RESULTS & DISCUSSION

4. *RESULTS AND DISCUSSION*

4.1. THE FIRST EXPERIMENT (Pot experiment)

Control of pollution with cadmium in lettuce plants:

In this experiment lettuce plants of two cultivars i.e. Balady and Great Lakes were grown under different levels of soil Cd pollution 0, 10, 20 or 30 ppm in a sandy soil amended with organic manure (15 gm/kg soil), clay (10 gm/kg soil), or $CaCO_3$ (5 gm/kg soil) as well as the control treatment (without amendments). The effect of cultivar, Cd stress and soil amendment on plant growth and the chemical constituents as indicators for the degree of pollution was investigated and the obtained results are presented and discussed hereafter:

4.1.1. Effect of cultivar, cadmium level and soil amendments on plant growth characteristics of lettuce

Data in table (1) illustrates the effect of cultivar, Cd level and soil amendments on growth parameters i.e., plant height, number of leaves/plant, fresh and dry weight of both shoot and root per plant as well shoot/root ratio on dry weight basis.

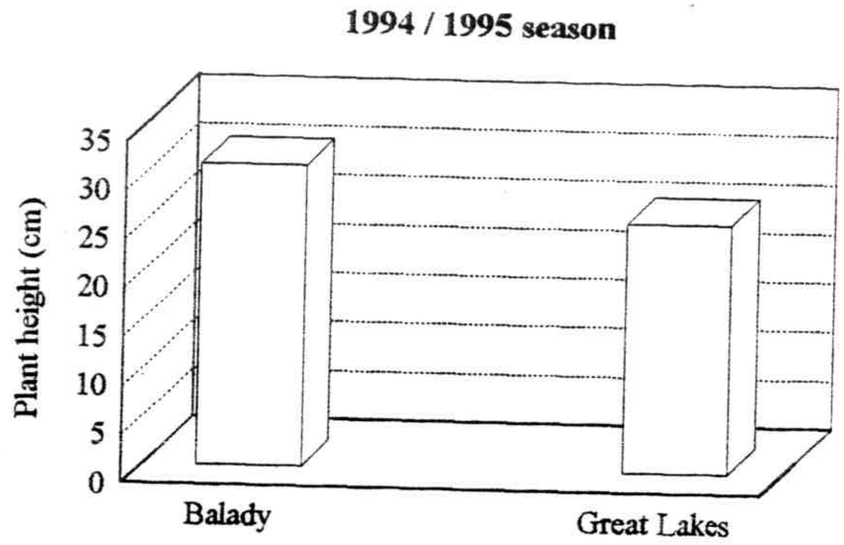
Cultivar effect: Regarding the effect of cultivar, it is clear that lettuce plants of Balady cv. preceded those of Great Lakes regarding plant height, fresh and dry weight of both shoots and roots . However, number of leaves/plant and shoot/root ratio on dry weight basis were not significantly affected. This held true in both growing seasons. Moreover, Fig. (1) shows a wide difference in plant height of the two cultivars indicating that this parameter is the most representative varietal character (which is highly correlated with plant growth).

These results are in harmony with those obtained by John and van Laerhoven (1976b) and Kobryn (1987), who reported varietial differences regarding lettuce growth characters. Also, Shafshak and Abo Sedera (1990) found that plants of Balady lettuce cultivar were taller

Table (1): Growth characters of lettuce as affected by cultivar, cadmium level and soil amendments:

Seasons	1994/95 Season							1995/96 Season						
Characters / Treatments	Plant ht. cm	No. of leaves/ Plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm	Shoot /Root DW	Plant ht. cm	No. of leaves/ Plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm	Shoot /Root DW
Cultivar														
Balady cv.	30.8	34	336	31.4	57.7	5.5	5.7	28.2	33	324	31.0	55.6	5.4	5.7
Great Lakes cv.	25.5	34	283	23.1	49.6	4.1	5.6	24.2	35	289	23.7	49.8	4.2	5.6
L.S.D. at 5%	**1.1**	**N.S.**	**27.0**	**1.9**	**0.8**	**0.3**	**NS**	**2.5**	**0.9**	**1.7**	**1.6**	**0.3**	**0.26**	**NS**
Cd level (ppm)														
0	30.2	36	316	27.5	60.7	5.4	5.1	24.7	35	331	30.3	56.8	5.3	5.7
10	28.7	34	311	27.4	53.5	4.8	5.7	27.3	33	295	26.0	50.8	4.6	5.6
20	27.3	33	306	27.1	52.7	4.8	5.6	25.9	32	291	25.7	50.0	4.5	5.7
30	26.5	34	304	27.1	52.2	5.2	5.2	26.9	35	310	27.5	53.4	4.8	5.7
L.S.D. at 5%	**0.7**	**0.6**	**N.S.**	**0.3**	**0.7**	**0.06**	**0.15**	**1.1**	**0.9**	**5.1**	**0.5**	**0.86**	**0.08**	**NS**
Amendments														
Control (0)	21.4	32	278	24.5	52.8	4.9	5.0	19.4	31	267	23.8	50.7	4.8	5.0
Organic manure	27.9	33	284	25.3	47.1	4.2	6.1	25.5	33	290	25.7	46.5	4.3	6.0
Clay	31.1	35	332	29.5	56.5	5.0	5.9	30.0	35	333	30.1	56.5	5.1	5.9
$CaCO_3$	32.3	37	343	29.8	58.3	5.1	5.8	29.8	36	337	29.8	57.2	5.1	5.8
L.S.D. at 5%	**0.7**	**0.9**	**16.5**	**0.6**	**0.9**	**0.1**	**0.26**	**0.8**	**1.0**	**5.8**	**0.7**	**1.0**	**0.13**	**0.3**

N.S. = Nonsignificant



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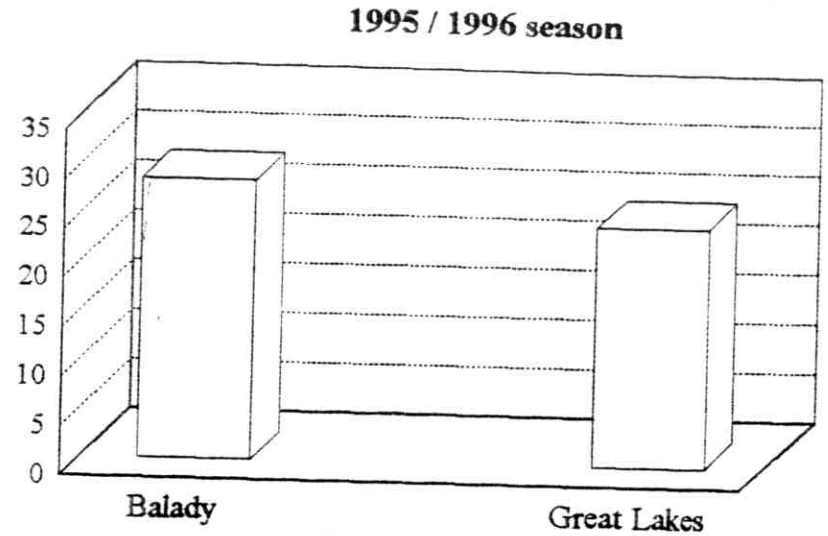

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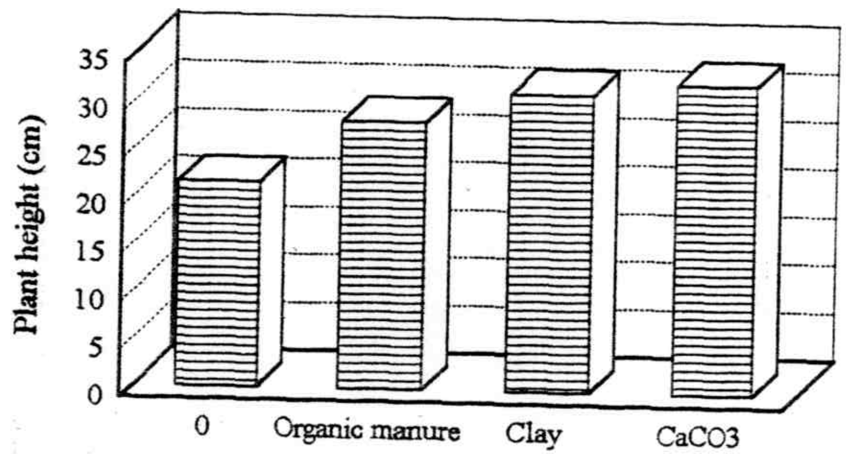

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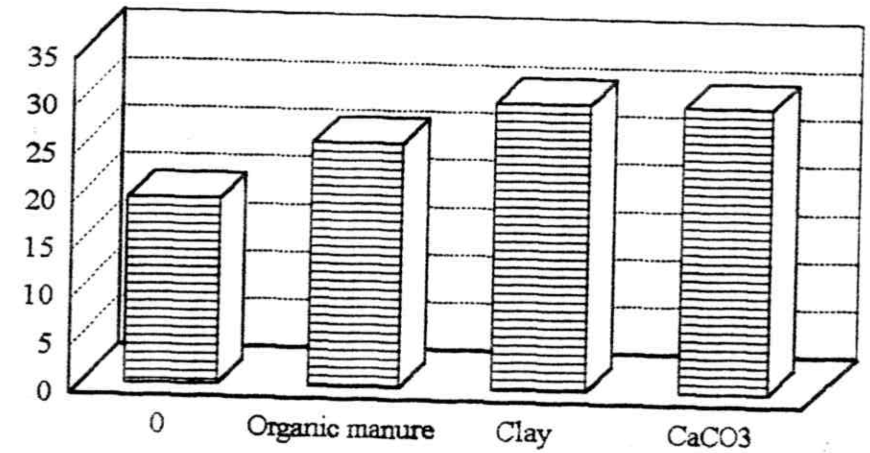

L.S.D. at 0.05 = 0.8

Fig. (1) : Effect of cultivar or amendments on lettuce plant height irrespective of Cd application

but less in average head weight than those of Dark Green leading to the assumption that the growth features are varietal characters.

Cadmium effect **:** Concerning the contamination with various Cd levels on growth parameters, it is clear from the data in Table (1) that Cd application had a depressive effect on plant growth. All growth parameters, in both growing seasons, negatively responded to the increase of Cd level from 0 up to 20 ppm. Some growth parameters i.e., number of leaves/plant, fresh and dry weights of shoots and roots of plants received 30 ppm Cd showed higher values than those grown in 20 ppm Cd with a varied significance between the two growing seasons. This result may be due to the many other environmental conditions affecting such growth parameters.

In this context, Plant growth retardation due to Cd toxicity was reported also by Bingham *et al.* (1975) on spinach, soybean, curlycress, lettuce, tomato and cabbage; Mahler *et al.* (1978) on lettuce and chard; Wichmann *et al.* (1983) on bush beans and carrots; Strnad *et al.* (1990) on potato and Salim *et al.* (1992) on *Vicia faba*. In this regard , Keshan and Mukherji (1992) working on mung bean, suggested that one mode of action by which Cd may affect shoot growth, is by inhibiting the synthesis and subsequent translocation of cytokinin to the meristematic regions of the shoot .

On the contrary, Jimmy *et al.* (1977) reported that rather high levels of Cd (up to 60 mg Cd/kg soil on a dry matter basis) may be present in lettuce leaves before either visual phytotoxic symptoms or any significant reduction in yield are encountered. Also, Costa and Morel (1994) on lettuce found that at low Cd concentrations (0.01, 0.1 m μM) biomass production increased, while 100 μM Cd was toxic to both root and shoot growth.

To search for an explanation with respect to Cd inhibitory action, Kloke (1974) reported that cadmium toxicity is no doubt, to some extent, due to

similarities in atomic structure which may allow it to replace Zn in enzyme systems in living organisms.

Amendment effect: With respect to amendments effect i.e., organic manure, clay and $CaCO_3$ application on lettuce plant growth, data presented in Table (1) clearly show that all the applied amendments significantly enhanced plant growth. A pronounced increase regarding values of all growth parameters were observed in plants grown under clay and $CaCO_3$ treatments in both growing seasons (having mostly insignificant difference in-between). It is noticeable that organic manure application led to a reduction of root fresh and dry weight in both growing seasons. This may be due to the fact that roots are restricted in the wet and nutrient rich zone and don't have to go down in search for water.

Regarding the effect of soil amendments on plant height as an indicative growth parameter, Fig. (1) shows that lettuce plants supplemented with either clay or $CaCO_3$ application showed superiority in their height and exceeded those treated with organic manure or untreated control treatment. This held true in both growing seasons. These results confirmed the results obtained by Hortenstine and Webber (1981), who tested the effect of cadmium, peat and lime additions on spinach . They reported that peat significantly increased the obtained yield of spinach, cv. Long Standing Bloomdale.

Interaction effect: Tables (2 and 3) illustrate the interaction effect of cultivar, Cd level in soil and soil amendments on growth characters of lettuce plants in 1994/95 and 1995/96 winter growing seasons, respectively.

Table (2) The interaction effect of cultivar, Cd level and soil amendments on growth characters of lettuce (1994/95).

Cd level ppm	Amendment	Plant ht. cm	No. of leaves/plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm
		Balady cv.					
0	0	34.9	35.3	351.4	32.4	59.7	5.5
	OM	31.7	35.9	363.2	34.1	61.7	5.8
	Clay	36.7	37.1	369.9	34.1	62.8	5.8
	CaCO3	38.7	39.1	389.3	33.4	66.2	5.6
10	0	33.5	33.4	338.1	33.5	57.4	5.7
	OM	33.7	36.4	366.4	35.0	62.3	5.9
	Clay	35.3	35.1	355.9	35.3	60.5	6.0
	CaCO3	37.1	37.0	374.6	32.6	63.7	5.5
20	0	29.3	32.1	306.5	28.7	49.0	4.7
	OM	30.3	32.7	330.0	31.4	52.8	5.2
	Clay	30.8	33.8	322.7	30.3	51.6	5.0
	CaCO3	32.4	35.5	339.6	28.3	54.3	4.7
30	0	20.9	28.9	273.5	26.2	51.9	5.2
	OM	22.8	32.0	295.9	28.7	56.2	5.7
	Clay	22.0	30.4	287.8	27.5	54.6	5.5
	CaCO3	23.1	32.1	302.9	29.4	57.5	5.9
		Great Lakes cv.					
0	0	28.5	33.4	289.2	23.8	50.0	4.0
	OM	27.7	33.4	304.3	25.0	52.6	4.2
	Clay	29.1	37.2	329.7	26.4	55.4	4.4
	CaCO3	30.7	40.1	339.1	28.6	57.6	4.8
10	0	25.7	32.3	286.7	22.7	48.6	3.8
	OM	26.4	34.7	301.1	23.9	51.1	4.0
	Clay	27.8	37.4	316.9	25.2	52.8	4.2
	CaCO3	29.3	36.2	317.3	27.0	53.9	4.5
20	0	19.9	32.9	193.3	20.4	41.3	3.4
	OM	25.3	30.8	258.2	19.8	40.3	3.3
	Clay	26.6	32.4	252.2	20.9	42.4	3.4
	CaCO3	28.0	34.1	265.5	22.0	44.7	3.6
30	0	18.9	31.2	245.3	19.4	46.6	3.8
	OM	19.9	32.9	258.2	20.4	49.0	4.0
	Clay	21.0	34.6	271.8	21.5	51.6	4.3
	CaCO3	22.1	36.5	285.1	22.6	54.3	4.5
LSD at 5%		*1.9*	*2.6*	*N.S.*	*1.6*	*2.6*	*0.3*

OM = Organic manure NS =Nonsignificant

Table (3) The interaction effect of cultivar, Cd level and soil amendments on growth characters of lettuce (1995/96).

Cd level ppm	Amendment	Plant ht. cm	No. of leaves/plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm
		Balady cv.					
0	0	28.9	36.1	333.8	30.7	56.7	5.2
	OM	34.9	35.3	351.4	32.4	59.7	5.5
	Clay	30.1	33.3	345.0	32.4	58.6	5.5
	CaCO3	33.1	33.5	397.4	37.8	67.5	6.4
10	0	31.8	31.7	321.2	31.8	54.6	5.4
	OM	33.5	33.4	338.1	33.5	57.4	5.7
	Clay	32.0	34.6	348.1	33.3	59.1	5.6
	CaCO3	34.3	38.1	406.6	39.4	69.1	6.7
20	0	26.5	30.5	291.2	27.3	46.6	4.5
	OM	28.8	31.1	313.5	29.8	50.1	4.9
	Clay	29.3	32.1	306.5	28.7	49.0	4.7
	CaCO3	29.3	35.5	327.8	31.9	52.4	5.3
30	0	19.8	27.5	259.7	24.9	49.3	4.9
	OM	21.6	30.4	281.1	27.3	53.4	5.4
	Clay	20.9	28.9	273.4	26.2	51.9	5.2
	CaCO3	20.9	28.9	285.1	27.8	54.1	5.5
		Great Lakes cv.					
0	0	25.1	31.1	271.7	21.6	46.2	3.6
	OM	26.4	32.7	286.0	22.7	48.6	3.8
	Clay	28.9	30.1	339.2	28.6	57.6	4.8
	CaCO3	28.3	30.8	349.0	29.7	59.3	5.0
10	0	27.7	33.4	294.3	23.8	50.0	4.0
	OM	26.3	31.8	279.5	22.6	47.5	3.8
	Clay	31.4	44.1	373.1	31.5	63.4	5.3
	CaCO3	31.4	44.1	317.3	27.0	53.9	4.5
20	0	21.9	30.8	252.2	19.8	30.3	3.3
	OM	24.0	35.2	284.0	18.8	38.3	3.1
	Clay	25.3	36.2	308.1	22.4	45.4	3.7
	CaCO3	25.3	36.2	308.1	26.0	49.3	4.3
30	0	19.9	32.9	228.2	20.4	49.0	4.0
	OM	18.9	31.2	245.3	19.4	46.6	3.8
	Clay	20.8	34.4	269.8	21.3	51.2	4.2
	CaCO3	20.8	34.4	269.8	23.1	49.8	4.6
LSD at 5%		*1.6*	*N.S.*	*16.4*	*2.0*	*2.9*	*0.4*

OM = Organic manure NS =Nonsignificant

It can be clearly noticed that all the recorded growth parameters were significantly affected by the triple interaction, with the exception of shoot fresh weight and number of leaves/plant in 1994/95 and 1995/96 seasons, respectively, which were insignificantly affected.. The interaction between cultivar x Cd level x soil amendment on shoot/root ratio did not reflect any significant effect. Therefore, the data of this character were neglected.

The maximum values of all growth parameters were obtained from plants of Balady cultivar grew in soil received zero Cd level but supplemented with $CaCO_3$. Data reveal that both cultivar choice and soil amendments application are important factors with respect to lettuce plant growth under Cd soil pollution of this experiment. Data also indicate the effective role of $CaCO_3$ application in enhancing plant growth. This may be due to the alkaline effect of such soil amendment which makes Cd less available to root absorption and reduces its negative effect on plant growth.

Such results can be interpreted through the work of Hortenstine and Webber (1981) on spinach ; Xue and Harrison (1991) on lettuce cultivars and Singh *et al.*(1995) on carrot and lettuce, who concluded that plant growth of the different cultivars grown under soil Cd pollution was enhanced through liming and increasing soil pH.

4.1.2. Effect of cultivar, cadmium level and soil amendments on macro and micro-nutrients content of lettuce leaves.

The elemental composition of plant leaves as affected by cultivar, Cd contamination and amendments application is presented in Table (4). All the studied factors showed significant effects on macro- and micro-nutrients content of lettuce leaves in both seasons of the study.

Cultivar effect: Macro and micro-nutrients concentration in plant leaves with respect to cultivar (Table, 4) reveals that plants of Great lakes cultivar preceded those of Balady in all nutrients mentioned. Such result

Table (4) Macro- and micro-nutrients content of lettuce leaves as affected by cultivar, Cd level and soil amendments.

Treatments		Macronutrients %					Micronutrients ppm			
		N	P	K	Ca	Mg	Zn	Cu	Mn	Fe
		1994/95 season								
Cultivars	Balady	2.98	0.33	1.15	0.68	0.53	108	43.2	86.4	518
	Great Lakes	3.13	0.35	1.21	0.71	0.56	118	47.1	94.2	565
LSD at 5%		**0.01**	**.001**	**0.01**	**0.02**	**.003**	**0.6**	**2.6**	**0.51**	**3.1**
Cd level ppm	0	3.44	0.38	1.33	0.78	0.62	122	48.8	97.7	586
	10	3.02	0.34	1.17	0.68	0.54	108	43.2	86.4	518
	20	2.94	0.33	1.12	0.66	0.52	111	44.3	88.6	532
	30	2.83	0.31	1.07	0.65	0.50	111	44.2	88.5	531
LSD at 5%		**0.01**	**.002**	**0.01**	**0.02**	**.002**	**0.2**	**0.08**	**0.17**	**1.0**
Amendment	0	2.77	0.31	1.07	0.61	0.49	113	45.3	90.7	544
	Organic manure	2.87	0.32	1.11	0.63	0.51	119	47.8	95.5	573
	Clay	3.39	0.38	1.31	0.74	0.60	110	44.0	88.0	528
	CaCO3	3.18	0.35	1.23	0.80	0.57	108	43.4	86.9	521
LSD at 5%		**0.01**	**.002**	**0.01**	**0.02**	**.002**	**0.1**	**0.05**	**0.11**	**0.6**
		1995/96 season								
Cultivars	Balady	2.46	0.27	0.91	0.56	0.60	89	35.7	71.4	428
	Great Lakes	2.59	0.29	1.03	0.59	0.64	96	38.4	76.8	461
LSD at 5%		**0.01**	**.001**	**0.01**	**0.01**	**0.01**	**0.5**	**0.18**	**0.36**	**2.1**
Cd level ppm	0	2.99	0.33	1.16	0.68	0.62	104	41.5	83.0	498
	10	2.44	0.27	0.95	0.55	0.68	87	35.0	69.9	420
	20	2.38	0.26	0.92	0.54	0.68	90	35.9	71.8	431
	30	2.29	0.25	0.88	0.52	0.56	90	35.8	71.7	430
LSD at 5%		**0.01**	**.002**	**0.01**	**0.02**	**.002**	**0.3**	**0.10**	**0.20**	**1.2**
Amendment	0	2.29	0.26	0.89	0.50	0.57	92	36.9	73.7	442
	Organic manure	2.38	0.26	0.92	0.52	0.60	97	38.7	77.3	464
	Clay	2.81	0.31	1.09	0.61	0.70	91	36.3	72.5	435
	CaCO3	2.63	0.29	1.02	0.66	0.62	91	36.4	72.8	437
LSD at 5%		**0.01**	**.001**	**0.01**	**0.02**	**.002**	**0.1**	**0.05**	**0.10**	**0.6**

leads to the conclusion that Great Lakes cultivar possess a higher nutritional value than Balady cultivar with respect to all studied macro- (N, P, K, Ca and Mg) as well as micronutrients (Zn, Cu, Mn and Fe).

Obtained results are in harmony with the varietal differences regarding elemental composition of leaves obtained by Ali (1995) who worked on two lettuce cultivars (Balady and Dark Green) and stated differences in the leaf contents of N, P and K between both studied cultivars .

Cadmium effect : It is obvious from the data shown in Table (4) that macro- and micro-nutrients concentration of lettuce leaves were mostly decreased due to the increase of Cd level from 0 up to 30 ppm. Narrow differences were obtained between nutrient concentrations of plants received 20 ppm Cd and those grown in soil supplemented with 30 ppm Cd. The same trend was obtained in both seasons of the experiment.

These results confirm the antagonistic relationship between Cd and other macro- and micro-elements reported by many investigators, who demonstrated that macronutrient uptake or/and concentration by different plant species is/are reduced by the presence of heavy metal ions in the cultivation media (Vakhmistrov, 1969; Wyn-Jones & Sutcliff, 1972; DeFilippis, 1979; Burzynski 1987 and El-Kassas, 1992).In this respect, Burzynski (1987) found that Cd inhibited the absorption and accumulation of K, Ca & Fe in cucumber seedlings. Moreover, the high doses of this heavy metal caused efflux of K from the roots, while, it had no influence on the absorption and translocation of Mg. Whereas, Sedky (1995) revealed that 10 ppm Cd caused an abrupt reduction in Mg content of lettuce roots grown in non-calcareous soil.

Regarding the depressive effect of Cd on phosphorus content at high levels of these metals, data are on line with those obtained by Abd El Kariem (1994), who explained the reduction in P uptake on basis of the joint effect of Cd on the dry matter yield and the possible formation of $Cd_3(PO_4)_2$ which has low solubility constant.

However, a number of investigators found the reverse results whereby heavy metals treatments resulted in a promotion rather than an inhibition of nutrient status (El-Sokkary, 1980; Prasad & Ram, 1988 and Norwal *et al.* 1993). These differences may be due to metal concentration, soil type and plant species

Amendment effect: The data in Table (4) show that each of organic manure, clay and $CaCO_3$ application had an additive effect on all macro-nutrients studied i.e., N, P, K ,Ca and Mg compared with the control treatment. The highest values of N,P,K and Mg content of lettuce leaves were obtained from plants received clay soil application, while adding CaCO3 to the soil resulted in the highest values of Ca content of leaves. This held true in both seasons of the experiment. With regard to the effect on micronutrients content, data in Table (4) show clearly that using organic manure significantly enhanced Zn, Cu, Mn and Fe content of lettuce leaves. This may be due to the considerable amounts of such nutrients available in organic manure, beside its enormous exchange capacity. Meanwhile, contra trend was detected in case of using either clay or $CaCO_3$ which may be attributed to the role of such amendments on cation exchange capacity (CEC) and pH of the soil, respectively. Results held true during both seasons of the experiment.

Interaction effect: Macro-and micro-nutrients content in lettuce leaves of both Balady and Great Lakes cultivars as affected by Cd soil levels and soil amendments application are shown in Tables (5 and 6) for 1994/95 and 1995/96 growing seasons, respectively.

For any specific Cd level, N, P, K and Mg leaves content were generally the highest due to clay application in plants of Great Lakes cultivar. Whileas, Ca content of plant leaves of Great Lakes cultivar was

Table (5) The interaction effect of cultivar, Cd level and soil amendments on macro and micronutrients content of lettuce leaves (1994/95).

Cd level ppm	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
		Balady cv.								
0	0	3.01	0.34	1.16	0.66	0.53	111.11	44.44	88.89	533
	OM	3.20	0.35	1.24	0.68	0.56	102.35	40.94	81.88	491
	Clay	3.69	0.41	1.43	0.70	0.66	107.33	42.93	85.86	515
	CaCO3	3.09	0.35	1.20	0.80	0.55	108.61	43.46	86.89	521
10	0	2.94	0.33	1.14	0.78	0.52	98.62	39.45	78.90	473
	OM	3.08	0.34	1.19	0.74	0.55	125.91	50.36	100.73	604
	Clay	3.56	0.39	1.38	0.77	0.64	104.74	41.90	83.79	502
	CaCO3	3.10	0.35	1.20	0.89	0.55	99.22	39.69	79.37	476
20	0	2.54	0.28	0.98	0.56	0.45	115.91	46.36	92.73	556
	OM	2.72	0.30	1.05	0.59	0.48	121.94	48.78	97.55	585
	Clay	3.23	0.36	1.25	0.59	0.58	102.93	41.17	82.35	494
	CaCO3	2.70	0.30	1.04	0.70	0.48	112.67	45.07	90.14	540
30	0	2.46	0.27	0.95	0.54	0.43	92.38	36.95	73.90	443
	OM	2.69	0.30	1.04	0.58	0.48	118.42	47.37	94.74	568
	Clay	3.08	0.34	1.19	0.59	0.55	103.57	41.43	82.86	497
	CaCO3	2.59	0.29	1.00	0.67	0.46	101.95	40.78	81.56	489
		Great Lakes cv.								
0	0	3.41	0.38	1.32	0.74	0.60	124.63	49.85	99.70	598
	OM	3.46	0.38	1.34	0.78	0.61	114.08	45.63	91.26	547
	Clay	3.51	0.39	1.36	0.76	0.64	117.44	46.98	93.95	563
	CaCO3	3.09	0.35	1.20	0.91	0.55	121.01	48.40	96.80	580
10	0	3.03	0.34	1.17	0.77	0.54	105.48	42.19	84.38	506
	OM	3.36	0.35	1.22	0.75	0.58	138.57	54.63	109.26	655
	Clay	3.44	0.43	1.50	0.76	0.70	101.89	40.76	81.51	489
	CaCO3	3.14	0.38	1.33	0.84	0.61	107.87	43.15	86.29	517
20	0	2.70	0.30	1.05	0.59	0.48	125.53	50.21	100.43	602
	OM	2.95	0.33	1.15	061	0.53	132.29	52.92	105.83	634
	Clay	3.35	0.37	1.30	0.65	0.60	120.23	48.09	96.19	577
	CaCO3	2.81	0.31	1.09	0.73	0.50	123.92	49.57	99.14	594
30	0	2.53	0.28	0.98	0.55	0.45	111.18	44.47	88.94	533
	OM	2.88	0.32	1.12	0.59	0.51	124.98	49.99	99.98	599
	Clay	3.23	0.36	1.25	0.63	0.58	106.98	42.79	85.59	513
	CaCO3	2.73	0.30	1.06	0.70	0.48	109.19	43.68	87.35	524
LSD at 5%		*0.01*	*0.004*	*0.02*	*N.S.*	*0.005*	*0.38*	*0.15*	*0.30*	*1.8*

OM = Organic manure NS =Nonsignificant

Table (6) The interaction effect of cultivar, Cd level and soil amendments on macro and micronutrients content of lettuce leaves (1995/96).

Cd level ppm	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
						Balady cv.				
0	0	2.44	0.27	0.94	0.53	0.66	90.00	36.00	72.00	432
	OM	3.09	0.34	1.20	0.60	0.45	89.04	35.62	71.24	427
	Clay	3.21	0.36	1.24	0.55	0.59	86.93	34.77	69.55	417
	CaCO3	2.50	0.28	0.96	0.77	0.68	87.97	35.19	70.38	422
10	0	2.38	0.26	0.94	0.63	0.65	79.88	31.95	63.91	383
	OM	2.51	0.28	0.97	0.62	0.68	109.54	43.82	87.63	526
	Clay	2.59	0.29	1.00	0.56	0.70	84.84	33.94	67.87	407
	CaCO3	2.51	0.28	0.97	0.70	0.68	80.36	32.15	64.29	386
20	0	2.06	0.23	0.80	0.45	0.56	93.89	37.56	75.11	451
	OM	2.20	0.25	0.85	0.48	0.57	106.09	42.44	84.87	509
	Clay	2.81	0.31	1.09	0.48	0.60	83.38	33.35	66.70	400
	CaCO3	2.19	0.24	0.85	0.61	0.59	91.26	36.51	73.01	438
30	0	1.99	0.22	0.77	0.43	0.54	74.82	29.93	59.86	359
	OM	2.68	0.30	1.04	0.46	0.51	103.03	41.21	82.42	495
	Clay	2.18	0.24	0.84	0.48	0.59	82.58	33.03	66.06	396
	CaCO3	2.09	0.24	0.81	0.59	0.57	83.89	33.56	67.11	402
						Great Lakes cv.				
0	0	2.77	0.31	1.07	0.60	0.74	100.95	40.38	80.76	485
	OM	2.80	0.31	1.08	0.59	0.69	89.30	35.72	71.44	429
	Clay	3.36	0.37	1.30	0.61	0.75	95.13	38.05	76.10	457
	CaCO3	2.78	0.31	1.08	0.73	0.75	98.02	39.21	78.41	470
10	0	2.45	0.27	0.95	0.62	0.66	85.44	34.18	68.35	410
	OM	2.54	0.28	0.98	0.61	0.69	115.09	46.04	92.08	552
	Clay	3.05	0.34	1.18	0.61	0.50	62.53	33.01	66.02	396
	CaCO3	2.50	0.28	0.97	0.79	0.68	87.37	34.95	89.90	419
20	0	2.19	0.24	0.82	0.48	0.59	101.68	40.67	81.35	488
	OM	2.40	0.26	0.89	0.50	0.65	99.25	39.70	79.40	476
	Clay	2.91	0.32	1.11	0.52	0.65	97.39	38.96	77.91	467
	CaCO3	2.27	0.25	0.86	0.64	0.62	100.37	40.15	80.30	482
30	0	2.05	0.23	0.78	0.45	0.55	90.05	36.02	72.04	432
	OM	2.33	0.26	0.90	0.48	0.54	118.82	47.53	95.05	570
	Clay	2.81	0.31	1.09	0.51	0.53	86.66	34.66	69.32	416
	CaCO3	2.21	0.25	0.83	0.61	0.60	88.44	35.38	70.75	425
LSD at 5%		*0.01*	*0.004*	*0.01*	*N.S.*	*0.01*	*0.35*	*0.14*	*0.28*	*1.7*

OM = Organic manure NS =Nonsignificant

the highest in the case of $CaCO_3$ application with insignificant difference. This held true in the two seasons of the experiment.

