



Variable Growth Responses of Radish, Turnip and Rocket Cultivars to Cadmium and Salinity Treatments

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TO examine the responses of three vegetable plants to cadmium and salinity stresses, this study was conducted in a greenhouse over two successive years, 2019 and 2020. The chosen plants are radish (*Raphanus sativus*), rocket (*Eruca sativa*) and turnip (*Brassica rapifera*). The treated plants were exposed separately to cadmium levels of 5, 25 and 50 ppm, and salinity levels of 1000, 1500 and 3000 ppm, through irrigation, in addition to the control treatments (0 ppm Cd or salinity).

Cadmium stress on the three vegetable plants caused clear reduction in plant height, root length, biomass, chlorophyll pigments and overall growth parameters over time. Radish, rocket and turnip plants were found to accumulate Cd in their leaves when exposed to different Cd concentrations. Accumulated Cd was increased in leaves tissue with the increase of Cd concentration level. A general decrease in chlorophyll, with the increase of Cd concentration was also detected. The growth of radish, rocket and turnip plants exposed to salinity has been affected and main reductions in plant height and root length with salinity level were observed on the last growth stage (120 days). The results indicated that cadmium treatments had a greatest impact than salinity treatment. Moreover, percentage levels of nitrogen, phosphorus and potassium in leaves of treated different plant species have been affected by cadmium and salinity treatments. In conclusion, radish, rocket and turnip exposed cultivars showed variation in response to these stresses and confirms that species and genotypes crops are differ in their sensitivities to abiotic stresses.

Keywords: Abiotic stress, Cadmium, Salinity, Vegetable crops, Mineral contents.

Introduction

Heavy metal contamination is one of the most serious environmental problems because of its toxicity, persistence, bioaccumulation and biomagnifications throughout the food chain (Keller et al., 2005, Sarwar et al., 2016), which threatens food safety and human health (WHO, 2011, Ehrampoush et al., 2015). Heavy metals are usually released by anthropogenic activities such as industrial and agricultural activities (Abou El-Anwar, 2019, Ali et al., 2019a). Amongst these metals, for example, lead (Pb) and cadmium (Cd)

contamination have attracted lots of special due to their irreversible damages to plants, animals and humans even at low concentration (Bolan et al., 2014).

Cadmium (Cd) concentration in the environment has increased in several countries (Choppala et al., 2014). Cd is highly mobile in soil-plant systems (Antoniadis et al., 2017), and plants grown in contaminated soils are able to absorb Cd through roots and accumulate the metal in their tissues, leading to yield reduction (DalCorso et al., 2008, Guo et al., 2011, Lin and

Aarts, 2012, Hartke et al., 2013, Ronzan et al., 2018). Cadmium is one of the most dangerous trace elements to the environment and human health, taking into consideration that plants grown in contaminated soils are able to absorb and accumulate the metal in their tissues (Hartke et al., 2013). Cadmium (Cd) is a non-essential, toxic heavy metal that is easily taken up by plants (Yang et al., 2009, Ding et al., 2013, Yang et al., 2017). Dietary exposure of Cd through vegetable consumption has been identified as a potential risk to human health (Jolly et al., 2013, Lin et al., 2015, Hu et al., 2017) and Cd accumulation in vegetable edible parts is one of the major threats for human health (Dziubanek et al., 2017). Heavy metals can be absorbed by vegetables from contaminated soils, as well as from deposits dust particles on the vegetables exposed to the air from polluted environments (Wang et al., 2005).

As the third major contaminant of greatest hazard to the environment, and can pose health risks for both animals and humans at low phytotoxic concentration in plant tissues (Jamers et al., 2013, Leenders et al., 2015). Cd has adverse health effects on the human body and the targeted organs for Cd are the kidneys and liver, which can accumulate up to about 70% Cd of the total Cd in the human body (Aitio and Tritscher, 2004, Ismael et al., 2019, Kjellström et al., 1979, Klaassen et al., 1999). Moreover, Cadmium and its compounds are categorized as Group 1 carcinogens for humans and the inhalation of high levels of Cd can produce severe damage to the lungs (Jaishankar et al., 2014, Satarug and Moore, 2004).

