in the second season. These values are much higher than the values of 1000 µg/g dry weight reported for Ni hyperaccumulator **(Baker and Brooks, 1989)**. The Ni concentrations in dried above ground parts of plants grown in polluted soils were 16 to 48 times in the first season and 24 to 48 times in the second season higher than that of plants grown in non-polluted soil. On the other hand, the Zn concentrations in the dried above ground parts of plants grown in polluted soils were low and still in the normal range; they ranged from 35.2 to 65.2 µg/g dry matter in the first season, and from 32.0 to 59.6 µg/g dry matter in the second season. These values were 1.7 to 3.7 times in the first season and 2 to 4.6 times in the second season higher than that of plants grown in non-polluted soil. Similar results were obtained by **Beckett *et al* (1990)** on *Betula papyrifera* and *Acer rubrum* and **Landberg *et al* (1996)** on salix.

Generally, no clear trend was noted for the Ni and Zn concentrations in the dried above ground parts of plants in response to N nutrition treatments in both seasons.

In both seasons, data showed that the Ni and Zn uptake by *Amaranthus tricolor* plants was increased as a result of the different N nutrition treatments, because of the increase in dry weight of above ground parts of plants, compared to the control. Also, raising the applied nitrogen level caused a steady increase in the Ni and Zn uptake in most cases. So, in general, plants supplied with 15 gm ammonium sulphate /pot/season showed the highest Ni and Zn uptake, in both seasons. The results showed that plants extracted enormous amounts of Ni. Moreover, using 15 gm ammonium sulphate /pot/season proved to be more efficient than using 7.5 gm ammonium sulphate/pot/season in remediating Ni polluted soils (i.e., taking up higher Ni concentrations from the soil). On the other hand, the results showed that the plants extracted normal amounts of Zn. This means that *Amaranthus tricolor* plants are non-hyperaccumulator plants for Zn and, therefore, cannot be used to remediate Zn polluted soils.

IV- DTPA extractable Ni and Zn

The effect of N nutrition and different soils on extractable Ni and Zn (µg/g soil) of the soils used in the experiment before and after treatments are presented in **Table (8)**. In both seasons the extractable Ni and Zn of each tested soil used in the experiment after treatments were markedly reduced as a result of the different N nutrition treatments (which increased the dry matter of *Amaranthus tricolor* plants and their Ni and Zn uptake), in most cases, compared to the unfertilized control. Also, in most cases, raising the applied nitrogen level caused a steady decrease in the extractable Ni and Zn of the used soils, with the lowest values being found in plants supplied with 15 gm ammonium sulphate /pot/season.

In general, Shobra El-Kheima soil gave the highest extractable Ni and Zn after treatments followed by El-Tebbin, Abou Rawash and Al-Gabal Al-Asfar soils, whereas Faculty of Agriculture soil gave the lowest extractable Ni and Zn. Generally *Amaranthus tricolor* plants reduced extractable Ni by 35% to 72% in the first season and 26 to 69% in the second season in the polluted soils. In contrast, *Amaranthus tricolor* plants caused only a negligible reduction in the extractable Zn in polluted soils (by 0.2 to 8.0% in the first season and 1.0 to 5.0% in the second season).

Table 8. DTPA extractable Ni and Zn (µg/ g soil) of the soils used in the experiment before and after treatments during the 2005 and 2006 seasons.

Soils	Fertilization treatments	DTPA extractable Nickel			DTPA extractable Zinc		
		Before	After		Before	After	
			2005	2006		2005	2006
S1	Control	0.2	0.06	0.09	7.0	6.8	6.9
	N1		0.04	0.08		6.8	6.7
	N2		0.07	0.05		6.7	6.8
S2	Control	8.6	3.3	4.2	86	84.2	84.6
	N1		2.8	3.5		83.2	83.7
	N2		2.4	2.7		82.9	81.8
S3	Control	7.9	4.7	4.2	91	90.8	90.0
	N1		3.9	3.7		90.6	88.4
	N2		3.8	3.2		86.6	87.2
S4	Control	8.4	5.1	5.2	96	94.8	94.6
	N1		4.3	4.2		93.9	93.2
	N2		3.8	3.3		88.2	91.9
S5	Control	9.2	6.0	6.8	102	101.8	99.0
	N1		4.7	5.7		100.0	99.2
	N2		4.9	5.2		98.9	98.8