With regard to micronutrient, data indicate that organic manure application was the most effective factor in this respect, whereby the highest values were obtained from plants of Great Lakes cultivar grown in soil receiving organic manure as soil amendment at any of applied Cd soil levels.

These results indicate that both macro-and micronutrients were significantly affected by the interaction effect of cultivar, Cd level, and soil amendments. The depressive effect of increasing Cd level can be reduced with clay and organic manure application. Irrespective of the varietal differences of nutrients absorption, the nutritional status of any of the soil amendments applied is a determining factor. Clay soil seems to be rich in N, P, K and Mg nutrient, while organic manure is rich in micronutrients besides to its active role in reducing soil pH and subsequently enhancing the absorption of micro -nutrients Zn, Cu, Mn and Fe by plant roots. On the contrary, $CaCO_3$ shows the opposite action in this respect.

The results are in accordance with those concluded by Chaney (1973) and Lindsay (1973), who stated that other materials present in the soil such as clays, organic matter, hydrous Fe and Mn oxides, carbonates, inorganic chemical compounds, organic acids, biological systems, and biological residues can react to immobilize cationic anions in soils.

4.1.3. Effect of cultivar, cadmium level and soil amendments on heavy metal content of lettuce leaves

A. Cadmium content of lettuce leaves:

Table (7) presents data on Cd content of lettuce leaves as affected by the studied factors and their interaction .

***Cultivar effect*:** Regarding the effect of cultivar on the concentration of Cd, data indicate that plants of Great Lakes cultivar absorbed and accumulated much more Cd than those of Balady one. Results reveal a significant differences in this respect due to cultivar in both seasons of the study.

This can be interpreted with the results obtained y many investigators including John (1976); John; Van Laerhoven (1976b); Crews and Davies (1985) on lettuce; Davies and Lewis (1985)on lettuce and radish varieties; Gunnaresson (1983) on leafy plants; Isermann *et al.* (1984) and Eysinga *et al.*,(1988) on different varieties of several crop species, who suggested possibilities of reducing Cd contents to below permitted values by choice of suitable cultivar.

On the other hand, Florijn *et al.* (1991) reported that lettuce cultivars showed close similarity in shoot Cd concentration. This result contradicts the abovementioned published data on a large genotypic variation in Cd concentration in lettuce, leading to the assumption that it is unwarranted to use lettuce as a pilot plant in comparative physiological investigations on Cd uptake and distribution.

***Cadmium effect* :** Considering the effect of Cd level on accumulation of Cd in lettuce leaves, data presented in Table (7) reveal that Cd content of lettuce leaves was significantly increased with increasing the level of Cd added to the soil. This increase amounted to be approximately 20 , 30 and 40 fold the value of control treatment in response to 10 , 20 and 30

Table (7): **Cadmium content (ppm) of lettuce leaves as affected by cultivar, level of cadmium pollution, soil amendments and their interactions:**

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					**Cd x Amendment** Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Cd level ppm	1994/95 season														
0	0.17	0.17	0.07	0.04	**0.11**	0.18	0.19	0.09	0.06	**0.13**	0.17	0.18	0.08	0.05	**0.12**
10	3.78	4.00	1.17	0.77	**2.43**	3.67	2.02	1.06	0.88	**1.91**	3.72	3.01	1.12	0.83	**2.17**
20	5.35	5.46	1.32	0.81	**3.24**	5.02	4.33	1.72	1.32	**3.10**	5.19	4.90	1.52	1.06	**3.17**
30	5.90	4.99	1.50	1.10	**3.37**	7.30	6.71	2.60	2.05	**4.67**	6.60	5.85	2.05	1.58	**4.02**
Mean	**3.80**	**3.66**	**1.02**	**0.68**	**2.29**	**4.04**	**3.31**	**1.37**	**1.08**	**2.45**	**3.92**	**3.48**	**1.19**	**0.88**	**2.37**
Cd level ppm	1995/96 season														
0	0.15	0.15	0.06	0.03	**0.10**	0.15	0.16	0.08	0.05	**0.11**	0.15	0.16	0.07	0.04	**0.10**
10	3.06	3.24	0.95	0.62	**1.97**	2.97	1.63	0.86	0.71	**1.54**	3.01	2.44	0.91	0.67	**1.76**
20	4.34	4.43	1.07	0.65	**2.62**	4.07	3.50	1.40	1.07	**2.51**	4.20	3.96	1.23	0.86	**2.57**
30	4.78	4.04	1.22	0.89	**2.73**	5.91	5.44	2.11	1.66	**3.78**	5.35	4.74	1.66	1.28	**3.26**
Mean	**3.08**	**2.69**	**0.82**	**0.55**	**1.58**	**3.28**	**2.68**	**1.11**	**0.87**	**1.99**	**3.18**	**2.82**	**0.97**	**0.71**	**1.92**

*** OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Cd level (Cd)**	**Amendment (AM)**	**cv x Cd**	**cv x AM**	**Cd x AM**	**cvxCdxAM**
1994/95	0.02	0.06	0.04	0.09	0.05	0.08	0.11
1995/96	0.01	0.05	0.03	0.07	0.04	0.06	0.09

ppm Cd of the soil, respectively in the first growing season, while it was 17, 25 and 32 fold in the second growing one.

Obtained results are going in line with those of Foroughi *et al.* (1976), who found that increasing Cd concentrations increased Cd accumulation by tomato plants, mainly in the roots. While, Chiba and Takahashi (1977) reported high Cd concentration in common turnip and low concentration in sweet potato grown under the same conditions of Cd in soil . Moreover, Weigel and Jäger (1980) on bean plants, found that Cd was accumulated mainly in roots and to a minor extent in leaves.

***Amendment effect*:** Data on the effect of soil amendments (Table, 7) reveal that all tested amendments had a favourable effect in reducing the Cd accumulated in lettuce leaves. Data clearly show that amendments efficiency had the order of descending magnitude : $CaCO_3$ > clay > organic manure which showed the least positive effect in this regard. This trend held true in both seasons of this experiment

These results confirmed the results obtained by Webber and Beauchamp (1975), who reported that Cd added to a soil may be (a) precipitated as relatively insoluble compounds if the soil pH is 6.5 to 7.0 (b) weakly chelated by soil organic matter as slowly soluble complexes and, (c) adsorbed on the cation exchange sites of organic matter and soil clays. Also, Stover *et al.* (1976) mentioned numerous forms of Cd that may occur in soils, some of these forms are the exchangeable, sorbed, and organic-bound as well as carbonates and sulfides. In this context, Singh (1979) indicated that fixed Cd was correlated with soil C.E.C., pH, organic matter and $CaCO_3$ content. Also, Hortenstine and Webber (1981) tested the effect of cadmium, peat and lime additions on spinach and reported that Cadmium addition led to large increases in Cd uptake, but the high rate of lime reduced Cd uptake to less than one-half of the uptake of the low rate of lime. Moreover, Behel *et al.* (1983) found that the percentage of Cd complexed by organic matter depended on the model used to represent metal interaction with soluble organic C, phosphate, sulfate and chloride forming inorganic complexes with Cd, but it constituted <10% of the total Cd present. It was indicated by Khen and Frankland (1983) that a very high proportion of Cd added to the soil in water-soluble form became insoluble within one hour of contact with the soil.

Interaction effect: With respect to the interaction effect of cultivar and Cd added level to the soil, it is obvious that Cd concentration increased in leaves of both cultivars with increasing added level of Cd during the two seasons of the experiment (Table, 7).

From foregoing results, it can be concluded that :

- In general, both cultivars showed a close similarity in increasing leaves content of Cd as the Cd level in soil increased.
- Plant leaves of Great Lakes cultivar contain (in average) higher concentration of Cd than those of Balady cultivar showing more sefety and tolerance with respect to Cd in soil, especeally at low levels (10 and 20 ppm). However, Great Lakes cultivar failed to tolerate the higher Cd soil levels (30 ppm), whereby its leaves contained considerable amounts of Cd.

The data of the interaction of amendments and Cd level on Cd accumulation in lettuce leaves show that $CaCO_3$ was the most effective amendment within Cd various levels followed by clay and then organic manure which had the least positive effect in this regard. It is also clear from the data presented in Table (7) that in spite of the reducing effect of the amendments, Cd leaf concentration increased , especially in case of organic manure when Cd soil level increased.

The cultivar x Cd level x amendment effect shown in Table (7) reveals that choice of Balady cultivar and application of $CaCO_3$ is the best treatment in reducing Cd accumulation under the conditions of this experiment.

B. Nickel content of lettuce leaves:

Table (8) shows data on Ni content of lettuce leaves as affected by the studied factors; i.e. cultivar, Cd level and soil amendments and their interaction .

***Cultivar effect*:** Regarding the effect of cultivar on the concentration of Ni in lettuce leaves, data indicate that plants of Great Lakes cultivar absorbed and accumulated much more Ni than those of Balady cultivar. The average Ni concentration of plant leaves of Great Lakes cultivar significantly exceeded those of Balady cultivar.

In this connection, the phytotoxic Ni concentrations range widely among plant species and cultivars have been reported for various plants to be from 40 to 246 ppm (DW). Generally the range of excessive or toxic amounts of Ni in most plant species varies from 10 to 100 ppm (DW). Most sensitive species are affected by much lower Ni concentrations, ranging from 10 to 30 ppm (DW). Several species are known for their great tolerance and hyperaccumulation of Ni. Usually these species are mainly those of the Boraginaceae., Cruciferae, Myrtaceae, Leguminosae, and Caryophyllaceae families (Kabata and Pendias, 1986).

***Cadmium effect* :** Concerning the effect of Cd level on accumulation of Ni in lettuce leaves, data in Table (8) reveal that Ni content of lettuce leaves significantly decreased with increasing the added level of Cd . Such decrement tendency may be due to the antagonistic relationship between Cd and Ni.

***Amendment effect*:** Data on the effect of soil amendments (Table, 8) confirm that all tested materials had a favourable effect in reducing the Ni accumulated in lettuce leaves. The most effective amendment was $CaCO_3$ followed by clay and then organic manure which showed the least positive effect in this regard. In this context, Bloomfield (1978) stated

Table (8) Nickel content (ppm) of lettuce leaves as affected by cultivar, level of cadmium pollution, soil amendments and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					**Cd x Amendment** Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Cd level	1994/95 season														
0	1.66	1.73	0.65	0.44	**1.12**	1.75	1.85	0.90	0.60	**1.28**	1.71	1.79	0.78	0.52	**1.20**
10	0.31	0.33	0.10	0.07	**0.20**	0.30	0.17	0.09	0.08	**0.16**	0.31	0.25	0.09	0.07	**0.18**
20	0.44	0.45	0.11	0.07	**0.27**	0.41	0.36	0.15	0.11	**0.26**	0.43	0.41	0.13	0.09	**0.26**
30	0.49	0.41	0.12	0.09	**0.28**	0.60	0.56	0.22	0.17	**0.39**	0.55	0.48	0.17	0.13	**0.33**
Mean	**0.72**	**0.73**	**0.24**	**0.17**	**0.47**	**0.77**	**0.73**	**0.34**	**0.24**	**0.52**	**0.75**	**0.73**	**0.29**	**0.20**	**0.49**
Cd level ppm	1995/96 season														
0	1.44	1.51	0.57	0.38	**0.97**	1.53	1.61	0.79	0.52	**1.11**	1.48	1.56	0.68	0.45	**1.04**
10	0.25	0.27	0.08	0.05	**0.16**	0.25	0.14	0.07	0.06	**0.13**	0.25	0.20	0.07	0.06	**0.15**
20	0.36	0.37	0.09	0.06	**0.22**	0.33	0.29	0.12	0.09	**0.21**	0.35	0.33	0.10	0.07	**0.21**
30	0.39	0.33	0.10	0.08	**0.23**	0.49	0.45	0.18	0.14	**0.31**	0.44	0.39	0.14	0.11	**0.27**
Mean	**0.61**	**0.62**	**0.21**	**0.14**	**0.39**	**0.65**	**0.62**	**0.29**	**0.20**	**0.44**	**0.63**	**0.62**	**0.25**	**0.17**	**0.42**

* **OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Cd level (Cd)**	**Amendment (AM)**	**cv x Cd**	**cv x AM**	**Cd x AM**	**cvxCdxAM**
1994/95	0.01	0.01	0.01	0.02	0.01	0.01	0.02
1995/96	0.01	0.01	0.01	0.02	0.01	0.01	0.01

that although organic matter is able to mobilize Ni from carbonates and oxides as well as to decrease Ni sorption on clays, the bonding of this metal to the organic legends could not be particularly strong. Complexing legends such as SO_4^{2-} and organic acids reduce the sorption of Ni. The remobilization of Ni from solid phases appears to be possible in the presence of FA and HA. Thus, Ni may be quite mobile in soils with high complexation ability (e.g., organic-rich and polluted soils). Also, Cataldo *et al.* (1981) reported that a large portion of Ni was composed of compounds with < 10,000 mol wt, whereas, Wiersma *et al.* (1986) found Ni complexing by compounds with a molecular weight in the range of 1,000 to 5,000, with a negative overall charge. Moreover, Alloway *et al.* (1992) stated that, Ni in sewage sludge that is present mainly in organic chelated forms is readily available to plants and therefore may be highly phytotoxic. Soil treatments, such as additions of lime, phosphate, or organic matter, are known to decrease Ni availability to plants. They also, stated that, like other divalent cations (Co^{2+}, Cu^{2+}, and Zn^{2+}), Ni^{2+} is known to form organic compounds and complexes.

Interaction effect: Regarding the interaction effect of used cultivar and Cd level in the soil, data presented in Table (8) show that Ni concentration decreased in leaves of both cultivars over the two growing seasons with increasing the level of Cd.

The data of the interaction between amendments and Cd level show that amendments efficiency in reducing Ni accumulation in leaves had the order of descending magnitude : $CaCO_3$ > clay > organic manure which showed the least positive effect in this regard. Regardless the reducing effect of the amendments, Ni leaf concentration decreased when Cd soil level increased within all amendment treatments.

The cultivar x Cd level x amendment effect shown in Table (8) reveals that Balady cultivar in case of using $CaCO_3$ is the best treatment in reducing Ni accumulation under conditions of this experiment.

C- Lead content of lettuce leaves:

Table (9) shows data on Pb content of lettuce leaves as affected by the studied factors and their interaction .

***Cultivar effect*:** Regarding the effect of cultivar on the concentration of Pb in lettuce leaves, data indicate that plants of Great Lakes cultivar absorbed and then accumulated much more Pb than those of Balady one, with significant differences in both seasons of this experiment.

Varietal response to lead accumulation by lettuce plants was indicated by John (1977). Also, Judel and Stelte (1977) studied varietal response to Pb by lettuce, radish, carrot and spinach plants and found that Pb concentration in the tops and roots of the corresponding edible tissues depended on variety among other interacting factors .

On the contrary, Crews and Davies (1985) worked on six varieties of lettuce and found that there was little evidence for cultivar control of Pb absorption. Also, Davies and Lewis (1985) studied the differences in uptake of Pb in five varieties of lettuce and four varieties of radish and concluded that it is not possible to select a single variety of either lettuce or radish to minimize metal uptake from soil.

***Cadmium effect* :** Concerning the effect of Cd level in soil on accumulation of Pb in lettuce leaves, data in Table (9) reveal that Pb content of lettuce leaves significantly decreased with increasing the added level of Cd. The highest values of Pb content in lettuce leaves corresponded to the untreated control treatment indicating that the absorption and translocation of Pb increase in the absence of Cd in soil. This held true in both seasons of the study. This trend may be due to the antagonistic relationship between Cd and Pb.

***Amendment effect*:** Data on the effect of soil amendments (Table, 9) confirm that all tested amendments had a favourable effect in reducing the Pb accumulated in lettuce leaves. The most effective amendment was

Table (9): **Lead content (ppm) of lettuce leaves as affected by cultivar, level of cadmium pollution, soil amendments and their interactions:**

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Cd x Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Cd level ppm	1994/95 season														
0	4.15	4.32	1.62	1.10	**2.80**	4.37	4.63	2.26	1.49	**3.19**	4.26	4.48	1.94	1.30	**2.99**
10	0.78	0.82	0.24	0.17	**0.50**	0.76	0.41	0.22	0.19	**0.39**	0.77	0.62	0.23	0.18	**0.45**
20	1.11	1.13	0.27	0.17	**0.67**	1.04	0.90	0.36	0.28	**0.64**	1.07	1.01	0.32	0.22	**0.66**
30	1.23	1.02	0.31	0.24	**0.70**	1.51	1.39	0.53	0.42	**0.96**	1.37	1.21	0.42	0.33	**0.83**
Mean	**1.82**	**1.82**	**0.61**	**0.42**	**1.17**	**1.92**	**1.83**	**0.84**	**0.59**	**1.30**	**1.87**	**1.83**	**0.73**	**0.51**	**1.23**
Cd level ppm	1995/96 season														
0	3.61	3.76	1.41	0.96	**2.43**	3.80	4.03	1.96	1.30	**2.77**	3.71	3.89	1.69	1.13	**2.60**
10	0.63	0.67	0.19	0.14	**0.41**	0.62	0.33	0.18	0.15	**0.32**	0.62	0.50	0.18	0.14	**0.36**
20	0.90	0.91	0.22	0.14	**0.54**	0.84	0.73	0.29	0.22	**0.52**	0.87	0.82	0.26	0.18	**0.53**
30	0.99	0.83	0.25	0.19	**0.57**	1.22	1.13	0.43	0.34	**0.78**	1.11	0.98	0.34	0.27	**0.67**
Mean	**1.53**	**1.54**	**0.52**	**0.35**	**0.99**	**1.62**	**1.55**	**0.72**	**0.50**	**1.10**	**1.53**	**1.55**	**0.62**	**0.43**	**1.04**

*** OM**= Organic Manure

L.S.D. at 5%	Cultivar (cv)	Cd level (Cd))	Amendment (AM)	cv x Cd	cv x AM	Cd x AM	cvxCdxAM
1994/95	0.01	0.04	0.01	0.06	0.02	0.03	0.04
1995/96	0.01	0.03	0.01	0.05	0.02	0.03	0.04

$CaCO_3$ followed by clay and then organic manure which showed the least positive effect in this regard. These results confirm the results obtained by Lagerwerff (1971) and Misra and Pandy (1976), who mentioned that as the pH increased, as a result of liming, the amount of extractable Pb decreased. In this regard, Mengel and Kirkby (1982) came to the conclusion that the availability of soil Pb is usually low and can be decreased even further by liming. A high soil pH may precipitate Pb as hydroxide, phosphate or carbonate, it possibly promotes the formation of Pb-organic matter complexes. Furthermore, they added that enhanced levels of Ca also increase competition with Pb for exchange sites on roots and soil surfaces.

Interaction effect: With respect to the interaction effect of cultivar and Cd level in the soil, Pb concentration decreased in the leaves of both cultivars with increasing Cd level during both seasons of this study (Table, 9).

The data of the interaction between amendments and Cd level in soil show that amendments efficiency in reducing Pb accumulation in leaves follows the order: $CaCO_3$ > clay > organic manure. Regardless the reducing effect of the amendments, Pb leaf concentration decreased when Cd soil level increased within all amendment treatments.

The cultivar x Cd level x amendment effect shown in Table (9) reveals that Balady cultivar in case of using $CaCO_3$ is the best treatment in reducing Pb accumulation under the conditions of this experiment.

To obtain a wide view on the behaviour of either cultivars or soil amendments studied, Fig.(2) presents Cd, Ni and Pb contents of lettuce leaves as affected by cultivar or soil amendment . It is clear that plants of Great Lakes cultivar accumulated more heavy metal amounts than those accumulated by Balady cultivar . It is also evident from Fig. (2) that amendments efficiency in reducing heavy metal accumulation in lettuce

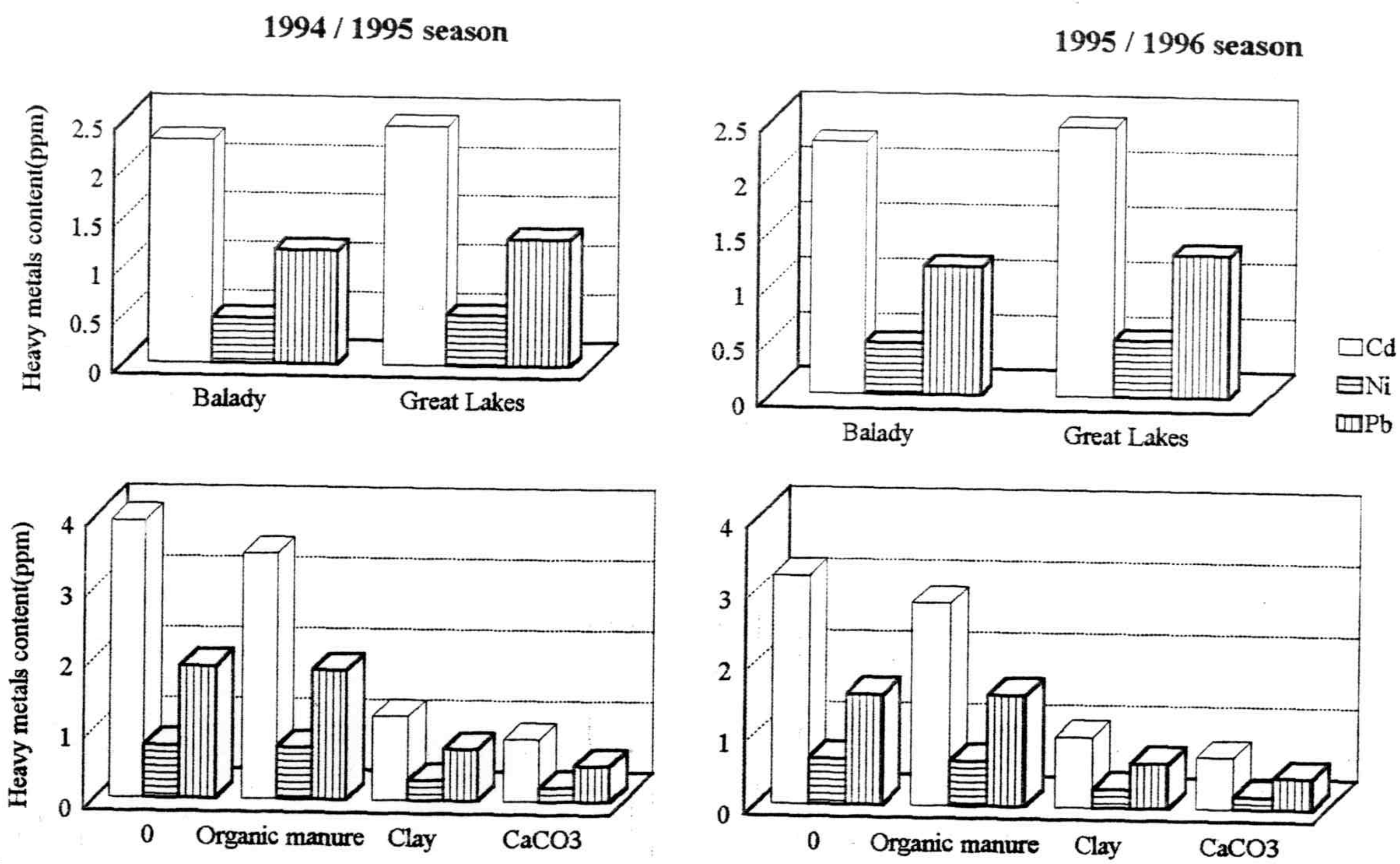

Fig. (2) : Heavy metals content of lettuce leaves. as affected by cultivar or amendments under Cd soil pollution.

All the differences within each variable are significant (p=0.05) leaves follows the order: $CaCO_3$ > clay > organic manure which showed least positive effect in this regard.

In this connection, Davies and White (1981) reported that vegetables grown on heavy metals contaminated soils absorb excessive quantities of these metals. They analyzed the roots and aerial parts of lettuce, onion, carrots and *Brussels* sprouts for determination of Cd and Pb. Lead tended to be retained in the roots but other metals were more mobile and cadmium accumulated in lettuce and carrot leaves. The Cd and Pb contents of edible parts constitute a possible risk to public health. Also, Mortvedt (1985) concluded that uptake of Cd, Ni and Pb by swiss chard generally increased with increasing levels of heavy metals added through Zn- contaminated fertilizer. Furthermore, Gaynor *et al.* (1976), Stover *et al.* (1976), Mahler *et al.* (1978), Herms *et al.* (1979), Singh (1979), Allinson and Dzialo (1981), Soon (1981), Hortenstine and Webber (1981), Tyler and McBride (1982), Behel *et al.* (1983), Khen and Frankland (1983), and Singh *et al.* (1995) all indicated that fixed Cd was correlated with soil C.E.C., pH, organic matter and $CaCO_3$ content.

On the contrary, Michel *et al.* (1978) reported that at relatively low soil treatments with sewage sludge enriched with Cd, Cu, Ni, or Zn; Cu and Pb were more toxic to lettuce grown in the calcareous soil (1.2% $CaCO_3$) than in the acid (pH 5.7) one.

4.1.4. Effect of cultivar, cadmium level and soil amendments on some metabolic changes in lettuce leaves:

A. photosynthetic pigments, ascorbic acid and NO_3.

Table (10) illustrates the data concerning photosynthetic pigments, ascorbic acid and NO_3 content of lettuce leaves as affected by cultivar, cadmium level and soil amendments. Data indicate that all lettuce leaves

Table (10) Photosynthetic pigments (mg/100 gm FW), ascorbic acid (mg/100 gm FW), and nitrate (mg/100 gm DW) content of lettuce leaves as affected by cultivar, Cd level and soil amendments.

Treatments		Chlorophylls a	Chlorophylls b	Chlorophylls Total	Carotene	Ascorbic Acid	Nitrate
1994/95 season							
Cultivars	Balady	134.0	47.7	181.7	82.2	10.9	125.6
	Great Lakes	131.8	49.4	181.2	80.8	11.1	134.9
LSD at 5%		**0.27**	**0.18**	**0.19**	**0.18**	**N.S.**	**6.1**
Cd level ppm	0	156.0	56.6	212.6	83.8	11.9	134.1
	10	129.6	46.7	176.3	83.5	11.2	121.0
	20	125.8	46.2	172.0	81.1	10.3	125.6
	30	120.2	44.7	164.9	77.5	10.3	129.3
LSD at 5%		**0.27**	**0.23**	**0.75**	**0.14**	**N.S.**	**1.5**
Amendment	0	131.6	46.6	178.2	80.6	10.6	136.0
	Organic manure	133.7	48.6	182.3	81.8	11.1	134.2
	Clay	135.1	50.8	185.9	82.9	11.1	125.6
	CaCO3	131.2	48.2	179.4	80.6	10.9	125.1
LSD at 5%		**0.13**	**0.13**	**0.15**	**0.08**	**N.S.**	**1.0**
1995/96 season							
Cultivars	Balady	110.9	39.5	150.4	71.7	15.0	122.1
	Great Lakes	109.1	40.9	150.0	70.5	16.2	125.2
LSD at 5%		**0.23**	**0.15**	**0.16**	**0.14**	**0.08**	**1.9**
Cd level ppm	0	135.7	49.2	184.9	88.2	18.9	146.5
	10	105.0	37.9	142.9	67.7	15.3	119.9
	20	101.9	37.4	139.3	65.7	14.6	118.1
	30	97.2	36.2	133.4	62.8	13.7	110.0
LSD at 5%		**0.61**	**0.24**	**0.82**	**0.40**	**0.08**	**5.4**
Amendment	0	108.9	38.6	147.5	70.4	16.5	127.7
	Organic manure	110.8	40.3	151.1	71.6	15.8	124.3
	Clay	111.8	42.0	153.8	72.3	14.9	121.8
	CaCO3	108.5	39.8	148.3	70.1	15.4	120.7
LSD at 5%		**0.11**	**0.11**	**0.13**	**0.07**	**0.01**	**0.7**

N.S.= nonsignificant

constituents recorded were significantly affected during both seasons of the experiment.

Cultivar effect : With respect to chlorophyll a, b and total chlorophyll as well as carotene content of leaves (Table,10), it is evident that leaves of Balady cultivar contained higher amounts of photosynthetic pigments than those of Great Lakes cultivar, except for the chlorophyll b in the second season of the experiment. The reverse was true for ascorbic acid and NO_3 content. Such trend held true during both growing seasons. The variation of such metabolic products appears to be due to a varietal effect .

These results are in accordance with those obtained by Ali (1995), who reported significant differences in such metabolic products between Balady cultivar and Green Dark one.

Cadmium effect: Data presented in Table (10) show that Cd soil application (10 - 30 ppm) had an adverse effect on chlorophylls (a, b and total) as weill as carotene compared with the control treatment. In this respect, increasing Cd level up to 30 ppm led to a gradual decrease in chlorophylls pigments. and carotene. This held true in both growing seasons. Respecting ascorbic acid and NO_3 content in lettuce leaves of plants, similler findings were reported except for NO_3 in the second season where it behaved differently in the second growing season. The amount of chlorophyll was found to be a function of the Cd concentration in plant tissues and has been proposed as an indicator of the upper critical Cd level in plant tissues . In this connection, Kloke *et al.*(1979) estimated the phytotoxic concentrations of Cd to be 5 to 10 ppm (DW) in sensitive plant species, while Macnicol and Beckett (1985)gave the range of 10 to 20 ppm (DW) as critical Cd levels .

Obtained results are also in agreement with those concluded by Cunningham *et al.*(1978), Baszynski *et al.* (1979), Krupa *et al.*(1987), Strnad *et al.* (1990) and Keshan and Mukherji (1992) on a variety of vegetable plants.

They stated that Cd caused inhibition of the accumulation of the chlorophylls and carotenoids.

Amendment effect : Data concerning photosynthetic pigments, ascorbic acid and NO_3 content of lettuce leaves as affected by soil amendments (Table,10) reveal that all of organic manure, clay and $CaCO_3$ application had favourable effect on chlorophylls (a, b and total) carotene and NO_3 leaves content, whereby the chlorophylls and carotene content increased and NO_3 accumulation decreased with adding the amendments. The order of magnitude of this effect followed the descending one clay > organic manure > $CaCO_3$. With respect to ascorbic acid content of leaves, it showed a diverse trend due to soil amendments, whereby it tended to decrease by the application of soil amendments as compared with the untreated control treatment in both growing seasons.

Interaction effect: Table (11) presents data on the interaction effect of cultivar, Cd level and soil amendments on photosynthetic pigments, ascorbic acid and nitrate of lettuce leaves.

Each of the variables tested was significantly affected by the triple interaction with the exception of ascorbic acid content character which showed insignificant difference in 1994/95 growing season.

Data reveal that the most important factor in this respect was soil amendment application which had a favourable effect on increasing pigments content and decreasing the NO_3 accumulation in plant leaves of both cultivars used in this experiment . It is noticeable that ascorbic acid tended to decrease with the application of soil amendments in plants of both cultivars grown under Cd soil pollution. The highest values obtained

Table (11) The interaction effect of cultivar, Cd level and soil amendments on photosynthetic pigments (mg/100 mg DW), ascorbic acid (mg/100 gm FW) and nitrate (mg/100 gm DW) of lettuce leaves.

Season		1994/95				1995/96			
Cd level ppm.	Amendment	Total Chlorophyll	Carotene	Ascorbic acid	NO_3	Total Chlorophyll	Carotene	Ascorbic acid	NO_3
		Balady cv.							
0	0	211.07	85.06	11.10	123.28	183.63	89.53	19.04	149.30
	OM	213.34	83.08	10.88	128.42	190.40	67.30	15.33	121.52
	Clay	239.93	80.70	9.98	128.06	177.65	65.37	14.94	119.00
	CaCO3	233.02	76.95	9.66	134.11	182.05	62.33	14.14	112.99
10	0	203.56	88.67	11.40	126.17	194.50	93.33	18.24	141.93
	OM	225.03	84.37	11.00	127.07	221.78	68.34	15.05	119.74
	Clay	230.06	81.04	9.88	129.60	227.75	66.65	14.33	116.82
	CaCO3	228.59	77.77	9.73	131.58	234.13	62.99	13.22	111.92
20	0	197.27	85.67	11.82	125.00	189.03	90.18	17.76	140.66
	OM	202.54	86.69	12.01	121.57	207.85	70.22	13.99	116.53
	Clay	220.44	85.53	11.13	121.57	216.15	69.28	12.68	122.77
	CaCO3	224.07	77.57	11.40	123.55	222.90	62.83	12.11	107.84
30	0	173.10	75.79	11.73	122.20	168.00	79.78	18.64	140.20
	OM	179.29	84.85	11.60	119.58	215.22	68.73	14.25	117.98
	Clay	175.25	82.28	10.93	124.72	221.96	67.46	13.81	115.31
	CaCO3	164.42	78.18	10.81	122.47	213.18	63.33	12.51	114.03
		Great Lakes cv.							
0	0	209.36	83.42	12.43	149.90	182.15	87.81	20.50	152.36
	OM	217.12	79.27	10.37	139.71	205.36	64.21	16.54	126.85
	Clay	223.24	79.61	10.40	142.42	216.27	64.49	15.92	121.10
	CaCO3	220.61	76.82	9.86	142.05	222.53	62.22	15./21	118.32
10	0	193.21	86.07	12.94	150.19	194.19	90.60	19.10	150.40
	OM	203.37	82.27	11.26	137.54	200.43	66.64	16.03	119.91
	Clay	205.71	78.04	11.19	139.62	214.23	63.21	15.23	119.17
	CaCO3	212.28	76.48	10.98	131.58	221.45	61.95	14.80	114.24
20	0	177.21	83.76	11.99	138.80	188.97	88.17	18.70	148.16
	OM	181.17	84.44	11.50	125.17	196.74	68.40	15.51	117.78
	Clay	184.35	80.76	11.40	126.17	201.23	65.42	14.69	114.86
	CaCO3	190.86	78.52	10.93	123.10	207.59	63.60	13.50	105.68
30	0	166.10	82.13	12.15	136.90	179.31	86.45	18.87	148.60
	OM	178.56	83.28	10.64	122.47	184.64	67.46	15.71	119.17
	Clay	171.77	79.81	9.63	126.52	199.13	64.64	14.98	115.65
	CaCO3	186.58	77.63	9.68	125.62	204.93	62.88	14.14	110.41
LSD at 5%		0.43	0.24	N.S.	2.8	0.36	0.20	0.03	1.8

OM = Organic manure NS =Nonsignificant

of total chlorophyll, carotene, ascorbic acid and NO3 were respectively resulted from combined treatments as follows:

- Balady cultivar + zero Cd level + clay application,
- Balady cultivar + 10 ppm Cd level + zero amendment application,
- Great Lakes cultivar +10 ppm and zero Cd level for the first and second seasons, respectively + zero amendment application

and Balady cultivar + zero Cd level + zero amendments application.

