Response of Potato Plants to Spraying with Titanium and Selenium

[1]Samer S.T.EL-Afify; [2]Mervat F. Farag and [1]Hamada M. B. EL-Metwally

[1]Veg. Res. Dept., Hort. Res. Inst., Agric. Res. Center, Giza, Egypt

[2]Hort. Dept., Fac. Agric., Beni Suef University, Egypt

ABSTRACT

This study was conducted on a private farm in Mit El-Karmeh village, Talkha District, Dakahlia Governorate, Egypt during the summer seasons of 2023 and 2024 to study the effect of foliar spraying with titanium (Ti) as form of titanium dioxide (TiO_3) and selenium as form of sodium selenite (Na_2SeO_3) at the following concentrations (0, 5, 10, and 15 mg/L each) and their interaction on the growth, productivity, and quality of potato tubers (Spunta cultivar) grown in clay soil. The most important results obtained were as follows: The interaction between spraying potato plants with both titanium (Ti) and selenium at a concentration of 15 mg/L for each of them) four times at 20, 40, 60, and 80 days after planting recorded the best values for each of the vegetative growth traits represented by plant height, number of leaves and stems per plant, leaf area per plant, fresh and dry weight of the foliage , and chemical characteristics of the shoot such as total chlorophyll in leaf tissues, the content of nitrogen, phosphorus and potassium at 90 days after planting Also this treatment increased the yield and its components (average tuber weight, plant yield and yield/fed.) and improved the quality characteristics of tubers at harvest, represented by the percentage of dry matter, specific gravity, tuber content of soluble solids, vitamin C, percentage of protein and starch, and selenium concentration.

Keywords: Potato- Titanium (Ti) - Selenium (Se)- Yield and tuber quality

INTRODUCTION

The Solanaceae family includes potatoes (*Solanum tuberosum* L.). It has enormous socio-economic value worldwide and is one of the most important dicotyledonous tuber crops (Andre et al., 2007). The cultivated area with Potato in Egypt reached 649.0 thousand feddans in 2022/2023, compared to 584.8 thousand feddans in 2021/2022, an increase of 11.0%, and the production quantity reached 8.6 million tons in 2022/2023, compared to 7.2 million tons in 2021/2022, an increase of 18.9%. with average 13.050 tons/ fed. in 2022/2023, (FAO, 2024).

Titanium (Ti) is considered a beneficial element for plant growth. Ti applied via roots or leaves at low concentrations has been documented to improve crop performance through stimulating the activity of certain enzymes, enhancing chlorophyll content and photosynthesis, promoting nutrient uptake, strengthening stress tolerance, and improving crop yield and quality (Lyu et al., 2017). Titanium applied via roots or leaves stimulates plant growth in a species-specific manner. The effect of titanium depends on the plant species, plant age and the tissue concentration of other minerals (Dumon and Ernst, 1988). The effect of foliar titanium application was substantially influenced by the nutrient nitrogen status of the plants. The plant response to titanium application was almost negligible under nitrogen deficiency (Tlustoš et al., 2005). Additionally, Ti improves photosynthetic efficiency, stimulates enzymatic processes, facilitates protein and chlorophyll synthesis, and enhances disease resistance in plants (Qureshi et al., 2018).

The positive effect of titanium on potato tuber yield was confirmed in a

study carried out by Szewczuk (2009). With a double Titanium application in a 0.07% concentration, the tuber yield of medium-late cultivar 'Bryza' on Luvisol was higher on average by 3.8 t/ha (16%) and reduced potato plant infestation by Phytophthora infestans. Also, Kalinowski and Wadas (2017) indicated that tuber number and tuber weight per plant were the highest by spraying with Titanium. In addition, Kleiber and Markivicz (2013) showed that spraying Ti to tomato plants increased nitrogen, phosphorus, calcium and magnesium biomass, chlorophyll content and high yields. Whoever, Bacilieri et al., 2022 showed that the ideal level of titanium applied by leaf for greater total chlorophyll and yield of tubers is 15.3 g of Ti /ha. as compared to other concentrations, 0, 10.2, 15.3, 20.4 and 22.9 g/ha.

