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Effect of Titanium Dioxide on Lettuce Plants Grown on Sandy Soil

El-Ghamry, A. M. ; D. A. Ghazi and Z. R. Mousa
Soils Department, Faculty of Agriculture, Mansoura University, Mansoura, Egypt

ABSTRACT

The titanium role in plants nutrition is not so far fully clear. Many positive beneficial influences and a few adverse influences of titanium addition are described in literature. The purpose of this investigation is to study the effect of different rates of Ti soil application on the plant growth parameters, chemical constituents, quality parameters and elements concentration in the soil after harvesting of lettuce plants grown on sandy soil with irrigation by H. Cooper's nutrient solution during the winter season of 2017/2018. The experimental design was randomize complete block with four replicates for each treatment. The titanium application rates were: (T_1) 0 ppm, (T_2) 25ppm, (T_3) 50 ppm and (T_4) 75ppm, added as Titanium dioxide (TiO_2). The results showed that, the values of all studied growth parameters of lettuce plant significantly increased with raising of titanium addition from 0.0 to 25 ppm and then significantly decreased with any increase in titanium dioxide. The same trend was found for N, P, K, Fe, carotein, vitamin C, chlorophyll a, b and total chlorophyll. On the contrary, of above trend; sharply and significantly decreases were happened in the mean values of nitrate (NO_3-N) and nitrite (NO_2-N) in lettuce leaves. For Ti concentration, the values significantly increased with increasing Ti application rates.
Keywords: Sandy soil, titanium element, lettuce plant, nitrate (NO_3-N) and nitrite (NO_2-N).

INTRODUCTION

Titanium, which has an atomic weight of 47.88 and atomic number 22, is a transition element belonging to Group 4 (IVB) in the middle of the Periodical Table. It is the ninth most abundant element in the earth's crust and makes up about 0.25% by moles and 0.57% by weight of the earth crust . Ti is the second most abundant transition metal, after iron, and the elemental abundance of titanium is about 5 times less than iron and 100 times greater than copper element (Buettner and Valentine, 2012). Ti is classified as a useful element for plants, which enhances their growth and development. Plants treated with titanium are characterized by a higher chlorophyll content and more intensive photosynthesis. Also, Ti has an effect on the uptake of nutrient and enzymatic activity (Malinowska and Kalembasa 2012; Kleiber and Markiewicz 2013 and Radkowski 2013).

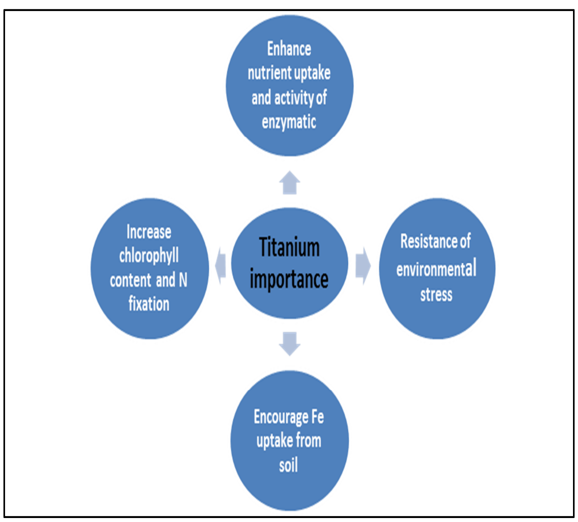

Fig. 1. Importance of titanium in agricultural (Kleiber and Markiewicz 2013 and Radkowski 2013).

The biological role of titanium in development and metabolism of plants has been studied for more than hundred years. Traetta-Mosca (1913) found that Ti improved the growth of tobacco leaves and also observed that titanium is an inherent constituent of the ash from all plants. A systematic study of Ti dose-response relationship was done on several crops by Nemec and Kas (1923).

