تراكم العناصر الثقيلة في بعض نباتات قطاع غزة–فلسطين والخواص الفسيولوجية لنبات السبانخ

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الملخص:

تمت هذه الدراسة بهدف تقييم بعض العناصر الثقيلة (كادميوم, رصاص, زنك وحديد) في التربة وبعض نباتات شمال قطاع غزة– فلسطين المزروعة عشوائيا في تلك المناطق. ولقد أظهرت نتائج هذه الدراسة أن تركيز هذه العناصر في التربة، وكذلك في النباتات، كان في الحدود المسموح بها عالميا بإستثناء عنصر الرصاص الذي كان مرتفعا وقد فاق الحدود المسموح بها في منطقة المنطار ومركز مدينة غزة. كما استهدف هذا البحث دراسة تأثير تلوث التربة بالكادميوم والزنك على صفات النمو المختلفة والصبغات النباتية لنبات السبانخ المزروع في أصص. ولقد أظهرت نتائج هذه الدراسة أن إضافة الكادميوم أدت إلى تقليل معظم صفات النمو المدروسة وكذلك تقليل تركيز كلوروفيل أ وتركيز العناصر. كما أن إضافة الزنك مع الكادميوم قد أدت إلى تقليل سمية الكادميوم لمعظم صفات النمو المدروسة. كما لوحظ أن للزنك تأثيراً ايجابياً على معظم صفات النمو والصبغات النباتية ، عند استخدامه منفرداً– باستثناء كلوروفيل ب – وعلى تركيز العناصر حيث ارتفع تركيزها باستثناء انخفاض تراكم عنصر الكادميوم.

Journal of the Association of Arab Universities for Basic and Applied Sciences (2011) **10**, 21–27

University of Bahrain
Journal of the Association of Arab Universities for Basic and Applied Sciences
www.elsevier.com/locate/jaaubas
www.sciencedirect.com

ORIGINAL ARTICLE

Accumulation of heavy metals in crop plants from Gaza Strip, Palestine and study of the physiological parameters of spinach plants

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Available online 22 July 2011

KEYWORDS
Heavy metals accumulation;
Cadmium;
Zinc;
Spinach plant;
Physiological parameters;
Soil

Abstract Measurements of Pb, Zn, Cd and Fe concentrations in the soils and accumulation in edible parts of several crop plants (spinach, wheat, strawberry, carrot, onion, squash, cabbage, potato, faba bean and cucumber) grown in three sites of the northern area of Gaza Strip, Palestine, revealed: (1) Concentrations of metals were in normal range in soil, except for lead concentrations which in some samples were higher, especially in the sites of Al-Monttar and Gaza city center. (2) Accumulation of heavy metals by the crop plants was within normal ranges, except for lead concentration which exceeded normal ranges, yet not reaching toxic levels in all plants but the onion bulb which reached toxic level. (3) Cadmium was concentrated at equal levels in different soil samples, while its accumulation in plant samples was very low and sometimes was not detectable. Measurements of physiological attributes of spinach plants revealed: (1) Growth characters such as root length, shoot height, fresh and dry weights of shoot and root were decreased with increasing Cd soil addition either alone or combined with Zn soil addition at all levels. (2) Plant pigments such as chlorophyll a, chlorophyll b and total carotenoids significantly decreased, with increasing Cd soil addition either alone or combined with Zn at all levels, except for chlorophyll a which increased with increasing Zn soil addition, with some exceptions. (3) Zn addition was highly correlated to growth characters, as well as when combined with Cd at different levels may be overcome the toxicity of Cd on growth characters, mineral concentrations and chlorophyll a content.

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Peer review under responsibility of University of Bahrain.
doi:10.1016/j.jaubas.2011.06.001

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1. Introduction

The Gaza strip–Palestine area is about 360 km^2. It is situated in the south part of Palestine and southeast of the Mediterranean sea. An estimate of 1.6 million people live in the Gaza Strip. This area, being one of the most densely populated areas in the world with limited and deteriorated resources, has already started to suffer the consequences of environment quality deterioration. The situation at the Gaza Strip is below the desired standard, which is attributed to the absence of environmental legislation and public awareness. One of the most important air pollutants near the city center of Gaza is thousands of motor vehicles commuting every day. Trace metals released in the environment may be considered a hazard to the natural biological system and human health. Plant and soil surfaces are the major sink for airborne metal. Moreover, plants form the basis of food chains by which bio-toxic trace metals are transmitted to man (Alfani et al., 1996).