B. Amino acids:

The effect of the highest Cd level added to the soil (30 ppm) on the free amino acids content of the two studied cultivars is illustrated in Table (12). It appears from such data that addition of 30 ppm Cd to the soil led to an increase of the total free amino acids content of plant leaves. This held true in both cultivars , irrespective of the significant differences occurred between the two cultivars in all the amino acids tested . The increase in the total free amino acids content for Balady cultivar was amounted to be 178.40 mg/100 gm compared with 122.66 mg/100 gm leaves sample for the control treatment and 225.24 and 152.21 for Great Lakes, respectively. Much more pronounced positive effect was observed for glutamic, proline and phenyle- alanine acids, whereby, its values were highly significant, with respect to its values of the control treatment .

On the other hand, methionine and histidine acids responded negatively with respect to Cd contamination in both cultivars for the first acid and in Balady cultivar only for the second acid .

In this respect, Afonova (1958) and Edelhoch (1958) showed that the reduction in SH-groups which runs parallel to change in conformation of protein and the blocking of carboxyl groups by Cd ions seems to play a major role in metabolism.

There are no known enzymes that depend on Cd for their normal activity. Roucoux and Dabin (1977) reported that Cd specifically induced

Table (12) Effect of soil cadmium pollution on various amino acids content (mg/100 gm DW) in two lettuce cultivars.

Treatment / Amino Acid	Balady cv. Soil Cd treatment		Great Lakes cv. # Soil Cd treatment	
	(0) ppm	30 ppm	(0) ppm	30 ppm
aspartic acid	8.88	16.88*	10.43	28.46**
serine	11.18	16.06*	14.68	19.38*
threonine	5.05	8.94*	6..92	11.29**
glycine	3.55	3.64	3.85	5.67*
glutamic	11.96	27.06**	16.47	21.58**
alanine	7.97	8.18	8.26	9.04
tyrosine	3.16	3.08	2.98	3.32
proline	3.06	13.27**	6.85	20.63**
leucine	8.29	8.09	10.86	10.27
valine	11.98	12.50	15.26	18.75*
methionine	4.18	2.28**	3.71	2.26*
phenyle-alanine	11.36	25.30**	18.36	30.25**
histidine	8.03	4.97**	6.74	7.82*
amonia	6.17	9.90*	9.45	15.63*
arganine	9.53	9.41	9.36	10.75
lysine	8.31	8.84	8.12	10.14*
Total	122.66	178.40*	152.21	225.24**

All the variables are highly significant due to cultivar
* Significance within each cultivar
** Highly significance within each cultivar

cysteine and methionine synthesis in soybeans. Wichmann *et al.* (1983) showed that bush beans and carrots protein content was decreased at low Cd concentrations, while at higher concentrations an increase in proteins containing sulfur was shown. In addition, Kastori *et al.* (1992) found that the concentration of free proline was significantly increased in the leaves of intact plants as well as in leaf discs incubated in the presence of heavy metals. It was concluded that excess concentrations of the heavy metal significantly affected plant water status, causing water deficit and subsequent changes in plant metabolism. Moreover, Costa and Morel (1994) noticed that, total amino acid levels increased at low Cd concentration in both roots and leaves of lettuce.

4.2. THE SECOND EXPERIMENT(Pot experiment)

Control of pollution with nickel in lettuce plants:

This pot experiment dealt with nickel effect on the two tested lettuce cultivars (Balady and Great Lakes) grown in sandy soil received soil amendments to examine the role of both cultivar and soil amendments in reducing heavy metal toxic action on plants in terms of growth, chemical and metabolic changes of plant leaves. The obtained data are presented and discussed in the following:

4.2.1. Effect of cultivar, nickel level and soil amendments on plant growth characteristics of lettuce.

Table (13) illustrates the effect of cultivar, Ni level and soil amendments on growth parameters i.e., plant height, number of leaves/plant, shoot fresh and dry weight of both shoot and root per plant as well shoot/root ratio on dry weight basis.

Cultivar effect : Balady cultivar behaved more vigorously than Great Lakes having the highest values of all growth parameters tested over the two growing seasons of the study with nonsignificant difference in number of leaves/plant (Table, 13). Moreover, Fig. (3) shows a significant wide difference in plant height between the two cultivars studied and the superiority of Balady cultivar which had taller plants than those of Great Lakes one.

These results are in harmony with those obtained by Kobryn (1987), who reported varietial differences of lettuce growth characters. Also, Shafshak and Abo-Sedera (1990) found that plants of Balady lettuce cultivar was taller but less in average head weight than those of Dark Green cultivar and added that normally, the growth features are varietal characters.

Table (13): Growth characters of lettuce as affected by cultivar, nickel level and soil amendment :

Seasons	1994/95 Season							1995/96 Season						
Characters / Treatments	Plant ht. cm	No. of leaves/ Plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm	Shoot /Root DW	Plant ht. cm	No. of leaves/ Plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm	Shoot /Root DW
Cultivar														
Balady cv.	33.4	35	363	33.9	53.4	5.2	6.5	30.5	33	349	33.5	50.2	4.8	7.0
Great Lakes cv.	24.5	33	293	24.0	50.5	4.2	5.7	23.6	33	274	22.2	47.1	3.9	5.7
L.S.D. at 5%	**1.1**	**N.S.**	**13.7**	**2.2**	**2.4**	**0.4**	**0.6**	**2.0**	**N.S.**	**2.4**	**1.6**	**0.5**	**0.3**	**0.5**
Ni level (ppm)														
0	28.2	36	353	30.8	60.7	5.4	5.7	24.7	35	331	30.3	56.8	5.3	5.8
50	27.6	35	337	29.6	55.8	4.2	7.0	23.5	34	318	28.0	51.2	4.8	5.8
100	26.3	33	330	29.2	53.2	4.0	7.3	21.9	33	314	27.8	49.8	4.6	6.0
150	24.8	32	331	27.4	50.4	3.9	7.0	21.5	31	301	26.5	48.9	4.3	6.2
L.S.D. at 5%	**0.6**	**1.0**	**5.9**	**0.8**	**0.9**	**0.1**	**0.2**	**1.1**	**1.0**	**4.8**	**0.6**	**0.8**	**0.1**	**0.2**
Amendments														
0	20.8	32	279	25.0	53.0	5.0	5.0	19.2	30	264	23.6	50.1	4.7	5.0
Organic manure	27.6	32	304	26.4	48.6	4.4	6.0	25.8	32	285	25.2	45.6	4.2	6.8
Clay	30.9	35	333	29.6	56.6	5.0	5.9	29.6	34	323	29.1	54.9	5.0	5.8
$CaCO_3$	31.5	36	342	29.8	58.1	5.1	5.8	29.0	34	323	28.6	54.9	4.9	5.8
L.S.D. at 5%	**0.9**	**1.0**	**6.1**	**0.8**	**1.1**	**0.1**	**0.3**	**0.8**	**1.0**	**5.6**	**0.7**	**1.0**	**0.1**	**0.3**

N.S. = Nonsignificant

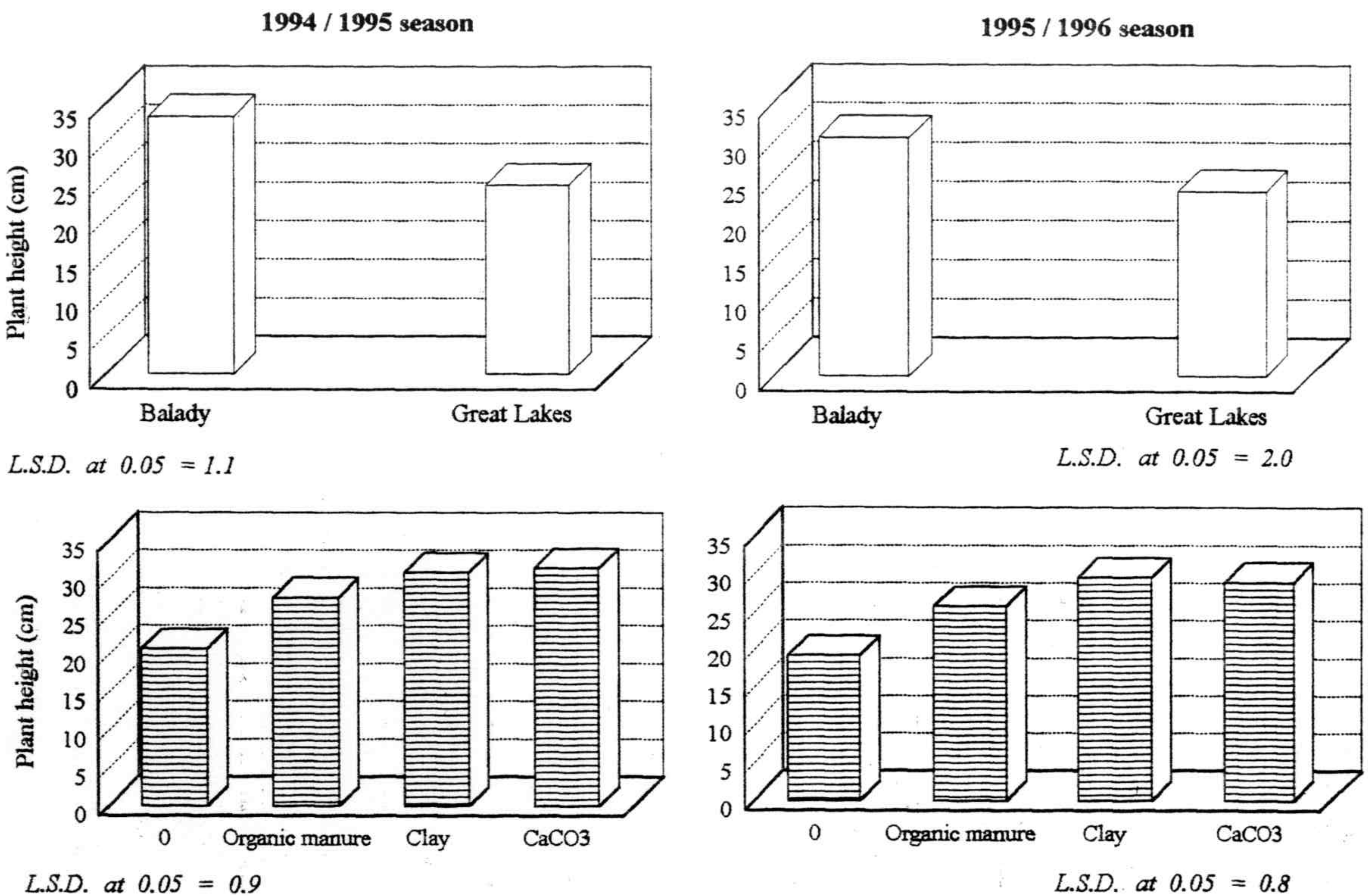

Fig. (3) : Effect of cultivar or amendments on lettuce plant height irrespective of Ni application.

Nickel effect : Data in Table (13) reveal that the Ni added to the soil (50-150 ppm) negatively affected all plant growth characters compared with untreated control treatment. It is noticeable that both fresh and dry weights of shoot were gradually decreased by increasing Ni level added to soil from 50 to 100 ppm. This held true in both seasons of the study. These results declare that Ni added to soil in low concentrations up to 150 ppm hardly affects plant growth characteristics.

This partly agrees with the finding of Davis (1979) on rape, who reported that plant yields were poorly correlated with total or extractable Ni concentration in the soil or the soil solution, possibly because the concentration in the plant tops were between the upper and lower critical concentration and other factors limited yield. Moreover, Foy *et al.* (1979) reported that before the acute Ni toxicity symptoms are evident, elevated concentrations of this metal in plant tissues are known to inhibit photosynthesis and transpiration.

Amendments effect: From the data illustrated in Table (13), it is easy to observe the favourable effect of organic manure, clay and $CaCO_3$ application on plant growth. It is worth mentioning that the effect of both clay and $CaCO_3$ exceeded that of organic manure on all the studied growth parameters in both growing seasons. The applied organic manure reduced both fresh and dry weights of the root, while it increased the fresh and dry weights of shoot in both seasons of this experiment. Moreover, from the data figured in Fig. (3), plant height increased due to amendments application. This confirms the aforementioned favourable effect of soil amendments application on plant growth.

Interaction effect: Data on the interaction effect of cultivar, Ni level in soil and soil amendments on growth of lettuce plants grown in 1994/95 and 1995/96 seasons are shown in Tables (14 and 15), respectively.

Table (14) The interaction effect of cultivar, Ni level and soil amendments on growth characters of lettuce (1994/95).

Ni level ppm	Amendment	Plant ht. cm	No. of leaves/plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm
		Balady cv.					
0	0	34.9	35.3	351.4	32.4	59.7	5.5
	OM	31.7	35.9	363.2	34.1	61.7	5.8
	Clay	36.7	37.1	369.9	34.1	62.8	5.8
	CaCO3	38.7	39.1	389.3	33.4	66.2	5.6
50	0	33.7	36.4	366.4	34.5	62.3	5.9
	OM	33.5	33.4	338.1	34.8	57.4	5.7
	Clay	35.3	35.1	355.9	34.2	60.5	6.0
	CaCO3	37.1	37.0	374.6	36.2	63.7	5.5
100	0	29.3	32.1	306.5	29.8	49.0	4.7
	OM	30.3	32.7	330.0	31.2	52.8	5.2
	Clay	30.8	33.8	322.7	30.8	51.6	5.0
	CaCO3	32.4	35.5	339.6	31.9	54.3	4.7
150	0	20.9	28.9	273.4	26.8	51.9	5.2
	OM	22.0	30.4	287.8	27.4	54.6	5.5
	Clay	22.8	32.0	295.9	28.6	56.2	5.7
	CaCO3	23.1	32.1	302.9	29.3	57.5	5.9
		Great Lakes cv.					
0	0	28.5	40.1	339.2	28.6	57.6	4.8
	OM	27.7	33.4	294.3	23.8	50.0	4.0
	Clay	29.1	35.2	309.7	25.0	52.6	4.2
	CaCO3	30.7	37.0	326.1	26.4	55.4	4.4
50	0	25.1	31.1	271.7	26.1	46.2	3.6
	OM	27.8	34.4	301.1	28.9	51.1	4.0
	Clay	26.4	32.7	286.0	27.1	48.6	3.8
	CaCO3	27.9	38.7	371.1	35.4	63.0	5.3
100	0	21.6	32.3	373.9	35.9	59.8	5.3
	OM	24.0	29.3	239.6	22.6	38.3	3.1
	Clay	25.3	30.8	252.2	24.7	40.3	3.3
	CaCO3	26.6	32.4	265.5	25.8	42.4	3.4
150	0	17.2	32.1	297.2	28.5	56.4	5.2
	OM	19.9	32.9	258.2	24.1	49.0	4.0
	Clay	18.9	31.2	245.3	22.9	46.6	3.8
	CaCO3	21.0	34.6	271.8	26.3	51.6	4.3
LSD at 5%		*N.S.*	*N.S.*	***17.2***	***1.2***	***3.1***	***0.4***

OM = Organic manure NS =Nonsignificant

Table (15) The interaction effect of cultivar, Ni level and soil amendments on growth characters of lettuce (1995/96).

Ni level ppm	Amendments	Plant ht. cm	No. of leaves/plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm
		Balady cv.					
0	0	28.9	36.1	333.8	30.7	56.7	5.2
	OM	34.9	35.3	345.0	32.4	58.6	5.5
	Clay	30.1	33.3	351.4	32.4	59.7	5.5
	CaCO3	33.1	33.5	397.4	37.8	67.5	6.4
50	0	28.9	36.1	351.4	32.6	58.6	5.5
	OM	30.1	33.3	333.8	31.6	56.7	5.5
	Clay	33.1	33.5	351.4	34.1	57.5	5.2
	CaCO3	34.9	35.3	397.4	37.9	59.7	6.4
100	0	26.5	35.5	291.2	27.8	46.6	4.5
	OM	27.8	30.5	313.5	30.2	50.1	4.9
	Clay	28.8	31.1	306.5	28.7	49.0	4.7
	CaCO3	29.3	32.1	327.8	30.8	52.4	5.3
150	0	17.0	27.9	259.7	24.2	49.3	4.9
	OM	19.8	27.5	273.4	26.1	51.9	5.2
	Clay	20.9	28.9	281.1	26.9	53.4	5.4
	CaCO3	21.6	30.4	285.1	27.6	54.1	5.6
		Great Lakes cv.					
0	0	25.1	31.1	271.7	21.6	46.2	3.6
	OM	26.4	32.7	286.0	22.7	48.6	3.8
	Clay	28.9	40.1	339.2	28.6	57.6	4.8
	CaCO3	28.3	30.8	349.0	29.7	59.3	5.0
50	0	25.0	30.2	265.6	24.7	45.1	3.6
	OM	25.7	37.1	317.3	30.1	53.9	4.5
	Clay	26.3	31.8	279.5	27.5	47.5	3.8
	CaCO3	27.7	33.4	294.3	26.9	50.0	4.0
100	0	20.4	35.2	308.1	29.6	49.3	4.3
	OM	24.0	29.3	239.6	22.1	38.3	3.1
	Clay	24.0	29.3	239.6	22.3	38.3	3.1
	CaCO3	25.3	30.8	252.2	23.4	40.3	3.3
150	0	16.0	31.4	262.1	25.6	49.8	4.6
	OM	18.9	31.2	245.3	23.5	46.6	3.8
	Clay	18.9	31.2	255.3	22.3	46.6	3.8
	CaCO3	19.8	32.9	258.2	23.1	49.0	4.0
LSD at 5%		*N.S.*	*N.S.*	*15.8*	*1.67*	*2.7*	*N.S.*

OM = Organic manure NS =Nonsignificant

From the data, it is evident that both fresh and dry weights of shoot as well as fresh weight of root were significantly affected by the triple interaction in both seasons of the experiment. The highest values of plant growth characters were obtained from lettuce plants of Balady cultivar grew in nonpolluted soil (zero Ni level) received CaCO3 treatment as a soil amendment. This held true in both seasons of the study with the exception of both fresh and dry weights of root, whereby the untreated control treatment had the highest values in this respect.

These results are in harmony with the conclusions reported by Singh *et al.* (1995), who mentioned that crop yields of carrot and lettuce plants were not consistently affected at increasing soil pH levels. The effect of pH was more pronounced in the moraine than the alum shale soil.

4.2.2. Effect of cultivar, nickel level and soil amendments on macro and micro-nutrients content of lettuce leaves.

Data in Table (16) reveal that both macro- and micro-nutrients concentrations of lettuce leaves significantly differed with respect to all studied factors i.e., cultivar, Ni level and soil amendments application in the two growing season.

Cultivar effect **:** Macro- and micro-nutrients content of leaves of Great Lakes cultivar preceded those of Balady cultivar (Table, 16), indicating more absorption efficiency and translocation of these nutrients. The same trend was obtained in both seasons of this experiment. This difference in nutrients uptake can be attributed to the differences in nature and absorption ability existed among cultivars .

These results are in accordance with those obtained by Ali (1995), who worked on two lettuce cultivars (Balady and Dark Green) and stated differences in the leaf contents of N, P and K between both studied cultivars . She came to the conclusion that there are varietal differences regarding elemental composition of plant leaves .

Table (16) Macro- and micro-nutrients content of lettuce leaves as affected by cultivar, Ni level and soil amendments.

Treatments		Macronutrients %					Micronutrients ppm			
		N	P	K	Ca	Mg	Zn	Cu	Mn	Fe
		1994/95 season								
Cultivars	Balady	3.22	0.36	1.23	0.73	0.62	117	46.7	93.4	560
	Great Lakes	3.38	0.38	1.31	0.76	0.67	127	50.9	101.8	611
LSD at 5%		**0.010**	**0.001**	**0.01**	**0.02**	**0.005**	**0.7**	**0.27**	**0.55**	**3.3**
Ni level ppm	0	3.44	0.38	1.33	0.78	0.56	122	48.8	97.7	586
	50	3.35	0.37	1.29	0.75	0.70	120	47.9	95.9	576
	100	3.27	0.36	1.26	0.73	0.68	123	49.2	98.5	591
	150	3.14	0.35	1.22	0.72	0.65	123	49.2	98.3	590
LSD at 5%		**0.004**	**0.003**	**0.006**	**0.02**	**0.003**	**0.06**	**0.02**	**0.05**	**0.3**
Amendment	0	2.99	0.33	1.14	0.65	0.59	123	49.2	98.3	590
	Organic manure	3.10	0.35	1.20	0.68	0.63	129	51.7	103.3	620
	Clay	3.67	0.41	1.42	0.80	0.72	119	47.5	94.9	569
	CaCO3	3.44	0.38	1.33	0.86	0.65	117	46.9	93.8	563
LSD at 5%		**0.005**	**0.002**	**0.006**	**0.02**	**0.002**	**0.14**	**0.06**	**0.11**	**0.7**
		1995/96 season								
Cultivars	Balady	2.80	0.31	1.08	0.64	0.58	102	40.6	81.2	487
	Great Lakes	2.94	0.33	1.14	0.66	0.61	111	44.3	88.6	551
LSD at 5%		**0.01**	**0.001**	**0.01**	**0.02**	**0.003**	**0.60**	**0.30**	**0.48**	**2.9**
Ni level ppm	0	2.99	0.33	1.16	0.68	0.62	106	42.5	85.0	510
	50	2.92	0.32	1.13	0.65	0.60	104	41.7	83.5	501
	100	2.84	0.32	1.10	0.64	0.59	107	42.8	85.7	514
	150	2.73	0.30	1.07	0.63	0.57	107	42.8	85.5	513
LSD at 5%		**0.004**	**0.002**	**0.005**	**0.02**	**0.002**	**0.05**	**0.02**	**0.04**	**0.3**
Amendment	0	2.60	0.29	1.01	0.57	0.54	107	42.8	85.5	513
	Organic manure	2.70	0.30	1.05	0.59	0.56	112	45.0	89.9	539
	Clay	3.19	0.35	1.23	0.69	0.66	103	41.3	82.6	495
	CaCO3	2.99	0.33	1.16	0.75	0.62	102	40.8	81.6	490
L.S.D. at 5%		**0.005**	**0.001**	**0.005**	**0.02**	**0.002**	**0.12**	**0.05**	**0.10**	**0.6**

Nickel effect : The concentrations of macro-and micro-nutrient of lettuce leaves as shown in Table (16) indicate a significant decrease of the N, P, K and Ca concentrations in response to the increase of Ni level up to 150 ppm. This held true in the two growing seasons, for the mentioned nutrients, while for Mg concentration a similar trend was observed in the second growing season and an irregular trend occurred in the first growing one. As for micro-nutrients concentration, it is clear that Zn, Cu, Mn and Fe concentrations fluctuated with increasing the added Ni up to 150 ppm, having the highest values mostly in plants grown under 100 ppm Ni treatment.

These results are confirmed with those of Foy *et al.* (1979),who reported that with plants under Ni stress, the absorption of nutrients, root development, and metabolism are strongly retarded. In this connection, the interaction between Ni and other trace metals, Fe in particular, is believed to be a common mechanism involved in Ni toxicity. Wallace *et al.* (1981) stated excess of Ni is believed to cause an actual Fe deficiency by inhibiting the translocation of Fe from roots to tops. Furthermore, both antagonistic and synergistic interactions have been observed between Ni and several trace elements.Khalid and Tinsley (1989), concluded that the Ni/Fe ratio, rather than the Ni and Fe concentrations in plants, has shown better relationships with the toxic effects of Ni. Both antagonistic and synergistic interactions have been observed between Ni and several trace metals

Amendments effect : In regard to the effect of soil amendments i.e. organic manure, clay and $CaCO_3$ on leaf content of macro and micro-nutrients, Table (16) shows an increase of macro-nutrient leaf concentrations for the plants grown on soil amended with any of the studied amendments with superiority of clay in enhancing the uptake of N, P, K and Mg. It is logic that plants grown under $CaCO_3$ treatments had the highest values of Ca concentrations.

With respect to leaf micro-nutrient concentration, it is evident from Table (16) that clay and $CaCO_3$ application reduced the uptake of Zn, Cu, Mn and Fe nutrients, while the uptake of these nutrients behaved oppositionally in response to organic manure. This may be attributed to the considerable amounts of such nutrients available in organic manure, beside its enormous exchange capacity. Meanwhile, contra trend was detected in case of using either clay or $CaCO_3$ which may be attributed to the role of such amendments on cation exchange capacity (CEC) and pH of the soil, respectively. Results held true during both seasons of the experiment.

Interaction effect: Macro-and micro-nutrients content in lettuce leaves of both Balady and Great Lakes cultivars as affected by Ni soil levels and soil amendments application are shown in Tables (17 and 18) for 1994/95 and 1995/96 growing seasons, respectively.

For any specific Cd level, N, P, K and Mg content of leaves were generally the highest due to organic manure application in plants of Great lakes cultivar. Whileas, Ca content of plant leaves of Great Lakes cultivar was the highest in case of $CaCO_3$ application with insignificant difference. This held true in the two seasons of the experiment.

With regard to micronutrients content, data indicate that among amendments applied, organic manure was the most important factor in this respect, whereby the highest values were mostly `obtained from plants of Great Lakes cultivar grown in soil contaminated with 50 ppm Ni and received organic manure as a soil amendment.

These results indicate that both macro-and micronutrients leaves content were significantly affected by the interaction effect of cultivar, Ni level of soil, and soil amendments. The depressive effect of increasing Ni level can be reduced with clay and organic manure application. Irrespective of the varietal differences of nutrients absorption, the nutritional status of any applied soil amendments applied is a determining factor. Clay soil seems to be rich in N, P,

Table (17) The interaction effect of cultivar, Ni level and soil amendments on macro and micronutrients content of lettuce leaves (1994/95).

Ni level ppm	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
		Balady cv.								
0	0	2.94	0.33	1.14	0.78	0.52	92.38	36.95	73.90	443
	OM	3.56	0.39	1.38	0.74	0.64	118.42	47.37	94.74	568
	Clay	3.08	0.34	1.19	0.77	0.55	103.57	41.43	82.86	497
	CaCO3	3.10	0.35	1.20	0.89	0.55	101.95	40.78	81.56	489
50	0	3.34	0.37	1.29	0.73	0.69	109.58	43.83	87.66	525
	OM	3.69	0.41	1.43	0.80	0.59	125.91	50.36	100.73	604
	Clay	3.56	0.39	1.38	0.77	0.74	116.38	46.55	93.10	558
	CaCO3	3.44	0.38	1.33	0.85	0.71	110.24	44.10	88.19	529
100	0	2.82	0.31	1.09	0.62	0.59	128.79	51.52	103.03	618
	OM	3.23	0.36	1.25	0.70	0.57	121.94	48.78	97.55	585
	Clay	3.02	0.34	1.17	0.66	0.63	114.37	45.75	91.50	548
	CaCO3	3.00	0.33	1.16	0.82	0.62	125.19	50.08	100.15	600
150	0	2.73	0.30	1.06	0.60	0.57	123.45	49.38	98.76	592
	OM	3.08	0.34	1.19	0.67	0.51	102.35	40.94	81.88	491
	Clay	2.99	0.33	1.16	0.65	0.62	119.25	47.70	05/40	572
	CaCO3	2.87	0.32	1.11	0.69	0.60	120.68	48.27	06.54	579
		Great Lakes cv.								
0	0	3.03	0.34	1.17	0.77	0.54	111.18	44.47	88.94	533
	OM	3.51	0.39	1.36	0.76	0.64	124.98	49.99	99.98	599
	Clay	3.14	0.35	1.22	0.75	0.58	106.98	42.79	85.59	513
	CaCO3	3.09	0.35	1.20	0.91	0.55	109.19	43.68	87.35	524
50	0	3.79	0.42	1.47	0.83	0.78	117.20	46.88	93.76	562
	OM	3.86	0.43	1.50	0.80	0.69	136.57	54.63	109.26	655
	Clay	3.84	0.43	1.49	0.84	0.79	113.21	45.28	90.57	543
	CaCO3	3.82	0.42	1.48	0.89	0.79	119.85	47.94	95.88	575
100	0	3.00	0.33	1.16	0.66	0.62	139.48	55.79	111.59	669
	OM	3.35	0.37	1.30	0.65	0.65	132.29	52.92	105.83	634
	Clay	3.29	0.36	1.27	0.72	0.68	133.59	53.44	106.87	641
	CaCO3	3.12	0.35	1.21	0.73	0.65	137.69	55.08	110.15	660
150	0	2.81	0.31	1.09	0.61	0.58	13848	55.39	110.78	664
	OM	3.23	0.36	1.25	0.66	0.54	112.08	45.63	91.26	547
	Clay	3.20	0.35	1.24	0.70	0.66	130.49	52.20	104.39	626
	CaCO3	3.02	0.34	1.17	0.74	0.63	134.45	53.78	107.56	645
LSD at 5%		*0.02*	*0.005*	*0.02*	*N.S.*	*0.01*	*0.4*	*0.16*	*0.32*	*1.9*

OM = Organic manure NS =Nonsignificant

Table (18) The interaction effect of cultivar, Ni level and soil amendments on macro and micronutrients content of lettuce leaves (1995/96).

Ni level ppm	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
		Balady cv.								
0	0	2.38	0.26	0.94	0.63	0.65	74.82	29.93	59.86	359
	OM	3.09	0.34	1.20	0.62	0.45	103.03	41.21	82.42	494
	Clay	2.51	0.28	0.97	0.60	0.68	82.58	33.03	66.06	396
	CaCO3	2.50	0.28	0.96	0.77	0.68	83.89	33.56	67.11	402
50	0	2.91	0.32	1.13	0.64	0.60	95.33	38.13	76.27	457
	OM	3.21	0.36	1.24	0.70	0.66	109.54	43.82	87.63	525
	Clay	3.09	0.34	1.20	0.67	0.64	101.25	40.50	81.00	486
	CaCO3	2.99	0.33	1.16	0.76	0.62	95.91	38.36	76.73	460
100	0	2.46	0.27	0.95	0.54	0.51	112.05	44.82	89.64	537
	OM	2.81	0.31	1.09	0.61	0.58	106.09	42.44	84.87	509
	Clay	2.63	0.29	1.02	0.57	0.55	99.50	39.80	79.60	477
	CaCO3	2.61	0.29	1.01	0.67	0.54	108.91	43.57	87.13	522
150	0	2.38	0.26	0.92	0.52	0.49	107.40	42.96	85.92	515
	OM	2.68	0.30	1.04	0.59	0.55	89.04	35.62	71.24	427
	Clay	2.60	0.29	1.01	0.57	0.54	103.75	41.50	83.00	497
	CaCO3	2.50	0.28	0.97	0.65	0.52	109.99	42.00	83.99	503
		Great Lakes cv.								
0	0	2.45	0.27	0.95	0.62	0.66	90.05	36.02	72.04	432
	OM	3.05	0.34	1.18	0.61	0.50	118.82	47.53	95.05	570
	Clay	2.54	0.28	0.98	0.61	0.69	86.66	34.66	69.32	415
	CaCO3	2.50	0.28	0.97	0.79	0.68	88.44	35.38	70.75	424
50	0	3.30	0.37	1.28	0.72	0.68	101.96	40.79	81.57	489
	OM	3.36	0.37	1.30	0.73	0.70	118.82	47.53	95.05	570
	Clay	3.34	0.37	1.29	0.73	0.69	98.49	39.40	78.79	472
	CaCO3	3.32	0.37	1.29	0.80	0.69	104.27	41.71	83.42	500
100	0	2.61	0.29	1.01	0.57	0.54	121.35	48.54	97.08	582
	OM	2.91	0.32	1.13	0.64	0.60	115.09	46.04	92.08	552
	Clay	2.86	0.32	1.11	0.63	0.59	116.22	46.49	92.98	557
	CaCO3	2.71	0.30	1.05	0.69	0.56	119.79	47.92	95.83	575
150	0	2.45	0.27	0.95	0.53	0.50	120.48	48.19	96.38	578
	OM	2.81	0.31	1.09	0.61	0.58	99.25	39.70	79.40	476
	Clay	2.78	0.31	1.08	0.61	0.58	113.53	45.41	90.82	544
	CaCO3	2.64	0.29	1.02	0.67	0.55	116.97	46.79	93.58	561
LSD at 5%		*0.01*	*0.004*	*0.01*	*N.S.*	*0.01*	*0.35*	*0.14*	*0.28*	*1.7*

OM = Organic manure NS =Nonsignificant

K and Mg nutrient, while organic manure is rich in micro nutrient besides to its active role in reducing soil pH and subsequently enhancing the absorption of micronutrients Zn, Cu, Mn and Fe by plant roots.