S1. Fac. Agric., Giza. S2. Al – Gabal Al-Asfar.
S3. Abou -Rawash.
S4: El-Tebbin. S5. Shobra El- Kheima.
N1 and N2 = N at 7.5 or 15 gm ammonium sulphate (20.5%N)/ pot/season

CONCLUSION

From the above results, it is clear that the best vegetative growth of *Amaranthus tricolor*, L. was obtained when the plants were grown in Al-Gabal Al-Asfar soil and supplied with the high nitrogenous fertilization rate. This treatment combination gave the highest values for most of the vegetative growth characteristics and chemical constituents. It is also worth mentioning that, in each of the tested soils, supplying the plants with 15 gm ammonium sulphate (20.5 % N) /pot/season gave the best results for most of the studied vegetative growth parameters, as well as for most of the plant chemical components, and increased the ability of plants to remediate Ni polluted soils. However, the results showed that *Amaranthus tricolor* plants cannot remediate Zn polluted soils.

REFERENCES

Abbaas, Mona M. (2002). Effect of Some Heavy Metals in the Irrigation Water on Growth and Chemical Constituents of Some Timber Trees. pp. 187-197. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

Agele, S.; O. Adeosun and D. Oluwadare (2004). A lysimeter study of nutrient release, leaching losses and growth response of amaranthus resulting from application of inorganic and organic nitrogen sources. **J. Food, Agriculture and Environment, 2(2): 301-306.**

Ahmed, Mai M. (2001). Effect of Some Heavy Metals on Some Tagetes Species. pp. 125-129. M.Sc. Thesis, Fac. Agric., Cairo Univ., Egypt.

Aidid, S.B. and H. Okamoto (1993). Responses of elongation growth rate, turgor pressure and cell wall extensibility of stem cells of *Impatiens balsamina* to lead, cadmium and zinc. **Bio Metals, 6(4): 245-249.**

Auwalu B.V. and A. Tenebe (1997). Growth rate, yield and protein content of two leafy vegetables as affected by nitrogen fertilization. **Advances in Hort. Sci, 11(2): 70-72.**

Azpiazu, M.N. (1989). Problems of irrigation with polluted water in greenhouse. **Acta. Hort., 246: 97-104.**

Baker, A.J.M. and R.R. Brooks (1989). Terrestrial higher plants which hyperaccumulate metallic elements: A review of their distribution ecology and phytochemistry. **Biorecovery, 1: 81-126.**

Bazaraa, W.M.S. (2005). Effect of Some Heavy Metals on Growth and Chemical Composition of Some Ornamental Plants. pp. 113-116, 158-165, 190, 223-231& 253-256. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

Beckett, P.J.; J. Negusanti; J. Skousen and D. Samuel (1990). Using land reclamation practices to improve tree condition in the Sudbury area. **Mining and Reclaimed Soils Conf. Ontario, Canada. Proceed, 1: 307-320.**

Brickell, C. (1999). The Royal Horticultural Society New Encyclopedia of Plants and Flowers, 3rd Ed. pp. 105-106. Dorling Kindersley, Ltd., London.

Carbajal, D.; A. Casaco; L. Arruzazabala; R. Gonzalez and V. Fuentes (1991). Pharmacological screening of plants decoctions commonly used in Cuban folk medicine. **J. Ethnopharmacology, 33(1-2): 21-24.**

Chen, H.; C. Range; Z. Wang and C. Tu (2000). Combined pollution and pollution index of heavy metals in red soil. **Pedosphere, 10(2): 117-124.**

Chunilall, V.; A. Kindness and S.B. Jonnalagadda (2005). Heavy metal uptake by two edible *Amaranthus* herbs grown on soils contaminated with lead, mercury, cadmium and nickel. **J. Environ. Sci. & Health. Part B- Pesticides Food Contamination and Agricultural Wastes, 40(2): 375-384.**

Das, N. and N. Ghosh (1999). Effect of sowing time and nitrogen level on seed yield of Amaranth (*Amaranthus tricolor*). **Hort. J. 12 (2): 77-82.**

Devlin, R.M. (1979). Plant Physiology, 3rd Ed. pp. 221-240, 284-298 & 353. Affiliated East-West Press Pvt. Ltd., New Delhi, India.