Soils and crops in many region areas in Egypt are contaminated with heavy metals such as lead and cadmium due to air pollution emissions as the main source of heavy metals in Egyptian environment (Abdel-Latif, 2001, Abdel-Latif et al., 2013, Alkhdhairi et al., 2018, Salman et al., 2019). Other essential reasons for contamination of agricultural soils and crops in Egypt are low-quality irrigation water, pesticides, fertilizers, agricultural activities and municipal waste (El-Hassanin, 2020, Elnazer et al., 2015, Ghoneim et al., 2014, Mahmoud and Ghoneim, 2016, Zeid et al., 2018).

Plant responses to Cd contamination are variable and species-specific (Paiva et al., 2004, Vatehová et al., 2012). Growth reductions, physiological impact, reductions in assimilation capacity, water balance disturbances, and

structural changes have been reported in Cd-exposed plants (Marques et al., 2000, Monni et al., 2001, Lux et al., 2004 and Wójcik et al., 2005).

Soil salinity is one of the major abiotic stresses that adversely affect plant productivity and quality (Ayyub et al., 2016). Crop salinity sensitivity varies with species, genotypes, and growth stages (Pujari and Chanda, 2002). The deteriorating trend of the global climate is worsening the situation. Response to salinity has rapidly expanded in recent decades as great economic losses and yield reduction by soil salinity. Soil and water salinization is an ever-growing problem which is amplified by the irrational use of fertilizers and agrochemicals, over pumping of groundwater for irrigation (Daliakopoulos et al., 2016, Libutti and Monteleone, 2017). Furthermore, high salinity was estimated to deteriorate 20% of total cultivated and 33% of irrigated agricultural lands worldwide, and 50% of the arable land is predicted to be salinized by the year 2050 (Jamil et al., 2011).

Morphological and physiological parameters, including the rate of germination, the lengths of roots and shoots, the weight of fresh biomass, the number of burnt-like injured leaves, the chlorophyll content, photosynthesis and nitrogen metabolism are some of the negative effects of salinity in plants (Ashraf et al., 2001, Azevedo-Neto et al., 2006, Vijayan et al., 2008, Ashraf, 2009, Shrivastava & Kumar, 2015, Kotagiri & Kolluru, 2017, Stavridou et al., 2017, Hussain et al., 2019 and Zahra et al., 2020).

This study aims to examine and compare the responses of three vegetable crops (radish *Raphanus sativus*, rocket *Eruca sativa* and turnip *Brassica rapifera*) grown in Egypt under greenhouse conditions to cadmium and salinity stresses at different growth stages.

Materials and Methods

To examine the responses of three vegetable plants to cadmium and salinity stresses, this study was conducted in clay soil in addition to the organic and chemical fertilizers in a greenhouse at the National Research Center, Dokki, Giza Governorate, Egypt, during the two successive seasons of 2019 and 2020. Illumination day levels in greenhouses (7 am – 5 pm) was adjusted to be tenth of the day field lighting (400 lux). Temperature and humidity inside the greenhouse were between 23-34 °C and 36-40%, respectively, over the two seasons.

Three vegetable species, radish *Raphanus sativus*, rocket *Eruca sativa* and turnip *Brassica rapifera* (Balady cultivars), were chosen and treated with cadmium or salinity separately. For each of cadmium or salinity treatment, the cultivated experimental plants were divided into four sub-groups of five pots. Each pot, of 25 cm in diameter, and 30 cm height, contained four plants with a total 20 plants for each treatment sub-group. Pots were filled with 15 kg soil obtained from rural cultivated land away from direct pollution source. Soil has been used after 30 days solar sterilization process to get rid from weed residues or seeds as well as from fungi, and adding required nutrients and organic fertilizers. Initial physical and chemical soil properties of the experimental soil are shown in Table (1).