Improvement of the nutritional quality of our food supply, especially with respect to essential nutrient minerals, could be an important goal of vegetable crops. Cd is classified as probable human carcinogen by inhalation; however, only limited data are available to determine if it causes cancer in humans. The total Zn content in adult human tissue is 2–4 g. The daily requirement of 6–22 mg is provided by a normal diet. Salim et al. (1992) treated the carrot plants by Cd and Pb foliar or root application of 0, 10 and 90 ppm Cd and 0, 18 and 80 Pb. Cd toxicity was more obvious than Pb toxicity and these symptoms were more severe in foliar treated than in root treated plants. Cd application decreased the dry weight of whole plants, shoot and roots, when compared with untreated control plants. William et al. (1977) reported that Cd in soils may be unavailable to plants by the application of hydrated lime and consequently involves the infection of toxicity. Liming is effective because cadmium probably forms an insoluble precipitate with hydroxide and thus becomes unavailable to plants. Somashekaraish et al. (1992) suggested that the inhibition of chlorophyll synthesis by Cd is achieved both by reaction with constituent biosynthetic enzymes as well as peroxide mediated degradation.

Zinc plays essential metabolic roles in the plant, the most significant of which is its activity as a component of a variety of enzymes, such as dehydrogenases, proteinases, peptidases and phosphohydroleases. Other functions related to the metabolism of carbohydrates, proteins, phosphates, RNA and ribosome formation. Baccio et al. (2005) have pointed out that transition metals such as Zinc are essential micronutrients for many physiological processes, but they become toxic at elevated levels, Zinc is one of the most abundant trace heavy metals present in agro-ecosystems. Misra et al. (1994) have mentioned that when *Vicia faba* seeds are treated with 0–10 mg l^{-1} solution of Zn chloride, Zn treatment increases its radical length at low concentrations, but are inhibitory at high concentrations.

The aim of this research was to study the elemental (Pb, Zn, Cd and Fe) concentration on different soils in three sites of the northern area of Gaza Strip, Palestine. The ability of some crop plants (spinach, wheat, strawberry, carrot, onion, squash, cabbage, potato, faba bean and cucumber) grown in the above soils to accumulate different metals was studied. Effects of different levels of Zn and Cd soil addition on the morphological parameters (root length, shoot height, fresh and dry weights of shoot and root, plant pigments such as chlorophyll a, chlorophyll b and total carotenoids) of spinach plants were also examined.

2. Materials and methods

Plant and soil samples were collected in 2006 from the Northern area (120 km^2) of the Gaza Strip, Palestine. The study area has several anthropogenic influences which could be divided into three different sites, (industrial, urban and rural site (Fig. 1), all lying between Israeli borders and the Mediterranean sea. Four samples were collected from each site of the study area, (A, B and C, Fig. 1). Samples of spinach, wheat, strawberry and carrot were collected from Beit-Hanon and Beit-Lahya, industrial and rural site (A). Onion, squash, spinach and cabbage were collected from Al-Monttar and Gaza City Center, industrial and urban site (B). Potato, carrot, faba bean and cucumber were collected from Al-Zytoon and Shakh Ejleen, rural and urban site (C).

All plant samples were taken at the flowering stage, were washed in water, dipped in distilled water and divided into their parts. They were then oven-dried at 70 °C for two days. Soil samples were also oven-dried at 40 °C for two days. Available Fe, Pb, Zn and Cd were extracted by DTPA according to Lindsay and Norvell (1978) and estimated by Atomic Absorption Spectrophotometer GBC 939.

Plastic pots of 80 cm length, 20 cm width and 25 cm depth were used at the pot experiments which carried out in the open field of the Agriculture Research Center (Ministry of Agriculture), Beit-Lahya City, during two successive seasons (2006 and 2007). Each pot was filled with 25 kg soil obtained from the Agriculture Research Center. Spinach seeds (*Spinacea oleracea* var. balady) were used, sown on the 17th of February in the first season (2006) and in the 18th of January in the second season (2007). Each pot received 22 g of ammonium sulfate, 18 g of potassium sulfate and 15 g of calcium superphosphate. The fertilizers were applied to the plants as soil dressing at three doses/season, the first dose was 15 days after seedling emergence and the second and the third dose were applied 15 days in time intervals.

In the second season, before seed sowing, four levels of Cd (0, 10, 20 and 40 mg kg^{-1}) were added to the soil, in contrast to the first season, where three levels of Cd (10, 20 and 40 mg kg^{-1}) were added in the form of cadmium sulphate salt. The pots were divided into four groups in the second season and into three groups in the first season. The first group received the normal level of fertilizers as mentioned above, but