They firstly reported optimal Ti content causing intensified plant growth and development, increased intensity of green colour (higher chlorophyll content). The detailed history of Ti research was reviewed by Kuzel *et al*.,(2003b). Titanium (Ti) has been considered as an inert element for a long time. However, since the 1930s its encouraging influence on metabolism of plant has begun to be appreciated. After the first observation, experiments have been conducted which suggest the encouraging influences on plant physiology leading us to suggest it as useful element. Ti can enhance and increase the yield from about 5 to 50% in various crops. Also, the use of titanium in crop production has been reported to decrease the severity of disease, encourage plant growth, and enhance rate of photosynthetic (Chao and Choi, 2005). Titanium through increasing rate of photosynthesis and uptake nutrients (by increasing root volume) involved in chlorophyll and photosynthesis led to increasing plant growth (Haghighi and Daneshmand, 2018). Lyu *et al*., (2017) proposed that Ti has a positive effect on plant growth and quality of crops. Plants can complete their life cycle without titanium; there is no reported Ti deficiency in plants; and mechanisms of Ti action are still uncertain. Ti, however, is not an essential nutrient for plant based on the criteria for essentiality (Lyu *et al*., 2017).

Lettuce (*Lactuca sativa* L.) is considered as an excellent nutritive source of vitamins and minerals as it is consumed as a fresh green salad. Also, its leaves are a rich source of, vitamins C and A, antioxidants and phytochemicals which are anti-carcinogenic. In Egypt, the cultivated area of lettuce is about 3100 hectares, which produced about 70000 tons (Shahein *et al*., 2014).This research aims to investigate the influence of Ti soil applications at different levels with irrigation by H. Cooper's nutrient solution on the yield and accumulation of nitrate and nitrite in lettuce plants grown on sandy soil.

MATERIALS AND METHODS

To achieve the goal of this study, the pot experiment was carried out at the greenhouse of Soils Dept. Faculty of Agriculture, Mansoura University, during the winter season of 2017/2018 to investigate the response of lettuce (*Lactuca sativa* L.) crop to titanium soil application and irrigation by H. Cooper's nutrient solution under sandy soil conditions. The effects of Ti on growth parameters of lettuce plants were investigated by four Titanium rates under a complete randomize design, with four replicates for each treatment. The titanium rates were: (T_1) 0.0ppm, (T_2) 25ppm, (T_3) 50ppm and (T_4) 75ppm, added as Titanium dioxide (TiO_2). To carry out the experiment, plastic pots (25 cm diameter and 35 cm length) were filled by air dry sandy soil equaled to 10 kg oven dry soil of the studied sandy soil after washing with HCl and distilled water.

Table 1. Some physical and chemical characteristics of the experimental soil.

Particle size distribution (%)			Textural class	EC, dSm^{-1}	pH **	$CaCO_3$	O.M	F.C	SP
Sand F.sand	Silt	Clay	Sand			(%)			
90.7	1.5	7.8		1.11	7.91	0.0	0.3	10	22

Soluble cataions (meq L^{-1})				Soluble anions (meq L^{-1})				Available elements, mg kg^{-1}				
								N	P	K	Ti	Fe
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^{--}	HCo_3^{-}	Cl^{-}	So_4^{--}					
2.12	2.61	3.16	3.21	0.00	3.34	4.55	3.21	9.5	0.95	39.5	0.03	0.10

*** Soil Electrical Conductivity (EC) and soluble ions were determined in saturated soil paste extract.**
**** Soil pH was determined in soil suspension (1: 2.5).**

H. Cooper's nutrient solution at full strength consisted of (mg L^{-1}) N-200, P 60.0, K 300, Ca 170, Mg 50.0, S 69, Fe (EDTA) 12, Mn 2.0, Zn 0.1, Cu 0.1, B 0.3, Mo 0.2. Table (2) shows the required weights of each salt to prepare 1000 liters of this solution according to Cooper (1996).

Table 2. Chemicals needed to prepare 1000 liters of H. Cooper's nutrient solution.

Nutrient chemicals	Calcium nitrate	Potassium nitrate	Potassium dihydrogen phosphate	Magnesium sulphate	EDTA iron	Manganous sulphate	Boric acid	Copper sulphate	Ammonium molybdate	Zinc sulphate
Weight in grams	1003	583	263	513	79	6.1	1.7	0.39	0.37	0.44

The planting date was in the 10th of December, 2017 during the studied season. Four seedlings of lettuce NADER S.C were sown in each pot and were thinned to 2 plants per pot after 50 days from planting. The nutrition of sandy soil depended on irrigation by H. Cooper's nutrient solution, which was carried out every 2 days to reach the soil moisture to field capacity by weight. After harvesting of lettuce plants, which was in March 20, 2018, shoot samples were cleaned, weighed for fresh weight dried at 70○ until the constant weight, weighed for dry weight, grounded and sieved for chemical analysis. Quality parameters of fresh plant; NO_3-N, NO_2-N and vitamin C were determined on fresh weight basis.