Layout of the experiment

Seeds (Balady cultivars) of the three crops were obtained from Horticultural Research Institute (HRI), ARC. 7-8 seeds of the same size and quality were sown directly per pot, on 8th and 5th October 2019 and 2020, respectively, and sufficiently irrigated with tap water. Once seedlings were established, they were thinned to remove the weak seedlings and give uniform plants per pot (4 plants per pot).

In addition to control sub-group (0 ppm Cd or 0 NaCl water salinity), plants were treated with cadmium concentrations of 5, 25 and 50 ppm (CdSO_4 solution), while water salinity levels were 1000, 1500 and 3000 ppm of NaCl. Both of cadmium and salinity treatments have been commenced after 15 days from germination. Cadmium and salinity treatments were carried out through soil irrigation. Both treatments were conducted using 15 ml solution for each pot once a week, beside the ordinary irrigation.

A five-split plot design was performed with 3 replicates, in which the three different classes

of randomly selected plants (radish, rocket and turnip) were arranged within the main plots, but different salinity and cadmium treatments were distributed within the sub-pots.

Morphological study and sampling,

Observations were taken for treated plants over the whole course of the experiment. One plant was randomly selected from each segment/pot on 30 and 45, 120 days after the date of germination, then transferred directly to the laboratory to examine and record the following parameters,

A- Characteristics of vegetative growth,

Plant height (cm), the number of leaves per plant (number/plant), fresh plant weight (g/plant) and dry plant weight (g/plant) were recorded.

B- Chemical examining,

Mineral content, nitrogen, phosphorous and potassium (%) was determined using 100 g of fresh plants dried at 70 °C to a constant weight. Mineral contents were determined in wet digested dried samples using nitric acid, perchloric acid and sulfuric acid as follows:

A-Total nitrogen, according to the method reported (Chapman and Pratt, 1961).

B-Phosphorous, using the method of ammonium molybdate (A.O.A.C., 2000).

C-Potassium, as explained by (Jackson, 1967).

Measurement of chlorophyll content was carried out according to Metzner et al. (1965). Cadmium was also determined in wet digested solution as described by Stewart (1972) using the Atomic Absorption Spectrophotometer, Perkin Elmer 3300.

Statistical analysis

All obtained data for both years 2019/2020 were combined together and statistically analyzed according to the procedure described

TABLE 1 Initial physical and chemical soil properties of the experimental soil

Particle size distribution (%)			Texture class	pH (1, 2.5)	EC (dS m ⁻¹) Soil paste	Organic Matter (%)	CaCO ₃ (%)
Sand	Silt	Clay					
30.98	42.36	27.92	Clay Loamy	7.16	5.62	0.92	1.94
Cations (meq l ⁻¹)				Anions (meq l ⁻¹)			
Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	CO ₃ ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻
3.71	0.58	2.31	1.46	0.00	1.28	3.55	3.39

by (Snedecor and Cochran 1980). Comparisons among means of treatments were tested using the least significant differences (LSD) at 5% level of probability.

Results and Discussion

Effects of cadmium contamination on growth

Abiotic stress of cadmium on three vegetable crops grown in Egypt was detected in the current study, and the applied cadmium concentrations caused a clear growth reduction over time. The effects of different Cd sprayed concentrations on plant height and root length of radish, rocket and turnip at different growth stages are shown in Tables (2-4). The results presented in Table (2) show that neither radish plant height nor root length of radish was affected by 5 ppm treatment at all growth stages (30, 45 and 120 days after germination). On the other hand, radish height and root length were reduced by other concentrations compared to control treatment. The percentage of reduction at the last growth stage (120 days after germination) in plant height and root length were 0, 33, 45% and 0, 17, 56% for 5, 25 and 50 ppm treatments, respectively.

As shown in Table (3), Cd treatment at 5 ppm had the lowest values or no significant effect realized on rocket plants on all growth stages compared to other Cd treatments and control treatment. Moreover, 5, 25 and 50 ppm Cd

treatments have reduced plant height with 5, 15 and 26%, respectively, by the last growth stage. Similarly, the percentage reduction in root length was 14, 14 and 21% in the same growth stage with different Cd treatments, respectively.