The results are in accordance with those concluded by Chaney (1973); and Lindsay (1973), who stated that other materials present in the soil such as clays, organic matter, hydrous Fe and Mn oxides, carbonates, inorganic chemical compounds, organic acids, biological systems and biological residues can react to immobilize cationic anions in soils.

4.2.3. Effect of cultivar, nickel level and soil amendment on heavy metals content of lettuce leaves:

A. Cadmium content of lettuce leaves:

Table (19) presents data on Cd content of lettuce leaves as affected by the studied factors and their interaction .

***Cultivar effect*:** Regarding the effect of cultivar on Cd content of plant leaves, data indicate that plants of Great Lakes cultivar absorbed and accumulated much more Cd than those of Balady cultivar, especially under high level of Ni pollution . Results reveal a significant differences in this respect due to cultivar in both seasons of the study.

This can be interpreted with the results obtained by many investigators including Crews and Davies (1985) on lettuce; Davies and Lewis (1985)on lettuce and radish varieties and Gunnaresson (1983) on leafy plants, who suggested possibilities of reducing Cd contents to below permitted values by choice of suitable cultivar.

***Nickel effect* :** Considering the effect of Ni level on accumulation of Cd in lettuce leaves, data reveal that Cd content of lettuce leaves significantly increased with increasing the level of Ni added to the soil. This increase amounted to be approximately 1.7, 2.4 and 2.6 fold the value of untreated

Table (19): Cadmium content (ppm) of lettuce leaves as affected by cultivar, level of nickel pollution, soil amendment and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Ni x Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Ni level ppm	1994/95 season														
0	0.17	0.17	0.07	0.04	**0.11**	0.18	0.19	0.09	0.06	**0.13**	0.17	0.18	0.08	0.05	**0.12**
50	0.34	0.36	0.11	0.07	**0.22**	0.33	0.18	0.10	0.08	**0.17**	0.34	0.27	0.10	0.08	**0.20**
100	0.49	0.50	0.12	0.07	**0.29**	0.46	0.39	0.16	0.12	**0.28**	0.47	0.45	0.14	0.10	**0.29**
150	0.54	0.45	0.14	0.10	**0.31**	0.66	0.61	0.24	0.19	**0.42**	0.60	0.53	0.19	0.14	**0.31**
Mean	**0.38**	**0.37**	**0.11**	**0.07**	**0.23**	**0.40**	**0.36**	**0.13**	**0.09**	**0.25**	**0.40**	**0.36**	**0.13**	**0.09**	**0.24**
Ni level ppm	1995/96 season														
0	0.15	0.15	0.06	0.03	**0.10**	0.15	0.16	0.08	0.05	**0.11**	0.15	0.16	0.07	0.04	**0.10**
50	0.30	0.32	0.09	0.06	**0.19**	0.29	0.16	0.08	0.07	**0.15**	0.29	0..24	0.09	0.07	**0.17**
100	0.42	0.43	0.10	0.06	**0.26**	0.40	0.34	0.14	0.10	**0.25**	0.41	0.39	0.12	0.08	**0.25**
150	0.47	0.39	0.12	0.09	**0.27**	0.58	0.53	0.21	0.16	**0.37**	0.52	0.46	0.16	0.12	**0.32**
Mean	**0.33**	**0.32**	**0.09**	**0.06**	**0.20**	**0.35**	**0.30**	**0.13**	**0.10**	**0.22**	**0.34**	**0.31**	**0.11**	**0.08**	**0.21**

*** OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Ni level (Ni)**	**Amendment (AM)**	**cv x Ni**	**cv x AM**	**Nix AM**	**cvxNixAM**
1994/95	0.001	0.004	0.004	0.006	0.005	0.007	0.010
1995/96	0.002	0.004	0.003	0.005	0.004	0.006	0.009

control treatment in response to 50, 100 and 150 ppm Ni of the soil, respectively in the first growing season, while it was 1.7, 2.5 and 3.2 fold in the second growing one. These results mean that there is a synergistic relationship between Ni and Cd under the levels tested in this experiment.

***Amendment effect*:** Data on the effect of soil amendments (Table,19) reveal that all tested amendments had a favourable effect in reducing the Cd accumulated in lettuce leaves. Data clearly show that amendments efficiency had the order of descending magnitude : $CaCO_3$ > clay > organic manure which showed the least positive effect in this regard. This trend held true in both seasons of this experiment. These results confirmed the results obtained by Singh (1979), who indicated that fixed Cd was correlated with soil C.E.C., pH, organic matter and $CaCO_3$ content. Also, Behel *et al.* (1983) found that the percentage of Cd complexed by organic matter depended on the model used to represent metal interaction with soluble organic C, phosphate, sulfate and chloride forming inorganic complexes with Cd, but it constituted <10% of the total Cd present.

Interaction effect: With respect to the interaction effect of cultivar and Ni level, it is evident that Cd concentration in leaves of both cultivars increased over the two seasons of the experiment with increasing the level of Ni applied to the soil (Table, 19).

Regarding the cultivar within Ni level, it can be indicated from the data that :

- A close similarity between both cultivars , whereby increasing the Ni level in soil increased Cd content of plant leaves .
- Eventhough plant leaves of Great lakes cultivar contained (in average) higher concentration of Cd than those of Balady cultivar, it showed to be more safe and tolerant with respect to Ni in soil at low levels (50 and 100 ppm) than Balady cultivar. Great Lakes cultivar failed to tolerate the higher Ni

soil levels (150 ppm), whereby its leaves contained considerable amounts of Cd.

As for the interaction effect of amendments and Ni level, data show that $CaCO_3$ was the most effective amendment within Ni various levels followed by clay and then organic manure which had the least positive effect in this regard. It is also clear from the data presented in Table (19) that in spite of the reducing effect of the amendments, Cd leaf concentration increased , especially in case of organic manure when Ni soil level increased.

The cultivar x Ni level x amendment effect shown in Table (19) reveals that choice of Balady cultivar and application of $CaCO_3$ is the best treatment in reducing Cd accumulation under the conditions of this experiment.

B. Nickel content of lettuce leaves:

Cultivar Effect : Data in Table (20) reveal that Ni concentration in lettuce leaves differed due to cultivar whereby higher values were detected in leaves of Great Lake compared with those of Balady cultivar. Such metal concentrations in lettuce leaf tended to increase by adding Ni up to 150 ppm. This trend appears the same for the two cultivars in both growing seasons.

In this connection, the phytotoxic Ni concentrations range widely among plant species and cultivars and have been reported for various plants to be from 40 to 246 ppm (DW).Allaway (1968) reported that the range of excessive or toxic amounts of Ni in most plant species varies from 10 to 100 ppm (DW). Most sensitive species are affected by much lower Ni concentrations, ranging from 10 to 30 ppm (DW). Several species are known for their great tolerance and hyperaccumulation of Ni. Usually these species, are mainly those of the Boraginaceae., Cruciferae, Myrtaceae, Leguminosae, and Caryophyllaceae families (Kabata and Pendias, 1986).

Table (20): Nickel content (ppm) of lettuce leaves as affected by cultivar, level of nickel pollution, soil amendments and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Ni x Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Ni level ppm	1994/95 season														
0	1.66	1.73	0.65	0.44	**1.12**	1.75	1.85	0.90	0.60	**1.28**	1.71	1.79	0.78	0.52	**1.20**
50	8.57	9.05	2.65	1.83	**5.52**	8.36	4.55	2.40	2.05	**4.34**	8.47	6.80	2.53	1.94	**4.93**
100	12.18	12.41	2.97	1.85	**7.35**	11.43	9.92	3.96	3.01	**7.08**	11.81	11.17	3.47	2.43	**7.22**
150	13.46	11.27	3.39	2.57	**7.67**	16.58	15.30	5.86	4.60	**10.59**	15.02	13.29	4.63	3.58	**9.13**
Mean	**8.97**	**8.62**	**2.42**	**1.67**	**5.42**	**9.53**	**7.91**	**3.28**	**2.57**	**5.82**	**9.25**	**8.26**	**2.85**	**1.99**	**5.32**
Ni level ppm	1995/96 season														
0	1.44	1.51	0.57	0.38	**0.97**	1.53	1.61	0.79	0.52	**1.11**	1.48	1.56	0.68	0.45	**1.04**
50	7.46	7.87	2.30	1.59	**4.81**	7.27	3.96	2.09	1.78	**3.78**	7.36	5.92	2.20	1.69	**4.29**
100	10.60	10.80	2.58	1.61	**6.4**	9.94	8.63	3.45	2.62	**6.16**	10.27	9.71	3.01	2.12	**6.28**
150	11.71	9.80	2.95	2.23	**6.67**	14.42	13.31	5.10	4.00	**9.21**	13.07	11.56	4.03	3.12	**7.94**
Mean	**8.71**	**7.12**	**2.10**	**1.45**	**4.71**	**8.29**	**6.88**	**2.86**	**2.23**	**5.07**	**8.05**	**7.19**	**2.48**	**1.85**	**4.89**

* **OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Ni level (Ni)**	**Amendment (AM)**	**cv x Ni**	**cv x AM**	**Nix AM**	**cvxNixAM**
1994/95	0.03	0.09	0.07	0.13	0.09	0.13	0.19
1995/96	0.03	0.08	0.06	0.12	0.08	0.12	0.16

Nickel Effect : Application of Ni up to 150 increased progressively the concentration of Ni in lettuce leaves (Table 20). This is the same when Ni level was increased within both cultivar and amendment treatments in both seasons of the experiment.

Pilegard (1978) studied the uptake of some heavy metals by carrot and radish which were grown in soils with added metal ions. There were linear correlations between plant species studied and soil metal concentrations . The results also revealed that Ni were translocated from the roots to the tops. Furthermore, Mortvedt (1985) conducted two greenhouse pot experiments to determine the significant quantities of Ni from Zn fertilizers prepared from industrial by-product and absorbed by corn (*Zea mays*) and swiss chard (*Beta vulgaris*). They found that uptake of Ni generally increased with increasing levels of Ni in the Zn-fertilizers in the acid soil only.

Amendment effect : It is evident from Table (20) that Ni content of lettuce leaves was generally significantly reduced due to the application of soil organic manure, clay and $CaCO_3$ amendments as compared with the control treatment. The efficiency of such amendments had the order of magnitude: $CaCO_3$ > clay > organic manure in reducing heavy metal uptake.

These findings are similarly concluded by Bloomfield (1978), who stated that although organic matter is able to mobilize Ni from carbonates and oxides as well as to decrease Ni sorption on clays, the bonding of this metal to the organic ligands could not be particularly strong. Complexing ligands such as SO_4^{2-} and organic acids reduce the sorption of Ni. The remobilization of Ni from solid phases appears to be possible in the presence of FA and HA. Thus, Ni may be quite mobile in soils with high complexation ability (e.g., organic-rich and polluted soils).

Information on the Ni ionic species in the soil solution is rather limited, but the Ni species described by Garrels and Christ (1979) such as Ni^{2+}, $NiOH^{+}$ $HNiO_2$, and $Ni(OH)_3$ are likely to occur when the Ni is not completely chelated.

Generally, the solubility of soil Ni is inversely related to the soil pH. Ni sorption on Fe and Mn oxides is especially pH-dependent, probably because $NiOH^+$ is preferentially sorbed and also because the surface charge on sorbents is affected by pH. Moreover, a greenhouse experiment was conducted by Singh *et al.* (1995) for three years to study the effect of different pH levels on metal concentrations in plants. Significant concentration differences between soil pH levels were only seen in wheat and carrot crops. Increasing soil pH also decreased the nickel (Ni)

On the contrary, Michel *et al.*, (1978) reported that at relatively low soil treatments with sewage sludge enriched with Cd, Cu, Ni, or Zn; Cu and Pb were more toxic to lettuce grown in the calcareous (1.2% $CaCO_3$) than in the acid (pH 5.7) soil.

Interaction effect: With respect to the interaction effect of cultivar and Ni level, it is evident that Ni concentration increased in leaves of both cultivars over the two seasons of the experiment with increasing the level of Ni added to the soil (Table, 20).

It can be concluded that :

- The effect of cultivar within amendments was the same for each of the two cultivars as the heavy metal concentrations were reduced by applying any of the soil amendments in both growing seasons
- Although plant leaves of Great Lakes cultivar contained (in average) higher concentration of Ni than those of Balady cultivar, it showed to be more safe and tolerant with respect to Ni in soil at low levels (50 and 100 ppm) than Balady cultivar. Great lakes cultivar failed to tolerate the higher Ni soil levels (150 ppm), whereby its leaves contained considerable amounts of Ni.

The data of the interaction of amendments and Ni level show that $CaCO_3$ was the most effective amendment within Cd various levels followed by clay and then organic manure which had the least positive effect in this regard. It is also clear from the data presented in Table (20) that in spite of the reducing effect of the amendments, Ni leaf concentration increased , especially in case of organic manure when Ni soil level increased.

The cultivar x Ni level x amendment effect shown in Table (20) reveals that choice of Balady cultivar and application of $CaCO_3$ is the best treatment in reducing Ni accumulation under the conditions of this experiment. This held true in both growing seasons under the interactive effect of amendments within cultivar and Ni level.

C. Lead content of lettuce leaves:

Table (21) presents data on Pb content of lettuce leaves as affected by the studied factors and their interaction .

***Cultivar effect*:** Regarding the effect of cultivar on Pb content of plant leaves, data indicate that plants of Great Lakes cultivar absorbed and accumulated much more Pb than those of Balady cultivar, especially under high level of Ni pollution . Results reveal a significant differences in this respect due to cultivar in both seasons of the study.

Varietal response to lead accumulation by lettuce plants was indicated by John (1977). Also, Judel and Stelte (1977) studied varietal response to Pb by lettuce, radish, carrot and spinach plants and found that Pb concentration in the tops and roots of the corresponding edible tissues depended on variety among other interacting factors .

On the contrary, Crews and Davies (1985) worked on six varieties of lettuce and found that there was little evidence for cultivar control of Pb absorption. Also, Davies and Lewis (1985) studied the differences in uptake of Pb in five varieties of lettuce and four varieties of radish and concluded that it is not possible to select a single variety of either lettuce or radish to minimize

Table (21): Lead content (ppm) of lettuce leaves as affected by cultivar, level of nickel pollution, soil amendment and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Ni x Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
	1994/95 season														
Ni level ppm															
0	4.15	4.32	1.62	1.10	**2.80**	4.37	4.63	2.26	1.49	**3.19**	4.26	4.48	1.94	1.30	**2.99**
50	3.43	3.62	1.06	0.73	**1.21**	3.34	1.82	0.96	0.82	**1.74**	3.39	2.72	1.01	0.78	**1.97**
100	4.87	4.96	1.19	0.74	**2.84**	4.57	3.97	1.59	1.21	**2.83**	4.72	4.47	1.39	0.98	**2.89**
150	5.38	4.51	1.35	1.03	**3.07**	6.63	6.12	2.35	1.84	**4.24**	6.01	5.31	1.85	1.44	**3.65**
Mean	**4.46**	**4.35**	**1.31**	**0.90**	**2.48**	**4.73**	**4.14**	**1.79**	**1.34**	**3.00**	**4.60**	**4.25**	**1.60**	**1.13**	**2.90**
	1995/96 season														
Ni level ppm															
0	3.61	3.76	1.41	0.96	**2.43**	3.80	4.03	1.96	1.30	**2.77**	3.71	3.89	1.69	1.13	**2.60**
50	2.98	3.15	0.92	0.64	**1.92**	2.91	1.59	0.84	0.72	**1.51**	2.95	2.37	0.88	0.68	**1.72**
100	4.24	4.32	1.03	0.65	**2.56**	3.98	3.45	1.38	1.05	**2.47**	4.11	3.88	1.21	0.85	**2.51**
150	4.68	3.92	1.18	0.90	**2.67**	5.77	5.32	2.04	1.60	**3.68**	5.23	4.62	1.61	1.25	**3.18**
Mean	**3.38**	**3.79**	**1.14**	**0.79**	**2.28**	**4.16**	**3.60**	**1.56**	**1.17**	**2.62**	**4.00**	**3.69**	**1.35**	**0.98**	**2.51**

*** OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Ni level (Ni)**	**Amendment (AM)**	**cv x Ni**	**cv x AM**	**Nix AM**	**cvxNixAM**
1994/95	0.01	0.03	0.03	0.05	0.04	0.05	0.08
1995/96	0.01	0.03	0.02	0.05	0.03	0.05	0.07

metal uptake from soil.

Nickel effect : Considering the effect of Ni level on accumulation of Pb in lettuce leaves, data reveal that Pb content of lettuce leaves significantly decreased by adding 50 or 100 ppm of Ni to the soil compared with the control treatment, while it tended to increase by increasing the Ni level up to 150 ppm. This held true in both seasons of the study.

These results mean that there is an antagonistic relationship between Ni and Pb under the low and medium levels tested in this experiment, while a synergistic effect occurred by increasing Ni level in soil.

Amendment effect: Data on the effect of soil amendments (Table,21) reveal that all tested amendments had a favourable effect in reducing the Pb accumulated in lettuce leaves. Data clearly show that amendments efficiency had the order of descending magnitude : $CaCO_3$ > clay > organic manure in both seasons of this experiment

Interaction effect: With respect to the interaction effect of cultivar and Ni level, it is evident that Pb concentration increased in leaves of both cultivars over the two seasons of the experiment with increasing the level of Ni (Table, 21).
Regarding the cultivar within Ni level, it can be indicated from the data that :

- A close similarity between both cultivars , whereby increasing the Ni level in soil increased Pb content of plant leaves .

- Eventhough plant leaves of Great lakes cultivar contained (in average) higher concentration of Pb than those of Balady it showed to be more safe and tolerant with respect to Ni in soil at low levels (50 and 100 ppm) than Balady cultivar. Great lakes cultivar failed to tolerate the higher Ni soil levels (150 ppm), whereby its leaves contained considerable amounts of Pb.

The data of the interaction of amendments and Ni level show that $CaCO_3$ was the most effective amendment within Ni various levels followed by clay and then organic manure. It is also clear from the data presented in Table (21), that in spite of the reducing effect of the amendments, Pb leaf concentration increased , especially in case of organic manure when Ni soil level increased.

The cultivar x Ni level x amendment effect shown in Table (21) reveals that choice of Balady cultivar and application of $CaCO_3$ is the best treatment in reducing Pb accumulation under the conditions of this experiment.

To obtain a wide view on the behaviour of either cultivars or soil amendments studied, Fig.(4) presents Cd, Ni and Pb contents of lettuce leaves as affected by cultivar or soil amendment . It is clear that plants of Great Lakes cultivar accumulated more heavy metal amounts than those accumulated by Balady cultivar . It is also evident from Fig. (4) that amendments efficiency in reducing heavy metal accumulation in lettuce leaves follows the order: $CaCO_3$ > clay > organic manure which showed least positive effect in this regard.

In this connection, Davies and White (1981) reported that vegetables grown on heavy metals contaminated soils absorb excessive quantities of these metals. They analyzed the roots and aerial parts of lettuce, onion, carrots and *brussels* sprouts for determination of Cd and Pb. Lead tended to be retained in the roots but other metals were more mobile and cadmium accumulated in lettuce and carrot leaves. The Cd and Pb contents of edible parts constitute a possible risk to public health. Also, Mortvedt (1985) concluded that uptake of Cd, Ni and Pb by swiss chard generally increased with increasing levels of heavy metals added through Zn- contaminated fertilizer.

On the contrary, Michel *et al.* (1978) reported that at relatively low soil treatments with sewage sludge enriched with Cd, Cu, Ni, or Zn; Cu and Pb were more toxic to lettuce grown in the calcareous (1.2% $CaCO_3$) than in the acid (pH 5.7) soil.

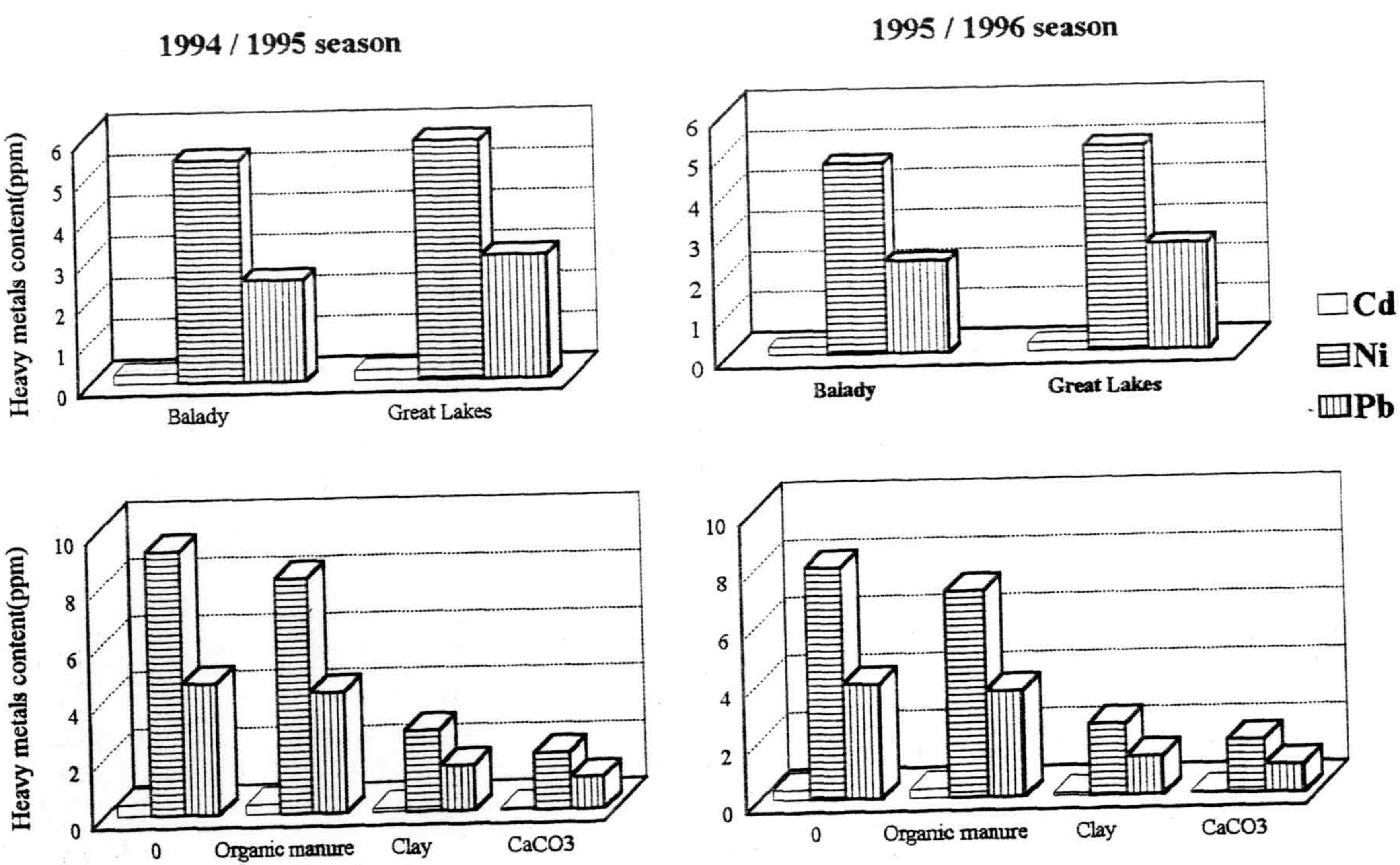

Fig. (4) : Heavy metals content of lettuce leaves. as affected by cultivar or amendments under Ni soil pollution.

**All the differences within each variable are significant (p=0.05)*

4.2.4. Effect of cultivar, nickel level and soil amendments on some metabolic changes:

A. photosynthetic pigments, ascorbic acid and NO_3

Table (22) shows clearly that all of chlorophyll a, b, total and carotene as well as ascorbic acid contents of lettuce leaves were significantly affected by the studied factors during both seasons of this experiment, with exception for ascorbic acid in response to cultivar in the second growing season.

Cultivar effect: As shown from Table (22), it is clear that leaves of Balady cultivar contained higher values of the metabolic products i.e., chlorophyll a, b and the total as well as carotene and ascorbic acid than those of Great Lakes cultivar in the two growing seasons except that of chlorophyll b and ascorbic acid in the second growing season in which Great Lakes cultivar preceded the Balady cultivar. As for NO_3 accumulation it is clear from the data that leaves of Great Lakes accumulated more amounts of NO_3. These results indicate the superiority of Balady cultivar whereby higher contents of such quality metabolic products and less content of NO_3 than Great Lakes cultivar could be detected.

Normally, lettuce colour which is highly correlated with photosynthetic pigments content is varietal character. For this reason, Thompson (1949) mentioned that lettuce varieties had been classified under 3 divisions according to colour.

Nickel effect: Values of photosynthetic pigments; i.e. chlorophyll a, b and carotene as well as ascorbic acid (Table, 22) tended to decrease consistently due to Ni addition up to 150 ppm compared with the control treatment. This held true during both seasons of this experiment with the exception of chlorophyll a and b in the first season as its values were increased due to Ni application with a decreasing tendency as Ni level increased from 50 to 150

Table (22) Photosynthetic pigments (mg/100 gm FW), ascorbic acid (mg/100 gm FW), and nitrate (mg/100 gm DW) content of lettuce leaves as affected by cultivar, Ni level and soil amendments.

Treatments		Chlorophylls a	Chlorophylls b	Chlorophylls Total	Carotene	Ascorbic Acid	Nitrate
1994/95 season							
Cultivars	Balady	153.0	54.5	207.5	100.6	11.4	135.8
	Great Lakes	142.6	53.1	195.7	97.7	11.1	145.5
LSD at 5%		**0.8**	**0.3**	**1.0**	**1.5**	**0.04**	**6.4**
Ni level ppm	0	140.6	50.1	190.7	103.7	15.9	134.1
	50	155.5	56.1	211.6	101.1	11.7	141.5
	100	151.0	55.4	206.4	98.1	11.1	143.9
	150	144.2	53.7	197.9	93.8	10.8	143.2
LSD at 5%		**0.3**	**0.2**	**0.5**	**1.2**	**0.03**	**1.9**
Amendment	0	146.0	51.9	197.9	97.9	11.0	147.0
	Organic manure	148.1	53.0	201.1	99.4	11.5	144.9
	Clay	150.6	56.2	206.8	101.0	12.0	135.6
	CaCO3	146.6	54.3	200.9	98.3	**11.2**	135.1
LSD at 5%		**0.2**	**0.2**	**0.2**	**0.1**	**0.03**	**1.1**
1995/96 season							
Cultivars	Balady	133.1	47.4	180.5	86.5	12.0	143.9
	Great Lakes	130.8	49.0	179.8	85.0	12.2	155.0
LSD at 5%		**0.3**	**0.19**	**0.20**	**0.19**	**N.S.**	**28.4**
Ni level ppm	0	135.7	49.2	184.9	88.2	18.9	141.4
	50	135.3	48.8	184.1	87.9	12.5	150.6
	100	131.3	48.2	179.5	85.4	11.8	153.2
	150	125.5	46.7	172.2	81.6	11.5	152.5
LSD at 5%		**0.23**	**0.15**	**0.28**	**0.15**	**0.21**	**16.8**
Amendment	0	130.6	46.4	177.0	84.9	11.6	155.9
	Organic manure	132.5	48.1	180.6	86.2	12.3	153.6
	Clay	134.2	50.4	184.6	87.2	12.7	144.4
	CaCO3	130.6	48.0	178.6	84.9	11.9	143.8
L.S.D. at 5%		**0.14**	**0.14**	**0.15**	**0.09**	**0.11**	**12.3**

N.S. = Nonsignificant

ppm. As for nitrate content, data reveal that Ni contamination of the soil led to a synergistic effect on NO3 accumulation in lettuce leaves. This might be due to the stimulative effect of Ni on nitrification and/or its depressive effect on reduction processes occurred in plants.

In this context, there is no evidence of an essential role of Ni in plant metabolism, although the reported beneficial effects of Ni on plant growth have stimulated speculation that this metal may have some function in plant. In this respect, Welch (1981) discussed reports that Ni is an essential component of the enzyme urease and thus Ni may be required by nodulated legumes that transport N from roots to tops in forms of ureide compounds. The stimulation effects of Ni on the nitrification and mineralization of N compounds are emphasized.

Amendment effect: Table (22) indicates that application of organic manure, clay and $CaCO_3$ led to a significant increase in the photosynthetic pigments and ascorbic acid values as compared with control treatment. This held true in both growing seasons with a pronounced effect of clay application. However, NO_3 content of plants grown in the amended soil tended to decrease showing the least values in case of $CaCO_3$ application, in both growing seasons of the experiment. This may be due to the action of the amendments on metabolism process through influencing the uptake of heavy metals and other nutrients.

Interaction effect: Table (23) presents data on the interaction effect of cultivar, Ni level and soil amendments on photosynthetic pigments, ascorbic acid and nitrate accumulation of lettuce leaves.

Each of the tested variables was significantly affected by the triple interaction. Data reveal that the most important factor in this respect was soil amendment application which had a favourable effect on increasing pigments

Table (23) **The interaction effect of cultivar, Ni level and soil amendments on photosynthetic pigments (mg/100 mg DW), ascorbic acid (mg/100 gm FW) and nitrate (mg/100 gm DW) of lettuce leaves.**

Season		1994/95				1995/96			
Ni level ppm.	Amendments	Total Chlorophyll	Carotene	Ascorbic acid	NO_3	Total Chlorophyll	Carotene	Ascorbic acid	NO_3
		Balady cv.							
0	0	211.07	107.50	11.10	123.28	183.63	89.53	11.32	126.07
	OM	208.00	100.53	11.46	142.30	200.96	87.46	12.18	151.49
	Clay	213.92	97.64	10.50	141.90	207.41	84.95	11.17	151.07
	CaCO3	215.62	93.11	10.17	148.60	218.19	81.00	10.82	158.20
50	0	203.56	112.06	11.40	126.17	194.50	93.33	11.63	129.02
	OM	210.04	102.09	11.58	140.80	202.73	88.82	12.31	149.90
	Clay	214.07	98.06	10.40	143.60	207.54	85.31	11.05	152.88
	CaCO3	208.71	94.09	10.24	145.80	212.88	81.86	10.89	155.22
100	0	197.27	108.28	11.82	125.00	189.03	90.18	12.57	133.07
	OM	219.04	104.89	12.64	134.70	190.57	91.25	13.44	143.40
	Clay	216.53	103.49	11.71	134.70	198.38	90.03	12.45	143.40
	CaCO3	226.88	93.86	12.01	136.90	213.29	81.65	12.77	145.74
150	0	193.10	95.80	11.73	122.00	168.00	79.78	12.47	130.09
	OM	215.15	102.67	12.21	132.50	187.18	89.32	12.98	141.06
	Clay	210.30	100.76	11.50	138.19	182.96	87.66	12.23	145.74
	CaCO3	197.31	94.59	11.37	135.70	171.66	82.30	12.09	144.47
		Great Lakes cv.							
0	0	165.20	99.17	12.43	149.90	182.15	87.81	13.21	159.58
	OM	200.54	95.91	10.92	154.80	194.47	83.44	11.61	164.80
	Clay	201.89	96.32	10.95	157.80	205.64	83.80	11.64	168.00
	CaCO3	196.33	92.94	10.38	157.40	200.81	80.86	11.03	167.57
50	0	170.12	102.11	12.94	150.19	194.19	90.60	13.75	159.90
	OM	208.04	99.54	11.86	152.40	201.00	86.60	12.61	162.25
	Clay	198.85	94.42	11.78	154.70	203.00	82.15	12.53	164.69
	CaCO3	194.74	92.53	11.56	145.80	209.42	80.50	12.29	155.22
100	0	174.25	102.73	11.99	138.80	188.97	88.17	12.74	147.77
	OM	217.40	102.17	12.10	138.70	189.14	88.89	12.87	147.66
	Clay	209.23	97.72	12.01	139.80	202.03	85.02	12.77	148.83
	CaCO3	203.84	95.00	11.50	136.40	207.34	82.65	12.23	145.21
150	0	170.94	101.57	12.15	136.90	179.31	86.45	12.92	145.74
	OM	214.28	100.76	11.20	135.70	186.42	87.66	11.91	144.47
	Clay	206.12	96.56	10.14	140.19	199.32	84.01	10.78	149.25
	CaCO3	199.90	93.93	8.87	139.19	193.91	81.72	9.62	148.19
LSD at 5%		*0.5*	*0.3*	*0.001*	*3.1*	*0.4*	*0.25*	*0.3*	*34.7*

OM = Organic manure

content and decreasing the NO_3 accumulation in plant leaves of both cultivars used in this experiment. The highest values obtained of total chlorophyll, carotene, ascorbic acid and NO3 were respectively resulted from combined treatments as follows:

- Balady cultivar + 100 ppm Ni level + CaCO3 application,
- Balady cultivar + 50 ppm Ni level + zero amendments application
- Great Lakes cultivar + 50 ppm Ni level + zero amendments application,

and Great Lakes cultivar + zero Ni level + clay application.