Selenium, a trace element, plays an important role in various biological processes, especially as an antioxidant (Abdalla et al., 2023). As an essential nutrient for humans, Selenium (Se) is important for many metabolic functions and helps plants to withstand separate violent and biological stresses. Se is essential for antioxidant reactions, hormone homeostasis, and other physiological processes in plant cells. It can improve the activity of glutathione peroxidase (GPX), which makes crops more resilient to biological impacts that are not traditional (El-Ramady et al., 2015). Selenium also has a positive impact on carbohydrate accumulation in potatoes and potentially on yield formation, spraying Se has been employed to enhance the selenium content in potatoes (Poggi, et al., 2000). In this regard, spraying potato plants with Se at 20 g /fed. gave an increase in all growth characters and nitrogen, phosphorus and potassium contents and its uptake by shoots, yield and its components of potato such as tuber diameter, tuber size, average tuber weight and tuber yield /feddan, tuber quality traits such as specific gravity, total protein, starch and total carbohydrates as well as N, P and K contents in tuber (Yassen et al., 2011). Also, Ibrahim and Ibrahim (2016) found that foliar application of Se at (10 µM), significantly increased potato fresh and dry weight of shoots as well as total chlorophyll in leaf tissues, tuber weight/plant and total yield than Se at high concentration (100 µM). In addition, El-Ghamry et al. (2024) indicated that plant height, both fresh and dry weight/plant of potato plant as well as total chlorophyll content in the leaves, average tuber weight number of tubers/ plant and total yield of potato as well as tuber quality significantly increased with selenium at 20.0 mg /L as compared to unsprayed plants

Therefore, the primary purpose of this research is to assess the effects of Ti and Se on the performance, quantitative and qualitative yield of potatoes by examining the potential benefits of these elements, this study aims to contribute to the development of sustainable strategies for improving potato cultivation.

MATERIALS AND METHODS

A controlled field investigation was performed to assess the impact of foliar-applied titanium (Ti) and selenium (Se) on potato (cv. Spunta) growth, productivity, and tuber quality. The study included 16 treatments which were the combinations between Ti at 0, 5, 10, and 15 mg/L and Se at 0, 5, 10, and 15 mg/L. The study employed a split-plot design with three replications; the main plots were Ti concentrations, while the sub-plots were Se levels across two consecutive growing seasons (2023 and 2024).

Experimental site: The trial was conducted during two successive seasons of 2023 and 2024 at a privately-owned farm in Mit-Elkorma village, Talkha District, El Dakhlia Governorate, Egypt.

Soil sampling (average of the two seasons): Initial soil analysis (0-30 cm depth) revealed:
Texture: Clayey (49% clay, 28.36% silt and, 22.64% sand), Chemical properties were Organic matter: 1.79%, available N: 44.5 mg kg^{-1}, available P: 10.94 mg kg^{-1}, available K: 219.3 mg kg^{-1}, pH: 7.65 and EC: 3.5 dS m^{-1}.

Experimental setup:
The plot area was 10.5 m^2, each plot had three ridges 0.7 m wide and 5 m long, and the distance between hills was 30 cm. Seed tubers (40 g pieces, approximately) were sourced from MASR (The Ministry of Agricultural and Soil Reclamation) and planted on 5 and 7th January in the 1st and 2nd season, respectively. Titanium and selenium were added in the form of titanium dioxide (TiO_3) and sodium selenite (Na_2SeO_3), which were supplied from Sigma-Aldrich (analytical grade), and then the studied concentrations were prepared. Plants were sprayed with different concentrations of Ti and Se four times every 20-day interval beginning 20 days after planting using a manual atomizer in the morning in both seasons. In the meantime, the untreated plants (control) received a single application of water. Standard agronomic practices and irrigation flood followed conventional potato production guidelines.

