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Influence of Nickel on Some Physiological Aspects of Tomato Plants

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Abstract: Seeds of tomato (*Lycopersicon esculentum* L.) cv. Marito, french were sown on August 15th 2005 and 2006, respectively in trays filed with a mixture of sand and peat moss (1:1 volume basis). The seedlings (at the first truly leaf) were irrigated with nickel sulphate at concentrations of zero, 15, 30, 45 and 60 ppm. The seedlings with almost the same stem thickness were transplanted in a newly reclaimed field at Nubaria, Research and Production Station of the National Research Centre. The aim of this work is designed to study the impact of nickel fertilization on fruit yield, fruit quality, mineral composition, enzymes activity and endogenous hormones of tomatoes. Nickel promote all the growth parameters of tomato plants during vegetative, flowering and fruiting stages of growth in the two growing seasons over that the control plants as well as those received 45 and 60 mg/ kg soil. The highest significant increase was obtained with 30 mg/kg soil. This level induced the highest plant height, number of branches, leaf area, root length in all plant stages. Auxins (IAA) and Gibberellins(GAs) contents of tomato shoots were significantly increased with increasing nickel addition up to 30 mg/ kg soil. Increasing Ni up to 45-60 mg / kg soil significantly reduced IAA and GAs for both tomato shoots and roots. Fruit length, diameter, weight and dry matter as well as vitamin C, total soluble solids and total soluble sugars were increased by nickel addition. Increasing nickel levels resulted in increases in the fruit quality up to level (60 mg Ni/kg soil). The highest increases in the fruit quality were obtained by 30 mg Ni/ kg soil. The fruits of the high nickel levels (45 and 60 mg/kg soil) were with less quality characteristics but its best from the untreated plants. Addition of all nickel concentration and had a significant promotive effect on nitrogen, phosphorus and potassium content in fruits as compared with that of control. Nickel level (i.e. 30 mg/kg sand soil) increased significantly not only tomato fruit yield but also it is visual quality, macro and micronutrient, total soluble solids, total soluble sugars, vitamin "C" and physical fruit parameters (length, diameter, weight and dry matter). This was also combined with a pronounced decrease in acidity, nitrate and ammonium contents indication safer product for human consumption

Key word: Nickel, some physiological aspects, tomato plants, Auxins, Gebberellins

INTRODUCTION

Nickel is an essential element for higher plants nutrition (Brown *et al,* 1987) since it is a component of ureas enzyme (Dixon *et al.*, 2004) required for nitrogen metabolism in higher plants (Eskew et al., 1984; Brown *et al.,* 1987,1990). Nickel deficiency depressed ureas enzyme activity (Eskew *et al.,* 1983) and other enzymes responsiblefor nitrate reduction (Brown *et al.,* 1990). As a result, a clear disruption in protein synthesis accompanied by a pronounced reduction in the level of total nitrogen has been noticed with nickel deficiency (Brown *et al.,* 1990). This was accompanied by accumulation of urea, nitrate and several; amino acids (Brown *et al.,* 1990; Eskew *et al.,* 1984; Shimada and Watanab, 2004) which caused clear symptoms of leaf chlorosis and meristem necrosis in several plants species such as soybeans (Eskew *et al.,* 1984), parsley and cucumber plants (Shimada and Watanab, 2004). Symptoms of growth depression, early senescence inhibition of grain development as well as grain inviability and reduction in the levels of iron in the tissues have been noticed in cereals such as barley, oat and wheat with nickel deficiency (Broen *et al.,* 1990) low leaves of nickel are therefore, required for increasing the yield of commercial crops regardless of the sort of nitrogen fertilizers used i.e. nitrate ammonium and urea (Eskew *et al.,* 1984; Brown *et al.,* 1987).

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Kukier and Chaney (2004) found that grass species were more resistance to nickel toxicity than dicots. Nickel increased fruit yield, fruit quality, and nutritional status of the tomato fruits (Palacois *et al.,* 1999 and Ozores-Hampton *et al.,* 1999).