Dubois, M.; F. Smith; K.A. Gilles; J.K. Hamilton and P.A. Rebers (1956). Colorimetric method for determination of sugars and related substances. **Annal. Chem., 28 (3): 350-356.**

Elbehri, A.; D. Putnam and M. Schmitt (1993). Nitrogen fertilizer and cultivar effects on yield and nitrogen-use efficiency of grain amaranth. **Agron. J., 85 (1): 120-128.**

El-Kady, Amira F.Y. (2005). Effect of Some Pollutants on *Brassaia arboricola* var. *variegata* L. and *Ficus microcarpa* var. *Hawaii* L. pp. 82-94, 133-138 & 153. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

El-Leithy, A.S. (1987). Physiological Studies on French Marigold (*Tagetes patula*) Plants. pp. 159-163. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

El-Saeid, H.M.; M.S. Hussein; S.E. El-Sherbeny and E.A. Omer (1996). Effect of nitrogen on yield and active constituents of *Tagetes patula*. **Egypt J. Hort., 23(1): 101-112.**

Farid, M.R.; E.E. Habba and M.E. Aly (1994). Effect of fertilization on growth and anthocyanins content of roselle plant (*Hibiscus sabdariffa*, L.). **Monoufia J. Agric. Res., 19(5): 2471-2484.**

Fernandes, J.C. and F.S. Henriques (1989). Metal contamination in leaves and fruits of holm-oak (*Quercus rotundifolia*, Lan.) trees growing in a pyrites mining area at Alijustrel, Portugal. **Water, Air and Soil Pollut., 48(3-4):409-415.**

Fuleki, T. and F.J. Francis (1968). Quantitative methods for anthocyanins extraction and determination of total anthocyanin in cranberries. **J. Food Sci., 33: 72- 77.**

Genc, N. and Z. Acar (1999). An investigation into N requirements, hay and seed yields and some traits of amaranth (*Amaranthus sp.*). **Ondokuzmayis Universitesi, Ziraat Fakultesi Dergisi, 14(3): 65-75.**

Gouda, H. A. H. (2002). Physiological and Biochemical Studies on *Tagetes erecta*, L. and *Amaranthus tricolor*, L. Plants as Source of Natural Pigments. pp. 100-104, 120-134, 148-153 &155. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

Hilman, Y. and Z. Abidin (1987). The effect of nitrogen fertilization on the growth and yield of 4 *Amaranthus* cultivars. **Buletin Penelitian Hortikultura, 15(4): 22-29.**

Hirano, M.; M. Nakagawa; E. Kuroda and K. Honjyo (1991). The effects of nitrogen application on the growth of amaranth. **Crop Science Society of Japan, 34: 1-3.**

Jackson, M.L. (1967). Soil Chemical Analysis, pp. 144-197. Prentice-Hall, India.

Jain, V.K. (1983). Fundamentals of Plant Physiology, 4th Ed. pp. 140-141. S. Chand and Co., Ltd., Ram Nagar, New Delhi.

Kabata-Pendias, A. and H. Pendias (2001). Trace Elements in Soils and Plants, 3rd Ed. pp. 180-181 & 208. CRC Press, Florida.