B. Amino acids:

The effect of the high Ni level added to the soil (150 ppm) on the free amino acids content of the two studied cultivars is illustrated in Table (24). It appears from such data that significant differences had been occurred between the two cultivars in all the amino acids tested . The addition of 150 ppm Ni to the soil led to an increase in the total free amino acid content of plant leaves . This held true in both cultivars. Such increase in the total free amino acids content was amounted to be approximately 32% and 23% for the Balady and Great Lakes cultivars, respectively over its control treatment. Some amino acids exhibited highly significant differences; i.e. aspartic, glutamic, proline and phenyle-alanine acids.

In this respect, Kastori *et al.* (1992), in solution culture found that the concentration of free proline was significantly increased in the leaves of intact plants as well as in leaf discs of sunflower cv. NS-H-26 RM incubated in the presence of heavy metals, while, the concentration of soluble proteins was decreased particularly at 10^{-4}M. It was concluded that excess concentrations of the heavy metals significantly affected plant water status, causing water deficit and subsequent changes in plant metabolism of protein.

Table (24) Effect of soil nickel pollution on various amino acids content (mg/100 gm DW) in leaves of two lettuce cultivars.

Treatment / Amino Acid	Balady cv. Soil Ni treatment		Great Lakes cv.# Soil Ni treatment	
	(0) ppm	150 ppm	(0) ppm	150 ppm
aspartic acid	8.88	13.25*	10.43	20.13**
serine	11.18	14.63*	14.68	16.84*
threonine	5.05	6.98*	6..92	9.65*
glycine	3.55	4.06	3.85	4.62
glutamic	11.96	20.15**	16.47	19.27*
alanine	7.97	7.87	8.26	8.39
tyrosine	3.16	3.52	2.98	3.57
proline	3.06	9.52**	6.85	16.32**
leucine	8.29	7.98	10.86	10.69
valine	11.98	10.49	15.26	16.35
methionine	4.18	3.15	3.71	3.05
phenyle-alanine	11.36	22.14**	18.36	24.38*
histidine	8.03	8.21	6.74	7.36
amonia	6.17	10.40*	9.45	11.80
arganine	9.53	9.07	9.36	9.82
lysine	8.31	9.46	8.12	8.65
Total	122.66	160.88*	152.21	190.89*

All the variables are highly significant due to cultivar

* Significance within each cultivar

** Highly significance within each cultivar

4. 3. THE THIRD EXPERIMENT (Pot experiment)

Control of pollution with lead in lettuce plants.

Vegetative growth, elemental composition, heavy metals content as well as metabolic changes of lettuce plants were recorded in response to cultivar, lead levels and soil amendments to clarify the role of some soil amendments i.e., organic manure, clay and $CaCO_3$ in reducing the deleterious effects of lead on plant growth and chemical composition of both studied lettuce cvs; i.e. Balady and Great Lakes. The data collected are presented in Tables and Figures, then discussed in the following:

4.3.1. Effect of cultivar, lead level and soil amendments on plant growth characteristics:

Data presented in Table (25) show a remarkable variation in the significance among growth parameters in response to factors studied and growing seasons.

Cultivar effect: Data presented in Table (25) show that plants of Balady cultivar grew more vigorously than did those of Great Lakes cultivar. Thus, all growth parameters of Balady cultivar plants exhibited higher values than those of Great Lakes one, with the exception of number of leaves/plant which had an opposite trend. Data also illustrate the following:

- Number of leaves/plant, fresh weight of shoot and dry weight of both shoots and roots showed a varied significance in both seasons, whereby differences reached the 5% level of significance only in the second season of this study.
- Shoot/root ratio on dry weight basis presented insignificant differences during both seasons.

Moreover, Fig. (5) declares the superiority of Balady cultivar growth in terms of plant height as affected by cultivar.

Table (25): Growth characters of lettuce as affected by cultivar, lead level and soil amendments:

Seasons	1994/95 Season							1995/96 Season						
Characters / Treatments	Plant ht. cm	No. of leaves/ Plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm	Shoot /Root DW	Plant ht. cm	No. of leaves/ Plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm	Shoot /Root DW
Cultivar														
Balady cv.	30.7	35	349	31.4	58.1	5.5	5.7	28.4	37	342	31.0	58.8	5.4	5.7
Great Lakes cv.	20.3	36	337	30.1	58.1	5.1	5.9	20.4	38	324	26.0	55.8	4.6	5.7
L.S.D. at 5%	**1.8**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**0.3**	**NS**	**2.0**	**0.7**	**10.7**	**2.3**	**1.9**	**0.4**	**NS**
Pb level (ppm)														
0	28.2	35	353	30.8	60.6	5.4	5.7	24.7	35	330	30.3	56.8	5.3	5.8
100	26.2	34	341	32.1	58.8	5.6	5.7	24.2	36	337	29.0	58.1	5.1	5.7
200	24.6	35	339	30.2	56.7	5.1	5.9	23.9	38	348	27.7	60.0	4.9	5.7
300	22.9	37	339	29.9	56.2	5.0	6.0	24.6	39	317	27.0	54.5	4.7	5.8
L.S.D. at 5%	**0.6**	**N.S.**	**N.S.**	**1.5**	**2.6**	**0.3**	**0.2**	**N.S.**	**1.0**	**20.9**	**1.7**	**3.6**	**0.2**	**NS**
Amendments														
Control (0)	17.4	33	300	26.8	56.2	5.2	5.2	16.7	34	283	23.8	53.8	4.8	5.0
Organic manure	23.3	34	318	27.6	50.2	4.5	6.1	22.5	36	318	26.4	51.0	4.4	6.0
Clay	30.6	37	374	34.0	63.3	5.7	5.9	29.7	39	377	32.2	64.2	5.5	5.9
CaCO3	30.7	37	379	34.6	62.7	5.7	6.1	28.6	39	354	31.6	60.3	5.4	5.9
L.S.D. at 5%	**1.3**	**1.5**	**10.5**	**1.3**	**1.7**	**0.2**	**0.1**	**1.1**	**1.0**	**22.7**	**0.7**	**3.9**	**0.1**	**0.1**

N.S. = Nonsignificant

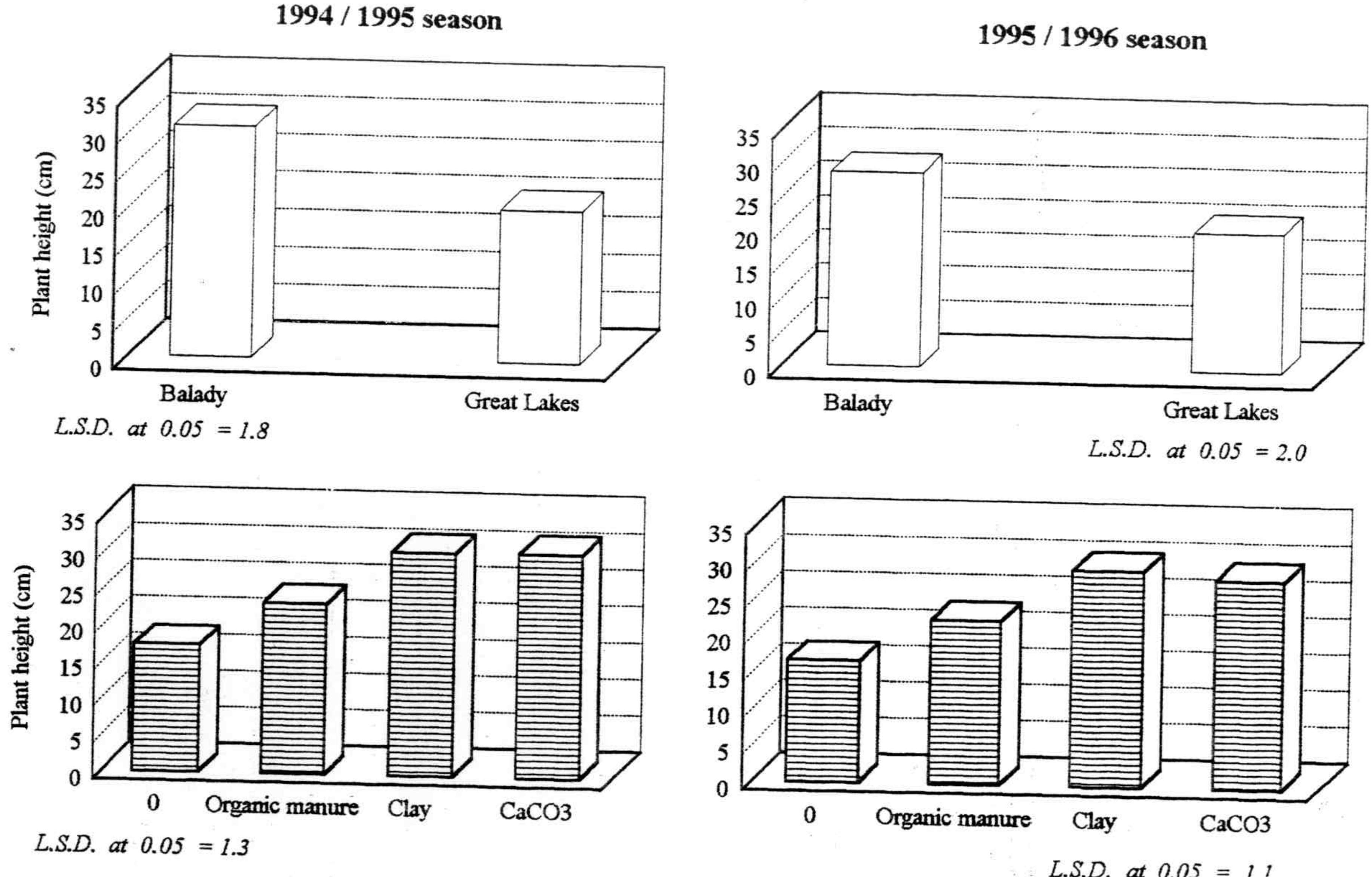

Fig. (5) : Effect of cultivar or amendment sn lettuce plant height irrespective of Pb application.

In this respect, the varietal response to lead by lettuce was studied by Misra and pandy (1974) and John (1977), who stated that low Pb concentrations stimulated the early growth of some varieties and high concentrations suppressed the growth of several varieties, but the growth of some varieties was not affected by the Pb.

Lead effect: Data in Table (25) illustrate the inhibiting effect of Pb on plant growth. A progressive growth retardation occurred due to the increase of soil Pb level up to 300 ppm could be detected. It is evident that plants received the treatment of 200 and 300 ppm Pb showed values with insignificant differences in most studied growth parameters. This means that the inhibiting effect of Pb on plant growth can be more acute as the level of pollution increases.

This finding is partly in accordance with those obtained by Judel and Stelte (1977) who concluded that no toxicity symptoms or yield reduction of radish, carrot and spinach plants occurred even if their content goes up to 500 ppm Pb. Also, Salim *et al.* (1992) working on broad bean, reported that stem growth showed the least effect due to Pb application.

Amendment effect: From the data shown in Table (25) it is evident to conclude that all amendments application were effective in enhancing plant growth compared with untreated control treatment. Plants grown under either clay or $CaCO_3$ treatments, which showed in-between insignificant differences in the values of most studied growth parameters, but both were higher than those of plants grown under organic manure treatment. Plant shoot/root ratio on dry weight basis presented insignificant differences due to all amendments in both growing seasons. Moreover, organic manure treatment produced plants that had a limited root growth if compared with control plants. These results held true in both growing seasons.

The indicative growth parameter, plant height, pronounced a favourable effect due to all amendments application (Fig. 5). Plant height values indicated in this Fig. due to amendment type had the descending order of magnitude: Clay $\geq$ $CaCO_3$ > organic manure. This result indicates the more favourable practice of claying or liming than that of manuring under the condition of this study.

In this connection, El-Kassas (1992) found that the effect of Pb on the growth and yield of rocket plants differed with soil type, and mentioned that some factors can reduce the inhibition effect of Pb on plant growth.

Interaction effect: Data on the interaction effect of cultivar, Pb level in soil and soil amendments on growth of lettuce plants grown in 1994/95 and 1995/96 seasons are shown in Tables (26 and 27), respectively.

From the data, it is evident that both fresh and dry weights of shoot as well as fresh weight of root were significantly affected by the triple interaction in both seasons of the experiment, whereby the highest values of these growth characters were obtained from lettuce plants of Balady cultivar grew in low contaminated soil (100 ppm Pb level) and received CaCO3 treatment as a soil amendment. This held true in both seasons of the study .

This goes with the work conducted by Wong and Lau (1985) on the ameliorative roles of refuse compost, pig manure, Na_4-pyro-phosphate, Na_2-EDTA and $CaCO_3$ in the reduction of Pb uptake by two crops, *Brassica chinensis* and *Raphanus sativus*. They found that growth of the two crops was enhanced by using any of the amendments used.

Table (26) The interaction effect of cultivar, Pb level and soil amendments on growth characters of lettuce (1994/95).

Pb level ppm	Amendments	Plant ht. cm	No. of leaves/plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm
		Balady cv.					
0	0	34.9	35.3	351.4	32.4	59.7	5.6
	OM	31.7	35.9	363.2	33.4	61.7	5.8
	Clay	36.7	37.1	369.9	34.1	62.8	5.8
	CaCO3	38.7	39.1	389.3	34.1	66.2	5.5
100	0	23.6	37.0	347.6	32.6	63.7	5.5
	OM	36.1	30.9	373.8	37.5	63.5	6.3
	Clay	36.7	38.3	391.0	37.1	66.4	6.3
	CaCO3	37.1	36.9	395.1	38.0	67.1	6.4
200	0	16.9	35.5	308.2	30.7	49.3	5.1
	OM	26.3	33.7	262.3	22.3	41.9	3.7
	Clay	29.2	34.0	264.8	22.6	42.3	3.7
	CaCO3	32.4	36.1	339.6	28.3	54.3	4.7
300	0	16.9	32.1	270.5	22.4	51.4	4.4
	OM	18.7	33.7	270.0	23.7	51.3	4.7
	Clay	20.8	32.1	278.2	28.0	52.8	5.6
	CaCO3	23.1	34.0	302.9	29.4	57.5	5.9
		Great Lakes cv.					
0	0	28.5	37.0	339.2	26.4	55.4	4.4
	OM	27.7	33.4	294.3	23.8	50.0	4.0
	Clay	29.1	35.2	309.7	25.0	52.6	4.2
	CaCO3	30.7	40.1	326.1	28.6	57.6	4.8
100	0	19.5	38.8	350.8	31.7	59.6	5.4
	OM	21.7	36.8	363.3	31.3	47.5	3.8
	Clay	24.1	36.0	373.2	32.3	63.4	5.3
	CaCO3	26.8	39.7	376.4	32.3	64.0	5.5
200	0	17.5	30.7	333.1	28.1	53.3	4.6
	OM	15.7	35.9	320.5	26.5	45.4	3.7
	Clay	19.4	33.8	345.4	29.7	55.2	4.9
	CaCO3	21.6	34.3	373.9	32.3	59.8	5.3
300	0	12.5	30.5	297.2	26.3	51.2	4.2
	OM	13.9	32.5	341.5	28.7	54.8	5.7
	Clay	15.5	33.1	334.4	26.3	63.5	5.7
	CaCO3	17.2	35.4	31.9	28.9	56.4	5.2
LSD at 5%		*1.3*	*1.8*	*29.7*	*3.5*	*4.9*	*0.6*

OM = Organic manure

Table (27) The interaction effect of cultivar, Pb level and soil amendments on growth characters of lettuce (1995/96).

Pb level ppm	Amendment	Plant ht. cm	No. of leaves/plant	Shoot FW gm	Shoot DW gm	Root FW gm	Root DW gm
		Balady cv.					
0	0	34.9	35.3	351.4	32.4	59.7	5.5
	OM	30.1	33.3	345.0	32.4	58.6	5.5
	Clay	33.1	33.5	333.8	30.7	56.7	5.2
	CaCO3	33.1	33.5	333.8	37.8	67.5	6.4
100	0	34.3	38.3	406.0	36.9	69.0	6.2
	OM	35.7	39.5	422.9	37.1	71.8	6.3
	Clay	38.0	38.9	376.4	31.5	63.9	5.3
	CaCO3	28.9	36.1	397.4	37.8	67.5	6.4
200	0	24.9	34.4	311.1	23.2	49.7	3.8
	OM	24.1	37.4	315.6	27.0	50.5	4.5
	Clay	26.5	35.5	327.8	31.9	52.4	5.3
	CaCO3	25.7	35.4	344.6	30.0	55.1	5.0
300	0	16.5	33.8	273.4	25.7	51.9	5.1
	OM	17.6	34.1	275.8	19.9	52.4	3.9
	Clay	17.5	34.8	270.0	22.7	51.3	4.5
	CaCO3	17.5	34.8	285.1	27.8	54.1	5.5
		Great Lakes cv.					
0	0	25.1	30.8	271.7	21.6	46.2	3.6
	OM	26.4	32.7	286.0	22.7	48.6	3.8
	Clay	28.9	40.1	339.2	28.6	57.6	4.8
	CaCO3	28.3	31.1	349.0	29.7	59.3	5.0
100	0	18.5	37.1	317.3	27.2	53.9	4.5
	OM	20.6	39.7	364.1	27.2	58.8	4.6
	Clay	22.9	36.7	329.0	26.6	55.9	4.5
	CaCO3	25.7	41.1	380.3	29.2	64.6	4.9
200	0	16.6	38.5	331.6	25.0	53.0	4.1
	OM	20.4	35.2	308.1	26.0	49.3	4.3
	Clay	22.7	37.8	287.9	23.2	46.0	3.8
	CaCO3	22.7	37.8	320.6	24.7	51.3	4.1
300	0	16.0	31.4	262.1	23.1	49.8	4.6
	OM	16.9	37.1	325.8	25.1	61.9	5.0
	Clay	16.8	40.4	258.2	21.6	49.0	4.3
	CaCO3	16.8	40.4	314.2	24.3	59.7	4.8
LSD at 5%		*3.2*	*3.9*	*64.2*	*1.9*	*10.9*	*0.4*

OM = Organic manure

4.3.2. Effect of cultivar, lead level and soil amendments on macro and micro-nutrients content of lettuce leaves.

Table (28) shows significant differences in macro and micro-nutrients concentration of plant leaves due to all the studied factors in both growing seasons. This indicates that the elemental composition of plant leaves is greatly affected by both cultivar and environmental condition in terms of Pb level and amendments application.

Cultivar effect: The comparison of the macro and micro-nutrients concentration contained in plant leaves with respect to cultivar (Table 28) reveals that values of Great lakes cultivar preceded those of Balady in all nutrients mentioned except K only in the second season. Thus, it can be concluded that Great Lakes cultivar has a higher nutritional value than Balady cultivar with respect to both macronutrients (P, Ca and Mg as well as K to a lesser extent) and micronutrients (Zn, Cu, Mn and Fe).

These results are in harmony with those reported by Elsokkary (1980) Prasad & Ram (1988) and Norwal *et al.* (1993), who stated that heavy metals treatments resulted in a promotion or inhibition of nutrient status and these differences may be due to metal concentration, soil type and plant species and cultivars .

Lead effect : The variation of macro - and micro-nutrients concentration in lettuce leaves as affected by Pb level is mainly due to the synergistic or antagonistic effects between Pb and each of these. The concentration of all elements recorded in Table (28) markedly decreased in response to the increase of Pb metal added up to 300 ppm. Thus, it appears that most elements absorption act in an antagonistic relationship with Pb. This confirms the conclusion that Pb pollution negatively affects the nutritional value of the plant with respect to the studied elements. In this connection, Goren-Suchodoller and Wanner (1969) showed that Mn^{2+} uptake was inhibited in the presence of Pb^{2+}. They concluded that the absorption sites of both Mn and Pb ions were possibly identical. However, the affinity of Pb ions to these sites was higher than that of Mn ions. Also,

Table (28) Macro- and micro-nutrients content of lettuce leaves as affected by cultivar, Pb level and soil amendments.

Treatments		Macronutrients %					Micronutrients ppm			
		N	P	K	Ca	Mg	Zn	Cu	Mn	Fe
					1994/95 season					
Cultivars	Balady	3.10	0.34	1.20	0.70	0.58	116	46.3	92.7	556
	Great Lakes	3.26	0.36	1.26	0.74	0.62	126	50.5	101.0	606
LSD at 5%		**0.01**	**0.001**	**0.012**	**0.017**	**0.004**	**0.7**	**0.3**	**0.5**	**3.3**
Pb level ppm	0	3.44	0.38	1.33	0.78	0.56	122	48.8	97.7	586
	100	3.19	0.35	1.23	0.71	0.63	119	47.5	95.0	570
	200	3.10	0.34	1.20	0.70	0.61	122	48.7	97.5	585
	300	2.99	0.33	1.16	0.68	0.59	122	48.7	97.3	584
LSD at 5%		**0.006**	**0.003**	**0.009**	**0.020**	**0.002**	**0.06**	**0.03**	**0.05**	**0.3**
Amendment	0	2.88	0.32	1.12	0.63	0.54	122	48.8	97.6	585
	Organic manure	2.99	0.33	1.16	0.66	0.58	128	51.3	102.6	615
	Clay	3.53	0.39	1.37	0.77	0.67	118	47.1	94.2	565
	CaCO3	3.31	0.37	1.28	0.83	0.60	116	46.6	93.1	558
LSD at 5%		**0.005**	**0.002**	**0.006**	**0.022**	**0.002**	**0.1**	**0.06**	**0.1**	**0.7**
					1995/96 season					
Cultivars	Balady	2.56	0.28	1.32	0.58	0.51	96	38.2	76.5	459
	Great Lakes	2.69	0.30	1.04	0.61	0.54	103	41.2	82.4	494
LSD at 5%		**0.01**	**0.001**	**0.01**	**0.01**	**0.002**	**0.5**	**0.2**	**0.4**	**2.3**
Pb level ppm	0	2.99	0.33	1.16	0.68	0.62	104	41.5	83.0	498
	100	2.58	0.29	1.00	0.56	0.51	96	38.5	76.9	462
	200	2.51	0.28	0.97	0.57	0.49	99	39.5	79.0	474
	300	2.42	0.27	0.94	0.55	0.47	99	39.4	78.9	473
LSD at 5%		**0.01**	**0.002**	**0.01**	**0.02**	**0.002**	**0.1**	**0.1**	**0.1**	**0.6**
Amendment	0	2.38	0.27	0.92	0.52	0.48	99	39.7	79.3	476
	Organic manure	2.47	0.27	0.92	054	0.49	104	41.5	83.0	498
	Clay	2.92	0.32	1.13	0.63	0.58	97	38.8	77.5	465
	CaCO3	2.73	0.30	1.06	0.68	0.55	97	39.0	77.9	467
LSD at 5%		**0.004**	**0.001**	**0.005**	**0.02**	**0.001**	**0.1**	**0.1**	**0.1**	**0.6**

Kannan and Keppel (1976) reported that lead in a Hoagland's nutrient medium was of highly inhibitory effect to the absorption of Fe, Mn and Zn ions in pea plants. They reasoned that the inhibition was of a physical nature, like blocking the entry or binding of the ions to the ion-carrier. Walker *et al.* (1977) came to similar conclusion. In addition, Burzynski (1987) treated cucumber seedlings for 24 hrs. or 48 hrs. with Pb in different concentrations 10-500 µM $PbCl_2$ added to the nutrient solution. He found that Pb inhibited the absorption and accumulation of K, Ca & Fe. Moreover, the high doses of Pb caused efflux of K from the roots . Furthermore, Rabie *et al.* (1990), found an antagonistic effect of applied Pb on the uptake of P, Fe, Mn and Zn. Moreover, El-Kassas (1992) found that adding Pb to the calcareous and sandy soils decreased N, K and Zn content in roots and shoots of both alfalfa and rocket while Mn concentrations increased. He reasoned the increase of Mn to the antagonistic relationship between Zn and Mn. Regarding the depressive effect of Pb on phosphorus content at high levels of these metals, data are in line with those obtained by Dahdoh *et al.* (1993), who found that adding Pb to soil cultivated with rocket crop, among others, decreased plant P content. Also, Abd El Kariem (1994) stated that increasing Pb application up to 50 ppm significantly decreased P uptake in roots and tops of spinach plant.

An opposite trend was recorded by El-Sherif and Yousry (1978), who found no significant correlations between Pb content and the uptake of micronutrients.

Amendment effect: Soil amendments, through its macro and micro-nutrients contents as well as their effects on soil chemical properties, enhance the absorption of nutrients by plant roots. For this reason, the concentration of macro and micro-nutrients observed in Table (28) in both growing seasons mostly increased with the application of any of the amendments studied if compared with control treatment. Clay application surpassed the other amendments with respect to macro-nutrients (N, P, K, Mg) , while $CaCO_3$ treatment preceded that of clay and organic manure treatments in case of Ca .

Concerning micronutrients, it is clear that Zn, Cu, Mn and Fe concentration of plants grown under organic manure treatment were higher than those grown under clay and $CaCO_3$ application.

These results indicate the additive effects of such soil amendments, particularly clay and organic manure which play a major role in reclaiming sandy soils due to its nutrients content.

Interaction effect: Macro-and micro-nutrients content in lettuce leaves of both Balady and Great Lakes cultivars as affected by Pb soil levels and soil amendments application are shown in Tables (29 and 30) for 1994/95 and 1995/96 growing seasons, respectively.

For any specific Cd level, N, P, K and Mg content of leaves were generally the highest due to clay application in plants of Great Lakes cultivar. Whileas, Ca content of plant leaves of Great Lakes cultivar was the highest in the case of $CaCO_3$ application with insignificant difference. This held true in the two seasons of the experiment.

With regard to the micronutrients, data indicate that organic manure application was the most important factor in this respect, whereby the highest values were obtained from plants of Great Lakes cultivar grown in soil receiving organic manure as a soil amendment at any of Pb soil level applied.

These results indicate that both macro-and micronutrients were significantly affected by the interaction effect of cultivar, Pb level of soil and soil amendments. The depressive effect of increasing Pb level can be reduced with clay and organic manure application. Irrespective of the varietal differences of nutrients absorption, the nutritional status of any of the soil amendments applied is a determining factor. Clay soil seems to be

Table (29) The interaction effect of cultivar, Pb level and soil amendments on macro and micronutrients content of lettuce leaves (1994/95).

Pb level ppm	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
		Balady cv.								
0	0	2.94	0.33	1.14	0.78	0.52	92.38	36.95	73.90	443
	OM	3.56	0.39	1.38	0.74	0.64	118.42	47.37	94.74	568
	Clay	3.08	0.34	1.19	0.77	0.55	103.57	41.43	82.86	497
	CaCO3	3.10	0.35	1.20	0.89	0.55	101.95	40.78	81.56	489
100	0	3.18	0.35	1.23	0.69	0.62	108.48	43.39	86.79	520
	OM	3.69	0.41	1.43	0.70	0.59	125.91	50.36	100.73	604
	Clay	3.38	0.37	1.31	0.73	0.66	115.22	46.09	92.17	553
	CaCO3	3.26	0.36	1.27	0.81	0.64	109.14	43.66	87.31	523
200	0	2.68	0.30	1.03	0.59	0.53	127.50	51.00	102.00	612
	OM	3.23	0.36	1.25	0.61	0.57	121.94	48.78	97.55	585
	Clay	2.87	0.32	1.11	0.63	0.56	113.23	45.29	90.58	543
	CaCO3	2.85	0.31	1.10	0.73	0.56	123.94	49.58	99.15	594
300	0	2.60	0.29	1.01	0.57	0.51	122.22	48.89	97.77	586
	OM	3.08	0.34	1.19	0.60	0.51	102.35	40.94	81.88	491
	Clay	2.84	0.31	1.10	0.62	0.56	118.06	47.22	94.45	566
	CaCO3	2.73	0.30	1.06	0.70	0.54	119.47	47.79	95.58	573
		Great Lakes cv.								
0	0	3.03	0.34	1.17	0.77	0.54	111.18	44.47	88.94	533
	OM	3.51	0.39	1.36	0.76	0.64	124.98	49.99	99.98	599
	Clay	3.14	0.35	1.22	0.75	0.58	106.98	42.79	85.59	513
	CaCO3	3.09	0.35	1.20	0.91	0.55	109.19	43.68	87.35	524
100	0	3.61	0.40	1.39	0.79	0.71	116.02	46.41	92.82	556
	OM	3.86	0.43	1.49	0.74	0.69	136.57	54.63	109.26	655
	Clay	3.65	0.41	1.41	0.80	0.71	112.07	44.83	89.66	537
	CaCO3	3.63	0.40	1.40	0.86	0.71	118.66	47.46	94.92	569
200	0	2.85	0.31	1.10	0.63	0.56	138.08	55.23	110.47	662
	OM	3.35	0.37	1.29	0.63	0.65	132.29	52.92	105.83	634
	Clay	3.12	0.34	1.21	0.68	0.62	132.25	52.90	105.80	634
	CaCO3	2.96	0.33	1.15	0.75	0.58	136.31	54.53	109.05	654
300	0	2.67	0.30	1.03	0.58	0.52	137.10	54.84	109.68	658
	OM	3.23	0.36	1.25	0.60	0.54	114.08	45.63	91.26	547
	Clay	3.04	0.33	1.18	0.66	0.60	129.18	51.67	103.35	620
	CaCO3	2.88	0.32	1.11	0.73	0.56	133.11	53.24	106.48	638
LSD at 5%		*0.01*	*0.001*	*0.02*	*N.S.*	*0.01*	*0.4*	*0.16*	*0.32*	*1.9*

OM = Organic manure NS =Nonsignificant

Table (30) The interaction effect of cultivar, Pb level and soil amendments on macro and micronutrients content of lettuce leaves (1995/96).

Pb level ppm	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
		Balady cv.								
0	0	2.38	0.26	0.94	0.63	0.65	74.82	29.93	59.86	359
	OM	3.09	0.34	1.20	0.62	0.45	103.03	41.21	82.42	494
	Clay	2.51	0.28	0.97	0.60	0.68	82.58	33.03	66.06	396
	CaCO3	2.50	0.28	0.96	0.77	0.68	83.89	33.56	67.11	402
100	0	2.57	0.29	0.99	0.56	0.51	87.87	35.15	70.30	421
	OM	3.21	0.36	1.24	0.58	0.66	109.54	43.82	87.63	525
	Clay	2.74	0.30	1.06	0.60	0.54	93.33	37.33	74.66	447
	CaCO3	2.64	0.29	1.02	0.68	0.52	88.40	35.36	70.72	424
200	0	2.10	0.23	0.81	0.46	0.41	99.00	39.60	79.20	475
	OM	2.68	0.30	1.03	0.49	0.55	89.04	35.62	71.24	427
	Clay	2.30	0.26	0.89	0.50	0.45	95.63	38.25	76.50	459
	CaCO3	2.21	0.25	0.86	0.60	0.43	96.77	38.71	77.42	464
300	0	2.17	0.24	0.84	0.47	0.43	103.28	41.31	82.62	495
	OM	2.81	0.31	1.09	0.50	0.58	106.09	42.44	84.87	509
	Clay	2.32	0.26	0.90	0.51	0.46	91.71	36.69	73.37	440
	CaCO3	2.31	0.26	0.89	0.61	0.45	100.39	40.16	80.31	481
		Great Lakes cv.								
0	0	2.45	0.27	0.95	0.62	0.66	90.05	36.02	72.04	432
	OM	3.05	0.34	1.18	0.61	0.50	118.82	47.53	95.05	570
	Clay	2.54	0.28	0.98	0.61	0.69	86.66	34.66	69.32	415
	CaCO3	2.50	0.28	0.97	0.79	0.68	88.44	35.38	70.75	424
100	0	2.92	0.33	1.13	0.64	0.57	93.98	37.59	75.19	451
	OM	3.36	0.37	1.30	0.63	0.70	115.09	46.04	92.08	552
	Clay	2.95	0.33	1.14	0.65	0.58	90.78	36.31	72.63	435
	CaCO3	2.94	0.33	1.14	0.72	0.58	96.11	38.44	76.89	461
200	0	2.31	0.26	0.89	0.51	0.45	111.85	44.74	89.48	536
	OM	2.91	0.32	1.13	0.64	0.60	99.25	39.70	79.40	476
	Clay	2.53	0.28	0.98	0.55	0.50	107.12	42.85	85.70	514
	CaCO3	2.40	0.27	0.93	0.72	0.47	110.41	44.17	88.33	529
300	0	2.16	0.24	0.84	0.47	0.42	111.05	44.42	88.84	533
	OM	2.81	0.31	1.09	0.51	0.58	89.30	35.72	71.44	428
	Clay	2.46	0.27	0.96	0.54	0.48	104.64	41.86	83.71	502
	CaCO3	2.33	0.26	0.9	0.61	0.46	107.82	41.13	86.25	517
LSD at 5%		*0.01*	*0.004*	*0.01*	*N.S.*	*0.004*	*0.37*	*0.15*	*0.30*	*1.8*

OM = Organic manure NS =Nonsignificant

rich in N, P, K and Mg nutrient, while organic manure is rich in micro nutrients besides its active role in reducing soil pH and subsequently enhancing the absorption of micro -nutrient Zn, Cu, Mn and Fe by plant roots. On the contrary, $CaCO_3$ shows the opposite action in this respect.