Despite that the last two growth stages were affected by Cd treatment at 5 ppm, other Cd treatments had the largest effect on plant height and root length of turnip plants (Table 4). By the last growth stage, plant height was reduced with 13, 24 and 37% with Cd treatments of 5, 25, and 50 ppm, respectively. The reduction in root length by the same Cd treatments was 21, 29 and 29%, respectively, compared to control treatment.

Concerning chlorophyll content (chlorophyll a, chlorophyll b and a/b ratio) are reported in Table (5). Cd treatment affected chlorophyll content in plants of radish, rocket and turnip. There was a general decrease, for both chlorophyll a and b, with the increase of Cd concentration.

Concerning the biomass, both fresh and dry weights was reduced by Cd foliar spraying treatments in all studied plants, and the reduction in fresh or dry weights increased with increasing of Cd concentration as shown in Table (6). For radish, the percentage of reduction in plants biomass (dry weight), in relation to control treatment was 56, 62 and 74% for 5, 25 and 50 ppm treatments, respectively. Similarly,

TABLE 2. The effect of cadmium treatment at different growth stages on plant height and root length of radish plants (*Raphanus sativus*) (combined data of both seasons of 2019/2020)

Cd (ppm)	Plant height (cm)			Root length (cm)		
	30 days	45 days	120 days	30 days	45 days	120 days
0	10	15.5	85	5	6	12
5	11	15.5	85	5	6	12
25	9	15	57	5	5	10
50	7	14	47	4.2	4.2	5.3
LSD 0.05	0.92	0.93	8.07	0.5	0.9	1.05

TABLE 3. The effect of cadmium treatment at different growth stages on plant height and root length of rocket plants (*Eruca sativa*) (combined data of both seasons of 2019/2020)

Cd (ppm)	Plant height (cm)			Root length (cm)		
	30 days	45 days	120 days	30 days	45 days	120 days
0	9	14	76	5	5	7
5	9	13.5	72	5	5	6
25	8.5	13	65	4.6	4.6	6
50	8	13	56	4.5	4.5	5.5
LSD 0.05	0.45	0.46	4.12	0.32	0.17	0.37

TABLE 4. The effect of cadmium treatment at different growth stages on plant height and root length of turnip plants (*Brassica rapifera*) (combined data of both seasons of 2019/2020)

Cd (ppm)	Plant height (cm)			Root length (cm)		
	30 days	45 days	120 days	30 days	45 days	120 days
0	15	17	75	5	6	6.3
5	15	16	65	5	5	5
25	13	15.5	57	4.5	4.5	4.5
50	12	14	47	4.2	4	4.5
LSD 0.05	0.91	0.84	5.12	0.16	0.26	0.85

TABLE 5. The effect of cadmium treatment on chlorophyll a, b, and a/b ratio ($\mu\text{g/g}$ fresh weight) in leaves of radish, rocket and turnip after 90 days from seeding (combined data of both seasons of 2019/2020)

Cd (ppm)	Radish			Rocket			Turnip		
	a	b	a/b	a	b	a/b	a	b	a/b
0	0.82	0.49	1.67	0.85	0.49	1.70	0.80	0.67	1.20
5	0.59	0.44	1.34	0.75	0.41	1.30	0.62	0.51	1.22
25	0.48	0.31	1.55	0.46	0.30	1.50	0.49	0.32	1.50
50	0.43	0.20	2.15	0.42	0.24	1.80	0.40	0.27	1.48
LSD 0.05	0.017	0.0021		0.013	0.009		0.012	0.007	

TABLE 6. Effect of different cadmium and salinity treatments on fresh and dry weights (g) of different three vegetable crops at final growth stage (combined data of both seasons of 2019/2020)