Data recorded:

Plant growth: During the late vegetative growth phase, corresponding to approximately two-thirds of the plant's life cycle (after 90 days from planting), five plants were randomly selected from each experimental unit for detailed morphological and physiological evaluation. The selected plants were carefully measured for several key growth parameters, including plant height in centimeters, number of both leaves and stem per plant , leaf area/ plant was measured in square meters, dry weight of foliage per plant in grams,

Leaf chemical analysis: At the same time 90 days after planting in both seasons, the photosynthetic capacity (SPAD) was assessed by the use of a spade meter through the measurement of chlorophyll material, and provided a unit - free value indicating a relative chlorophyll concentration which was analyzed as described by Picazo et al. (2013). Nitrogen, phosphorus, and potassium contents in leaves at were determined according to the methods described by according to AOAC (2006).

Yield and its components: After 120 days from planting, tubers from each plot were measured weighed to evaluate the yield properties. The evaluation included measurement of the average weight of individual tubers (in grams), counts the number of tubers per plant, tuber weight per plant and calculated the total tuber (in ton Feddan).

Tuber quality: Several parameters for tuber quality were evaluation: Dry matter (%), specific gravity, total soluble solid (TSS %), Vitamin C concentration (mg per 100 grams), total protein (%), total sugar content (%) and starch percentage. All tubers quality measurements followed the standard procedures mentioned in AOAC (2006). In addition, selenium concentrations were quantified through electrothermal atomic absorption spectrometry using a Perkin Elmer Model 5100, following the methodology described by (Kumpulainen et al. 1983).

Statistical analysis: According to Snedecor and Cochran (1980), the data were properly subjected to statistical analysis of variance. Duncan's' multiple range test (Duncan, 1958) was used to compare the differences among treatments, with means having different letters being statistically significant and means following the same letter being statistically insignificant.

RESULTS AND DISCUSSION

1. Plant growth:

Effect of titanium (Ti) concentrations:

Data in **Table (1)**show that spraying potato plants with Ti at 15 mg /l gave the highest values of plant height (61.26 and

60.72 cm) number of leaves/ plant (31.24 and 31.12), number of stems/plant (5.37 and 5.32) leaf area/plant (0.593 and 0.605 m^2), and foliage dry weight (21.59 and 21.46 g), followed by Ti at 10 mg /l at 90 days after planting in both seasons. The increases in foliage dry weight (g) were about 1.90 and 2.09 for Ti at 5 mg /l , 4.34 and 4.21 for Ti at 10 mg /l and 4.75 and 4.74 for Ti at 15 mg /l over the control treatment (spraying with water) in the 1st and 2nd seasons, respectively.

Table (1). Effect of spraying with titanium on plant growth at 90 days after planting of potato plants during 2023 and 2024 seasons

Treatments	Plant height (cm)	Number of leaves/ plant	Number of stems/plant	Leaf area/ plant (m^2)	Foliage fresh weight (g)	Foliage dry weight (g)
			2023 season			
Control	53.20 d	19.12 d	4.50 c	0.415 c	168.70 d	16.84 c
5 mg/l	55.93 c	24.25 c	4.50 c	0.535 b	182.02 c	18.74 b
10 mg/l	59.32 b	27.25 b	5.12 b	0.552 b	210.75 b	21.23 a
15 mg/l	61.26 a	31.24 a	5.37 a	0.593a	225.90 a	21.59 a
			2024 season			
Control	54.74 c	20.12 d	4.62 b	0.421 d	176.33 c	16.72 c
5 mg/l	56.44 b	24.00 c	4.25 c	0.533 c	186.35 c	18.81 b
10 mg/l	59.82 a	27.12 b	5.62a	0.560 b	218.85 b	20.93 a
15 mg/l	60.72 a	31.12a	5.62a	0.605 a	235.45 a	21.46 a

Control: spraying with water

Titanium applied via leaves stimulates plant growth in a species-specific manner. The effect of titanium depends on the plant species, plant age and the tissue concentration of other minerals (Dumon and Ernst, 1988). Titanium has many beneficial physical effects including plant tissue, including elevated iron and magnesium concentrations, expanded leaf assimilation area and stimulated chlorophyll biosynthesis (Baiceler et al., 2017). These outcomes are consistent with Wadas and Kalinowsk (2017) indicated that spraying potato plants during leaf development stage with Ti had a greater effect on the leaf weight ratio (LAR) as compared to control treatment. Also, Al-Khafaji et al. (2024) stated that spraying titanium dioxide produced the best results for increasing potato plant leaf area and shoot dry weight, when compared to non-spraying (T0).