Particle size distribution of the investigated soil was carried out according to Piper, (1950). F.C of soil was determined according to Richards (1954). pH and EC of studied soil were determined by the methods described by Richards (1954). Soluble ions meq L^{-1} were determined according to Hesse (1971). .Total carbonate was estimated using Collin's Calcimeter and calculated as calcium carbonate by the method described by Piper, (1950). Ti and Fe of soil were extracted with (DTPA) according to Mathieu and Pieltain, (2003). Chlorophyll content was estimated on fresh leaves according to Sadasivam and Manickam, (1996). To determine the concentrations of nutrients in lettuce plant tissues, 0.2 g from each shoot sample was digested using 5.0 cm^3 from the mixture of perchloric and sulphuric acids (1:1) as described by (Jackson, 1967). N was determined by micro-Kjeldahl method according to Hesse (1971). P was determined colorimetrically by using spectrophotometer according to (Olsen and Sommers, 1982).K was determined by using flame photometer as described by Jackson (1967). Fe was extracted from the samples using the method as described by Kumpulainen *et al.,* (1983).Titanium concentration was measured using X-ray fluorescence (Unisantis XMF104, Germany) (Simabuco and Nasciment Filho,1994).Vitamin C was determined according to the method described by Mazumdar and Majumder, (2003) .Nitrate content in plant was extracted according to the method described by Singh, (1988). Statistical analysis at a significance level of (0.05) was performed according to Gomez and Gomez, (1984) using CoStat (Version 6.303, CoHort, USA, 1998–2004).

RESULTS AND DISCUSSION

1- Vegetative growth parameters of lettuce plant as affected by different rates of titanium application under irrigation by H. Cooper's nutrient solution.

Data illustrated in Table (3) show the effect of different rates of titanium application on vegetative growth parameters i.e. fresh and dry weight of shoot and root, number of leaves, stem diameter and height of lettuce plant grown on sandy soil**.** It could be observed that; all studied vegetative growth parameters significantly increased with increasing the titanium level from T_1 to T_2 and then significantly decreased with any increasing addition of titanium dioxide. The significant highest values of all growth parameters were obtained from the treatment $\mathbf{T_2}$ (25ppm), followed by T_3 (50ppm) then T_1 (0.0 ppm).The lowest values in this regard were obtained from the treatment T_4 (75 ppm)**.**

In this connection, the highest values of all studied vegetative growth parameters were found at T_2 treatment, it were 145.43, 6.15, 25.6 and 5.67 for fresh and dry weights of shoot and root(g $plant^{-1}$), respectively and it were 11.0, 13.0, 2.10 and 45.0 for No. of internal and external leaves $plant^{-1}$, stem diameter (cm) and plant height (cm), respectively, while the lower values were obtained at T_4 treatment, it were 125.6, 3.23,18.43and 3.40 for fresh and dry weight of shoot and root (g $plant^{-1}$), respectively and it were 5.0, 6.0, 1.63 and 29.67 for No. of internal and external leaves $plant^{-1}$, stem diameter (cm) and plant height (cm), respectively. The decreasing rate due to raising Ti level from T_2 (25 ppm) to T_4 (75 ppm) was 13.6, 47.47, 28.0 and 40.0 % for fresh and dry weights of lettuce shoot and root, respectively and it was 54.54, 53.84, 22.38 and 34.0% for No. of internal and external leaves, stem diameter and height of plant, respectively, while the increasing rate due to raising Ti level from T_1 (control) to T_2 (25 ppm) was 9.34, 62.69,27.80 and 52.01% for fresh and dry weight of lettuce shoot and root, respectively and it was 57.14, 62.50, 21.38 and 35.0 % for No. of internal and external leaves, stem diameter and height of plant, respectively. It can be concluded that adding 25 and 50 ppm titanium as soil application induced favorite effect and significantly increased the all studied vegetative growth parameters of lettuce plant, while raising titanium level more than 50 ppm had a negative influence on lettuce plant under sandy soil condition. From the data in the same Table, it can be noticed that the decrease in shoots and roots dry weights due to raising the titanium added level from 25 to 75 ppm is higher than the decrease in fresh weight, that means the moisture % in the plant was increased with increasing the added titanium level. The obtained results revealed that titanium element encouraged lettuce plant to retain more water. The present results agree with those obtained by Chao and Choi, (2005), Yang *et al*., (2012), Bacilieri *et al*., (2017) and Lyu *et al*., (2017).