Species	Biomass (g)	Cd concentration (ppm)					Salinity level (ppm)				
		0	5	25	50	LSD 0.05	0	1000	1500	3000	LSD 0.05
Radish	Fresh wt.	32.8	18.7	14.7	11.5	1.83	32.8	12.3	10.7	5.8	1.37
	Dry wt.	6.1	3.4	2.3	1.6	0.94	6.1	1.4	1.8	0.8	0.96
Rocket	Fresh wt.	11.3	6.6	4.8	4.7	0.85	11.3	7.9	5.2	4.6	0.98
	Dry wt.	2.8	1.6	1.2	1.3	0.24	2.8	1.9	1.3	1.3	0.2
Turnip	Fresh wt.	12	5.4	5.3	7	0.89	12.1	8	3.5	2.1	0.85
	Dry wt.	2.2	1.5	1.5	1.3	0.47	2.2	2.2	1.6	1.7	0.09

biomass of rocket and turnip was reduced with the corresponding cadmium concentrations. The percentage of reduction was 43, 57 and 54% for rocket and 32, 32 and 41% for turnip, respectively.

The above results agreed with previous studies which reported similar effects of Cd on growth (Dias et al., 2013, Ding et al., 2014, Liu et al., 2014, Rady et al., 2016, Qin et al., 2018, Qin et al., 2020.). For example, Devi et al. (2007) reported a reduction of about 40% in shoot and 70% in root lengths in pea seedlings (*Pisum sativum* L) with 50 µmol/l Cd (~6 ppm Cd), and observed more inhibition with the increase in concentration of cadmium. Similarly, Shukla et al. (2003) observed that the root, shoot-leaf lengths and the root, shoot-leaf biomass of wheat (*Triticum aestivum* L) were decreased with the increasing of cadmium concentration in the nutrient medium. This study reported also a reduction of chlorophylls a and b as a response to Cd treatments of 2.5 and 5 ppm.

In another study, plant height and leaf area of cotton (*Gossypium hirsutum* L.) were found to decrease along with the increase of Cd concentrations of 50 and 100 µM (~6-12 ppm Cd) Liu et al. (2014). Cd concentrations resulted in a loss in biomass and enhanced the reduction of chlorophyll a and b.

Cadmium was reported to affect plant growth and metabolism in different ways and its toxic effects intensity depends on plant species/cultivar and varied with planting date (Romero-Puertas et al., 2002, Hsu and Kao, 2003, Pena et al., 2006). Also, the reduction in growth could be a consequence of interference with a number of metabolic processes associated with normal development, especially synthesis of proteins (Stiborova et al., 1987, Shukla et al., 2003, Ali et al., 2019b). It has demonstrated that toxic metals often result in the production of reactive oxygen species (ROS) causing oxidative stress in plants which disturb the metabolic activities of a plant and result in reduced biomass production (Apostolova et al., 2006, Pitzschke et al., 2006, Gratão et al., 2008). Moreover, Ali et al. (2019b) attributed the significant decreased in length, biomass and chlorophyll contents in the plant grown under Cd stress, at vegetative and reproductive stages, to the negative effect of Cd on metabolism of nitrate, a major component of proteins and other organic compounds constituting the biomass of a plant.

Effect of salinity stress on growth

Salt stress is a critical factor that adversely

affects plant growth and metabolism and involves complex and variable mechanisms that related to different metabolic pathways of various organs (Rahnesan et al., 2018). Salinity effects on plant height and root length of radish, rocket and turnip as shown in Tables (7-9). The obtained results show that main reductions in plant height and root length with increasing salinity level for radish, rocket and turnip, with some exceptions, were observed on the last growth stage (120 days after seeding). Moreover, the growth reduction was greater for plant height than root length with all studied plants. Table (7) shows that salinity level of 3000 ppm induced the highest reduction in radish plant height after 120 days with 45% reduction, although this reduction was decreased from 30% in the first growth stage to only 7% in the second growth stage. Despite radish root growth was more tolerant against salinity levels of 1000 ppm and 1500 ppm at the first two growth stages. In addition, Table (5) showed a percentage of reduction in root length with 8, 17 and 17% with 1000, 1500 and 3000 ppm salinity treatments, respectively, at the last growth stage. These results confirmed that cadmium treatment had a greatest impact on radish compared to the corresponding results of salinity treatment.