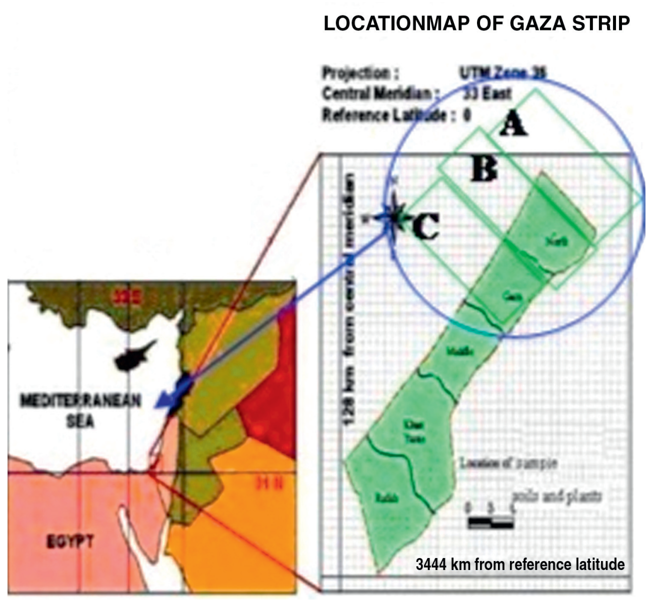

Figure 1 The three sampling sites at the northern area of the Gaza Strip, Palestine.

without any other soil additions. The second, third and fourth group were similar to the first group but the pots received Zn with the soil addition before sowing in the form of Zinc sulphate at the rates (0, 100, 200 and 400 mg kg^{-1}). Therefore, there were three and four levels of Cd soil addition in the first and second season respectively, while four levels of Zn soil addition in the two seasons served as sub-treatment. Sixteen treatments in the second season and 12 treatments in the first season were examined. Two samples were taken from each treatment after 30 and 60 days from sowing and the plant was divided into roots and leaves. The following measurements were recorded: root length (cm), shoot height (cm), fresh and dry weights of the shoot and root (g) and leaf area were estimated in the two seasons, according to the methods described by Hunt (1978). Fe, Zn, and Cd were determined in the two samples (70 and 140 days after sowing) for root and shoot in the 2nd season. Chlorophyll and total carotenoids (mg/g FW) were extracted from the fresh leaves of plants by acetone 80% and were calorimetrically determined according to the method described by Hoyden (1965). Data were statistically analyzed by using factorial experiments and the means of different treatments were compared using the least significant different test (L.S.D.) at 0.05 level of probability in the two samples as average of two successive seasons (Snedecor and Cochran, 1980).

3. Results and discussion

3.1. Bioaccumulation of heavy metals in crop plants

Data in Table 1 reveal that in site A (Beit Hanoun and Beit Lahya site), the extractable mean values of heavy metals (Pb, Zn, Cd and Fe) were 9.9, 41.2, 0.0075 and 333.6 mg kg^{-1}, in site B (Monttar and Gaza City Center site) 20.9, 42.9, 0.0075 and 186.0 mg kg^{-1}, while in site C (Al Zytone and Shakh Ejleen site), 16.3, 53.9, 0.00 and 248.9 mg kg^{-1}, respectively. Similar results were obtained by Shomar (2006) for all metals except for Fe. The author mentioned that in the open farm soils of the Gaza Strip the total Pb, Zn, Cd and Fe concentrations were 32, 50, 0.0052 mg kg^{-1} and 2.2% respectively, while metal concentrations in the strawberry farm soils of the Gaza Strip were 61, 60, 0.0067 mg kg^{-1} and 1% for iron, respectively (1% = 10.000 ppm). The concentration of heavy metals (Cd, Zn, Pb and Fe) are in the normal range in soils, except concentration of lead in some samples which were higher especially in area **B** (Al Montar and Gaza Center) as well as the concentration of iron in area **A** (Beit Hanon and Beit Lahya).

As far as the heavy metals concentration in the plants growing in the study area is concerned, data in Table 1 indicate that Pb concentration in plants is dependent on plant organs. The highest concentration of Pb in site A was 22.1 mg kg^{-1}, recorded in the root of carrots, while the lowest concentration was 12.1 mg kg^{-1}, recorded in strawberry (fruit). Pb concentration in the edible parts of the plants studied can be arranged in the following order: carrot (root), spinach (leaves), wheat (shoot) and strawberry (fruit). Moreover, the highest Pb concentration in site B was 95.0 mg kg^{-1} and was detected in the bulb of the onion, while the lowest concentration (0.11 mg kg^{-1}) was recorded in spinach leaves. Values can be arranged in the following order according to Pb concentration in site B: onion (bulb), cabbage (leaves), squash (fruit) and spinach (leaves). At site C, the highest Pb concentration (12.5 mg kg^{-1}) was recorded in potato tuber, while the lowest Pb concentration (10.1 mg kg^{-1}) was detected in cucumber (fruit). The values of Pb concentration in site C can be arranged in the following order: potato (tuber), faba bean (seeds), carrot (root) and cucumber (fruit). In this respect, one may argue that the highest Pb concentration is recorded in root, bulb and tuber, when compared with another parts of plants (leaves, fruit and seeds). Moreover, it is important to mention that the increase in Pb concentration in the different organs of plants among the three different sites can be arranged in the following order: onion bulb, carrot roots, wheat shoots, potato tuber, strawberry fruit, faba bean seeds, cucumber fruit, spinach leaves, cabbage leaves and squash fruit. In this respect, Bowen (1997) reported that the normal range of Pb in edible vegetables range between 0.20 and 20 mg kg^{-1}. Thus, based on these data, it can be suggested that Pb

Table 1 Heavy metal concentration (mg kg^{-1}) in the soil and plants growing in the study area.