Table 3. Plant growth parameters of lettuce as affected by different levels of titanium under sandy soil condition.

Treatments	Shoot Fresh	Shoot Dry	Root Fresh	Root Dry	No. of leaves plant^{-1} Internal	No. of leaves plant^{-1} External	Stem diameter	Height of plant
	(g plant^{-1})						(cm)	
T_1 (Control)	133.00c	3.78c	20.03c	3.73c	7.00c	8.00c	1.73c	33.33c
T_2 (Ti 25 ppm)	145.43a	6.15a	25.60a	5.67a	11.00a	13.00a	2.10a	45.00a
T_3 (Ti 50 ppm)	139.10b	4.65b	22.87b	4.23b	9.00b	10.00b	1.88b	40.67b
T_4 (Ti ppm 75)	125.60d	3.23d	18.43d	3.40d	5.00d	6.00d	1.63c	29.67d
F test	**	**	**	**	**	**	**	**
LSD $_{at\ 5\%}$	2.05	0.26	0.63	0.31	1.88	1.88	0.13	3.26

2- Chemical constituents of lettuce plants as affected by different rates of titanium application under irrigation by H. Cooper's nutrient solution.

- Photosynthetic pigments

Data in Table (4) show the effect of added titanium levels on chlorophyll a, b and total chlorophyll (mg g^{-1} F.W) of lettuce plant grown on sandy soil. The statistical analysis of the data indicated that increase of Ti level from the control T_1 (0.0 ppm) to the fourth one T_4 (75 ppm) significantly affected the chlorophyll a, b and total chlorophyll (mg g^{-1} F.W) of lettuce plant under sandy soil condition. It is clear to observe that the chlorophyll a, b and total chlorophyll (mg g^{-1} F.W) of lettuce plant significantly increased with increasing titanium treatment from 0.0 to 25ppm and then significantly decreased with any increase in titanium element**.** The significant highest values of chlorophyll a, b and total chlorophyll (mg g^{-1} F.W) were obtained from the treatment T_2, followed by T_3 and lately $\mathbf{T_1}$**.** The lowest values in this regard were those of the treatment T_4 (75 ppm).

Table 4. Chlorophyll content (mg g^{-1} F.W) of lettuce plant leaves as affected by different levels of titanium under sandy soil condition.

Treatments	Chlorophyll a	Chlorophyll b	Total Chlorophyll
		(mg g^{-1} F.W)	
T_1 (Control)	0.567c	0.399c	0.965c
T_2 (Ti 25 ppm)	0.678a	0.480a	1.158a
T_3 (Ti 50 ppm)	0.622b	0.441b	1.062b
T_4 (Ti ppm 75)	0.517d	0.365d	0.882d
F test	**	**	**
LSD $_{at\ 5\%}$	0.028	0.019	0.036

The second titanium level (T_2) showed the highest values; it was 0.678, 0.480 and 1.158 (mg/g F.W) for chlorophyll a, b and total chlorophyll, respectively. In the contrary, the fourth titanium level (T_4) showed the lowest values; it was 0.517, 0.365 and 0.882 (mg/g F.W) for chlorophyll a, b and total chlorophyll, respectively. These results are supported by the findings of Lyu *et al*., (2017) who suggested that plants treated with Ti are characterized by a higher chlorophyll content and more intensive photosynthesis.

- Nutritional elements

Nitrogen, phosphorus and potassium concentration (%) in internal and external leaves, stem and root of lettuce plant as influenced by different levels of titanium in sandy soil are presented in Table (5).The data show a significant effect for Ti element on the mean values of the concentrations above mentioned nutrients, where the values significantly increased with increasing titanium treatment from 0.0 to 25ppm and then significantly decreased with any increase in titanium element under sandy soil condition. The second titanium level (T_2) showed the highest values of nitrogen, phosphorus and potassium concentration (%) in internal and external leaves, stem and root of lettuce plant. In the contrary, the fourth titanium level (T_4) showed the lowest values.