4.3.3. Effect of cultivar, lead level and soil amendments on heavy metals content of lettuce leaves.

A. Cadmium content of lettuce leaves:

Table (31) presents data on Cd content of lettuce leaves as affected by the studied factors and their interaction .

***Cultivar effect*:** Regarding the effect of cultivar on Cd content of plant leaves, data indicate that plants of Great Lakes cultivar absorbed and accumulated much more Cd than those of Balady cultivar, especially under the highest level of Pb added to the soil (300 ppm). Results reveal significant differences in this respect due to cultivar in both seasons of the study.

This can be interpreted with The results obtained by many investigators including Crews and Davies (1985) on lettuce; Davies and Lewis (1985)on lettuce and radish varieties; Gunnaresson (1983) on leafy plants; Isermann *et al*. (1984) and Eysinga *et al*.,(1988) on different varieties of several crop species, who suggested possibilities of reducing Cd contents to below permitted values by choice of suitable cultivar.

On the other hand, Florijn *et al*. (1991) reported that lettuce cultivars showed close similarity in shoot Cd concentration. This results contradict the abovementioned published data on a large genotypic variation in Cd concentration.

Lead effect **:** Considering the effect of Pb level on accumulation of Cd in lettuce leaves, data reveal that Cd content of lettuce leaves significantly

Table (31): Cadmium content (ppm) of lettuce leaves as affected by cultivar, level of lead pollution, soil amendments and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Pb x Amendment Amendment				
	0	OM	Clay	$CaCO_3$	Mean	0	OM	Clay	$CaCO_3$	Mean	0	OM	Clay	$CaCO_3$	Mean
Pb level ppm	1994/95 season														
0	0.17	0.17	0.07	0.04	**0.11**	0.18	0.19	0.09	0.06	**0.13**	0.17	0.18	0.18	0.05	**0.12**
100	0.36	0.36	0.13	0.09	**0.24**	0.35	0.20	0.12	0.10	**0.19**	0.36	0.29	0.12	0.08	**0.22**
200	0.51	0.50	0.14	0.09	**0.31**	0.48	0.41	0.18	0.14	**0.30**	0.48	0.47	0.16	0.10	**0.31**
300	0.56	0.45	0.16	0.12	**0.33**	0.68	0.63	0.26	0.21	**0.44**	0.62	0.55	0.21	0.14	**0.39**
Mean	**0.40**	**0.39**	**0.12**	**0.09**	**0.25**	**0.43**	**0.36**	**0.17**	**0.12**	**0.27**	**0.42**	**0.38**	**0.15**	**0.09**	**0.26**
Pb level ppm	1995/96 season														
0	0.15	0.15	0.06	0.05	**0.10**	0.15	0.16	0.08	0.05	**0.11**	0.15	0.16	0.07	0.04	**0.10**
100	0.30	0.29	0.11	0.08	**0.20**	0.29	0.16	0.10	0.08	**0.16**	0.29	0.24	0.10	0.08	**0.18**
200	0.41	0.40	0.12	0.08	**0.26**	0.39	0.33	0.15	0.12	**0.25**	0.40	0.38	0.13	0.10	**0.25**
300	0.45	0.37	0.13	0.10	**0.27**	0.56	0.51	0.21	0.17	**0.36**	0.51	0.45	0.17	0.14	**0.32**
Mean	**0.33**	**0.32**	**0.11**	**0.08**	**0.21**	**0.35**	**0.30**	**0.14**	**0.11**	**0.23**	**0.34**	**0.31**	**0.12**	**0.09**	**0.22**

* OM= Organic Manure

L.S.D. at 5%	Cultivar (cv)	Pb level (Pb)	Amendment (AM)	cv x Pb	cv x AM	Pbx AM	cvxPbxAM
1994/95	0.001	0.004	0.004	0.006	0.005	0.007	0.010
1995/96	0.002	0.003	0.003	0.005	0.004	0.006	0.008

increased with increasing the level of Pb added to the soil. For Cd concentration, it was markedly increased by the progressive increase of Pb level up to 300 ppm. These results mean that there is a synergistic relationship between Pb and Cd which was reported by Bjerre and Schierup (1985).

***Amendment effect*:** Data on the effect of soil amendments (Table 31) reveal that all tested amendments had a favourable effect in reducing the Cd accumulated in lettuce leaves. Data clearly show that amendments efficiency had the order of descending magnitude : $CaCO_3$ > clay > organic manure which showed the least positive effect in this regard. This trend held true in both seasons of this experiment

These results confirmed the results obtained by Singh (1979), who indicated that fixed Cd was correlated with soil C.E.C., pH, organic matter and $CaCO_3$ content. Also, Behel *et al.* (1983) found that the percentage of Cd complexed by organic matter depended on the model used to represent metal interaction with soluble organic C, phosphate, sulfate and chloride forming inorganic complexes with Cd, but it constituted <10% of the total Cd present.

Interaction effect: With respect to the interaction effect of cultivar and Pb level, Cd concentration increased in both cultivars leaves over the two seasons of the experiment with increasing the level of Pb (Table 31).

Regarding the cultivar within Pb level, it can be indicated from the data that there was a close similarity between both cultivars, whereby the increase of the Pb level in soil increased the Cd content in plant leaves. Eventhough plant leaves of Great Lakes cultivar contained (in average) higher amounts of Cd than those of Balady cultivar, it showed more safe and tolerant with respect to Pb in soil at low levels, especially 100 ppm. Great Lakes cultivar failed to tolerate the higher Pb soil levels (300 ppm), whereby its leaves contained considerable amounts of Cd. The same trend of results was obtained in both seasons of the experiment.

The data of the interaction of amendments and Pb level show that $CaCO_3$ was the most effective amendment within Pb various levels which reduced the absorbed and accumulated cadmium in plant leaves followed by clay and then organic manure which had the least positive effect in this regard. It is also clear from the data presented in Table (31), that in spite of the reducing effect of the amendments, Cd leaf concentration increased , especially in case of organic manure when Pb soil level increased.

The cultivar x Pb level x amendment effect shown in Table (31) reveals that choice of Balady cultivar and application of $CaCO_3$ is the best treatment in reducing Cd accumulation under the conditions of this experiment.

Herms *et al.* (1979) showed that in soil rich in organic matter increases in the Cu, Zn, Cd and Pb content of the soil solution occurred as a result of the presence of microbially formed soluble organic complexes. Khen and Frankland (1983) reported that a very high proportion of Cd and Pb added to the soil in water soluble form became insoluble within one hour. of contact with the soil.

B. Nickel content of lettuce leaves:

Cultivar Effect: Data in Table (32) reveal that Ni concentration in lettuce leaves differed due to cultivar with higher values of Great Lake cultivar compared with those of Balady one. Such metal concentrations in lettuce leaf tended to increase by adding Pb up to 300 ppm. This trend appears the same for the two cultivars in both growing seasons.

Lead Effect : Application of Pb up to 300 ppm increased progressively the concentration of Ni in lettuce leaves (Table 32). This is the same when Ni level was increased within both cultivar and amendment treatments in both seasons of the experiment.

Table (32): Nickel content (ppm) of lettuce leaves as affected by cultivar, level of lead pollution, soil amendments and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Pbx Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Pb level ppm	1994/95 season														
0	1.66	1.73	0.65	0.44	**1.12**	1.75	1.85	0.90	0.60	**1.28**	1.71	1.79	0.78	0.52	**1.20**
100	1.82	1.93	0.56	0.39	**1.18**	1.78	0.97	0.51	0.43	**0.92**	1.80	1.45	0.54	0.41	**1.05**
200	2.59	2.64	0.63	0.39	**1.56**	2.43	2.11	0.84	0.64	**1.51**	2.5.1	2.38	0.74	0.52	**1.54**
300	2.86	2.40	0.72	0.55	**1.63**	3.53	3.26	1.25	0.98	**2.25**	3.20	2.83	0.99	0.76	**1.94**
Mean	**2.23**	**2.17**	**0.64**	**0.44**	**1.37**	**2.37**	**2.05**	**0.88**	**0.66**	**1.49**	**2.30**	**2.11**	**0.76**	**0.55**	**1.43**
Pb level ppm	1995/96 season														
0	1.44	1.51	0.57	0.38	**0.97**	1.53	1.61	0.79	0.52	**1.11**	1.48	1.56	0.68	0.45	**1.04**
100	1.48	1.56	0.46	0.32	**0.95**	1.44	0.78	0.41	0.35	**0.75**	1.46	1.17	0.44	0.33	**0.85**
200	2.10	2.14	0.51	0.32	**1.27**	1.97	1.71	0.66	0.52	**1.22**	2.03	1.92	0.60	0.42	**1.24**
300	2.32	1.49	0.58	0.44	**1.32**	2.86	2.64	1.01	0.79	**1.82**	2.59	2.29	0.80	0.62	**1.57**
Mean	**1.83**	**1.79**	**0.53**	**0.36**	**1.13**	**1.95**	**1.69**	**0.72**	**0.55**	**1.23**	**1.89**	**1.74**	**0.63**	**0.46**	**1.18**

* **OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Pb level (Pb)**	**Amendment (AM)**	**cv x Pb**	**cv x AM**	**Pbx AM**	**cvxPbxAM**
1994/95	0.009	0.015	0.015	0.021	0.021	0.030	0.042
1995/96	0.008	0.012	0.012	0.016	0.017	0.024	0.034

Pilegard (1978) studied the uptake of some heavy metals by carrot and radish which were grown in soils with added metal ions. There were linear correlations between plant species studied and soil metal concentrations . The results also revealed that Ni were translocated from the roots to the tops.

Mortvedt (1985) conducted two greenhouse pot experiments to determine the significant quantities of Ni from Zn fertilizers prepared from industrial by-product and absorbed by corn (*Zea mays*) and swiss chard (*Beta vulgaris*). They found that uptake of Ni generally increased with increasing levels of Pb in the Zn-fertilizers in the acid soil only.

Amendment effect : It is evident from Table (32) that Ni content of lettuce leaves was generally significantly reduced due to the application of soil organic manure, clay and $CaCO_3$ amendments as compared with the control treatment. The efficiency of such amendments had the order of magnitude: $CaCO_3$ > clay > organic manure in reducing heavy metal uptake.

These findings are in accordance with those of Bloomfield (1978), who stated that although organic matter is able to mobilize Ni from carbonates and oxides as well as to decrease Ni sorption on clays, the bonding of this metal to the organic ligands could not be particularly strong. Complexing ligands such as SO_4^{2-} and organic acids reduce the sorption of Ni. The remobilization of Ni from solid phases appears to be possible in the presence of FA and HA. Thus, Ni may be quite mobile in soils with high complexation ability (e.g., organic-rich and polluted soils).

Interaction effect: With respect to the interaction effect of cultivar and Pb level, Ni concentration increased in leaves of both cultivars during the two seasons of the experiment with increasing the level of Pb (Table 32).
From the aforementioned results, it can be concluded that:

- The effect of cultivar within amendments was the same for each of the two studied cultivars as the heavy metal concentrations in leaves were reduced by applying any of the soil amendments in both growing seasons.

- Although plant leaves of Great lakes cultivar contained (in average) higher concentration of Ni than those of Balady it showed more safe and tolerant with respect to Pb in soil at low levels (100 ppm)compared with Balady cultivar. Great lakes cultivar failed to tolerate the highest Pb soil level (300 ppm), whereby its leaves contained considerable amounts of Ni.

The data of the interaction of amendments and Pb level show that $CaCO_3$ was the most effective amendment within various Pb levels followed by clay and then organic manure which had the least positive effect in this regard. It is also clear from the data presented in Table (32), that in spite of the reducing effect of the amendments, Ni leaf concentration increased when Pb soil level increased.

The cultivar x Pb level x amendment effect shown in Table (32) reveals that choice of Balady cultivar and application of $CaCO_3$ is the best treatment in reducing Ni accumulation under the conditions of this experiment. This held true in both growing season under the interactive effect of amendments within both cultivars and Pb level.

C. Lead content of lettuce leaves:

Table (33) presents data on Pb content of lettuce leaves as affected by the studied factors and their interaction .

***Cultivar effect*:** Regarding the effect of cultivar on Pb content of plant leaves, data indicate that plants of Great Lakes cultivar absorbed and accumulated much more Pb than those of Balady cultivar, especially under high level of Pb pollution. Results reveal significant differences in this respect due to cultivar in both seasons of the study.

This can be interpreted with the results obtained by many investigators including Crews and Davies (1985) on lettuce; Davies and Lewis (1985)on lettuce and radish varieties. They suggested possibilities

Table (33): Lead content (ppm) of lettuce leaves as affected by cultivar, level of lead pollution, soil amendments and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Pb x Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Pb level ppm	1994/95 season														
0	8.26	17.45	4.26	2.16	**8.03**	6.82	18.46	5.25	3.14	**8.42**	7.54	17.96	4.76	2.65	**8.23**
100	8.57	9.05	2.65	1.83	**5.52**	8.36	4.55	2.40	2.05	**4.34**	8.47	6.80	2.53	1.94	**4.93**
200	12.18	12.41	2.97	1.85	**7.35**	11.43	9.92	3.96	3.01	**7.08**	11.81	11.17	3.47	2.43	**7.22**
300	13.46	11.27	3.39	2.57	**7.67**	16.58	15.30	5.86	4.60	**10.59**	15.02	13.29	4.63	3.58	**9.13**
Mean	**10.62**	**12.55**	**3.32**	**2.10**	**7.14**	**10.80**	**12.06**	**4.37**	**3.20**	**7.61**	**10.73**	**12.31**	**3.85**	**2.65**	**7.38**
Pb level ppm	1995/96 season														
0	7.43	15.7	3.83	1.94	**7.23**	6.14	16.62	4.72	2.82	**7.58**	6.79	16.16	4.28	2.38	**7.40**
100	6.94	7.33	2.14	1.48	**4.47**	6.77	3.69	1.95	1.66	**3.52**	6.86	5.51	2.05	1.57	**3.99**
200	9.87	10.05	2.41	1.50	**5.96**	9.26	8.04	3.21	2.44	**5.73**	9.56	9.04	2.81	1.97	**5.85**
300	10.90	9.13	2.75	2.08	**6.21**	13.43	12.40	4.75	3.72	**8.57**	12.16	10.76	3.75	2.90	**7.39**
Mean	**8.79**	**10.55**	**2.78**	**1.75**	**5.97**	**8.90**	**10.19**	**3.66**	**2.66**	**6.35**	**8.89**	**10.37**	**3.22**	**2.21**	**6.16**

* **OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Pb level (Pb)**	**Amendment (AM)**	**cv x Pb**	**cv x AM**	**Pbx AM**	**cvxPbxAM**
1994/95	0.030	0.094	0.066	0.133	0.093	0.133	0.187
1995/96	0.025	0.074	0.054	0.105	0.076	0.108	0.152

of reducing heavy metal contents to below permitted values by choice of suitable cultivar.

***Lead effect*:** Considering the effect of Pb level on accumulation of Pb in lettuce leaves, data reveal that Pb content of lettuce leaves increased significantly and consistently with increasing the level of Pb added to the soil. This held true in both seasons of the study.

These results mean that when Pb concentration increases in soil, its content increases in plant leaves. In this connection, Judel and Stelte (1977) noticed that low levels of the highly soluble Pb acetate slightly increased the vegetables Pb contents, but 500 ppm caused considerable increases in Pb content. Zimdahl and Koeppe (1977) summarized results of translocation and uptake studies and showed that under certain conditions Pb is mobile within the plant. However, they mentioned that, in general, Pb from a soil source is not readily transolocated to edible portions of plants. These authors stated that the main process responsible for Pb accumulation in root tissue is its deposition especially as pyrophosphate along the cell walls. Also, Davies and White (1981) reported that vegetables grown on heavy metals contaminated soils absorb excessive quantities of these metals. They analysed the roots and aerial parts of lettuce, onion, carrots and *Brussels* sprouts for determination of Pb. Lead tended to be retained in the roots . They pointed out that Pb contents of edible parts constitute a possible risk to public health. Moreover, El-Kobbia and Ibrahim (1986) showed that increasing Pb application to the sandy soil increased progressively and significantly Pb content in shoots and roots of plants. They added that Pb-content in roots was generally higher than that of shoots at all levels of applied Pb, which might be due to precipitation of Pb in roots.

Oppositionaly, Nasralla and Ali (1985) found that there was no relationship between lead content of the soil and its concentrations in different parts of the plant. They indicated that the soil is not the only route of plant uptake of lead, but foliar absorption may also be another route.

Amendment effect: Data on the effect of soil amendments (Table 33) reveal that CaCO3 and clay had a favourable effect in reducing the Pb accumulated in lettuce leaves. On the other hand, organic manure showed adverse effects whereby it increased lead content of leaves as compared with the control treatment. Data clearly show that amendments efficiency had the order of descending magnitude: $CaCO_3$ > clay > organic manure in both seasons of this experiment

In this connection, it was stated that the availability of soil Pb is usually low and can be decreased even further by liming. A high soil pH may precipitate Pb as hydroxide, phosphate or carbonate, it possibly promotes the formation of Pb-organic matter complexes. Enhanced levels of Ca also increase competition with Pb for exchange sites on roots and soil surfaces (Mengel and Kirkby, 1982).

Interaction effect: With respect to the interaction effect of cultivar and Pb level, Pb concentration increased in leaves of both cultivars over the two seasons of the experiment with increasing the level of Pb (Table 33). Furthermore, data indicate that:

- A close similarity between both cultivars , whereby increasing the Pb level in soil increased Pb content of plant leaves.
- Eventhough plant leaves of Great lakes cultivar contained (in average) higher concentration of Pb than those of Balady which proved to be more safe and tolerant with respect to Pb in soil at low levels (100 and 200 ppm) than Balady cultivar. Great Lakes cultivar failed to tolerate the highest Pb soil levels (300 ppm), whereby its leaves contained considerable amounts of Pb.

The data of the interaction of amendments and Pb level show that $CaCO_3$ was the most effective amendment within Pb various levels followed by clay and then organic manure. It is also clear from the data presented in Table (33), that in spite of the reducing effect of the amendments, Pb leaf concentration increased , especially in case of organic manure when Pb soil level increased. This effect of organic manure on lead accumulation was repored by Patel *et al.* (1977), who showed that chelating agents facilitated lead movement and increased lead uptake by plants.

The cultivar x Pb level x amendment effect shown in Table (33) reveals that choice of Balady cultivar and application of $CaCO_3$ is the best treatment in reducing Pb accumulation under the conditions of this experiment.

To get a wide view of heavy metals; i.e., Cd, Ni and Pb concentrations in lettuce leaves which were significantly affected by cultivar, Pb level and soil amendments, Figure (6) indicates that Pb content recorded the highest values followed by Ni, then Cd. These results go in line with the findings of workers on the variations of cultivars to accumulate heavy metals with respect to lead. Under the Egyptian environment, El-Sokkary (1980) found that Pb content in the edible parts of seven crops ranged between 6.0 to 19.0 ppm while it was 0.9 ppm in the grains of wheat. Nasralla and Ali (1985) showed that leafy vegetables such as lettuce and cabbage accumulated 78.4 ppm Pb in their edible portions while the least lead accumulators were carrots and radish where the highest Pb concentration in carrot adjacent to the busiest traffic road was 10.2 ppm. This finding was already reported by many investigators who stated that certain soil and plant factors (e.g., low pH, low P content of soil, organic ligands) are known to promote both Pb uptake by roots and Pb translocation into plant tops.

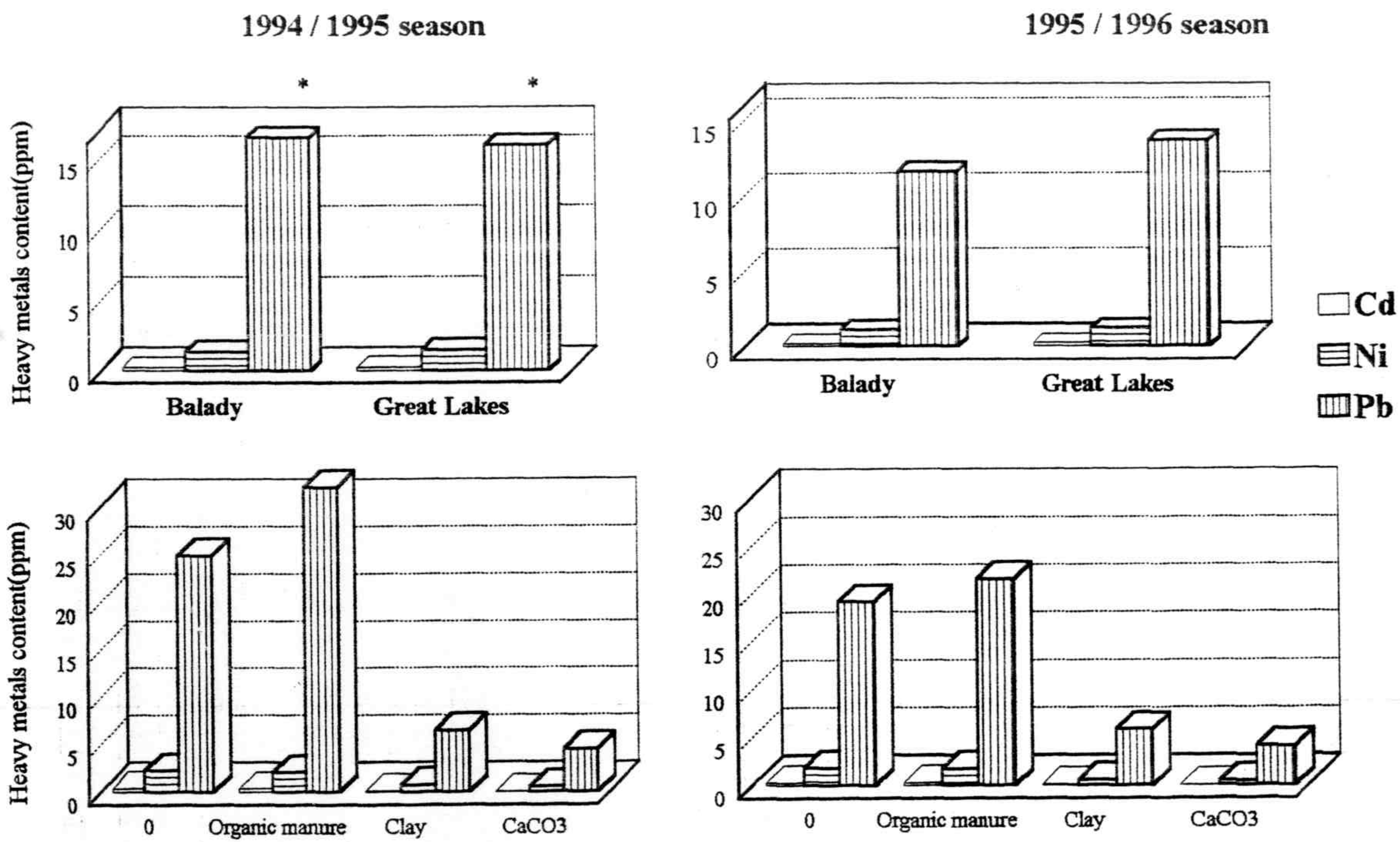

Fig. (6) : Heavy metals content of lettuce leaves as affected by cultivar or amendments under Pb pollution.

**All the differences within each variable are significant except Pb with cultivars in 1994/1995 season (p=0.05)*

4.3.4. Effect of cultivar, lead level and soil amendments on some metabolic changes:

A. Photosynthetic pigments, ascorbic acid and NO_3

Table (34) depicts data concerning photosynthetic pigments, ascorbic acid and NO_3 content of lettuce leaves as affected by cultivar, lead level and soil amendments. Data indicate that all leaves constituents recorded were significantly affected except for carotene in response to the effect of lead level in the first growing season.

Cultivar effect : With respect to chlorophyll a, total chlorophyll and carotene content of leaves (Table 34), it is evident that plants of Balady showed higher values than those of Great Lakes cultivar. The reverse was true in case of chlorophyll b, ascorbic acid and NO_3 . These trends were the same in both growing seasons. This effect of cultivar on such metabolic products are logic and was previously reported .

Lead effect: Data presented in Table (34) show that Pb level had adverse effect on chlorophylls (a, b and total) whereas values of chlorophyllus pigments were gradually decreased when Pb level added to the soil increased up to 300 ppm. Increasing Pb level up to 200 ppm led to an increase in carotene, ascorbic acid (insignificant increase) and NO_3 . Plants of both growing season followed the same trend with respect to the mentioned parameters. These effects of lead were reported by many researcher:

Miles *et al.* (1972) observed a severe inhibition of photosystem II and electron transport of isolated chloroplasts due to using 2.4 mM **lead** concentration. They also found that lead at concentration of 0.25 mM, affected oxygen evolution (Hill reaction). Also, Strnad *et al.* (1990) noticed marked changes in the luminescence spectra of leaf mesophyll cells of potatoes, and other plants with increasing Pb concentrations from 10 mg Pb /kg soil to 10 fold. Even the lower heavy metal concentrations

Table (34) Photosynthetic pigments (mg/100 gm FW), ascorbic acid (mg/100 gm FW), and nitrate (mg/100 gm DW) content of lettuce leaves as affected by cultivar, Pb level and soil amendments.

Treatments		Chlorophylls a	Chlorophylls b	Chlorophylls Total	Carotene	Ascorbic Acid	Nitrate
1994/95 season							
Cultivars	Balady	175.8	62.7	238.5	119.4	15.4	130.5
	Great Lakes	172.6	64.7	237.3	117.3	22.3	140.1
LSD at 5%		**0.4**	**0.3**	**0.3**	**0.001**	**0.4**	**6.2**
Pb level ppm	0	140.6	50.1	190.7	103.7	15.9	141.0
	100	138.9	47.4	186.3	123.0	17.3	134.4
	200	135.6	46.3	181.9	117.6	16.4	136.7
	300	132.2	43.7	175.9	105.9	19.7	136.1
LSD at 5%		**0.5**	**0.3**	**0.6**	**N.S.**	**0.5**	**1.3**
Amendment	0	172.2	61.3	233.5	116.9	14.8	143.4
	Organic manure	174.7	63.4	238.1	118.7	15.5	139.4
	Clay	177.2	66.5	243.7	120.3	16.2	130.5
	CaCO3	172.7	63.6	236.3	117.3	18.8	129.9
LSD at 5%		**0.2**	**0.2**	**0.2**	**0.001**	**0.3**	**1.0**
1995/96 season							
Cultivars	Balady	144.8	51.6	196.4	97.3	18.4	150.8
	Great Lakes	142.2	53.3	195.5	95.6	19.9	153.5
LSD at 5%		**0.3**	**0.2**	**0.2**	**0.01**	**0.1**	**2.1**
Pb level ppm	0	135.7	49.2	184.9	88.2	18.9	146.5
	100	133.9	48.5	182.4	99.6	20.3	158.7
	200	130.8	45.8	176.6	95.3	19.3	156.3
	300	130.2	44.4	174.6	88.2	18.1	145.6
LSD at 5%		**0.3**	**0.2**	**0.4**	**1.5**	**0.03**	**2.3**
Amendment	0	141.9	50.4	192.3	95.3	20.2	156.8
	Organic manure	143.9	52.2	196.1	96.8	19.3	152.7
	Clay	145.9	54.8	200.7	98.1	18.2	149.5
	CaCO3	142.1	52.3	194.4	95.6	18.8	148.1
L.S.D. at 5%		**0.2**	**0.2**	**0.2**	**0.03**	**0.01**	**0.8**

N.S. = Nonsignificant

caused changes in the photosynthetic systems of the studied crops which could be used for early diagnosis of damage.

Ali (1992) found a close relationship between Pb as inhibiting factor and both protein and chlorophyll content of tomato plants .He pointed out that these plant constituents considered as a bioindicator to the level of pollution with such metal.

Amendment effect : Data concerning photosynthetic pigments, ascorbic acid and NO_3 content of lettuce leaves as affected by soil amendments (Table 34) reveal that all of organic manure, clay and $CaCO_3$ application had favourable effect on chlorophylls (a, b and total) carotene and NO_3 leaves content, whereby the chlorophylls and carotene content increased and NO_3 accumulation decreased with adding the amendments. The order of magnitude of this effect followed the descending one clay > organic manure > $CaCO_3$. With respect to ascorbic acid content of leaves, it showed a diverse trend due to soil amendments and growing season, whereby it tended to increase by the application of soil amendments in the first growing season and had the opposite trend in the second growing one.

Interaction effect: Table (35) indicates that the highest values of total chlorophyll, carotene, ascorbic acid and NO_3 in plant leaves resulted from the combination of treatment as follows: Balady cultivar + 200 ppm Pb + organic manure for total chlorophyll and carotene as well as for ascorbic acid in the first season, and Great Lakes cultivar without any treatment for ascorbic acid and NO_3 in the second season, while NO_3 was the highest in leaves of Great Lakes plants received 100 ppm Pb without any amendment application in the first season.

Table (35) The interaction effect of cultivar, Pb level and soil amendments on photosynthetic pigments (mg/100 mg DW), ascorbic acid (mg/100 gm FW) and nitrate (mg/100 gm DW) of lettuce leaves.

Season		1994/95				1995/96			
Pb level ppm	Amendment	Total Chlorophyll	Carotene	Ascorbic acid	NO_3	Total Chlorophyll	Carotene	Ascorbic acid	NO_3
		Balady cv.							
0	0	211.07	107.50	11.10	123.28	183.63	89.53	19.04	149.30
	OM	249.60	126.01	16.87	135.18	202.18	102.07	20.30	160.83
	Clay	244.70	122.40	15.47	134.80	198.21	99.14	19.77	157.50
	CaCO3	234.74	116.71	14.98	141.17	190.14	94.54	18.72	149.55
100	0	223.56	112.06	11.40	126.17	194.50	93.33	18.24	141.93
	OM	252.05	127.97	17.05	133.76	204.16	103.65	19.92	158.47
	Clay	244.89	122.92	15.31	136.42	198.36	99.57	18.96	154.61
	CaCO3	238.45	117.94	15.08	138.51	193.15	95.53	17.49	148.12
200	0	217.27	108.28	11.82	125.00	189.03	90.18	17.76	140.66
	OM	262.85	131.49	18.62	127.96	212.91	106.51	18.52	154.23
	Clay	259.83	129.72	17.25	127.96	210.46	105.08	16.78	162.48
	CaCO3	236.26	117.64	17.68	130.05	191.37	95.29	16.03	142.72
300	0	193.10	95.80	11.73	122.20	168.00	79.78	18.64	140.20
	OM	258.18	128.70	17.98	125.87	209.12	104.24	18.86	156.15
	Clay	252.36	126.31	16.94	131.28	204.41	102.31	18.28	152.62
	CaCO3	236.77	118.58	16.75	128.91	191.78	96.05	16.55	130.23
		Great Lakes cv.							
0	0	209.36	105.43	22.43	149.91	182.15	87.81	20.50	152.36
	OM	240.65	120.23	26.08	146.96	194.92	79.39	21.89	167.88
	Clay	242.26	120.74	26.12	132.81	196.23	97.80	20.06	160.27
	CaCO3	235.60	116.51	25.28	133.18	190.84	94.37	20.13	156.60
100	0	223.21	108.79	22.94	150.19	194.19	90.60	19.10	150.40
	OM	249.65	124.78	20.46	144.78	202.22	101.07	21.22	158.70
	Clay	238.62	118.36	23.35	146.96	193.29	105.87	20.16	157.72
	CaCO3	233.69	116.87	22.02	138.51	189.29	94.67	19.59	151.20
200	0	217.21	105.87	11.99	138.80	188.97	88.17	18.70	148.16
	OM	260.88	128.07	19.82	131.76	211.31	103.74	20.53	155.88
	Clay	251.07	122.50	20.68	132.81	203.37	99.23	19.44	152.02
	CaCO3	244.61	119.08	19.94	129.58	198.14	96.45	17.87	139.87
300	0	206.10	103.80	12.15	136.90	179.31	86.45	18.87	148.60
	OM	257.13	126.31	18.49	128.91	208.28	102.31	20.79	157.72
	Clay	247.35	121.04	19.93	133.18	200.35	98.04	19.82	153.07
	CaCO3	239.88	117.74	19.52	132.23	194.30	95.37	18.72	146.13
LSD at 5%		*0.57*	*0.01*	*0.82*	*2.9*	*0.47*	*0.1*	*0.04*	*2.4*

B. Amino acids:

The effect of the high Pb level added to the soil (300 ppm) on the free amino acids content of the two studied cultivars is illustrated in Table (36). It appears from the data that adding 300 ppm Pb to the soil led to an increase in the total free amino acids content of plant leaves. This held true in both cultivars , irrespective of the significant differences occurred between the two cultivars for all tested amino acids . The increase in the total free amino acids content was amounted to be 33% and 41% for the Balady and Great Lakes cultivars, respectively over its control treatment. Much more pronounced effect was observed for glutamic, proline, phnyle-alanine and histidine acids, whereby, its values were highly significantly differed with respect to its corresponding control
treatment. It is worth mentioning that histidine acid was greatly depressed due to the lead pollution with respect to Balady cultivar.