Effect of selenium (Se) concentrations: The obtained results in **Table (2)** indicate that plant growth of potato plants significantly increased with increasing Se up to 15 mg/l and Se at 15 mg /l gave the highest values of plant height (59.20 and 58.91cm) number of leaves/plant (29.24 and29.50), number of stems/plant (5.50 and 5.37), leaf area/plant (0.575 and 0.582 m^2), and foliage dry weight (21.13 and 21.06 g), followed by Ti at 10 mg/l at 90 days after planting in both seasons, followed by Se at 10 mg /l at 90 days after planting in both seasons. The increases in foliage dry weight (g) were about 3.07 and 2.59 for Se at 5 mg /l, 4.04 and 4.15 for Se at 10 mg/l and 4.41 and 4.36 for Se at 15 mg /l over the control treatment (spraying with water) in the 1st and 2nd seasons, respectively.

Table (2). Effect of spraying with selenium on plant growth at 90 days after planting of potato plants during 2023 and 2024 seasons.

Treatments	Plant height (cm)	Number of leaves/plant	Number of stems/plant	Leaf area/ plant (m^2)	Foliage fresh weight (g)	Foliage dry weight (g)
			2023 season			
Control	55.06 c	18.50 d	4.25 d	0.407 d	158.52 d	16.72 c
5 mg/l	56.56 b	26.50 c	5.00 b	0.550 c	188.53 c	19.79 b
10 mg/l	58.89 a	27.62 b	4.75 c	0.563 b	212.63 b	20.76a
15 mg/l	59.20 a	29.24 a	5.50 a	0.575 a	227.70 a	21.13a
			2024 season			
Control	55.60 c	19.00 d	4.50 c	0.437 d	162.35 d	16.70 c
5 mg/l	57.83 b	26.25 c	5.12 b	0.541 c	200.78 c	19.29 b
10 mg/l	59.39 a	27.62 b	5.12 b	0.558 b	220.05 b	20.85 a
15 mg/l	58.91 ab	29.50 a	5.37a	0.582a	233.80 a	21.06 a

Control: spraying with water

Se's effect on plant growth primarily depends on its concentration; at moderate levels, it can boost antioxidant levels by boosting superoxide dismutase (SOD) activity and halting the depletion of tocopherols, which in turn can enhance plant growth (Xue et al., 2001). These results are agreement with those obtained with (Yassen et al., 2011) showed that spraying potato plants with 20 g /fed. gave an increase in all growth characters Also, Ibrahim and Ibrahim (2016) found that foliar application of Se at (10 µM), significantly increased dry weight of shoots than Se at high concentration (100 µM). In addition, El-Ghamry et al. (2024) indicated that plant height , both fresh and dry weight / plant of potato plant significantly increased with selenium at 20.0 mg /L as compared to unsprayed plant.

Effect of the interaction:

The interaction between spraying with Ti at 15 mg/l and Se at 15 mg/l increased plant height, number of leaves/plant, number of stems/plant, leaf area/plant, and foliage dry weight, with no significant differences with the interaction between Ti at 15 mg/ and Se at 10 mg/l in the 2nd season with respect to plant height, number of leaves/plant, number of stems/plant and leaf area/plant and in both seasons with respect to foliage dry weight. This means that the interaction between Ti at 15 mg/l and Se at 15 mg/l increased plant height, number of leaves/plant, number of stems/plant and leaf area/ plant; whereas, the interaction between Ti at 15 mg/l and Se at 10 mg/l increased foliage dry weight. This study revealed that the combined application of titanium (Ti) and selenium (Se) effectively improves potato plant growth. Both elements show the biostimulant properties shown by Du Jordin (2015), these elements work through many physiological mechanisms, including increased cell wall stability, better osmoregulation, stimulation of phytohormone synthesis, increase in nutritional efficiency and increase evaporation rates.