It can be stated that increasing titanium levels from the first T_1 (0.0 ppm) to the second T_2 (25 ppm) and third T_3 (50 ppm) significantly increased the photosynthetic pigments such as chlorophyll a, b and total chlorophyll of lettuce plants under sandy soil condition. The increase of chlorophyll a, b and total chlorophyll contents will enhance the photosynthetic efficiency and consequently increase plant growth at T_2 and T_3 treatments compared to control T_1 and T_4 treatments (Table 4). The obtained results are in agreement with those obtained by by Botia *et al*., (2002), Tlustos *et al*., (2005) ,Yang *et al*.,(2012), Bacilieri *et al*., (2017) and Lyu *et al*.,(2017).

Table 5. N, P and K (%) in leaves, stem and root of lettuce plant as affected by different levels of titanium under sandy soil condition.

Treatments	N%				P%				K%			
	leaves		Stem	Root	Leaves		Stem	Root	leaves		Stem	Root
	Internal	External			Internal	External			External	External		
T_1	1.66c	1.34c	0.23c	0.15c	0.153b	0.130bc	0.203b	0.103b	1.27c	1.07c	0.85c	0.25d
T_2	2.36a	1.99a	0.50a	0.24a	0.243a	0.203a	0.287a	0.173a	1.84a	1.62a	1.65a	0.45a
T_3	2.00b	1.70b	0.35b	0.18b	0.177b	0.150b	0.227b	0.130b	1.61b	1.36b	1.30b	0.35b
T_4	1.33d	1.05d	0.15d	0.10d	0.120c	0.103c	0.167c	0.070c	1.10d	0.88c	0.75d	0.15d
F test	**	**	**	**	**	**	**	**	**	**	**	**
$LSD_{at\ 5\%}$	0.11	0.08	0.07	0.03	0.032	0.031	0.027	0.030	0.14	0.19	0.09	0.07

3- Quality parameters of lettuce plants as affected by different rates of titanium application under irrigation by H. Cooper's nutrient solution.

The mean values of carotene (mg $100g^{-1}$)**,** vitamin C, (mg $100g^{-1}$) and nitrate and nitrite concentrations (mg kg^{-1}) found in lettuce plant as influenced by different levels of titanium under sandy soil condition are presented in Table (6).

Obtained data of the same Table indicated that, except for NO_3-N and NO_2-N the average values of all the above mentioned traits were significantly increased with increasing titanium treatment from 0.0 to 25ppm and then significantly decreased with any increase in titanium element level; the highest values (0.823 and 20.80 mg $100g^{-1}$ for carotene and vitamin C, respectively) were recorded for the second Ti treatment (25 ppm) while , the lowest values (0.609 and 17.20 mg $100g^{-1}$ for carotene and vitamin C, respectively) were recorded for the fourth Ti treatment (75 ppm). On the contrary, of this trend; sharply and significantly decreases were happened in the mean values of NO_3-N and NO_2-N in lettuce leaves due to an addition of the various studied titanium levels than those obtained from the control treatment.

Table 6. Carotene, vitamin C and nitrate and nitrite contents of lettuce plants as affected by different levels of titanium under sandy soil condition.

Treatments	Carotein	V.C	NO_3-N	NO_2-N
	mg $100g^{-1}$		mg kg^{-1}	
T_1 (Control)	0.674c	18.23c	200.80a	2.75a
T_2 (Ti 25 ppm)	0.823a	20.80a	155.50b	2.12b
T_3 (Ti 50 ppm)	0.746b	19.70b	131.43c	1.69c
T_4 (Ti ppm 75)	0.609d	17.20d	94.80d	1.18d
F test	**	**	**	**
$LSD_{at\ 5\%}$	0.029	0.41	17.36	0.16

The percentage of decreases for the main value of nitrate (NO_3-N) accumulation less than the control treatment was accounted to be (22.55, 34.50 and 52.78 %) for the treatments of T_2, T_3 and T_4, respectively. also, the decrease percentage for the main value of nitrite (NO_2-N) accumulation less than the control treatment was accounted to be (22.9, 38.5 and 57.09 %) for the treatments of T_2, T_3 and T_4, respectively. The highest values of nitrate and nitrite (200.8 and 2.75 mg kg^{-1}), respectively were recorded for the untreated plants, while the lowest values (94.8 and 1.18 mg kg^{-1}) was connected with the plants treated with titanium at rate of 75 ppm. The favorable role of Ti on decreasing the content of nitrate accumulation in the tissues of lettuce to be less than the permissible limits weakly intake (15.5 mg/kg of body weight for No_3-N) given by WHO (1999) may be referred to the role played by titanium element in relevant to the enzymatic system responsible for biosynthesis of amino acids , protein and the other N-compounds and consequently decrease the nitrate accumulation in lettuce tissues (titanium as a non-biological nitrogen fixation). The increased photosynthesis would enhance the expression of nitrate transporter genes, consequently increasing N uptake. The increased uptake of NO_3^- could improve plant growth and in turn enhance absorption of other ions. These results are confirmed with those of Bacilieri *et al*., (2017) and Lyu *et al*.,(2017).