In this connection, Kastori *et al.* (1992) investigated the effect of 10^{-4} or 10^{-6} M of Cd, Cu, Pb or Zn in solution culture on water relations, amino acids and protein contents in sunflower cv. NS-H-26 RM. They found that the concentration of free proline was significantly increased in the leaves of intact plants as well as in leaf discs incubated in the presence of heavy metals, while, the concentration of soluble proteins was decreased particularly at 10^{-4}M. It was concluded that excess concentrations of the heavy metals significantly affected plant water status, causing water deficit and subsequent changes in plant metabolism.

Table (36) Effect of soil lead pollution on various amino acids content (mg/100 gm DW) in leaves of two lettuce cultivars.

Treatment / Amino Acid	Balady cv. Soil Pb treatment (0) ppm	Balady cv. Soil Pb treatment 300 ppm	Great Lakes cv.# Soil Pb treatment (0) ppm	Great Lakes cv.# Soil Pb treatment 300 ppm
aspartic acid	8.88	15.21*	10.43	24.29**
serine	11.18	18.27*	14.68	18.67*
threonine	5.05	7.92*	6..92	9.86*
glycine	3.55	3.24	3.85	3.98
glutamic	11.96	25.98**	16.47	19.85*
alanine	7.97	7.59	8.26	8.24
tyrosine	3.16	2.97	2.98	3.08
proline	3.06	10.47**	6.85	17.69**
leucine	8.29	9.10	10.86	9.76*
valine	11.98	10.96	15.26	19.87*
methionine	4.18	3.05*	3.71	2.06*
phenyle-alanine	11.36	22.35**	18.36	29.18**
histidine	8.03	3.84**	6.74	6.82
amonia	6.17	7.59*	9.45	13.91*
arganine	9.53	10.02	9.36	9.93
lysine	8.31	7.98	8.12	12.28*
Total	122.66	166.54*	152.21	210.44*

All the variables are highly significant due to cultivar

* *Significance within each cultivar*

** Highly significance within each cultivar

4.4. THE FOURTH EXPERIMENT (Field experiment)

This experiment dealt with the effect of sludge borne heavy metals on the two tested lettuce cultivars (Balady and Great Lakes) grown in plots received soil amendments; i.e., organic manure, clay and $CaCO_3$ The obtained data are presented and discussed in the following:

4.4.1. Effect of cultivar, sewage sludge rate and soil amendments on plant growth characteristics:

The data concerning growth parameters of lettuce plants as affected by cultivar, rate of sludge and soil amendments are presented in Table (37). Such data reveal that all studied factors significantly affected all plant growth parameters except for number of leaves/ plant in the first growing season and shoot fresh weight in the second growing one, both due to cultivar, as well as shoot dry weight due to sludge rate in the first growing season, where differences did not reach the 5% level of significance.

Cultivar effect: Regarding the effect of cultivar on growth parameters, data in Table (37) indicate that Balady preceded Great Lakes cultivar in plant height, shoot fresh as well as dry weights. However, no significant differences between the two tested cultivars for number of leaves/plant and plant fresh weight in the first and second seasons, respectively, were detected. Fig. (7) shows great differences in lettuce plant height due to cultivar. It is obvious that plants of Balady cultivar were taller than those of Great Lakes and the differences were highly significant. Such variations between the two cultivars may be referred to that plants of Balady cultivar are much more adapted to the prevailing environmental conitions. This explanation agrees with the finding of Nicoloud *et al.* (1990) who mentioned significant differences among lettuce cultivars.

Table (37): Growth characters of lettuce as affected by cultivar, rate of sludge and soil amendments:

Seasons		1994/95 Season				1995/96 Season			
Treatments	Characters	Plant ht. cm	No. of Leaves/ Plant	Shoot FW gm	Shoot DW gm	Plant ht. cm	No. of Leaves/ Plant	Shoot FW gm	Shoot DW gm
Cultivars	Balady	38.3	41	424	39.2	39.3	42	302	38.7
	Great Lakes	31.1	42	401	33.6	31.8	44	266	30.3
L.S.D. at 5%		**5.6**	**N.S.**	**13.0**	**0.9**	**3.6**	**0.9**	**N.S.**	**0.6**
Sludge Application (ton/fad)	0	29.1	42	393	35.8	27.5	39	263	33.6
	15	35.3	42	408	37.4	33.9	42	280	35.1
	30	36.7	43	425	36.2	39.3	45	294	35.0
	45	37.9	45	426	36.4	41.6	46	298	34.4
L.S.D. at 5%		**2.0**	**3.0**	**11.0**	**N.S.**	**1.3**	**1.2**	**14.6**	**0.7**
Amendments Application	0	30.7	40	394	33.7	29.2	40	259	31.0
	Organic manure	34.1	41	407	34.9	34.7	42	274	32.8
	Clay	37.8	43	425	38.3	40.1	46	303	37.5
	$CaCO_3$	36.5	43	436	38.9	38.2	45	299	36.6
L.S.D. at 5%		**1.9**	**2.0**	**11.0**	**1.5**	**1.0**	**1.2**	**11.5**	**0.8**

N.S. = Nonsignificant

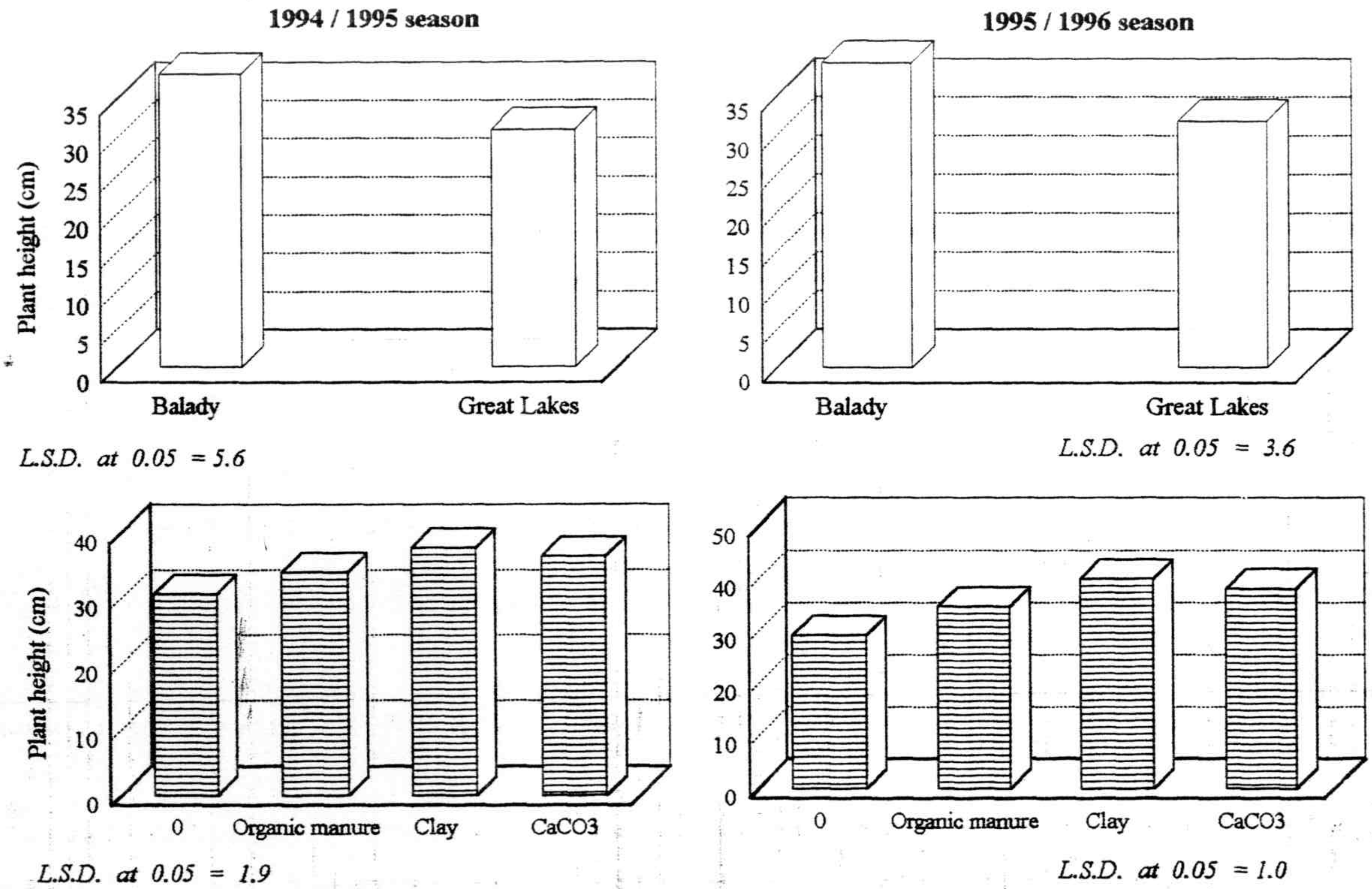

Fig. (7) : Effect of cultivar or amendments on lettuce plant height irrespective of sludge application.

Sludge rate effect: With respect to plant growth characteristics as affected by sludge application rate, it is obvious from the same data in Table (37) that all plant growth parameters i.e., plant height, number of leaves/plant, as well as fresh and dry weights of shoot, positively responded to the increase of sludge applied rate up to 45 ton/ fad. Indeed the differences among the sludge applied rates were highly significant for all the parameters recorded in both seasons of the experiment.

These results are in harmony with those obtained by Anid *et al.* (1983), who carried out a pot trials with increasing rates of town refuse compost on lettuce , spinach and rye grass (*Lolium perenne*). Both soil and sand were employed. Effects on plant nutrition, yield and heavy metals content were followed. Pots containing more than 20% compost, decreased vegetative growth of spinach and lettuce while those with highest compost rate gave maximum dry matter for rye grass. Also, These results agree with those obtained by El-Kassass (1996), who reported that the growth of spinach plants increased until 40 gm sludge /kg soil addition, then decreased with over addition .

Amendment effect: Concerning growth characteristics in response to soil amendment application, it appears from the data presented in Table (37) that all of soil amendments applied had a promoting effect on plant growth parameters as compared with the control treatment. However organic manure came in the last rank in this respect, no significant differences are shown between clay and calcium carbonate as soil amendments applied for any of the growth parameters recorded. This held true in both growing seasons. With respect to plant height as an indicative growth parameter, Fig. (7) shows that this character followed the same trend in response to soil amendment within sludge rate.

These results are in line with those obtained by Sorteberg (1982), who carried out on 3 rates (low, medium and high) of a mixture of heavy metals (Cd, Ni, Zn, Hg, Cr, Cu and Pb) were added to 9 crop species, including carrots and lettuces, grown in pots of sandy or clay soils with or without lime. Results are discussed in terms of visual observations and dry matter yield. Growth retardation by heavy metals was less severe where lime was added than without it. In clay soil, pH 5-5.5 without lime, lettuces were killed by a high rate of heavy metals.

4.4.2. Effect of cultivar, sludge rate and soil amendments on lettuce yield.

Data on lettuce yield/fad as affected by cultivar, sludge rate and soil amendments are presented in Table (38). These data show that lettuce yield was markedly affected by the application of sludge or amendments. It appears that most of the interactive effects between factors studied were nonsignificant.

Cultivar effect: From data presented in Table (38), it is evident that Balady cultivar produced higher yield compared with Great Lakes one. However, no significant difference was observed in the yield of the first season between both cultivars. These results were attributed to the results obtained concerning plant fresh weight which is considered an indicative parameter to lettuce yield. Results could be referred to the genetical character of each cultivar. This explanation agree with the finding of Nicoloud *et al.* (1990), who mentioned significant differences among lettuce cultivars.

Sludge rate effect: As indicated before, there is a close relationship between lettuce plant fresh weight and its yield/fad whereby, both characters increased progressively in response to application of sludge, whereby the highest yield/fad, as recorded in Table (38), was in association with the highest sludge rate applied (45 ton/fad.).

In this respect, Valdares *et al.* (1983) studied the effects on yield, and their uptake by plants of some heavy metals in soils treated with sewage sludge . Mixtures of two sludges were added to 3 soils in various proportions up to 4% sludge content. One sludge was rich in Ni and Cd, Table (38): Total yield (ton/fad) of lettuce as affected by cultivar, rate of sludge, soil amendment and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Sludge x Amendment Amendment				
	0	OM	Clay	CaCO3	Mean	0	OM	Clay	CaCO3	Mean	0	OM	Clay	CaCO3	Mean
Sludge ton/fad.	1994/95 season														
0	14.29	14.62	12.78	18.57	**15.07**	14.02	17.64	17.51	17.76	**16.73**	14.16	16.13	15.14	18.17	**15.90**
15	16.96	18.62	18.57	18.82	**18.24**	16.61	17.15	18.00	17.42	**17.30**	16.78	17.88	18.28	18.12	**17.77**
30	18.37	18.06	19.62	19.28	**18.83**	16.96	16.54	17.84	18.04	**17.35**	17.67	17.30	18.73	18.66	**18.09**
45	18.40	17.99	19.42	20.58	**19.08**	16.81	16.79	18.45	18.54	**17.65**	17.61	17.39	18.93	19.53	**18.37**
Mean	**17.01**	**17.32**	**17.59**	**19.30**	17.80	**16.10**	**17.03**	**17.95**	**17.94**	17.26	**16.55**	**17.18**	**17.77**	**18.62**	17.53
Sludge ton/fad.	1995/96 season														
0	13.65	15.37	19.38	18.65	**16.76**	12.49	14.58	15.85	14.74	**14.41**	13.07	14.97	17.62	16.70	**15.59**
15	15.60	16.95	18.96	18.92	**17.61**	14.87	15.15	15.79	15.51	**15.33**	15.24	16.05	17.38	17.22	**16.47**
30	16.17	18.01	19.44	18.57	**18.05**	15.32	15.30	16.59	16.10	**15.83**	15.75	16.66	18.02	17.34	**16.94**
45	17.87	16.93	19.96	20.36	**18.78**	15.74	15.08	16.88	17.90	**16.40**	16.80	16.01	18.42	19.13	**17.59**
Mean	**15.82**	**16.81**	**19.44**	**19.12**	17.80	**14.61**	**15.03**	**16.28**	**16.06**	15.49	**15.21**	**15.92**	**17.86**	**17.59**	16.65

* **OM**= Organic Manure , **N.S.**= Nonsignificant

L.S.D. at 5%	**Cultivar (cv)**	**Sludge rate (SR)**	**Amendment (AM)**	**cv x SR**	**cv x AM**	**SR x AM**	**cvxSRxAM**
1994/95	N.S.	0.83	1.25	1.18	N.S.	N.S.	N.S.
1995/96	0.27	0.47	0.51	N.S.	0.72	0.02	N.S.

and the other was relatively poor in heavy metals. The soils varied in pH from 7.7 to 5.5. In all soils the metal-poor sludge hardly affected the yield of the relatively salt-resistant Swiss chard (cv. Ford Hook Giant). The metal-rich sludge reduced the yield markedly in noncalcareous soils (pH 5.5 and 7.0) after a critical amount (1.5%) was added. However in the calcareous soil (pH 7.7) even 4% of metal-rich sludge increased the yield of Swiss chard as compared with the sludge-free control. Also, El-Kassass (1996) reported that the yield of spinach plants increased until 40 gm sludge /kg soil addition, then decreased with over addition .

Amendment effect: Lettuce yield was positively responded to amendments application (Table 38). The effect of organic manure application was nonsignificant, while clay and $CaCO_3$ application led to a similar significant increase in yield/fad as compared with the control treatment. This holds true in both growing seasons, with non-significant differences among the interactions of amendments within sludge rate. These results are in confirmity with those obtained by Alloway (1992), who stated that metal concentrations in soil which could prove harmful to crops at pH values below 6.0 may have little effect on plant growth if the pH is raised to 6.5- 7.0. It is therefore important to maintain soil pH above 6.5 by frequent liming in all situations where sewage sludge has been applied to agricultural land.

4.4.3. Effect of cultivar, sludge rate and soil amendments on macro- and micro-nutrients content of lettuce leaves:

Macro and micro-nutrients as chemical constituents of lettuce leaves were greatly affected by the studied factors (Table 39).

Cultivar effect: From the data presented in Table (39), it can be indicated that the uptake of all the tested macronutrients by plants of Great Lakes cultivar was greater than that of Balady cultivar except with Mg whereby, plants of Balady cultivar contained more Mg during frist season of

Table (39) Macro-and micro-nutrients content of lettuce leaves as affected by cultivar, sludge rate and soil amendments.

Treatments	Macronutrients %					Micronutrients ppm			
	N	P	K	Ca	Mg	Zn	Cu	Mn	Fe
	1994/95 season								
Cultivars Balady	2.98	0.34	1.16	0.71	0.75	110	42.5	85.4	753
Great Lakes	3.25	0.37	1.29	1.13	0.66	92	35.1	73.3	583
LSD at 5%	**0.18**	**.002**	**0.04**	**.027**	**.005**	**1.2**	**0.5**	**0.8**	**0.6**
Sludge rate (ton/fad) 0	2.85	0.32	1.09	0.81	0.54	80	34.1	70.8	560
15	3.06	0.35	1.23	0.87	0.60	98	38.3	77.1	574
30	3.20	0.37	1.29	0.91	0.65	112	40.7	82.0	587
45	3.36	0.39	1.31	1.09	0.67	116	42.3	87.5	594
LSD at 5%	**0.01**	**.001**	**0.01**	**.005**	**.002**	**0.5**	**0.1**	**0.2**	**0.5**
Amendment 0	2.85	0.37	1.18	0.68	0.59	102	38.6	79.0	576
Organic manure	3.09	0.39	1.26	0.81	0.64	117	42.5	86.6	587
Clay	3.32	0.35	1.35	0.89	0.69	107	40.5	81.9	596
CaCO3	3.21	0.32	1.13	1.29	0.54	80	33.8	69.8	554
LSD at 5%	**0.01**	**.001**	**0.01**	**.004**	**.001**	**0.3**	**0.1**	**0.1**	**0.3**
	1995/96 season								
Cultivars Balady	2.83	0.33	1.10	0.67	0.54	99	38.3	76.9	516
Great Lakes	3.09	0.35	1.23	1.07	0.62	83	31.6	66.0	525
LSD at 5%	**0.02**	**.002**	**0.03**	**.026**	**.005**	**1.1**	**0.4**	**0.7**	**0.6**
Sludge rate (ton/fad) 0	2.70	0.31	1.03	0.77	0.51	72	30.7	63.8	504
15	2.91	0.33	1.16	0.82	0.57	89	34.4	69.4	517
30	3.04	0.35	1.23	0.86	0.61	100	36.6	73.8	528
45	3.19	0.37	1.25	1.04	0.64	104	38.1	78.8	534
LSD at 5%	**0.01**	**0.001**	**0.01**	**.004**	**.002**	**0.5**	**0.1**	**0.2**	**0.5**
Amendment 0	2.70	0.35	1.12	0.65	0.56	92	34.7	71.1	519
Organic manure	2.93	0.37	1.19	0.77	0.60	105	38.2	78.1	529
Clay	3.16	0.33	1.28	0.84	0.65	97	36.5	73.7	537
CaCO3	3.05	0.31	1.07	1.23	0.52	72	30.4	62.8	498
LSD at 5%	**0.01**	**.001**	**0.01**	**.004**	**.001**	**0.2**	**0.1**	**0.1**	**0.3**

this experiment. This indicates a higher nutritional value of lettuce plants belongs to Great Lakes cultivar compared to those of Balady one. As for micronutrients content, contra trend could be detected, whereby Balady cultivar exceded Great Lakes one in Zn, Cu, Mn and Fe accumulated in their leaves. Thus the elemental composition of lettuce plants appears to be a varietal characteristic as reported before.

Sludge rate effect : As stated in Table (39), sludge rate positively affected the uptake of all the nutrient recorded. A progressive increase of nutrients content was recorded due to the increase of sludge rate application. The highest content of nutrients mentioned were contained in lettuce leaves grown on plots receiving the highest sludge rate (45 ton/fad.). This may be due to the high nutrients content of such sludge which are readily uptaken by plant roots.

Such results agree with those obtained by Checkai *et al.* (1987), who studied the uptake of micronutrient metals by intact tomato plants in solution cultures. The concentrations of all nutrients were maintained at values similar to those occurring in solutions of sludge-amended soils. Neither Cd nor EDTA treatments affected the plant yield, and Cd treatments did not significantly affect uptake of other elements. EDTA treatments inhibited Fe uptake, while enhanced Cu uptake, and had little effect on the uptake of Cd, Zn and Mn. Results also, showed that accumulation of Cd, Zn Mn and Cu in tomato shoots appear to be related to their concentration in solution culture. Also, Abou Seeda *et. al.* (1992) in a column experiment, concluded that as the sludge application rate increase, the percentage of available trace elements increase . Moreover, El-Kassas (1996) confirmed this conclusion in his work on spinach plants .

Amendment effect : In the same Table (39), the data concerning amendment effect clarify the additive effects of tested soil amendments. Using clay proved to be the most effective amendment in enhancing N, K, Mg and Fe accumulation in lettuce leaves. Meanwhile, organic manure showed superiority in case of P, Zn, Cu and Mn. However, $CaCO_3$ had a depressive effect on the uptake of P, K, Mg and all micronutrients by plant. This effect may due to the low availability of such nutrients in the presence of CO_3^{--} ion and the antagonestic effect of Ca^{++} on cationic nutrients indicated by El-Kassas (1992). In this respect, application of $CaCO_3$ led to maximum plant uptake of Ca in comparison with other amendments tested.

Interaction effect: Macro-and micro-nutrients content in lettuce leaves of both Balady and Great Lakes cultivars as affected by sludge application rate and soil amendments application are shown in Tables (40 and 41) for 1994/95 and 1995/96 growing seasons, respectively.

At the 30 ton/fad. sludge application rate, N, P, K, Mg and Ca leaves content were generally the highest due to $CaCO_3$ application in plants of Great lakes cultivar. This holdss true in the two seasons of the experiment.

With regard to micronutrient, data indicate that sludge application was the most important factor in this respect, whereby the highest values were obtained from plants of Balady cultivar grown in soil no amendments at the 15 ton sludge/fad.

These results indicate that both macro-and micronutrients uptake were significantly affected by the interaction effect of cultivar, sludge application rate, and soil amendments. The depressive effect of increasing sludge application rate can be reduced by amendments application. Irrespective of the varietal differences of nutrients absorption, the nutritional status of any of the soil amendments applied is a determining factor. Clay soil seems to be rich in N, P, K and Mg nutrient, while organic manure is rich in micro nutrients besides to its active role in reducing soil pH and subsequently enhancing the absorption of micro - nutrient Zn, Cu, Mn and Fe by plant roots. On the contrary, $CaCO_3$

Table (40) The interaction effect of cultivar, Sludge rate and soil amendments on macro and micronutrients content of lettuce leaves (1994/95).

Sludge rate ton/fad.	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
		Balady cv.								
0	0	2.57	0.37	0.98	0.55	0.49	82.90	34.20	74.60	546.60
	OM	2.71	0.39	1.13	0.57	0.52	128.80	46.80	93.90	590.50
	Clay	2.70	0.33	1.21	0.55	0.58	126.30	45.50	87.40	582.20
	CaCO3	2.82	0.32	1.17	0.59	0.53	109.80	42.80	82.00	566.50
15	0	2.69	0.39	1.10	0.58	0.54	112.60	41.60	80.90	562.30
	OM	2.95	0.41	1.20	0.58	0.54	138.20	49.20	106.50	596.80
	Clay	3.16	0.36	1.20	0.66	0.63	133.80	48.30	96.50	593.60
	CaCO3	3.08	0.34	1.11	0.69	0.55	123.20	46.40	88.3	578.20
30	0	2.91	0.37	1.05	0.62	0.56	98.20	38.40	77.40	569.40
	OM	3.13	0.36	1.28	0.64	0.62	129.50	47.50	98.90	603.50
	Clay	3.29	0.33	1.31	0.70	0.69	122.20	46.20	90.20	598.90
	CaCO3	3.30	0.31	1.14	0.73	0.60	118.00	44.20	85.20	586.50
45	0	2.96	0.29	1.09	0.85	0.44	76.50	35.60	72.60	542.00
	OM	3.03	0.33	1.24	0.89	0.51	97.60	40.20	79.20	556.10
	Clay	3.27	0.30	1.28	0.93	0.53	89.40	38.10	77.30	553.50
	CaCO3	3.17	0.30	1.13	1.23	0.44	80.40	36.20	75.70	548.30
		Great Lakes cv.								
0	0	2.69	0.39	1.17	0.73	0.52	63.40	29.20	64.50	560.50
	OM	3.11	0.43	1.32	0.78	0.65	116.20	39.80	82.60	598.40
	Clay	3.25	0.38	1.38	0.83	0.67	106.20	37.80	76.80	592.20
	CaCO3	2.92	0.33	1.23	0.90	0.59	80.80	32.40	70.10	573.50
15	0	2.79	0.42	1.17	0.80	0.62	76.50	33.60	69.70	569.70
	OM	3.14	0.46	1.32	0.93	0.68	123.60	42.40	89.80	609.30
	Clay	3.64	0.39	1.37	0.98	0.70	117.50	40.20	84.50	599.00
	CaCO3	3.26	0.37	1.22	1.23	0.65	108.60	38.10	77.80	589.20
30	0	3.23	0.37	1.31	0.98	0.66	70.60	31.50	65.80	573.30
	OM	3.37	0.39	1.41	0.97	0.72	114.80	40.60	84.30	630.40
	Clay	3.93	0.36	1.50	1.01	0.74	111.60	39.00	79.30	613.40
	CaCO3	3.45	0.33	1.32	1.46	0.71	96.20	36.70	74.00	594.00
45	0	2.93	0.33	1.03	1.35	0.48	60.20	28.90	61.20	552.20
	OM	3.25	0.39	1.15	1.57	0.59	82.60	32.00	65.00	563.00
	Clay	3.68	0.33	1.23	1.63	0.63	78.40	30.20	63.90	559.40
	CaCO3	3.37	0.30	1.12	1.88	0.55	70.50	29.30	63.50	555.60
LSD at 5%		***0.01***	***0.001***	***0.02***	***0.01***	***0.003***	***0.7***	***0.17***	***0.34***	***0.8***

OM = Organic manure

Table (41) The interaction effect of cultivar, Sludge rate and soil amendments on macro and micronutrients content of lettuce leaves (1995/96).

Sludge rate ton/fad.	Amendments	N%	P%	K%	Ca%	Mg%	Zn ppm	Cu ppm	Mn ppm	Fe ppm
		Balady cv.								
0	0	2.44	0.31	0.93	0.52	0.47	74.61	30.78	67.14	491.94
	OM	2.57	0.30	1.07	0.54	0.49	115.92	42.12	84.51	531.45
	Clay	2.68	0.37	1.11	0.52	0.55	113.67	40.95	78.66	523.98
	CaCO3	2.56	0.35	1.15	0.56	0.60	98.82	38.52	73.80	509.85
15	0	2.56	0.32	1.04	0.55	0.52	101.34	37.44	72.81	506.07
	OM	2.80	0.34	1.14	0.55	0.52	124.38	44.28	95.85	537.12
	Clay	3.00	0.37	1.23	0.63	0.60	120.42	43.47	86.85	534.24
	CaCO3	2.93	0.39	1.16	0.66	0.62	110.88	41.76	79.47	520.38
30	0	2.76	0.29	0.99	0.59	0.53	88.38	34.56	69.66	512.46
	OM	3.12	0.35	1.25	0.61	0.59	110.26	42.75	89.01	543.15
	Clay	3.13	0.34	1.28	0.66	0.65	116.28	41.58	81.18	539.01
	CaCO3	2.97	0.31	1.22	0.70	0.66	106.20	39.78	76.68	527.85
45	0	2.81	0.27	0.9	0.81	0.41	68.85	32.04	65.34	487.80
	OM	3.01	0.32	1.06	0.85	0.48	87.84	36.18	71.28	500.49
	Clay	3.10	0.28	1.09	0.88	0.50	80.46	34.29	69.57	498.15
	CaCO3	2.88	0.28	1.02	1.17	0.52	72.36	32.58	68.13	493.47
		Great Lakes cv.								
0	0	2.56	0.32	1.03	0.69	0.49	57.06	26.28	58.05	504.45
	OM	2.96	0.37	1.22	0.74	0.62	104.58	35.82	74.34	538.56
	Clay	3.09	0.40	1.24	0.78	0.64	95.58	34.02	69.12	532.98
	CaCO3	2.77	0.36	1.17	0.85	0.65	72.72	29.16	63.09	516.15
15	0	2.65	0.35	1.11	0.76	0.59	68.85	30.24	62.73	512.73
	OM	3.10	0.40	1.31	0.88	0.65	111.24	38.16	80.82	548.37
	Clay	3.46	0.44	1.35	0.93	0.66	105.75	36.18	76.05	539.10
	CaCO3	2.98	0.37	1.25	1.17	0.69	97.74	34.29	70.02	530.28
30	0	3.06	0.31	1.27	0.93	0.63	63.58	28.35	59.22	515.97
	OM	3.28	0.35	1.09	0.92	0.68	103.32	36.54	75.87	567.36
	Clay	3.73	0.37	1.54	0.96	0.71	100.44	35.10	71.37	552.06
	CaCO3	3.20	0.35	1.31	1.39	0.77	86.58	33.03	66.60	534.60
45	0	2.78	0.29	0.97	1.28	0.46	54.18	26.01	55.08	496.98
	OM	3.20	0.33	1.19	1.49	0.56	74.34	28.80	58.50	506.70
	Clay	3.50	0.37	1.23	1.55	0.59	70.56	27.18	57.51	503.46
	CaCO3	3.08	0.31	1.09	1.79	0.61	63.45	26.37	57.15	500.04
LSD at 5%		*0.01*	*0.001*	*0.02*	*0.01*	*0.003*	*0.66*	*0.2*	*0.3*	*0.8*

OM = Organic manure

shows the opposite action in this respect.

Such results was shown by Chumbley and Unwin (1982), who conducted a survey of eleven vegetable crop species grown on land with a history of sewage sludge application .

4.4.4. Effect of cultivar, sludge rate and soil amendments on heavy metals content of lettuce leaves.

Heavy metals i.e., Cd, Ni and Pb content in lettuce leaves in response to the studied factors are illustrated in Tables (42, 43 and 44), respetively. It is evident from the L.S.D. values mentioned below these tables that all of the variables i.e. Cd, Ni and Pb were significantly different in response to the single effect of the studied factors and their interactions.

Cultivar effect: From the data stated in Tables (42, 43 and 44), as well as Fig. (8), it can be concluded that plants of Great Lakes cultivar accumulated higher contents of Cd, Ni and Pb metals compared with those of Balady one. This finding agree with those stated in the previous sections of the pot experiments. However, each metal of the pot experiments (i.e., Cd, Ni or Pb in the pot experiments dealing with its effect) was higher than its content with respect to this field experiment. This may be attributed to the enhancing effects of organic matter existed in sewage sludge which led to higher plant growth compared with the limited plant growth occurred in the pot experiments.