2. Total chlorophyll and N, P and K contents:

Effect of Ti concentration:

Foliar spray with Ti at 10 mg /l increased total chlorophyll (SPAD), N, P and K contents in shoots with no significant differences with Ti at 15 mg /l in both seasons, with respect to K content in 1st season at 90 days after planting (Table, 4). In this regard, titanium application was almost negligible under nitrogen deficiency (Tlustoš et al., 2005). Additionally, Ti improves photosynthetic efficiency, stimulates enzymatic processes, facilitates protein and chlorophyll synthesis **(**Qureshi et al., 2018). These results are harmony with those reported with Kleiber and Markivicz (2013) on tomato. They showed that spraying Ti to tomato plants increased nitrogen, phosphorus, and chlorophyll content. In addition, Bacilieri et al. (2022) showed that the ideal level of titanium applied by leaf for greater total chlorophyll in leaf of potato.

Table (3). Effect of the interaction between Spraying with titanium and selenium on plant growth at 90 days after planting of potato plants during 2023 and 2024 seasons.

Treatments		Plant height (cm)	Number of leaves/plant	Number of stems/plant	Leaf area/ plant (m^2)	Foliage dry weight (g)
Titanium (mg/l)	**Selenium (mg/l)**			**2023 season**		
Control	**Control**	50.18 h	15.50 l	4.00 e	0.335 j	13.76 f
	5	52.29 g	18.50 k	4.50 d	0.430 h	15.88 e
	10	54.64 f	20.50 i	4.50 d	0.440 gh	18.49 d
	15	55.71 f	22.00 h	5.00 c	0.455 g	19.23 cd
5	**Control**	54.75 f	18.50 k	4.00 e	0.385 i	14.43 f
	5	55.30 f	25.50 g	4.50 d	0.580 e	19.85 bc
	10	57.82 de	26.50 f	4.50 d	0.585 de	20.15 bc
	15	55.87 ef	26.50 f	5.00 c	0.590 c-e	20.55 b
10	**Control**	56.00 ef	19.50 j	4.50 d	0.400 i	19.19 cd
	5	58.09 d	28.50 e	5.50 b	0.585 de	21.70[a]
	10	60.82 a-c	28.50 e	4.50 d	0.615 b	21.90[a]
	15	62.40 ab	32.50 d	6.00 a	0.610 bc	22.13[a]
15	**Control**	59.34 cd	20.50 i	4.50 d	0.510 f	19.51 b-d
	5	60.57 bc	33.50 c	5.50 b	0.605 b-d	21.75a
	10	62.30 ab	35.01 b	5.50 b	0.615 b	22.50a
	15	62.83 a	35.98 a	6.00 a	0.645 a	22.62a
				2024 season		
Control	**Control**	51.78 j	16.50 k	4.50 d	0.355 h	13.12 g
	5	54.86 i	19.00 ij	4.50 d	0.405 g	15.43 f
	10	55.93 hi	21.50 h	4.50 d	0.425 g	19.09 e
	15	56.41 g-i	23.50 g	5.00 c	0.500 f	19.24 de
5	**Control**	55.14 hi	18.50 j	4.00 e	0.405 g	15.53 f
	5	57.17 e-h	24.50 fg	4.00 e	0.570 e	19.02 e
	10	58.45 d-g	25.50 f	4.50 d	0.575 de	20.19 cd
	15	55.02 hi	27.50 de	4.50 d	0.585 c-e	20.50 c
10	**Control**	56.65 f-i	20.50 hi	5.00 c	0.425 g	18.74 e
	5	59.43 c-e	27.50 e	6.00 a	0.590 c-e	20.93 bc
	10	61.30 a-c	29.00 d	5.50 b	0.610a-c	21.96 a
	15	61.92 ab	31.50 c	6.00 a	0.615ab	22.09 a
15	**Control**	58.84 d-f	20.50 hi	4.50 d	0.565 e	19.44 de
	5	59.88 b-d	34.00 b	6.00 a	0.600 b-d	21.80 ab
	10	61.89 ab	34.50 ab	6.00 a	0.625a	22.19 a
	15	62.30 a	35.50 a	6.00 a	0.630a	22.44 a