Study areas	Sites	Name and organs of plant	Metals concentration (mg kg^{-1})							
			Plants (dry matter)				Soils			
			Pb	Zn	Cd	Fe	Pb	Zn	Cd	Fe
Beit Hanon and Beit Lahya	A1	Spinach (leaves)	15.5	32.0	0.0000	19.4	18.1	46.8	0.0200	711.0
	A2	Wheat (shoot)	13.1	90.3	0.0200	13.5	6.5	38.7	0.0000	412.0
	A3	Strawberry (fruit)	12.1	33.2	0.0000	78.3	8.9	34.7	0.0000	112.0
	A4	Carrot (root)	22.1	25.6	0.0100	114.0	6.0	44.7	0.0100	99.4
Mean A			15.7	45.2	0.0075	56.3	9.8	41.2	0.0075	333.6
Monttar and Gaza City Center	B1	Onion (bulb)	95.0	33.2	0.0200	55.3	5.8	54.6	0.0300	447.2
	B2	Squash (fruit)	1.12	54.2	0.0300	66.0	20.1	51.2	0.0000	111.2
	B3	Spinach(leaves)	0.11	25.4	0.0000	65.2	24.5	5.80	0.0000	71.0
	B4	Cabbage(leaves)	1.21	33.2	0.0100	114.0	33.2	60.1	0.0000	115.5
Mean B			24.3	36.5	0.0150	75.1	20.9	42.9	0.0075	186.0
Al Zytoon and Shahk Ejleen	C1	Potato (tuber)	12.5	41.5	0.0400	54.0	12.2	41.2	0.0000	211.0
	C2	Carrot (root)	11.1	42.0	0.0000	88.0	14.2	55.5	0.0000	324.2
	C3	Faba bean (seed)	11.2	32.7	0.0000	22.4	22.5	65.2	0.0000	211.5
	C4	Cucumber (fruit)	10.1	30.1	0.0100	41.0	–	–	–	–
Mean C			11.1	36.7	0.0120	51.3	16.4	53.9	0.0000	248.9

concentration in all plants grown in the study area were within the normal range except for onions and carrots which accumulated Pb up to the normal concentration range.

It is clear from the results in Table 1 that the levels of Zn concentration in the studied plants grown in site A could be arranged in the following order: wheat shoot, strawberry fruit, spinach leaves and carrot root; yet, in site B it can be arranged in the following order; squash fruit, onion bulb, cabbage leaves, spinach leaves, while in site C it can be arranged in the following order: carrot root, potato tuber, faba bean seed and cucumber fruit. However, it is important to mention that the uptake of Zn depends on plant species and their plant parts. Moreover, the data revealed that leaves of some plant and root of another plant contained the highest values of Zn compared with other plants parts. It is reported that the normal Zn range in the plant is 8–400 mg kg^{-1}, while the toxic level is above 400 mg kg^{-1} (Kabata Pendias and Pendias, 1984). Therefore, it can be suggested that Zn concentration in all plants grown in the study areas was within the normal range.

It is also clear from the results in Table 1 that the levels of Fe concentration in the different parts of plants grown in site A can be arranged in the following order: carrot root, strawberry fruit, spinach leaves and wheat shoot. In site B Fe concentration level can be arranged in the following order: cabbage leaves, squash fruit, spinach leaves and onion bulb, while in site C it can be arranged in the following order: carrot root, potato tuber, cucumber fruit, faba bean seed. In this respect, Das (2000) reported that the normal iron level in plants is between 50 and 250 mg kg^{-1}. Therefore, it can be suggested that Fe concentration in all plants grown in the study areas was within the normal range.

Results in Table 1 indicated that Cd concentration in wheat shoot and carrot root of the plants grown in site A 0.02 and 0.01 mg kg^{-1}, respectively. In site B, though, Cd concentrations were 0.02, 0.03 and 0.012 mg kg^{-1} in onion bulb, squash fruit and cabbage leaves, respectively, while in site C the concentrations were 0.04 and 0.01 mg kg^{-1} for potato tuber and cucumber fruit, respectively. However, Cd could not be detected in the other plants. Kabata Pendias and Pendias (1984) have reported that the Cd concentration in contaminated plants ranges between 5 and 30 mg kg^{-1}, therefore, Cd concentration in all plants grown in the three different study sites was within the normal range.

3.2. The effect of Zn and Cd on spinach plants

The effect of heavy metals (Cd and Zn) on growth, yield and chemical composition of spinach plants as well as the

Table 2 Root length, shoot height (cm), leaf area, fresh and dry weight (g) of whole spinach plant of the second season in the two samples (30 and 60 days after sowing) as affected by different levels of Cd and Zn soil additions.