Rao and Shantarom (2000) showed that nickel gave the promotive effect on both dry matter and concentrations of Fe, Zn, Cu, Mn, Ni and Cr. Karagiannidis *et al.,* (2002) found that nickel improved the tomatoes yield by 1.6 times for biomass by 2.5 times for fruit yield, by 1.69 times for number of fruits and by 1.5 times for average fruit weight comparing the control. Brake *et al.,* (2004) pointed that the tomato plant grown in soils amended with 5, 10 and 20 pm nickel increase the growth, early yield and fruit quality. Watanab *et al.,* (2005) found that the addition of nickel increased tomato dry matter and decreased the No3-N content of plants. Tripathi and Sadhna-Tripathi (2000) showed that nickel gave promotive effect on root and shoot growth, leaf area and biomass, chlorophyll, protein, carbohydrate and sugar in leaves which were positively and significantly correlated with leaf area, root and shoot length and biomass of Albizia Iebbek plants. Rahmatullah *et al.,* (2001) showed that nickel improved tomatoes shoot and root growth and N uptake compared with control. Wallace *et al.,* (1997) found that when tomato plants were grown in solution culture at low level of nickel of leaves, stem and roots were considerably increased while high nickel decreased Fe, Mn, Zn and Cu in leaves. High nickel level also reduces phosphorus translocation.

Nalini-Panday and Sharma (2003) pointed that the exposure to excess concentration, of nickel decreased tomato plants uptake of Fe and its translocation to leaves as well as chlorophyll content, concomitant with decrease in the activities of the Fe enzymes, catalase and peroxidase. Sheoran *et al.,* (2004) found that it is suggested that this may primarily be to facilitate the assimilation of urea from the ambient environment. Puckett and Lane (1979) found that sunflower plants grown in solution culture, high rates of nickel decreased the IAA-oxidase activity and the level of free IAA content in apical leaves, whereas the content of IAA bound with proteins was markedly increased.

Kleszozwska and Koczorowski (2001) showed that nickel has a role in metabolism of lipids, in the amino acids structural through activating enzyme activity. Nickel also occurs in trace levels in several human diets including flowers, fruits, vegetables, fish and animal products with higher levels in legumes, tomato, lettuce and parsley (Anke, 1991).

The aim of this work is designed to study the impact of nickel fertilization on fruit yield, fruit quality, mineral composition, enzymes activity and endogenous hormons of tomatoes grown in Nobaria location, Research and Production Station, National Research Centre.

MATERIALS AND METHODS

Seeds of tomato (*Lycopersicon esculentum* L.) cv. Marito, french were sown on August 15th 2004 and 2005, respectively in trays filed with a mixture of sand and peat moss (1:1 volume basis). The trays were kept under greenhouse conditions with all agricultural managements required for the production of tomato seedlings as usually recommended till germination.

The seedlings (at the first truly leaf) were irrigated with nickel sulphate at concentrations of zero, 15, 30, 45 and 60 ppm. When the seedlings formed the third truly leaf (5 weeks), uniform ones with almost the same stem thickness were transplanted in a newly reclaimed field at Nubaria, Research and Production Station of the National Research Centre.

The experiment in could five treatments (control, 4 nickel concentrations). Each treatment was represented by 3 plots. The plot area was 5 X 3 meter, consisting rows. Ten seedlings were transplanting in each row (50 cm apart).

Soil Analysis:

Representative soil samples were taken from chosen profiles at depths of 0-30; 30-60 and 60-90 cm, respectively, from Nubaria field. Particle size distribution along with soil moisture constants of representative soil samples, as described by Blackmore (1972) was determined. Organic matter content, $CaCO_3$ %, pH, EC, soluble cations and anions were assayed according to Black *et al.,* (1982). Determination of soluble and available micronutrients was run according to the method described by Jackson (1973). Total nickel was determined in Aqua regia extract, the water soluble nickel as well as available cobalt (DTPA extractable) being assayed to Cottenei *et al.,* (1982). Soil physical and chemical properties were analyzed as shown in Table (A).

Determination of Peroxidase, Catalase and Ureas Enzymes Activity:

After 45 days from nickel treatment, peroxidase, catalase and urease enzymes activity were determined according to Maxwell and Bateman (1967) and Seevers *et al.,* (1971).

Table A: Physical and chemical properties of Nubaria location, Research and Production Station, National Research Centre.