Rocket did not respond to salinity levels of 1000 ppm and 1500 ppm at the end of the first two stages as shown in Table (8). However, salinity level of 3000 ppm was reduced the plant height and root length with similar growth reductions over the first two stages with 7 and 10%, respectively. At the last stage (120 days), the percentage of reductions in rocket plant height were 24, 26 and 32% with salinity levels of 1000, 1500 and 3000 ppm, respectively. While rocket root length was increased in salinity level of 1500 ppm treatment, the corresponding root length was reduced with 14 and 36% by 1000 and 3000 ppm NaCl salinity treatments, respectively.

Data presented in Table (9) reflects fluctuated responses of turnip to different NaCl water salinity levels at different growth stages. Salinity level of 3000 ppm had the highest effect on turnip plant height compared to control treatment with a percentage of reduction of 13, 24 and 37% over the three growth stages, respectively. Root length was also reduced by the salinity treatment of 1500 ppm with a percent of 20, 33 and 30% over the corresponding growth stages, respectively.

Water Salinity treatments have been affected fresh and dry weights of exposed plant species

with the same trend of Cd treatment. In relation to control treatment, the percentage of reductions in biomass due to treatments with 1000, 1500 and 3000 ppm salinity were 77, 71, 87% for radish plant, 32, 54, 54 for rocket plant, and 0, 27 and 23% for turnip plant, respectively.

It has been considered that plant growth is highly controlled by different physiological mechanisms and its reduction after salt treatment has been widely described by previous studies (Munns, 2002, Munns and Gilliam, 2015). The lengths of roots and shoots, the weight of fresh biomass, the number of burnt-like injured leaves and the chlorophyll content are examples from

morphological and physiological parameters which reflect the negative effects of salinity in plants (Meng et al., 2011). Moreover, crop salinity sensitivity varies with species, genotypes, and growth stages (Pujari and Chanda, 2002).

In agreement with the current study, Sanoubar et al. (2020) found that red radish plants exposed to 200 mmol L⁻¹ NaCl salinity showed a reduction in plant yield and plant leaf area from control with 71% and 81%, respectively, compared to the white cultivar with 91% and 94%, respectively. Similarly, In a greenhouse experiment investigated NaCl salinity stress on growth of 18 pomegranate cultivars, dry weight, shoot length, new shoot

TABLE 7. Effect of different NaCl water salinity levels on plant height and root length of radish plants (*Raphanus sativus*) at different growth stages (combined data of both seasons of 2019/2020)

Salinity (ppm)	Plant height (cm)			Root length (cm)		
	30 days	45 days	120 days	30 days	45 days	120 days
0	10	15	85	5	5	12
1000	8.5	14	80	5	5	11
1500	10.5	15	60	5	5	10
3000	7	14	47	4	4.2	10
LSD 0.05	0.9	0.5	4.48	0.19	0.12	0.95

TABLE 8. Effect of different NaCl water salinity levels on plant height and root length of rocket plants (*Eruca sativa*) at different growth stages (combined data of both seasons of 2019/2020)

Salinity (ppm)	Plant height (cm)			Root length (cm)		
	30 days	45 days	120 days	30 days	45 days	120 days
0	8.5	14	76	5	5	7
1000	8.5	14	58	5	5	6
1500	8.7	14	56	5	5	8
3000	7.9	13	52	4.5	4.5	4.5
LSD 0.05	0.08	0.4	2.83	0.03	0.03	0.96

TABLE 9. Effect of different NaCl water salinity levels on plant height and root length of turnip plants (*Brassica rapifera*) at different growth stages (combined data of both seasons of 2019/2020)

Salinity (ppm)	Plant height (cm)			Root length (cm)		
	30 days	45 days	120 days	30 days	45 days	120 days
0	15	17	75	5	6	6.3
1000	14	15	70	5	5	5.5
1500	14	15.5	60	5	4.5	6.5
3000	13	13	47	4	4	4.5
LSD 0.05	0.55	0.68	1.5	0.06	0.12	0.25

number, root length and number, leaf area, leaf relative water content, and net photosynthesis of salt-treated plants were negatively impacted by salt stress, with a significant difference among tested cultivars (Liu *et al.*, 2020). Moreover, there were a few occurrences of leaf burn, necrosis, or discoloration in some pomegranate cultivars.