Growth character		30					60				
Plant age(days)	Treatment	Control	Zn1	Zn2	Zn3	Mean Cd	Control	Zn1	Zn2	Zn3	Mean Cd
Root length (cm)	Control	11.80	13.37	14.90	12.10	13.04	16.00	17.97	18.47	14.57	16.75
	Cd1	10.73	12.50	11.07	10.67	11.24	13.70	15.20	16.03	14.63	14.89
	Cd2	9.47	9.93	9.43	9.80	9.66	12.20	14.17	12.93	14.13	13.36
	Cd3	8.40	9.23	9.17	9.10	8.98	10.17	12.23	13.17	11.43	11.75
	Mean Zn	10.10	11.26	11.14	10.42		13.02	14.89	15.15	13.69	
	L.S.D. 0.05	Cd = 2.55Zn = NS Cd * Zn = 3.87					Cd = 1.55Zn = 1.55Cd * Zn = 2.20				
Shoot height (cm)	Control	21.2	22.3	23.9	22.2	22.4	29.6	31.60	32.7	27.0	30.2
	Cd1	18.5	16.5	19.0	19.5	18.4	25.8	28.3	25.8	27.1	26.7
	Cd2	12.9	16.9	17.7	19.4	16.7	22.9	26.2	24.9	23.3	24.4
	Cd3	12.1	14.0	16.1	15.9	14.5	15.8	24.9	23.9	21.8	21.6
	Mean Zn	16.2	17.4	19.2	19.2		23.5	27.77	26.8	24.8	
	L.S.D. 0.05	Cd = 5.60Zn = NS Cd * Zn = 7.90					Cd = 2.48Zn = 2.48 Cd * Zn = 3.53				
Leaf area	Control	325.5	374.7	429.8	334.9	366.2	1080.0	1306.3	1355.2	1135.5	1219.2
	Cd1	263.70	327.4	251.3	297.8	285.0	856.9	1221.0	1146.6	1054.5	1069.7
	Cd2	217.6	278.0	258.3	251.8	251.4	679.3	877.2	1101.1	1035.1	923.2
	Cd3	159.2	282.00	205.8	193.1	210.0	830.6	945.4	790.3	906.5	868.2
	Mean Zn	241.5	315.5	286.3	269.4		861.7	1087.5	1098.3	1032.9	
	L.S.D. 0.05	Cd = 122.1Zn = 122.1 Cd * Zn = 173.6					Cd = 136.6 Zn = 136.6 Cd * Zn = 194.3				
Fresh weight (g)	Control	14.38	14.60	14.01	12.42	13.85	33.16	36.34	37.91	31.01	34.6
	Cd1	11.96	12.74	12.36	11.81	12.22	26.35	33.75	31.79	31.59	30.87
	Cd2	10.39	12.35	10.93	10.25	10.98	21.06	27.15	28.81	24.90	25.48
	Cd3	9.13	10.80	10.06	9.67	9.91	17.36	23.68	26.62	25.16	23.20
	Mean Zn	11.46	12.62	11.84	11.04		24.48	30.23	31.28	28.16	
	L.S.D. 0.05	Cd = 3.49 Zn = NS Cd * Zn = 4.96					Cd = 3.43 Zn = 3.43 Cd * Zn = 4.89				
Dry weight (g)	Control	1.241	1.219	1.379	1.049	1.222	3.98	4.39	4.57	3.56	4.12
	Cd1	0.870	1.065	0.952	0.970	0.964	2.96	3.76	3.83	3.20	3.44
	Cd2	0.716	0.912	0.833	0.732	0.798	2.40	3.06	3.40	2.93	2.94
	Cd3	0.605	0.836	0.749	0.706	0.724	1.90	2.96	3.16	2.64	2.66
	Mean Zn	0.858	1.008	0.978	0.864		2.81	3.54	3.74	3.08	
	L.S.D. 0.05	Cd = 0.402 Zn = NS Cd * Zn = 0.572					Cd = 0.51 Zn = 0.51 Cd * Zn = 0.72				

Zn1 = 100 mg kg^{-1}, **Zn2 = 200** mg kg^{-1}, **Zn3 = 400** mg kg^{-1}**. Cd1 = 10** mg kg^{-1}, **Cd2 = 20** mg kg^{-1}, **Cd3 = 40** mg kg^{-1}.

interaction between Cd and Zn in plants, at pot experiments, were also examined. Moreover, attempts were made to reduce the toxicity effect of Cd by using different rates of Zn. Growth of spinach at the different ages (30 and 60 days after sowing) was measured by recording root length, shoot height, fresh and dry weights of the shoot, root and leaf area. At harvesting, yield and yield components were recorded. It is worthy mentioning that during the two seasons plants showed similar response to Cd and Zn soil additions, either alone or in combination.