The varietal variation regarding heavy metals uptake was stated by Yuran and Harrison (1986), who investigated the effects of genotype and sewage sludge on cadmium concentration in lettuce leaf tissue. Leaf Cd concentrations were determined for 60 commercial cultivars. Each genotype was evaluated during a 2-year study in field plots receiving an industrial sludge, a municipal sludge or no sludge. Although the genotype X year interaction was significant, the Cd concentrations of some cultivars (Waldmann's Green and Summer Queen) were consistently low while

Table (42): Cadmium content (ppm) of lettuce leaves as affected by cultivar, rate of sludge, soil amendment and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Sludge x Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Sludge ton/fad.	1994/95 season														
0	0.98	1.25	0.68	0.42	**0.83**	0.84	1.44	0.69	0.62	**0.90**	0.91	1.35	0.69	0.52	**0.87**
15	1.30	1.40	0.96	0.58	**1.06**	1.27	1.62	0.78	0.49	**1.04**	1.29	1.51	0.87	0.54	**1.05**
30	1.62	1.71	0.84	0.53	**1.17**	1.52	1.88	0.84	0.55	**1.20**	1.57	1.79	0.84	0.54	**1.19**
45	1.48	2.08	0.92	0.65	**1.37**	1.96	2.54	1.12	0.64	**1.57**	1.90	2.31	1.02	0.65	**1.47**
Mean	**1.44**	**1.61**	**0.85**	**0.55**	1.11	**1.40**	**1.87**	**0.86**	**0.58**	1.18	**1.42**	**1.74**	**0.85**	**0.56**	1.14
Sludge ton/fad.	1995/96 season														
0	0.93	1.19	0.65	0.40	**0.79**	0.85	1.37	0.66	0.59	**0.85**	0.86	1.28	0.65	0.49	**0.82**
15	1.24	1.44	0.91	0.55	**1.04**	1.21	1.54	0.74	0.46	**0.99**	1.22	1.49	0.83	0.51	**1.01**
30	1.54	1.85	0.80	0.50	**1.17**	1.44	1.78	0.80	0.52	**1.14**	1.49	1.82	0.80	0.51	**1.15**
45	1.75	1.94	0.87	0.62	**1.29**	1.86	1.86	1.06	0.61	**1.35**	1.81	1.90	0.97	0.61	**1.32**
Mean	**1.36**	**1.61**	**0.81**	**0.52**	1.07	**1.33**	**1.64**	**0.81**	**0.55**	1.08	**1.35**	**1.62**	**0.81**	**0.53**	1.08

* **OM**= Organic Manure

L.S.D. at 5%	Cultivar (cv)	Sludge rate (SR)	Amendment (AM)	cv x SR	cv x AM	SR x AM	cvxSRxAM
1994/95	0.05	0.02	0.03	0.04	0.04	0.05	0.08
1995/96	0.01	0.02	0.02	0.02	0.02	0.03	0.04

Table (43): Nickel content (ppm) of lettuce leaves as affected by cultivar, rate of sludge, soil amendment and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Sludge x Amendment Amendment				
	0	OM	Clay	$CaCO_3$	Mean	0	OM	Clay	$CaCO_3$	Mean	0	OM	Clay	$CaCO_3$	Mean
Sludge ton/fad.	1994/95 season														
0	3.28	4.66	1.82	0.84	**2.65**	3.82	6.18	1.50	1.24	**3.19**	3.55	5.42	1.66	1.04	**2.92**
15	5.62	7.26	2.06	0.88	**3.96**	7.85	10.12	2.38	1.40	**5.44**	6.74	8.69	2.22	1.14	**4.70**
30	8.14	8.56	2.48	1.26	**5.11**	9.84	13.20	2.92	1.61	**6.89**	8.99	10.88	2.70	1.44	**6.00**
45	9.81	14.16	2.66	1.45	**7.02**	14.29	18.02	2.94	1.87	**9.28**	12.05	16.09	2.80	1.66	**8.15**
Mean	**6.71**	**8.66**	**2.26**	**1.11**	**4.68**	**8.95**	**11.88**	**2.44**	**1.53**	**6.20**	**7.83**	**10.27**	**2.35**	**1.32**	**5.44**
Sludge ton/fad.	1995/96 season														
0	2.96	4.21	1.64	0.76	**2.39**	3.45	5.58	1.35	1.12	**2.87**	3.20	4.89	1..50	0.94	**2.63**
15	5.07	8.07	1.86	0.79	**3.95**	7.09	9.13	2.15	1.27	**4.91**	6.08	8.60	2.00	1.03	**4.43**
30	8.31	9.87	2.24	1.14	**5.39**	8.88	11.91	2.64	1.45	**6.22**	8.60	10.89	2.44	1.30	**4.43**
45	12.91	11.43	2.40	1.31	**7.01**	12.90	16.26	2.65	1.69	**8.38**	12.91	13.85	2.53	1.50	**7.69**
Mean	**7.31**	**8.39**	**2.04**	**1.00**	**4.69**	**8.08**	**10.72**	**2.20**	**1.38**	**5.59**	**7.70**	**9.56**	**2.12**	**1.19**	**5.14**

*** OM**= Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Sludge rate (SR)**	**Amendment (AM)**	**cv x SR**	**cv x AM**	**SR x AM**	**cvxSRxAM**
1994/95	0.18	0.18	0.17	0.25	0.23	0.33	0.47
1995/96	0.24	0.21	0.19	0.30	0.27	0.39	0.55

Table (44): Lead content (ppm) of lettuce leaves as affected by cultivar, sludge rate , soil amendment and their interactions:

Treatments	Balady cv. Amendment					Great Lakes cv. Amendment					Sludge x Amendment Amendment				
	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**	0	**OM**	Clay	$CaCO_3$	**Mean**
Sludge ton/fad.	1994/95 season														
0	4.15	4.32	1.62	1.10	**2.80**	4.37	4.63	2.26	1.49	**3.19**	4.26	4.48	1.94	1.30	**2.99**
15	16.85	20.22	5.30	4.12	**11.62**	20.68	27.25	6.11	3.82	**14.47**	18.77	23.73	5.71	3.97	**13.04**
30	23.89	25.37	8.18	5.92	**15.84**	25.86	34.60	6.82	4.63	**17.98**	24.88	29.98	7.50	5.28	**16.91**
45	29.19	31.84	8.92	6.24	**19.05**	33.28	42.69	8.71	5.88	**22.64**	31.24	37.27	8.82	6.06	**20.84**
Mean	**18.52**	**20.44**	**6.01**	**4.35**	12.33	**21.05**	**27.29**	**5.98**	**3.69**	14.57	**19.79**	**23.87**	**5.99**	**4.15**	13.45
Sludge ton/fad.	1995/96 season														
0	3.61	3.76	1.41	0.96	**2.43**	3.80	4.03	1.96	1.30	**2.77**	3.71	3.89	1.69	1.13	**2.60**
15	15.17	22.63	4.77	3.71	**11.57**	18.61	24.53	5.50	3.44	**13.02**	16.89	23.58	5.14	3.57	**12.29**
30	24.61	25.72	7.36	5.33	**15.76**	23.28	31.14	6.14	4.17	**16.18**	23.95	28.43	6.75	4.75	**15.94**
45	36.66	36.98	8.03	5.62	**21.82**	29.95	38.42	7.84	5.29	**20.38**	33.31	37.70	7.94	5.45	**21.10**
Mean	**20.01**	**22.27**	**5.40**	**3.91**	12.90	**18.91**	**23.53**	**5.36**	**3.55**	13.09	**19.47**	**23.40**	**5.38**	**3.73**	12.98

*** OM=** Organic Manure

L.S.D. at 5%	**Cultivar (cv)**	**Sludge rate(SR)**	**Amendment (AM)**	**cv x SR**	**cv x AM**	**SR x AM**	**cvxSRxAM**
1994/95	0.14	0.37	0.36	0.52	0.50	0.71	1.01
1995/96	0.10	0.26	0.31	0.37	0.44	0.62	0.88

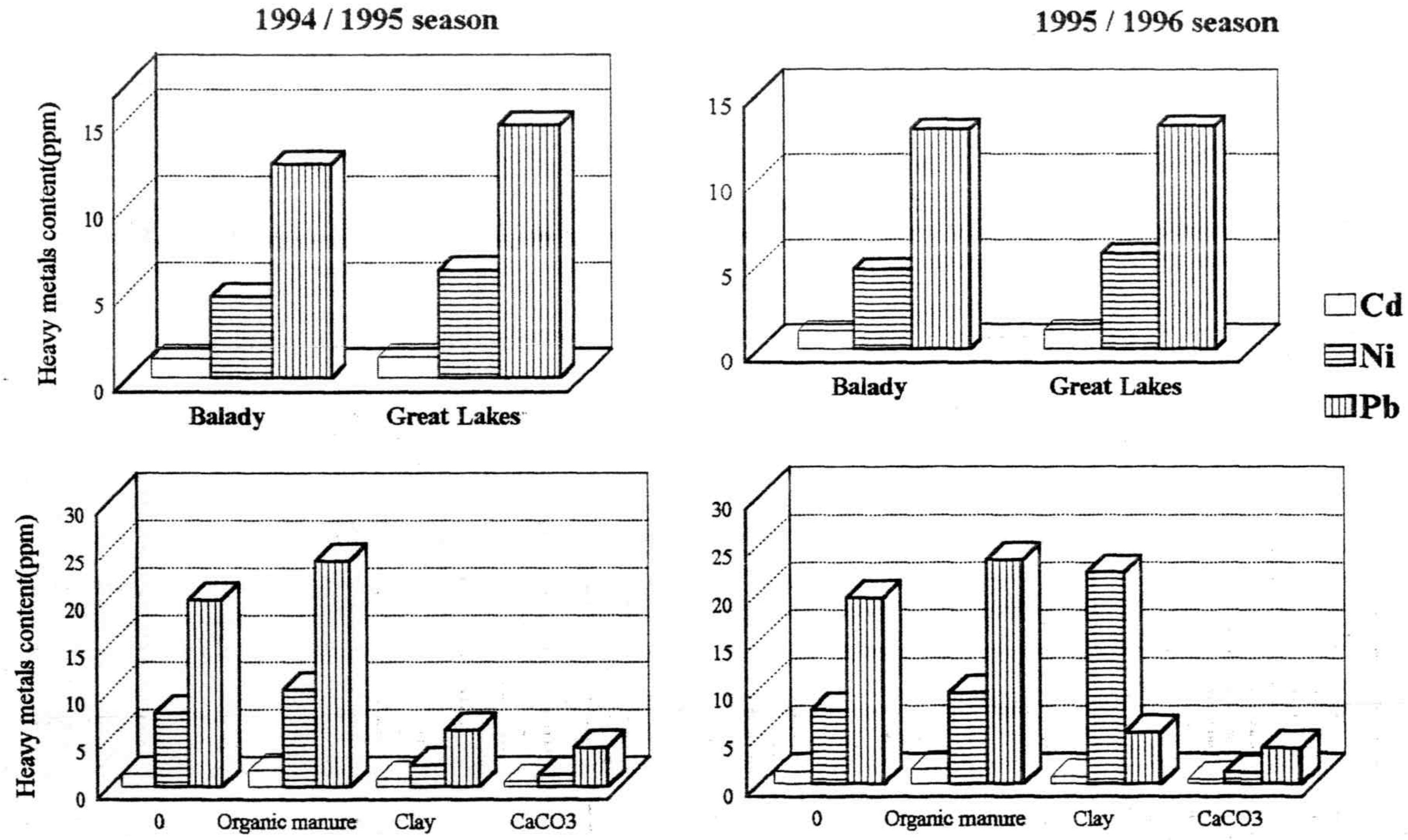

Fig. (8) : Heavy metals content of lettuce leaves as affected by cultivar or amendments under sludge application.

All the differences within each variable are significant ($p=0.05$)

those of others (P1278080, P1167148 and Citation) were consistently high. Plants receiving industrial sludge had the highest Cd content. Furthermore, in addition to high levels of heavy metals occurring naturally, considerable amounts of the elements can also be introduced into soils via anthropogenic pathways such as dumping industrial effluents and agricultural applications of sewage sludge (Dudka and Chlopecka,1990) and the application of commercial fertilizers (Singh, 1994).

Sludge rate effect: Tables (42, 43 and 44), show significant increase of heavy metal content in lettuce leaves due to the application of sludge, irrespective of lettuce cultivar used. A progressive increase in Cd, Ni, and Pb contents was detected as sludge rate increased up to 45 ton/fad. This result is due to the additive effect of sludge borne heavy metals which are readily absorbed by plant roots and accumulated in plant organs.

This effect was stated by many researches among them Friberg *et al.*, (1971) and Linuman *et al.*, (1973), who suggested that dietary Cd intake by man will increase with the increased use of sewage sludge in agricultureThey added also that the provisional tolerable weekly intake of Cd is from 400 to 500 µg per individual. This tolerable intake level could be exceeded when an individual consumes the equivalent of 61 to 76 g of dried lettuce grown on soil treated with Edmonton sewage sludge (23 ppm Cd). World Health Organization (1972) recommends that the weekly intake should not exceed 400-500 µg per individual. Heavy-metal uptake by lettuce, radish, spring wheat and *Festuca rubra* from 4 highly contaminated sediments and one uncontaminated fluvial sediment under oxidized soil conditions was studied by Driel *et al.* (1985). In nearly all crops cultivated on contaminated substrates, Cd, Ni, Pb and Zn were markedly accumulated. Only in *F. rubra* the accumulation was limited to Pb and Zn; there was no response to the increased concentrations of the other metals in the substrate. The Cd concentrations in consumable products and feeds grown on contaminated river sediments exceeded the tentative maximum values for consumable products; Cu and

Pb remained well under the limits for feeds in all products. The concentrations of the other metals were considered to be harmless. Other findings indicated a high toxicity of organo lead compounds to a variety of plants. Toxic effects are related mainly to disturbance of fundamental biological processes such as photosynthesis, growth, mitosis, etc. Furthermore, the accumulation of cadmium by four crops (cabbage, carrot, lettuce and radish) grown on soils contaminated from a variety of sources was investigated by Xue and Harrison (1991) and Alloway *et al.* (1992),who indicated that the most frequently occurring soil parameter was the total heavy metal content which was inversely related to plant heavy metal content. Obtained results are in agreement with those reported by El-Kassas (1996) whereby increasing sludge addition up to 200 gm sludge /kg soil, increased Cd, Ni, Pb and Co concentrations in both roots and leaves of spinach plants.

On the contrary, Michel *et al.* (1978) reported that at relatively low soil treatments with sewage sludge enriched with Cd, Cu, Ni, or Zn; Cu and Cd were more toxic to lettuce grown in the calcareous (1.2% $CaCO_3$) than in the acid (pH 5.7) soil.

Amendment effect: The tabulated and figured data (Tables 42, 43 and 44 as well as Fig. (8), concerning leaves content of Cd, Ni and Pb indicate the favourable effect of both clay and $CaCO_3$ application on reducing heavy metals accumulation through affecting its availability to plant uptake. In this connection, it is noticeable, that $CaCO_3$ showed superiority and surpassed the clay effect.

In this context, the action and mechanisms of $CaCO_3$ in reducing heavy metal uptake by plant were reported in other works: Lagerwerff (1971) found that increasing soil pH from 5.9 to 7.2 decreased Pb content of the radish plant. Misra and Pandy (1976) mentioned that as the pH increased the amount of extractable Pb decreased. Mahler *et al.* (1978) found that tissue concentration of Cd associated with 50% yield decrement for acid and calcareous soils were as follows: Lettuce 470 and 160 µg/g; chard 714 and 203 µg/g, respectively. The corresponding concentrations of Cd in soils were: lettuce 214 and 139 μg/g and chard 250 and 175 μg/g for acid and calcareous soils, respectively.

On the contrary, Michel *et al.* (1978) reported that at relatively low soil treatments with sewage sludge enriched with Cd, Cu, Ni, or Zn; Cu and Cd were more toxic to lettuce grown in the calcareous (1.2% $CaCO_3$) than in the acid (pH 5.7) soil.

As for organic manure, it is of paramount importance to point out its deleterious role in increasing heavy metal uptake by plants due to its content of such metals and or the effect in lowering the soil pH value which may enhance the heavy metals availability and absorption by plant roots. Also, the obtained results are in accordance with those indicated by Alloway *et al.* (1992) and McBride (1995).

As for clay effect, Gaynor *et al.* (1976) showed that Cd uptake and tissue concentrations of lettuce plants grown on clay soil mixed with sludge were equal to or less than those found in lettuce harvested from the fertilizer only treatment. To a lesser extent, similar trends were observed with the tomato crop. Kiekens *et al.* (1984) evaluated the chemical activity and the uptake by Italian ryegrass (*Lolium perenne* cv. S24) of Cd and Ni added to a sandy and a heavy clay soil as inorganic salts or in sewage sludge. The chemical activity of heavy metals as evaluated with different extractants was greater with the inorganic salt treatment and in the sandy soil, indicating that the chemical form of the metal and soil characteristics largely affect their extractability. They found that the differences in chemical activity were reflected in plant uptake of all metals, which decreased in the following order: sandy soil-salt > sandy soil-sludge > clay soil-salt > clay soil-sludge.

On the other hand, Haan *et al.* (1985) worked on three clay soils of differing clay content supplied with cadmium, nickel or lead as acetate in amounts up to 50, 100 and 800, respectively to determine the critical load for yield of oats. They found that yield depression and metal content of the crop corresponded well with the clay content of the tested soils.

Interaction effect: From the data presented in Tables (42, 43 and 44), , it can be concluded that:

- The effect of cultivar within sludge rate, was the same for each of the two studied cultivars as the heavy metals content in leaves were increased by increasing the rate of sludge applied to the soil in both growing seasons.
- The effect of cultivar within amendments was the same for each of the two studied cultivars as the heavy metals content in leaves were reduced by applying clay or CaCO3, while heavy metals contents of leaves were increased by applying organic manure compared with its contents in leaves of the control treatment.

The data of the interaction of amendments and sludge rate show that $CaCO_3$ was the most effective amendment within various sludge rates followed by clay and then the control treatment , while organic manure had a negative effect in this regard.

With respect to the sludge rate X cultivar X soil amendment, it is evident that the lowest accumulation of the heavy metals recorded was obtained in leaves of the Balady cultivar plants grown on nonsludged soil amended with CaCO3. This held true in both seasons of the study.

4.4.5. Effect of cultivar, sludge rate and soil amendments on some metabolic changes in lettuce leaves.

A. photosynthetic pigments, ascorbic acid and NO_3

The data concerning photosynthetic pigments, ascorbic acid and NO_3 contents as bioindicators to the tested factors are presented in Table (45). These data indicate significant differences in all mentioned metabolic products due to cultivar, sludge rate and soil amendments.

Cultivar effect: Data in Table (45) reveal that leaves of Balady cultivar plants contained higher concentration of photosynthetic pigments (Chlorophyll a, total chlorophyll and carotene) than those of Great Lakes.

Table (45) Photosynthetic pigments (mg/100 gm FW), ascorbic acid (mg/100 gm FW), and nitrate (mg/100 gm DW) content of lettuce leaves as affected by cultivar, sludge rate and soil amendments.

Treatments		Chlorophylls a	Chlorophylls b	Chlorophylls Total	Carotene	Ascorbic Acid	Nitrate
1994/95 season							
Cultivars	Balady	120.5	40.6	161.1	97.6	16.0	149.7
	Great Lakes	118.5	42.1	160.6	96.0	17.4	153.4
LSD at 5%		**0.13**	**0.10**	**0.03**	**0.11**	**0.13**	**2.5**
Sludge rate (ton/fad)	0	113.1	39.8	152.9	91.6	17.8	159.8
	15	118.3	41.1	159.4	95.9	17.2	153.9
	30	122.3	41.9	164.2	99.0	16.4	151.6
	45	124.5	42.6	167.1	100.8	16.2	141.2
LSD at 5%		**0.17**	**0.04**	**0.21**	**0.14**	**0.03**	**2.7**
Amendment	0	115.7	39.4	155.1	93.7	17.7	156.6
	Organic manure	119.4	39.7	159.1	96.7	16.9	152.5
	Clay	122.7	43.7	166.4	99.4	16.0	149.4
	CaCO3	120.4	42.6	163.0	97.5	16.3	148.0
LSD at 5%		**0.05**	**0.03**	**0.08**	**0.04**	**0.03**	**0.8**
1995/96 season							
Cultivars	Balady	108.5	38.6	147.1	92.8	15.3	124.8
	Great Lakes	106.7	40.0	146.7	91.2	16.6	127.9
LSD at 5%		**0.12**	**0.09**	**0.02**	**0.10**	**0.10**	**2.0**
Sludge rate (ton/fad)	0	101.8	37.9	139.7	87.0	17.1	133.1
	15	106.5	39.1	145.6	91.1	16.4	128.3
	30	110.0	39.8	149.8	94.1	15.6	126.3
	45	112.0	40.0	152.0	95.8	14.7	117.6
LSD at 5%		**0.15**	**0.04**	**0.20**	**0.14**	**0.04**	**2.2**
Amendment	0	104.1	37.4	141.5	89.0	16.8	130.6
	Organic manure	107.4	37.7	145.1	91.9	16.1	127.0
	Clay	110.4	41.5	151.9	94.4	15.2	124.5
	CaCO3	108.4	40.5	148.9	92.7	15.6	123.3
LSD at 5%		**0.04**	**0.03**	**0.07**	**0.04**	**0.02**	**0.7**

Whereas, plants of Great Lakes had greater contents of chlorophyll b, ascorbic acid and NO_3. This held true in both growing seasons. The variation of such metabolic products appears to be a varietal character. These results are in accordance with those obtained by Ali (1995), who reported significant differences in such metabolic products between Balady and Green Dark lettuce cultivars.

Sludge rate effect: From Table (45), it is evident that photosynthetic pigments indicate a progressive increase of the pigments (chlorophyll a, b and total as well as carotene) in association with the increased rate of sludge up to 45 ton/fad. In contrast, both ascorbic acid and NO_3 gradually decreased as sludge rate increased up to 45 ton/fad. Similar trends were obtained in both growing seasons. This reflects the enhancing effect of sewage sludge on photosynthesis and consequently on plant production. This may be due to the occurrence of N as a major component in the sewage sludge which play an effective role in this regard. This conclusion is in accordance with that of Lehr *et al.* (1962) who emphasized that nitrogen deficieny lowered chlorophyll content of leafy plant crops.

Amendment effect: It is clear from the data shown in Table (45) that all of the amendments applied i.e., organic manure, clay and $CaCO_3$ increased the photosynthetic pigments content (chlorophylls and carotene). On the contrary, ascorbic acid and NO_3 content were reduced according to the amendment application. This holds true in both growing seasons. The effect of these amendments on such parameters were well decumented in the previous experiments.

Interaction effect: Table (46) shows data on the interaction effect of cultivar, sludge application rate and soil amendments on photosynthetic pigments, ascorbic acid and nitrate content of lettuce leaves.

Each of the variables tested was significantly affected by the triple interaction during both seasons of this experiment.

Table (46) **The interaction effect of cultivar, Sludge rate and soil amendments on photosynthetic pigments (mg/100 mg DW), ascorbic acid (mg/100 gm FW) and nitrate (mg/100 gm DW) of lettuce leaves.**

Season		1994/95				1995/96			
Sludge rate ton /fad.	Amendment	Total Chlorophyll	Carotene	Ascorbic acid	NO_3	Total Chlorophyll	Carotene	Ascorbic acid	NO_3
		Balady cv.							
0	0	145.04	87.89	18.22	162.90	132.37	83.49	15.24	135.75
	OM	153.50	92.99	17.26	155.95	140.09	88.34	16.51	129.96
	Clay	158.64	95.99	16.82	152.76	144.79	91.19	14.84	127.30
	CaCO3	161.87	98.82	15.92	145.00	147.68	93.88	14.48	120.83
15	0	152.15	91.53	17.45	154.81	138.90	86.95	16.28	129.01
	OM	158.78	96.39	16.94	153.67	144.89	91.57	16.36	128.06
	Clay	153.50	100.36	16.13	149.91	149.13	95.34	14.43	124.92
	CaCO3	164.32	101.17	14.88	143.64	149.86	96.11	14.72	119.70
30	0	154.52	92.50	17.00	153.44	141.08	87.88	16.89	127.87
	OM	168.44	101.74	15.75	149.56	153.74	96.65	17.58	124.63
	Clay	170.41	103.11	14.27	157.54	155.52	97.96	14.71	131.28
	CaCO3	173.94	105.46	13.63	138.39	158.73	100.19	17.25	115.30
45	0	153.14	92.26	16.17	152.98	139.79	87.65	15.49	127.48
	OM	163.61	99.06	16.04	151.39	149.32	94.11	17.26	126.16
	Clay	167.35	100.92	15.55	147.97	152.76	95.88	16.18	123.31
	CaCO3	169.00	101.90	14.08	126.31	154.26	96.80	16.35	105.26
		Great Lakes cv.							
0	0	150.18	90.15	19.62	166.21	137.11	85.65	17.85	135.51
	OM	152.67	91.37	18.62	162.79	139.40	86.80	16.59	135.66
	Clay	157.04	94.69	17.92	155.38	143.34	89.95	15.48	129.48
	CaCO3	161.84	97.85	17.12	151.84	147.71	92.96	15.92	126.53
15	0	154.65	92.83	18.28	164.04	141.19	88.18	16.36	136.70
	OM	156.00	94.28	18.05	153.90	142.38	89.57	16.51	128.25
	Clay	160.38	97.69	17.15	152.98	146.33	92.80	16.39	127.48
	CaCO3	162.91	99.23	16.66	146.60	148.65	94.27	16.87	122.17
30	0	158.41	93.40	17.90	161.65	144.73	88.72	16.49	134.71
	OM	162.61	96.07	17.46	151.16	148.55	91.26	17.31	125.97
	Clay	169.00	100.44	16.53	147.40	154.35	95.42	17.29	1228.3
	CaCO3	173.47	102.39	15.20	135.66	158.48	97.27	16.30	113.05
45	0	155.40	92.34	18.06	162.10	141.93	87.72	17.27	135.08
	OM	160.22	94.93	17.68	152.98	146.35	90.18	16.42	127.48
	Clay	166.58	99.06	16.86	148.43	152.14	94.11	15.47	123.69
	CaCO3	168.81	99.63	15.92	141.17	154.22	94.65	14.38	118.08
LSD at 5%		*0.2*	*0.1*	*0.1*	*2.2*	*0.2*	*0.1*	*0.1*	*1.9*

OM = Organic manure

Table (46) **The interaction effect of cultivar, Sludge rate and soil amendments on photosynthetic pigments (mg/100 mg DW), ascorbic acid (mg/100 gm FW) and nitrate (mg/100 gm DW) of lettuce leaves.**

Season		1994/95				1995/96			
Sludge rate ton /fad.	Amendment	Total Chloro-phyll	Caro-tene	Ascor-bic acid	NO_3	Total Chloro-phyll	Caro-tene	Ascor-bic acid	NO_3
		Balady cv.							
0	0	145.04	87.89	18.22	162.90	132.37	83.49	15.24	135.75
	OM	153.50	92.99	17.26	155.95	140.09	88.34	16.51	129.96
	Clay	158.64	95.99	16.82	152.76	144.79	91.19	14.84	127.30
	CaCO3	161.87	98.82	15.92	145.00	147.68	93.88	14.48	120.83
15	0	152.15	91.53	17.45	154.81	138.90	86.95	16.28	129.01
	OM	158.78	96.39	16.94	153.67	144.89	91.57	16.36	128.06
	Clay	153.50	100.36	16.13	149.91	149.13	95.34	14.43	124.92
	CaCO3	164.32	101.17	14.88	143.64	149.86	96.11	14.72	119.70
30	0	154.52	92.50	17.00	153.44	141.08	87.88	16.89	127.87
	OM	168.44	101.74	15.75	149.56	153.74	96.65	17.58	124.63
	Clay	170.41	103.11	14.27	157.54	155.52	97.96	14.71	131.28
	CaCO3	173.94	105.46	13.63	138.39	158.73	100.19	17.25	115.30
45	0	153.14	92.26	16.17	152.98	139.79	87.65	15.49	127.48
	OM	163.61	99.06	16.04	151.39	149.32	94.11	17.26	126.16
	Clay	167.35	100.92	15.55	147.97	152.76	95.88	16.18	123.31
	CaCO3	169.00	101.90	14.08	126.31	154.26	96.80	16.35	105.26
		Great Lakes cv.							
0	0	150.18	90.15	19.62	166.21	137.11	85.65	17.85	135.51
	OM	152.67	91.37	18.62	162.79	139.40	86.80	16.59	135.66
	Clay	157.04	94.69	17.92	155.38	143.34	89.95	15.48	129.48
	CaCO3	161.84	97.85	17.12	151.84	147.71	92.96	15.92	126.53
15	0	154.65	92.83	18.28	164.04	141.19	88.18	16.36	136.70
	OM	156.00	94.28	18.05	153.90	142.38	89.57	16.51	128.25
	Clay	160.38	97.69	17.15	152.98	146.33	92.80	16.39	127.48
	CaCO3	162.91	99.23	16.66	146.60	148.65	94.27	16.87	122.17
30	0	158.41	93.40	17.90	161.65	144.73	88.72	16.49	134.71
	OM	162.61	96.07	17.46	151.16	148.55	91.26	17.31	125.97
	Clay	169.00	100.44	16.53	147.40	154.35	95.42	17.29	1228.3
	CaCO3	173.47	102.39	15.20	135.66	158.48	97.27	16.30	113.05
45	0	155.40	92.34	18.06	162.10	141.93	87.72	17.27	135.08
	OM	160.22	94.93	17.68	152.98	146.35	90.18	16.42	127.48
	Clay	166.58	99.06	16.86	148.43	152.14	94.11	15.47	123.69
	CaCO3	168.81	99.63	15.92	141.17	154.22	94.65	14.38	118.08
LSD at 5%		*0.2*	*0.1*	*0.1*	*2.2*	*0.2*	*0.1*	*0.1*	*1.9*

OM = Organic manure

Data reveal that the most important factor in this respect was soil amendment application, which had a favourable effect on increasing pigments content and decreasing the NO_3 accumulation in plant leaves of both cultivars used in this experiment . It is noticeable that ascorbic acid tended to be decreased with the application of soil amendments in plants of both cultivars grown under sludge amended soil.

Table (46) indicates that the highest values recorded in plant leaves resulted from the combinations as follows: Balady cultivar + 30 ton sludge/fad.+ $CaCO_3$ for total chlorophyl! and carotene, Balady cultivar + 0 ton sludge/fad.+ none amendments for ascorbic acid. As for NO3, leaves of Balady cultivar plants grown on soil supplemented with sludge at the rate of 45 ton/fad + CaCO3 induced the least NO3 content amog all studied treatments.

B. Amino acids:

The effect of the high sludge application level added to the soil (45 ton/fad.) on the free amino acids content of the two studied cultivars is illustrated in Table (47). It appears from such data that at the addition of (45 yon/fad.) an increase of the total free amino acids content of plant leaves was observed. This held true in case of both cultivars,whereby they showed a great significant differences inbetween regarding all tested amino acids. The increase in the total free amino acid content was amounted to be 35% and 20% for the Balady and Great Lakes cultivars, respectively over its control treatment and a much more pronounced effect was observed for aspartic, glutamic, phenyle-alanine and proline acids, whereby, its values differed significantly. This held true for both cultivars tested. With respect to histidine acid in the Balady cultivar, it was greatly depressed..

Such effects were concluded by Kastori *et al.* (1992), who investigated the effect of 10^{-4} or 10^{-6} M of Cd, Cu, Pb or Zn in solution

Table (47) Effect of sludge application on various amino acids content (mg/100 gm DW) in leaves of two lettuce cultivars.

Treatment / Amino Acid	Balady cv. Sludge treatment		Great Lakes cv.# Sludge treatment	
	(0) ppm	45 ton/fad	(0) ppm	45 ton/fad
aspartic acid	8.88	16.69*	10.43	20.49**
serine	11.18	17.94*	14.68	18.09*
threonine	5.05	7.32*	6..92	9.38*
glycine	3.55	3.75	3.85	3.95
glutamic	11.96	25.57**	16.47	19.67*
alanine	7.97	8.34	8.26	8.92
tyrosine	3.16	3.59	2.98	3.47
proline	3.06	9.07**	6.85	13.59**
leucine	8.29	9.62*	10.86	10.39
valine	11.98	8.83*	15.26	19.91*
methionine	4.18	3.28*	3.71	2.86*
phenyle-alanine	11.36	20.19**	18.36	26.27*
histidine	8.03	5.81**	6.74	6.98
amonia	6.17	5.19*	9.45	16.27*
arganine	9.53	9.79	9.36	9.38
lysine	8.31	7.95	8.12	16.17*
Total	122.66	163.93*	152.21	181.79*

All the variables are highly significant due to cultivar

* Significance within each cultivar

** Highly significance within each cultivar

culture on water relations, amino acids and protein contents in sunflower cv. NS-H-26 RM. They found that the concentration of free proline was significantly increased in the leaves of intact plants as well as in leaf discs incubated in the presence of heavy metals, while, the concentration of soluble proteins was decreased particularly at 10^{-4}M. It was concluded that excess concentrations of the heavy metals significantly affected plant water status, causing water deficit and subsequent changes in plant metabolism.