Stavridou *et al.* (2017) in their study to examine the effects of salinity on the commercial perennial grass *Miscanthus x giganteus* biomass crop, it was observed that final plant height was negatively associated with salt concentration and changed significantly with time. Moreover, root dry matter inhibition occurred at the highest salt concentration tested. Biomass yield was reported to be reduced also by 50% on response to NaCl concentrations.

N, P, K and Cd contents

The percentage of cadmium, nitrogen, phosphorus and potassium in leaves of treated plants with cadmium at different growth stages are shown in Table (10). Cd treatment induced an accumulation of Cd in all plant species which increased with increasing the level of Cd treatment. At lowest treatments of 5 and 25 ppm Cd, turnip

accumulated Cd more than radish and rocket, respectively. However at the highest treatments (50 ppm), radish was the highest in accumulation of Cd, followed by turnip. The percentage of accumulated Cd by radish leaves treated with 50 ppm Cd as foliar spraying, compared to other treatments, was higher than the corresponding percentages for turnip and rocket plants. These findings are coincided with Zheng *et al.* (2008) who demonstrated that Cd has the ability to be accumulated in different concentrations in the same organ depending on the cultivar that even within the same plant species. Accumulation of Cd in plants was reported to be controlled by many factors including plant species, genotype, environmental factors, bioavailability and presence of other minerals and nutrients (Volpe *et al.*, 2015). Moreover, López-Millán *et al.* (2009) demonstrated that cadmium concentrations increased significantly in all plant parts when increasing Cd in the nutrient solution.

In the same regards, Table (10) reflected variable effects of Cd treatments on nitrogen, phosphorus and potassium contents among different studied species. In radish, N, P and K

TABLE 10. The effect of foliar spraying of cadmium on cadmium (ppm), nitrogen (%), phosphorus (%) and potassium (%) in leaves of radish, rocket and turnip (combined data of both seasons of 2019/2020)

Cd (ppm)	Radish				Rocket				Turnip			
	Cd	N	P	K	Cd	N	P	K	Cd	N	P	K
0	0.01	3.61	0.16	5.14	0.06	1.13	0.13	2.04	0.01	3.28	0.16	2.75
5	10.4	3.61	0.21	3.37	9.0	1.64	0.18	2.30	14.7	3.28	0.10	2.84
25	12.8	3.36	0.20	2.84	10.25	1.60	0.21	3.72	20.2	3.28	0.07	3.46
50	29.2	3.07	0.06	4.25	16.92	1.43	0.06	2.66	22.9	3.53	0.12	4.16
LSD 0.05	4.3	0.034	0.002	0.95	1.14	0.04	0.06	0.09	1.62	0.03	0.003	0.20

TABLE 11. Effect of different NaCl water salinity levels on the percentage of nitrogen, phosphorus and potassium in leaves of radish, rocket and turnip plants (combined data of both seasons of 2019/2020)

Salinity (ppm)	Radish			Rocket			Turnip		
	N	P	K	N	P	K	N	P	K
0	3.61	0.16	5.14	1.35	0.13	2.15	1.35	0.13	2.04
1000	3.15	0.23	3.63	1.34	0.12	1.68	1.34	0.12	1.68
1500	3.57	0.13	4.43	1.23	0.18	2.14	1.23	0.18	4.34
3000	3.15	0.08	2.20	0.99	0.13	1.77	0.99	0.13	1.77
LSD 0.05	0.35	0.017	0.94	0.28	0.013	0.29	0.43	0.012	1.32

contents were decreased with increasing of Cd level treatment. Although there was an increase in phosphorus content in radish plant treated with 5 and 25 ppm Cd compared to control treatment, there was a reduction in the corresponding content in plants treated with 50 ppm Cd. In contrast, the contents of nitrogen and potassium in leaves of rocket and turnip treated plants were lower than control treatment. However, corresponding phosphorus contents were reduced with increasing of Cd level treatment. It was found that The N, P, and K contents in plants decreased after the addition of Cd (Zhang et al., 2020) due to the impacts of Cd on nutrient uptake. Moreover, Zafar-ul-Hye et al. (2020) demonstrated that low uptake of nutrients in the presence of cadmium is a well-documented fact due to its antagonistic relationship with macronutrients. Consequently, due its high water solubility, Cd has the ability to disturb the uptake of those nutrients.