Table 2 clearly demonstrates that Cd soil addition, either alone or combined with Zn, gradually and significantly decreased all of the studied growth characters. Reduction significantly increased when increasing the addition of Cd soil, either alone or combined with Zn, in order to reach its maximum reduction at the highest Cd level of (40 mg kg^{-1}) in the two samples of two seasons, with some exceptions being reported. Similar results have been observed for spinach (El Nabarawy, 2002) and carrot plants (Salim et al., 1992).

Data in Table 2 indicated that at the three levels of Zn all of the studied growth characters significantly increase, except for the fresh and dry weight of shoot, root and whole plant and root length, shoot height in the first sample, which were not significantly affected when compared to the control Zn-untreated plants. In this respect, Zn is an essential component of over 300 enzymes (Fox and Guerimot, 1998). In most of these enzymes, Zn constitutes an integral of the enzyme structure. It is important to mention that for both seasons, the lowest parameter values were monitored on the plants treated with the highest rate of Zn, alone or combined with Cd soil addition, as compared to the plants treated with the lowest rate of Zn alone, or plants treated with the three different rates of Cd. In this respect, Abd El Aziz et al. (1987) working on faba bean mentioned that increasing Zn soil addition from 0.5 to 1.0 kg generally reduced dry weight of shoot. It might be suggested that the favorable effect of Zn soil application on plant growth as well as the detrimental effect of high Zn soil addition might be attributed to its effect on enzymatic systems responsible for the biosynthesis of amino acid, protein, chlorophyll and photosynthesis.

Data in Table 3 reveals that, the concentration of all of the plant pigments (chlorophyll a, chlorophyll b and total carotenoids) significantly decreased with increasing Cd soil addition, either alone or combined with Zn at all levels. Concentrations of the total carotenoids in the two samples of the first season and chlorophyll b in the first sample of the first season were not significantly affected, as compared to the control untreated-Cd plants, with some exceptions. In this connection, Bazzaz and Govindjee (1974) reported that Cd adversely affects the emerge producing mechanisms of chloroplasts and mitochondria.

Moreover, all plant pigments (chlorophyll a and b) in the two samples significantly increased with increasing Zn soil addition, but chlorophyll b in the two samples of the second season which was not significantly affected, while total carotenoids in the two samples of the two seasons were not significantly affected with increasing zinc soil addition, as compared to the control untreated-Zn plant. In this respect, Garg et al. (1986) reported that the application of Zn increased chlorophyll a and b concentration.

Concerning the effect of Cd soil addition on Cd concentration in the shoots of spinach plants, it is clear from the results in Table 4 that in the two successive samples, significant and gradual increases in Cd concentrations were recorded at the spinach shoot supplied with the three rates of Cd either alone or combined with Zn when compared to the control-untreated or the control-Cd untreated plants. Cutler and Rains (1974) working on barley found three passive mechanisms for Cd uptake: exchange absorption, irreversible binding and diffusion.

Concerning the Zn concentration in the spinach shoot, the results showed that in the second sample the shoot always

Table 3 Chlorophyll a and b as well as carotenoids concentrations (mg/g fresh weight) in the leaves of spinach plant in the two samples (30 and 60 days after sowing) as affected by different levels of Cd and Zn soil additions in the second season.

Plant age (days)		30					60				
Plant Pigment	Treatment	Control	Zn1	Zn2	Zn3	Mean Cd	Control	Zn1	Zn2	Zn3	Mean Cd
Chlorophyll a	Control	3.81	3.58	2.80	3.57	3.44	5.47	5.45	4.78	5.62	5.33
	Cd1	3.20	3.31	3.15	3.38	3.26	3.58	4.17	4.22	4.36	4.08
	Cd2	2.67	2.77	2.10	3.06	2.65	3.23	4.03	4.15	4.41	3.95
	Cd3	3.04	3.06	2.75	3.04	2.97	2.93	3.87	4.22	4.38	3.85
	Mean Zn	3.18	3.18	2.70	3.26		3.80	4.38	4.34	4.69	
	L.S.D.	Cd = 0.558Zn = 0.558Cd * Zn = 0.794					Cd = 0.662Zn = 0.662 Cd * Zn = 0.941				
Chlorophyll b	Control	1.330	1.150	1.160	1.470	1.278	1.607	1.813	1.557	1.853	1.708
	Cd1	1.180	1.120	1.087	1.010	1.099	1.480	1.540	1.477	1.603	1.525
	Cd2	0.940	1.113	1.120	1.340	1.128	0.920	1.250	1.367	1.623	1.290
	Cd3	1.427	1.263	1.387	1.357	1.358	1.313	1.490	1.287	1.227	1.329
	Mean Zn	1.219	1.162	1.188	1.294		1.330	1.523	1.422	1.577	
	L.S.D. 0.05	Cd = 0.219 Zn = NS Cd * Zn = 0.311					Cd = 0.289 Zn = NS Cd * Zn = 0.411				
Carotenoids	Control	1.457	1.413	0.790	1.387	1.262	1.413	1.837	1.270	1.537	1.514
	Cd1	1.357	1.230	1.047	1.297	1.233	1.443	1.343	1.293	1.143	1.306
	Cd2	1.027	1.053	0.927	1.263	1.068	0.803	1.327	1.320	1.013	1.116
	Cd3	1.293	1.067	0.943	1.057	1.090	1.247	1.133	1.137	1.417	1.233
	Mean Zn	1.283	1.191	0.927	1.251		1.227	1.410	1.255	1.278	
	L.S.D. 0.05	Cd = NS Zn = 0.197Cd * Zn = 0.2.79					Cd = 0.228Zn = NS Cd * Zn = 0.325				