4- Ti and Fe concentrations in lettuce plants as affected by different rates of titanium application under irrigation by H. Cooper's nutrient solution.

Statistical analysis of the data presented in Table (7) indicated the concentration of Ti and Fe; (mg kg^{-1}) as affected by the investigated levels of titanium in lettuce plant under sandy soil condition. The data show that Ti concentration of lettuce plant (mg kg^{-1}_{DM}) increased with increasing Ti application levels. The values of lettuce Ti concentration were 0.10, 0.19, 0.23 and 0.29 (mg kg^{-1}_{DM}) at zero, 25, 50 and 75 ppm addition levels .On the contrary, of this trend; the values of Fe concentration in lettuce leaves increased with increasing titanium level from 0.0 to 25 and 50 ppm and then decreased at 75ppm treatment where, the highest values of Fe concentration were at T_2 and T_3 treatments, it was 7.08 and 7.00 (mg kg^{-1}_{DM}) while the lowest value was obtained at T_4 (75 ppm) treatment, it was 6.14 (mg kg^{-1}_{DM})**.**

Table 7. Ti and Fe concentrations (mg kg^{-1} DM) in lettuce plant as affected by different levels of titanium under sandy soil condition.

Treatments	Ti	Fe
	mg kg^{-1}_{DM}	
T_1 (Control)	0.10	6.45
T_2 (Ti 25 ppm)	0.19	7.08
T_3 (Ti 50 ppm)	0.23	7.00
T_4 (Ti ppm 75)	0.29	6.14

The values of Fe concentration in lettuce leaves significantly increased with increasing titanium level from 0.0 to 25 and 50 ppm due to iron and titanium have synergistic and antagonistic relationship. When plants suffer from iron deficiency, titanium helps induce the expression of genes related to iron acquisition, thereby improving iron uptake and utilization, thus improving plant growth. The negative effect of Ti on the concentration of iron and other elements appear at high titanium concentration (75 ppm). This results agree with findings of Radkowski (2013) who stated that titanium element encourages Fe uptake from soil and increases N fixation.

Figure (2) shows the correlation between concentration of added titanium and concentration of Ti in lettuce plant under sandy soil condition. It can be stated that the concentration of Ti in lettuce leaves gradually and significantly increased with increasing titanium additions.

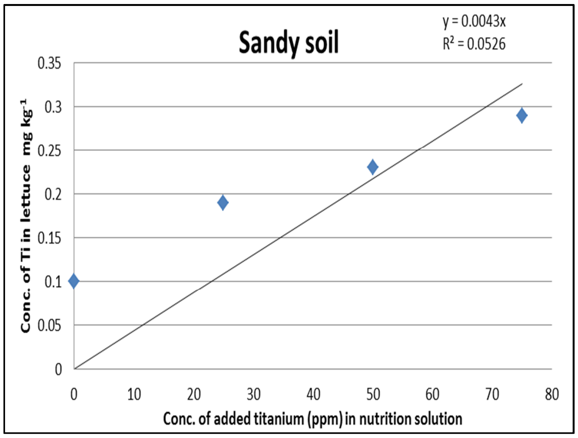

Fig. 2. Correlation between conc. of added Ti (ppm) and conc. of Ti in lettuce plant grown on sandy soil.

5- N, P, K, DTPA-extractable Ti and Fe in soil after harvesting.

Concentrations of nitrogen, potassium, phosphorus, titanium and iron found in the experimental soil after harvesting of lettuce plants under sandy soil condition are presented in Table (8). Statistical analysis of the data showed that, the values of N, P, K and Fe (mg kg^{-1}) in the soil after harvesting of lettuce plants significantly were decreased with increasing titanium level from 0.0 to 25ppm and then significantly increased with any increasing in titanium element. While, for Ti (mg kg^{-1}), the values of residual titanium significantly increased with increasing Ti application rates. For the concentration of N, P, K and Fe (mg kg^{-1}) in the soil after harvesting lettuce plant, the highest values were at T_4 (75 ppm) treatment, it were 33.5, 9.5, 200.2 and 1.45 (mg kg^{-1}), respectively. While the lowest values were obtained at T_2 (25 ppm) treatment, it were 25.6, 7.00, 180.2 and 1.06 (mg kg^{-1}) for N, P, K and Fe, respectively.