Percentage of nitrogen, phosphorus and potassium in leaves of different studied plants with different salinity levels salinity at different growth stages are presented in Table (11). The obtained results show a general reduction in the percentages of N, P and K due to different salinity treatments compared to control treatments for radish, rocket and turnip, despite of some exceptions, especially for phosphorus levels in rocket and turnip. In agreement for the current study, a significant decrease in the K⁺ content was observed in root and stem of two pistachio cultivars with increasing salt treatment level (Rahneshan et al., 2018).

Conclusion

It is recommended that cultivation of vegetable plants near crowded places with cars, highways and industrial areas should be avoided, as vegetable plants are highly affected by heavy metals, and absorb heavy metals from car exhaust. It is also preferred to use irrigation water that contains salinity levels less than 3000 ppm.

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Conflict of interest

The authors declare that they have no conflict of interest.

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استجابات نمو الفجل واللفت والجرجير لمعالجات الكاديوم والملوحة

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أجريت تجربتان منفصلتان فى الاصل لفحص استجابات ثلاث نباتات خضر للكاديوم والملوحة. النباتات التى تم اختبارها هى الفجل - *Raphanus sativus* والجرجير - *Eruca sativa* واللفت *Brassica rapifera* ، بالإضافة إلى المعاملة الضابطة، تم تعريض النباتات لتركيزات من الكاديوم ٥ ، ٢٥ ، ٥٠ جزء فى المليون فى التجربة الأولى ومعاملات تحتوى على مستويات ملوحة تبلغ ١٠٠٠ ، ١٥٠٠ ، ٣٠٠٠ جزء فى المليون وتمت المعاملتين مع ماء الرى فى التجريبتين، وذلك بالصوبة الزراعية للمركز القومى للبحوث بالدقى.

نتج عن تعرض نباتات الخضر الثلاثة للكاديوم فى انخفاض واضح بطول النبات وطول الجذر والكتلة الحيوية والكلوروفيل ومعايير النمو الكلية بمرور الوقت . كما أوضحت النتائج المتحصل عليها تراكم الكاديوم فى أوراق الفجل والجرجير واللفت عند تعرضهم للتركيزات المختلفة من الكاديوم، مع زيادة الكاديوم المتراكم فى أنسجة الأوراق مع مراحل النمو المختلفة (٣٠ ، ٤٥ ، ١٢٠ يوماً بعد الأنبات) وأيضاً زيادة مستوى تركيز الكاديوم المستخدم. كما تسبب التعرض للكاديوم فى انخفاض عام فى الكلوروفيل أ ، ب، وذلك مع زيادة تركيز الكاديوم. تأثر نمو نباتات الفجل والجرجير واللفت المعرضة للملوحة ولوحظ انخفاضاً فى طول النبات وطول الجذر مع مستوى الملوحة المستخدم، وخاصة فى مرحلة النمو الأخيرة (١٢٠ يوماً بعد الأنبات). كما أشارت النتائج إلى أن معاملات الكاديوم كان لها تأثير أكبر من معالجة الملوحة. علاوة على ذلك، تأثرت مستويات عناصر النيتروجين والفوسفور والبوتاسيوم فى أوراق النباتات تحت الدراسة المختلفة نتيجة التعرض لمعاملات الكاديوم والملوحة.

وأشارت الدراسة إلى وجود تباين فى استجابة الأصناف المعرضة من الفجل والجرجير واللفت لهذه الضغوط، وهو ما يتوافق مع الدراسات السابقة من اختلاف حساسية المحاصيل للضغوط اللاأحيائية طبقاً لأنواعها وأنماطها الجينية.