Soil property								
	Particle size distribution %				Soil Moisture constant %			
	Sand	Silt	Clay	Texture	Saturation	FC	WP %	AW
	68.7	24.5	6.8	S L	32.0	19.2	6.1	13.1
Physical	pH^a		$EC^b dS/m$		$CaCO_3\%$		$OM\ ^c\%$	
	7.8		0.18		7.07		0.16	
	Soluble cations (meq/l)				Soluble anions (meq/l)			
	Ca^{++}	Mg^{++}	K^+	Na^+	$CO_3^{=}$	HCO_3^-	Cl^-	$SO^{=}$
	3.00	2.00	0.32	2.09	0.00	1.41	0.70	5.30
	Total	Available			Available micronutrients			
	N	P	K		Fe	Mn	ZN	Cu
Chemical	Mg/100 g soil				ppm			
	15.0	9.4	16.0		7.8	3.3	1.86	4.0
	Nickle (ppm)				Cobalt (ppm)			
	Soluble	Available	Total		Soluble	Available	Total	
	0.09	1.12	9.56		0.49	4.43	15.00	

a: Soil pH was measured in 1:2.5 soil-water suspension,
b: EC was measured as dSm^{-1} in soil paste, S L: sandy loam
c: organic matter.

Determination of Endogenous Hormones as Auxins (Iaa), Gibberellins (Gas) and Abscisic Acid (ABA):

After 45 days from nickel treatment, IAA, GAs and ABA were determined from both tomato shoots and roots according to Shindy and Smith (1975).

Measurement of Plant Growth Parameters:

After 105 days (fruiting stage), plant height, stem diameter, number of leaves per plant, and leaf area were determined according to Gabal *et al.,* (1984). Also, fresh and dry weight for both shoots and roots were recorded.

Fruit Yield:

Fruit yield was considered as early and calculated as ton /fed.

Measuring Fruit Quality:

- Total soluble solids (%) and total soluble sugars were determined according to Man and Hens (1949) and FAO (1980).
- Titratable acidity and ascorbic acid content were determined according to A.O.A.C. (1980).
- Fruit mineral contents namely, (N, P, K, Co, Fe, Mn, Zn and Cu) were determined according to Black et al (1982),

RESULTS AND DISCUSSIONS

Vegetable Growth:

Data presented in table (1) outline the response of tomato growth parameters to different nickel levels (15 and 30 mg/kg soil). It is clear that nickel promot all the growth parameters of tomato plants during vegetative, flowering and fruiting stages of growth in the two growing seasons over that the control plants as well as those received 45 and 60 mg/ kg soil. The highest significant increase was obtained with 30 mg/kg soil. This level induced the highest plant height, number of branches, leaf area, root length in all plant stages. These data are in harmony with those reported by Rahmatullah *et al.,* (2001) who found that nickel improved shoot and root growth of tomato compared with control.

Table 1: Effect of nickel fertilization on morphological parameters of tomato plants after 45, 75 and 105 days from transplanting.

Days after transplanting	45 days				75 days				105 days			
Nickel treatment (ppm)	Plant height (cm)	Number of branches	Plant leaf area (cm^2)	Root length (cm)	Plant height (cm)	Number of branches	Plant leaf area (cm^2)	Root length (cm)	Plant height (cm)	Number of branches	Plant leaf area (cm^2)	Root length (cm)
First season (2005)												
Control	107	3	156	23	121	4	224	35	137	4	281	46
15	123	4	192	28	129	5	286	41	145	6	329	53
30	134	5	227	32	141	6	312	48	156	6	359	60
45	111	4	160	25	125	4	251	39	142	5	288	51
60	100	3	143	22	118	4	210	33	132	4	244	44
LSD 5%	5	1	13	3	3	ns	12	3	5	ns	22	3
Second season (2006)												
Control	100	3	152	21	116	4	219	32	131	4	276	43
15	115	4	188	25	130	5	277	38	146	5	319	49
30	129	5	211	31	142	5	305	44	151	6	343	56
45	104	3	161	24	121	4	246	36	142	5	279	49
60	94	3	148	19	112	3	206	28	128	4	223	40
LSD 5%	7	1	3	3	5	ns	12	3	4	ns	19	3

Table 2: Effect of nickel fertilization on the fresh and dry weight of tomato plants after 45, 75 and 105 days from transplanting.