Table 8. N, P , K, Ti and Fe in soil after harvesting of lettuce as affected by different levels of titanium under sandy soil condition.

Treatments	N	P	K	Ti	Fe
	(mg kg^{-1})				
T_1 (Control)	30.50a	8.30b	190.50b	0.000d	1.32b
T_2 (Ti 25 ppm)	25.60d	7.00d	180.20d	0.150c	1.06d
T_3 (Ti 50 ppm)	28.50c	7.50c	185.50c	0.200b	1.18c
T_4 (Ti ppm 75)	33.50b	9.50a	200.20a	0.290a	1.45a
F test	**	**	**	**	**
LSD $_{at\ 5\%}$	0.57	0.30	0.66	0.021	0.08

On the other hand, the highest value of Ti (mg kg^{-1}) in the studied sandy soil after harvesting of lettuce plant was at T_4 (75 ppm) treatment, it was 0.290(mg kg^{-1}), while the lowest value was at control treatment T_1, it was 0.00 (mg kg^{-1}). These results agree with various findings obtained by Botia *et al*., (2002), Tlustos *et al*., (2005), Yang *et al*.,(2012), Bacilieri *et al*., (2017) and Lyu *et al*.,(2017).

CONCLUSION

Under the same condition of this investigation it could be concluded that; titanium has positive effects on plant growth and crop quality of lettuce plant at (25 and 50 ppm) treatment and it has negative effects at (75 ppm) treatments but the positive effects at 25 ppm treatment was better than at 50 ppm treatment. Also, a reduction effect was happened on the content of nitrate in lettuce leaves due to an addition of Ti.

Finally, based on the obtained results of this investigation, it could be detected that; titanium is considered a beneficial element because it improves plant health status at low concentrations but has toxic effects at high concentrations.

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تأثير ثاني أكسيد التيتانيوم علي نبات الخس المزروع بأرض رملية

أيمن محمد الغمري، دينا عبد الرحيم غازي و زينب رجب موسي
قسم الأراضي ، كلية الزراعة ، جامعة المنصورة

دور التيتانيوم في تغذية النباتات ليس واضحا تماما حتى الآن. وتم وصف العديد من التأثيرات المفيدة الإيجابية وبعض التأثيرات السلبية لإضافة التيتانيوم .والغرض من هذا البحث هو دراسة تأثير الاضافات الأرضية المختلفة من عنصر التيتانيوم على عوامل النمو ، المكونات الكيميائية ، الجودة ، تركيز العناصر المتبقية في التربة بعد حصاد نبات الخس المزروع تحت ظروف التربة الرمليه والري بمحلول كوبر المغذي خلال الموسم الشتوي ٢٠١٨/٢٠١٧. وقد استخدم التصميم التجريبي في قطاعات كاملة العشوائيه مع تكرار كل معامله ٤ مرات. ومعدلات التيتانيوم كانت (٠.٠ مليجرام /اللتر) T_1 & (٢٥ مليجرام /اللتر) T_2 &(٥٠ مليجرام /اللتر) T_3 & (٧٥ مليجرام /اللتر) T_4 ومصدره ثاني أكسيد التيتانيوم.أوضحت النتائج أن قيم كل عوامل النمو المدروسة لنبات الخس زادت بشكل كبير مع زيادة مستوي التيتانيوم من ٠.٠ إلى٢٥ مليجرام /اللتر ، ثم يلي ذلك نقص معنوي مع أي زيادة في عنصر التيتانيوم. ايضا وجد نفس الاتجاه لكل من النيتروجين ، الفسفور ، البوتاسيوم ، الحديد ، الكاروتين ،فيتامين C ، الكلوروفيل أ ،كلوروفيل ب، الكلوروفيل الكلي. على العكس من هذا الاتجاه حدث انخفاض حاد و ملحوظ في متوسط قيم النترات (NO_3-N) والنتريت (NO_2-N) في أوراق الخس. أما بالنسبة لتركيز التيتانيوم في الاوراق زادت القيم بشكل ملحوظ مع زيادة مستويات التيتانيوم المضاف.