Control: spraying with water

Table (4). Effect of spraying with titanium and selenium on total chlorophyll in leaves and N, P and K contents in shoots at 90 days after planting of potato plants during 2023 and 2024 seasons.

Treatments	Total chlorophyll (SPAD)		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Effect of titanium								
Control	43.32 c	43.67 c	2.76 c	2.79 b	0.423 c	0.422 c	2.19 d	2.18 c
5 mg/l	46.23 b	46.33 b	3.33 b	3.36 a	0.444 b	0.452 b	2.59 c	2.60 b
10 mg/l	46.99 a	46.97 a	3.41ab	3.43 a	0.464 a	0.472 a	2.91 b	2.97 a
15 mg/l	47.29 a	47.29 a	3.50a	3.41 a	0.472 a	0.477 a	3.15 a	3.06 a
Effect of selenium								
Control	44.54 d	44.92 c	2.98 c	3.01 d	0.428 c	0.437 c	2.33 c	2.28 c
5 mg/l	45.55 c	45.70 b	3.25 b	3.19 c	0.449 b	0.455 b	2.65 b	2.64 b
10 mg/l	46.62 b	46.72 a	3.27 b	3.32 b	0.457 b	0.462 ab	2.86 a	2.87 a
15 mg/l	47.12 a	46.92 a	3.51a	3.47a	0.468 a	0.469 a	2.99 a	3.03 a

1st season = 2023, 2nd season = 2024 season, Control: spraying with water

Effect of Se concentration:

Data in **Table (4)** indicate that spraying with Se at 15 mg/l gave the highest values of total chlorophyll (SPAD), N and P contents in shoots, whereas Se at 10 mg/l gave the highest values of K content in both seasons.

In this regard, spraying potato plants with Se at 20 g/fed. produced the highest values of nitrogen, phosphorus and potassium contents and its uptake by shoots (Yassen et al., 2011). Also, Ibrahim and Ibrahim (2016) found that foliar application of Se at (10 µM), significantly increased total chlorophyll in leaf tissues than Se at high concentration (100 µM). In addition, El-Ghamry et al. (2024) indicated that total chlorophyll content in the leaves of potato significantly increased with selenium at 20.0 mg/L as compared to unsprayed plant.

Effect of the interaction:

The interaction between Ti at 15 mg/l and Se at 15 mg/l significantly increased total chlorophyll (SPAD), P and K contents in shoots of potato, whereas, the interaction between Ti at 15 mg/l and Se at 10 mg/l significantly increased N contents in shoots at 90 days after planting in both seasons **(Table 5).**

Table (5). Effect of the interaction between spraying with titanium and selenium on total chlorophyll in leaves and N, P and K contents in shoots at 90 days after planting of potato plants during 2023 and 2024 seasons.