Days after transplanting	45 days				75 days				105 days			
Nickel treatment (ppm)	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight
	gm / plant											
First season (2005)												
Control	155	35.7	14.2	2.62	213	49.0	23.8	4.23	448	101	42.4	5.65
15	179	48.0	17.5	3.28	240	63.5	29.6	5.57	479	124	48.2	6.46
30	191	53.1	19.8	3.71	258	71.2	31.4	5.90	492	131	52.5	7.03
45	173	47.2	16.3	2.98	220	59.4	27.3	5.11	473	125	47.2	6.16
60	146	38.5	13.6	2.50	201	53.9	25.0	4.65	441	117	39.3	5.20
LSD 5%	5	3.2	1.1	0.14	8	2.3	1.2	0.23	6	7	2.4	0.31
Second season (2006)												
Control	149	33.8	12.8	2.34	210	47.3	22.9	4.04	385	89.2	37.7	4.98
15	163	45.0	16.6	3.13	227	59.2	27.5	5.10	397	107.0	44.6	5.96
30	179	49.3	18.9	3.55	243	65.7	30.0	5.89	406	109.0	49.9	6.73
45	156	40.7	15.4	2.89	217	55.6	26.6	5.20	388	102.0	42.2	5.69
60	144	37.6	13.3	1.74	198	50.5	23.9	4.42	377	98.7	36.3	4.82
LSD 5%	4	2.4	0.9	0.18	10	2.6	0.6	0.45	13	7.8	1.6	0.14

Table 3: Effect of nickel application on enzyme (ureas, catalase and pyroxidase) activity of tomato shoots and roots during 2005, 2006 seasons..

Nickel treatment (ppm)	First season 2004						Second season 2005					
	Shoot			Root			Shoot			Root		
	Ureas	Catalase	Pyroxidase	Ureas	Catalase	Pyroxidase	Ureas	Catalase	Pyroxidase	Ureas	Catalase	Pyroxidase
	Content ug / gm tissue											
Control	2.614	4.410	6.331	5.122	7.761	12.223	2.166	4.101	6.112	4.001	8.012	11.870
15	2.111	4.142	4.988	4.013	7.981	9.200	2.011	3.980	4.730	3.988	7.133	9.145
30	1.320	3.201	3.224	2.416	6.002	6.005	1.132	3.198	3.099	2.004	6.008	6.004
45	5.713	6.830	5.820	11.051	9.895	10.624	4.540	5.418	5.230	8.788	11.022	11.112
60	7.913	8.320	8.222	14.263	14.628	15.800	6.819	7.420	8.187	13.101	13.989	16.155
LSD 5%	1.121	0.227	1.021	1.184	0.123	2.312	0.091	0.524	0.515	1.524	1.026	3.122

Growth Parameters:

Adding 15 and 30 mg/kg soil caused significant increase in tomatoes fresh and dry weights of shoots and roots (Table 2). These increases were found in the two seasons over that of untreated plants or those received 45 and 60 Ni mg/kg soil. The highest and significant increase was obtained with 30 mg Ni/kg soil. On the other hand, higher nickel concentration, namely 45 and 60 mg Ni/kg soil, resulted in significant reduction in tomato, fresh and dry weight. The results add more support to those reported by Tripathi and Sadhna Tripathi (2000) who showed that nickel caused promotive effects on root and shoot growth.

Enzymes Activity:

The results of this work showed that tomato plants exposed to low levels of nickel (15 and 30 mg/kg soil) enhanced plant net photosynthesis. On the other hand, Sheoran *et al.,* (2004) showed that bean plants exposed higher nickel levels decreased plant photosynthetic electron transport capacity.

Data in Table (3) showed that the increase of the activity of catalase, peroxidase and urease with high levels of nickel is known to enhanced plant respiration and this may cause further consumption of plant net photosynthesis. Therefore, it could be concluded that, low level of nickel enhanced plant anabolism on the contrary, higher levels enhanced plant catabolism.

Table 4: Effect of nickel fertilization on both endogenous hormons (IAA, GAs)and ABA (ug/g fresh tissue) of tomato shoots and roots during 2005, 2006 seasons..

Nickel treatment (ppm)	First season (2004)						Second season (2005)					
	Shoot			Root			Shoot			Root		
	IAA	GAs	ABA	IAA	GAs	ABA	IAA	GAs	ABA	IAA	GAs	ABA
	Content ug / gm tissue											
Control	1.720	1.902	0.432	1.844	1.972	0.988	1.661	1.840	0.381	1.776	1.880	0.891
15	3.854	3.660	0.870	2.745	2.146	1.215	2.755	2.853	0.840	3.645	2.346	1.215
30	5..002	3.984	1.506	4.842	3.680	2.583	3.676	3.788	1.267	4.780	4.286	2.145
45	3.854	2.763	2.789	2.595	2.128	3.649	2.997	2.554	2.860	3.571	3.481	3.750
60	2.755	1.979	3.898	1.428	1.825	4.787	1.955	1.501	3.766	2.089	1.438	4.377
LSD 5%	1.025	1.231	0.123	0.327	0.145	0.224	0.136	0.221	0.425	0.218	0.361	0.235

Table 5: Effect of nickel fertilization on the fresh and dry weight of tomato yield (ton/fed).