Landberg, T.; M. Greger; R. Fuge; M. Billett and O. Selinus (1996). Differences in uptake and tolerance to heavy metals in salix from unpolluted and polluted areas. **Appl. Geochemist., 11(1-2) : 175-180.**

Lindsay, W.L. and W.A. Norvell (1978). Development of a DTPA soil test for Zn, Fe, Mn and Cu. **Soil Sci. Soc. Amer. J., 42: 421-428.**

Little, T.M. and F.J. Hills (1978). Agricultural Experimentation-Design and Analysis, pp. 61-63. John Wiley & Sons, Inc., New York, USA.

Lombi, E.; F.J. Zhao; S.J. Dunham and E.P. McGrath (2001). Phytoremediation of heavy metal contaminated soil. **J. Environ. Qual., 30: 1919-1926.**

Makus, D. (1992). Fertility requirements of vegetable amaranth (*Amaranthus tricolor*, L.) in an upland mineral soil of the mid-south. **Acta Hort., 318: 291-298.**

Naadasy-Iharosi, E. (1999). Effect of N fertilizer application and N forms on the yield and NO_3 content of *Amaranthus hybridus*. **Agrokemia es Talajtan, 48 (3/4): 369-380. (C.f. Hort. Abst., 70 (3): 2103).**

Nawawi, M.; W. Santoso and S. Notodimejo (1985). The effect of shading and nitrogen fertilizer application on the yield of spinach (*Amaranthus tricolor*, L.). **Agrivita, 8 (2): 17-18.**

Nie, J.; L. XiuMei and W. QingRen (2004). Influence of N, P, K nutrient levels on Pb uptake ability of hyperaccumulators. **Transactions of the Chinese Society of Agricultural Engineering, 20(5): 262-265.**

Nornai, R. (1982). Formula for determination of chlorophyll pigments extracted with N.N. dimethyl formamide. **Plant Physiol., 69: 1371-1381.**

Panchal, D.; R. Patel and K. Dalal (1991). Effect of nitrogen and phosphorus on grain yield and nutrients uptake by amaranth. **Gujarat Agric. Univ. Res. J., 16 (2): 71-72.**

Paredes-Lopez, O. (1994). Amaranth Biology, Chemistry and Technolog, pp. 155-160. CRC Press, Boca Raton, Florida.

Piper, C.S. (1947). Soil and Plant Analysis, pp. 258-275. Univ. of Adelaide, Adelaide, Australia.

Pregl, P. (1945). Quantitative Organic Microanalysis, 4th Ed. pp. 78-85. Churchill Publishing Co., London.

Rathore, M.S.; I. Singh and M.S. Chandawat (2004). Suitability of grain amaranth (*Amaranthus hypocondriacus*) cultivars for arid western plains zone of Rajasthan and their response to nitrogen application. **Crop Research Hisar., 27 (1): 54-57.**

Revees, R.D. and A.S.M. Baker (2000). Metal accumulation in plants. **In: Raskin, I.; B.D. Ensley (Eds.): Phytoremediation of Toxic Metals Using Plants to Clean Up the Environment, pp. 193-229.** John Wiley and Sons, Inc., New York, USA.

Richards, L.A. (1949). Methods of measuring soil moisture tension. **Soil Sci., 68: 95-112.**

Saini, J. and J. Shekhar (1998). Effect of nitrogen fertilizer on growth and yield of grain amaranth (*Amaranthus hypochondriacus*) cultivars under dry-temperate condition. **Indian J. Agron., 43 (4): 743-746.**

Salt, D.E.; R.R. Smith and I. Raskin (1998). Phytoremediation. **Ann. Rev. Plant Physiol. Plant Mol. Bio. 49: 54-68.**

Taiz, L. and E. Zeiger (2002). Plant Physiology, 3rd Ed. pp. 109 &110. Sinauer Associates, Inc., Publishers, Sunderland, Massachusetts, USA.

U.S. EPA (1998). Citizen Guide to phytoremediation. EPA / 542 / F- 98 / 001, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Responses. Washington, DC 20460.