Zn1 = 100 mg kg^{-1}, **Zn2 = 200** mg kg^{-1}, **Zn3 = 400** mg kg^{-1}. **Cd1 = 10** mg kg^{-1}, **Cd2 = 20** mg kg^{-1}, **Cd3 = 40** mg kg^{-1}.

Table 4 Cd, Zn and Fe concentrations (mg kg^{-1}) of spinach shoot in the two samples (30 and 60 days after sowing) as affected by different levels of Cd and Zn soil additions in the second season.

Plants age		30					60				
(Days)	Treatment	Control	Zn1	Zn2	Zn3	Mean Cd	Control	Zn1	Zn2	Zn3	Mean Cd
Cadmium (mg kg^{-1})	Control	1.15	1.44	1.44	1.11	1.28	1.88	1.88	2.32	2.02	2.03
	Cd1	4.93	3.55	5.47	6.39	5.08	9.07	8.91	8.20	8.75	8.73
	Cd2	5.06	5.78	7.42	6.96	6.30	8.25	9.91	8.48	7.33	8.49
	Cd3	6.66	6.53	6.85	7.80	6.96	8.72	8.59	8.71	8.76	8.70
	Mean Zn	4.45	4.32	5.29	5.56		6.98	7.32	6.93	6.72	
	L.S.D. 0.05	Cd = 1.64 Zn = NS Cd * Zn = 2.34					Cd = 1.45 Zn = NS Cd * Zn = 2.06				
Zinc (mg kg^{-1})	Control	27.0	57.4	63.0	58.0	51.4	30.5	57.0	54.5	59.0	50.3
	Cd1	22.5	55.0	53.5	59.0	47.5	29.0	30.5	40.0	47.5	36.8
	Cd2	26.5	58.5	60.0	51.0	49.0	27.0	36.5	58.5	53.5	43.9
	Cd3	25.0	55.0	57.5	52.0	47.4	25.5	29.5	42.0	57.0	38.5
	Mean Zn	25.3	56.5	58.5	55.0		28.0	38.4	48.8	54.3	
	L.S.D. 0.05	Cd = 0NS Zn = 4.8 Cd * Zn = 6.7					Cd = 7.8 Zn = 7.8 Cd * Zn = 11.1				
Iron (mg kg^{-1})	Control	58.0	69.5	74.5	71.5	68.4	71.0	94.0	77.0	85.0	81.8
	Cd1	50.5	59.5	75.5	62.5	62.0	62.0	89.5	71.5	72.5	73.9
	Cd2	44.5	64.5	74.0	62.5	61.4	57.5	69.0	75.5	86.0	72.0
	Cd3	33.0	57.0	62.0	75.5	56.9	46.0	68.0	73.5	91.5	69.8
	Mean Zn	46.5	62.6	71.5	68.0		59.1	80.1	74.4	83.8	
L.S.D. 0.05		Cd = 5.8 Zn = 5.8 Cd * Zn = 8.2					Cd = 5.5 Zn = 5.5 Cd * Zn = 7.8				

Zn1 = 100 mg kg^{-1}, **Zn2 = 200** mg kg^{-1}, **Zn3 = 400** mg kg^{-1}**. Cd1 = 10** mg kg^{-1}, **Cd2 = 20** mg kg^{-1}, **Cd3 = 40** mg kg^{-1}.

contained the highest values of Cd when compared with the values in the first sample. Thus, it can be suggested that the time of explosion is a very important factor for Cd uptake and accumulation in plants. Kabata Pendias and Pendias (1984) reported that cadmium concentration in contaminated plants ranges between 5 and 30 ppm.

The results in Table 4 reveal that the range of Cd concentration in the shoots of spinach plant treated with the three different rates of Cd alone (10, 20 and 40 mg kg^{-1}) was between 2.22 and 4.93 mg kg^{-1} in the first sample and between 8.73 and 9.06 mg kg^{-1} in the second sample. Thus, it can be concluded that Cd concentrations in the shoot of spinach Cd treated plant were within the normal range and not at a toxic level. It was concluded that when Cd soil was >22.3 mg /kg the yield, nutrient content as well as physiological and biochemical properties of mulberry leaves showed distinct change, and the damage became greater as cadmium concentration increased (Chen et al., 1996).