Nickel treatment (ppm)	First season 2004				Second season 2005			
	Early	Total	Marketable	Unmarketable	Early	Total	Marketable	Unmarketable
Control	1.160	5.400	4.913	0.558	0.950	4.400	3.953	0.446
15	2.186	8.020	7.453	0.667	1.813	6.553	5.880	0.673
30	4.493	10.706	9.980	0.726	3.838	8.480	7.620	0.840
45	4.413	8.253	7.373	0.880	5.026	10.366	9.333	1.033
60	3.733	7.807	7.193	0.613	4.626	9.660	8.660	1.000
LSD 5%	0.08	1.024	0.165	0.046	0.651	1.238	1.652	0.029

Table 6: Effect of nickel fertilization on tomato fruits quality.

Nickel treatment (ppm)	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Dray matter (g/fruit)	Vitamin C mg/ 100 g fresh weight	Titrable acidity as citric acid (%)	Total soluble solids (%)	Total soluble sugars
				First season (2004)				
Control	3.96	4.23	73.96	4.46	13.6	479	3.23	2.42
15	5.80	5.66	104.53	5.58	17.9	582	3.80	2.51
30	6.16	6.73	111.53	5.96	24.4	668	3.93	2.98
45	5.53	5.56	102.03	5.51	22.2	553	3.66	2.37
60	5.40	5.34	100.15	5.12	20.1	540	3.60	2.26
LSD 5%	0.12	0.26	1.92	0.12	2.3	22	0.03	0.02
				Second season (2005)				
Control	3.62	3.79	60.36	4.12	13.9	634	3.46	2.31
15	5.27	5.48	99.04	5.47	24.2	696	3.93	2.40
30	5.44	5.63	105.56	5.55	22.4	705	4.45	2.91
45	5.40	5.48	94.69	5.45	20.0	668	3.66	2.28
60	5.23	5.43	92.91	5.22	17.8	611	3.34	2.19
LSD 5%	0.14	0.33	2.59	0.10	1.4	20	0.06	0.03

Endogenous Hormones:

Data in table (4) clearly indicate that Auxins (IAA) and Gibberellins contents of tomato shoots were significantly increased with increasing nickel addition up to 30 mg/N kg soil. Increasing Ni up to 45-60 mg / kg soil significantly reduced IAA and GAs for both tomato shoots and roots.

Analyzing ABA levels in either tomato shoots and roots showed that as nickel concentration increased, ABA levels increased. These results agrees with those of Lui *et al.,* (2000) who reported that with the increasing of Ni addition parallel to ABA content on peanut plants.

Total Fruit Yield and its Components:

Data concerning the effect of nickel on yield parameters of tomatoes are given in Table (5). The results clearly indicate that nickel addition gave a pronounced promotive effect on fruit yield /plant as compared with control. The significant increase was obtained with 30 mg Ni/kg soil which increased the total fruit yield and its components, i.e. early, marketable and non-marketable fruit yield, 3.87, 2.17, 2.03 and 1.56 ton/fed, respectively for first fruit season. While for the second season, 5.87, 2.36, 2.36 and 4.13ton/fed, respectively comparing the control. High nickel concentrations, namely 45 and 60 mg/kg soil, resulted in proportion significant reduction in tomatoes fruit yield. These results agrees with those of Karagiannidis *et al* (2002) who found that nickel improved tomatoes fruit yield by 2.5 times for fruit yield comparing the control.

Fruit Quality:

Physical and chemical properties of tomato fruits (Table 6) were enhanced by nickel applications. Fruit length, diameter, weight and dry matter as well as vitamin C, total soluble solids and total soluble sugars were increased by nickel addition. Increasing nickel levels resulted in increases in the fruit quality up to level (60 mg Ni/kg soil). The highest increases in the fruit quality were obtained by 30 mg Ni/ kg soil. The fruits of the high nickel levels (45 and 60 mg/kg soil) were with less quality characteristics but

Table 7: Effect of nickel fertilization on mineral composition and nitrogen form of tomato fruits.