Vos, B. (1989). Use of contaminated dredged sludge as a substratum for forest growth-case study. **Sliva Grandavensis, 54: 29-55.**

Wallace, A. (1994, a). Soil organic matter is essential to solving soil and environmental problems. Commun. **Soil Sci. Plant Anal., 25 (2): 15.**

Wallace, A. (1994, b). Ten reasons why organic growers do not use synthetically compounded fertilizers. Commun. **Soil Sci. Plant Anal., 25 (2): 125.**

Zerfus V. and A. Shchitov (1995). Effect of mineral fertilizers and sowing rate and productivity of *Amaranthus cruentus*. **Agrokhimiya, 12: 93-9.**

حوليات العلوم الزراعية
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استجابة نباتات الأمرنتس *Amaranthus tricolor*, L. للتغذية النتروجينية ودورها في علاج بعض الأراضى الملوثة بالعناصر الثقيلة

[١٧]

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أجريت هذه التجربة في أصص بمشتل تجارب قسم بساتين الزينة بكلية الزراعة، جامعة القاهرة، الجيزة، خلال موسمي ٢٠٠٥ و٢٠٠٦ بهدف دراسة إستجابة نباتات الأمرنتس (*Amaranthus tricolor*, L.) النامية فى أنواع مختلفة من التربة تشمل تربة من كلية الزراعة – جامعة القاهرة – كتربة غير ملوثة، وأربعة أنواع من التربة ملوثة بالنيكل والزنك من مناطق الجبل الأصفر وأبو رواش والتبين و شبرا الخيمة للتغذية النتروجينية [٧,٥ أو ١٥ جم سلفات الأمونيوم (٢٠,٥% ن) / أصيص/ موسم] ودورها فى علاج الأراضى الملوثة السابقة.

أدت كلا من معاملتى النتروجين لزيادة معنوية في صفات النمو الخضرى مقارنة بنباتات الكنترول الغير معاملة (فى معظم الأحيان). بصفة عامة أدت زيادة مستوى النتروجين المضاف الى زيادة طردية معنوية فى هذه الصفات وزيادة الكلوروفيل الكلى والكاروتينويدات والأنثوسيانينات والكربوهيدرات الكلية والنتروجين والفوسفور والبوتاسيوم فى الأوراق وكذلك النيكل والزنك الممتص، بينما أدت الى انخفاض تدريجى فى تركيز النيكل والزنك بأنواع التربة المستخدمة.

فى معظم الأحيان كانت تربة الجبل الأصفر الأكثر تأثيرا فى زيادة نمو نباتات الأمرنتس ومحتوياتها الكيماوية (الكلوروفيلات الكلية والكاروتينويدات والكربوهيدرات الكلية والنتروجين والفوسفور والبوتاسيوم)، يليها تربة كلية الزراعة. على النقيض من ذلك فإن النباتات النامية فى تربة شبرا الخيمة أعطت أقل القيم لصفات النمو الخضرى مقارنة بالنباتات التى نمت فى أنواع أخرى من التربة فى معظم الأحيان، وإحتوت على أقل تركيز من المحتويات الكيماوية السابق ذكرها وأعلى تركيز من الأنثوسيانينات والنيكل والزنك.

بصفة عامة أعطت النباتات النامية فى تربة الجبل الأصفر والمسمدة بأعلى معدل من النتروجين أعلى قيم لمعظم صفات النمو الخضرى والمحتويات الكيماوية التى تم تقديرها بالنبات، بينما أعطت النباتات التى نمت فى تربة شبرا الخيمة والغير مسمدة بالنتروجين أقل القيم.

يمكن التوصية بتسميد نباتات الأمرنتس فى مختلف أنواع التربة التى تم دراستها بمعدل ١٥ جم من سلفات الأمونيوم (٢٠,٥% ن)/ إصيص/ موسم للحصول على أفضل نمو خضرى. أعطت هذه المعاملة أفضل نتائج لمعظم صفات النمو الخضرى ومعظم المحتويات الكيماوية التى تمت دراستها بالنبات، وكذلك أدت لزيادة قدرة هذه النباتات على علاج الأراضى الملوثة بالنيكل. هذا ويجدر الإشارة إلى عدم قدرة نباتات الأمرنتس على علاج الأراضى الملوثة بالزنك.

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