As regards the effect of Zn soil addition to Cd concentration in spinach shoots, it is clear from the results that, there was non significant affect in the second sample but in the first sample significant decrease of Cd concentration was obtained by the shoot of the spinach plant supplied with the lowest level of Zn treatments when compared with control plants untreated Zn. In this respect, it can be suggested that Zn soil addition may be overcome to some extent, the inhibition effects of Cd on absorption, accumulation and translocation within spinach plant. Similar results were reported by Choudhary et al. (1994) on wheat plant However, Dabin et al. (1978) concluded that Zn and Cd are bound to different legends in rice roots. Also, Zn was found in some cases to depress Cd uptake indicating some kind of interaction between these two metals. On the other hand, it is important to mention that as reported before high values of Cd concentration were obtained by the shoots of spinach plants supplied with the three different rates of Zn combined with the three different rates of Cd when compared with control-untreated plants or plants supplied with the same level of Zn or Cd soil addition, in this respect, it can be suggested that the effect of Zn soil addition on plant Cd concentration might depend on the concentration of Cd and Zn in the soil.

Concerning the effect of Cd and Zn soil addition to Zn concentration in spinach plants, the results in Table 4 indicated decrease in Zn concentrations by the shoot of spinach plant supplied with the three different rates of Cd soil addition either alone or combined with Zn in the second sample alone, while no significant affect on the first sample when compared with control-untreated plant or control-Cd untreated plant. Moreover, the results revealed that the range of Zn concentration in the shoots of spinach plants treated with the three different rates of Cd alone (10, 20 and 40 mg kg^{-1}) was between 22.5 and 25.0 mg kg^{-1} in first sample and between 25.5 and 29.0 mg kg^{-1} in the second sample. As regards the effect of Zn soil addition to zinc concentration in spinach plants, the results in Table 4 revealed that significant and gradual increases in Zn concentration were recorded by shoot of spinach plant supplied with the three different rates of Zn either alone or in combined with Cd soil addition when compared with control-untreated plants or plant supplied with Cd soil addition alone. Moreover, it is clear from the results, that Zn concentration in shoot of spinach plant was in accordance to its levels in soil. It has been reported by many researchers that certain essential heavy metals, such as Zn are taken into plant cells by metabolic mechanisms (Marschner, 1995).

Regarding the Zn concentration in the shoot of spinach plants the results in Table 4, one may notice that the range of Zn concentration in the shoots of spinach plants treated with the three different rates of Zn alone (100, 200 and 400 mg kg^{-1}) was between 57.4 and 58.0 mg kg^{-1} in the first sample and between 57.0 and 59.0 mg kg^{-1} in the second sample. The normal Zn level in plant dry weight is reported to be 8–400 mg kg^{-1}, while the toxic level is >400 mg kg^{-1} (Kabata

Pendias and Pendias, 1984). Thus, zinc concentration in the spinach shoot was within the normal rang regardless of zinc soil addition levels.

Data in Table 4 also indicate gradual decreases in Fe concentrations in the shoot of spinach plant supplied with the three different rates of Cd soil addition, either alone or combined with Zn in the two samples, when compared with control-untreated plants or plants supplied with the three different rates of Cd combined with any of the three different rates of Zn. In this respect, Siedlecka and Krupa (1999) report that Cd is one of the most dangerous environmental pollutants, it interacts with Fe modifying effects of deficient or excessive Fe supply. Their distribution, plant growth and photosynthesis are explained. Also, Fe transporters have been shown to be able to transport several metals including Cd in Arabidopsis (Korshunova et al., 1999). Moreover, Yang et al. (1996) reported that influx of Fe decreased with increasing external Cd levels, in maize plant grown with Cd up to 14 μM compared to control. Thus, it can be suggested that the several detrimental effects of Cd soil addition on growth and yield of spinach plant may be partially due to decreases in Fe concentration within the plants. Regarding the effect of Zn soil addition on iron concentration in spinach shoots, results in Table 4 reveal significant increases in Fe concentration were recorded at the shoot of spinach plant, supplied with the three different rates of Zn, either alone or in combined with Cd soil addition when compared with control-untreated plants or plants supplied with Cd soil addition alone.

4. Conclusions

In conclusion, the concentration of Pb, Cd, Zn and Fe is within normal range in soils except the concentration of lead and iron in some sites of the study area. However, the accumulation of heavy metals was within the normal range and is dependent on plant species and their organs. Work is in progress to estimate toxic metal concentration in different sites of Gaza Strip–Palestine. Regarding to the effect of cadmium and zinc on spinach plants at pot experiments, the observed reduction of growth characters and plant pigments, with increasing cadmium soil addition either alone or combined with zinc soil addition might be partially due to the increase in cadmium concentration and consequently its negative effects on net photosynthesis, transpiration, chlorophyll a as well as nutrient contents.

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