Days after transplanting / Nickel treatment (ppm)	Macro-nutrients (%)			Micro-nutrients (ppm)						Nitrogen form (mg/plant)		
	N	P	K	Fe	Mn	Zn	Cu	Ni		NH_4^+	NO_3^-	Total
								Shoot	Fruit			
First season 2004												
Control	3.19	0.25	0.30	117	64.2	29.2	23.5	0.40	0.15	220	380	600
15	3.25	0.36	0.44	128	68.5	35.3	27.3	10.2	1.71	180	350	530
30	3.40	0.42	0.51	139	75.9	43.0	31.6	21.6	3.12	150	320	470
45	3.33	0.34	0.39	143	79.4	48.8	36.0	36.5	8.00	120	280	400
60	3.27	0.22	0.32	146	80.9	51.2	39.7	42.0	11.50	90	250	340
LSD 5%	0.03	0.01	0.02	5	3.1	3.2	2.7	7.3	1.25	23	29	124
Second season 2005												
Control	3.15	0.23	0.30	115	61.2	26.0	21.8	0.36	0.12	205	365	570
15	3.22	0.33	0.41	125	65.9	33.6	25.5	9.82	1.66	167	351	508
30	3.35	0.39	0.50	133	72..5	41.1	29.0	19.5	3.01	135	322	457
45	3.30	0.32	0.38	140	77.0	45.7	33.8	33.7	7.82	105	283	388
60	3.24	0.28	0.32	145	79.2	49.0	36.6	39.1	10.70	78	251	329
LSD 5%	0.05	0.03	0.03	6	3.4	3.5	2.9	6.1	1.12	22	27	128

its best from the untreated plants. In general the tomatoes fruit quality improved with increasing Ni level (30 mg/kg soil). This may be explained positive role of nickel in increasing fruit yield and yield quality in tomato plants. Increasing Ni level from 30 mg to 45 mg and 60 mg /kg soil gave the adverse effect. These data were in agreement with Ozores-Hampton *et al.,* (1999).

Mineral Content in Tomatoes Fruits:

Data in Table (7) revealed that the addition of all nickel concentration and had a significant promotive effect on nitrogen, ,phosphorus and potassium content in fruits as compared with that of control. Mineral content is an essential component of nutritive value of vegetables (Pennington and Church, 1985). However, with high Ni concentrations (45 and 60 mg/kg soil) the amount of such elements reduced the levels of Mn, Zn, Cu and Fe however, showed significant increases with increasing Ni application for two season. Eskew *et al.,* (1984). Reported that nitrate and ammonium levels in tomato fruits accumulated in nickel deficient plants. In this work, all concentrations of nitrate, ammonium and toatal N of Ni addition reduced fruit content which is essential for human health, particularly for children and ill people (Karlowski, 1990). The most significant increase was obtained with 30 mg/kg soil. Being a component of ureas enzyme (Dixon et al, 2004) how reported that Ni is an essential not only of nitrogen metabolism but also for protein synthesis in higher plants (Karlowski, 1990). Such finding may conform the role of Ni in arresting nitrate and ammonium accumulation by stimulating N metabolism and protein synthesis in higher plants (Brown *et al.,* 1990).

Sandy soils required Ni levels lower than 10 mg/kg soil while higher levels, i.e. 45 and 60 mg /kg soil were require for clay soils. Nickel content fro tomato shoot and fruits increased with the increasing addition of Ni. Nickel content in tomato fruits reached about 0.15 – 10.5 ppm (Anke *et al,* 1998) who reported that the daily nickel requirements for human nutrition ranged between 25 – 35 mg. yet, in control Europe and several German towns, nickel intake by adult humans reached 142 – 222 mg/day, depending on Ni levels in the local supply of drinking water, without human health hazard. Level of 10.5 ppm Ni for even the highest Ni treatment (60 mg/kg soil) is below the dangerous level, since the daily consumption of tomato fruits does not exceed a few grams.

Conclusion:

In conclusion, nickel level (i.e. 30 mg/kg sand soil) increased significantly not only tomato fruit yield but also it is visual quality, macro and micronutrient, total soluble solids, total soluble sugars, vitamin “C” and physical fruit parameters (length, diameter, weight and dry matter). This was also combined with a pronounced decrease in acidity, nitrate and ammonium contents indication safer product for human consumption.

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