Treatments		Total chlorophyll (SPAD)		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
Titanium (mg/l)	Selenium (mg/l)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	**Control**	41.52 i	42.25 j	2.46 h	2.51 h	0.402 i	0.406 g	1.66 i	1.57 g
	5	42.94 h	42.59 j	2.71 g	2.63 h	0.417 hi	0.423fg	2.14 h	2.06 f
	10	44.09 g	44.83 i	2.84 g	2.92 g	0.430gh	0.427e-g	2.32 gh	2.39 ef
	15	44.74 f	45.02 hi	3.05 f	3.11 fg	0.443e-g	0.435d-f	2.64d-g	2.73c-e
5	**Control**	45.79de	45.95e-h	3.14ef	3.09fg	0.429gh	0.438d-f	2.25gh	2.14f
	5	45.80de	46.09e-g	3.33c-e	3.38 b-e	0.442e-g	0.450c-e	2.44fgh	2.64de
	10	46.21cd	46.51d-g	3.36 cd	3.41 a-e	0.446d-g	0.454b-d	2.81 c-f	2.71 c-e
	15	47.12 b	46.77 c-f	3.51 bc	3.56 a-d	0.459c-e	0.467a-c	2.86c-e	2.94 a-d
10	**Control**	45.36 ef	45.66g-i	3.11 f	3.21ef	0.432f-h	0.450c-e	2.52e-h	2.61 de
	5	46.60bc	46.90b-e	3.42 bc	3.35de	0.464b-d	0.472 a-c	2.91 b-d	2.86 b-d
	10	47.88 a	47.53a-c	3.53 bc	3.59 ab	0.475a-c	0.482 a	3.05 a-c	3.19ab
	15	48.14 a	47.80 ab	3.60 b	3.58 a-c	0.487a	0.485 a	3.17 a-c	3.23a
15	**Control**	45.51e	45.82f-i	3.21d-f	3.25ef	0.452d-f	0.454b-d	2.90c-e	2.81 cd
	5	46.87 bc	47.23a-d	3.57 b	3.42 a-e	0.474a-c	0.476 ab	3.11 a-c	3.01a-c
	10	48.32 a	48.02 a	3.36 cd	3.36cde	0.480ab	0.488 a	3.28 ab	3.21ab
	15	48.48 a	48.11 a	3.88a	3.63 a	0.485a	0.490 a	3.32 a	3.22a

1st season = 2023, 2nd season = 2024 season, Control: spraying with water

3. Yield and its components:-

Effect of Ti concentration:

Data in **Table (6)** indicate that average tuber weight, tuber weight/plant and total yield/fed. increased with increasing Ti concentration up to 15 mg/l in both seasons. Ti at 15 mg/l gave the highest average tuber weight (160.09 and 158.90 g), tuber weight/plant (787.12 and 794.56 g) and total yield (15.504 and 15.314 ton /fed) in the 1st and 2nd seasons, respectively. As for average number of tubers/plant, there were no significant differences among Ti treatments in both seasons. The increase in total yield (ton) were about 0.526 and 0.716 for Ti at 5 mg /l, 1.418 and 1.975 for Ti at 10 mg /l and 3.395 and 3.390 for Ti at 15 mg /l over the control treatment in the 1st and 2nd seasons, respectively.

Ti improves photosynthetic efficiency, stimulates enzymatic processes, facilitates protein and chlorophyll synthesis, and enhances disease resistance in plants and then increased the productivity of potato (Qureshi et al., 2018**)**. These results are in agreement with those of Szewczuk (2009) indicated that a double Ti application in a 0.07% concentration, the tuber yield of medium-late cultivar 'Bryza' on Luvisol was higher on average by 3.8 t/ha (16%). Also, Kalinowski and Wadas (2017) indicated that tuber number and tuber weight per plant were the highest by spraying with Ti. In addition, Bacilieri et al., (2022) showed that the ideal level of titanium applied by leaf for greater yield of tubers is 15.3 g of Ti /ha. as compared to other concentrations , 0, 10.2, 15.3, 20.4 and 22.9 g/ha. In addition Al-Khafaji et al. (2024) showed that highest values of tuber weight, and marketable yield when compared to the lowest in non-spraying (T0).

Effect of Se concentration:

The obtained results in **Table (6)** illustrate that average tuber weight, tuber weight/plant and total yield /fed. significantly increased with increasing Se concentration up to 15 mg /l wit no significant differences with Se at 10 mg /l in both seasons. Se at 15 mg/l produced the highest values of average tuber weight (155.88 and 155.47 g), average number of tuber (4.58 and 4.83), tuber weight/plant (715.57 and 752.54 g) and total yield (14.096 and 14.744 ton /fed.) in both seasons. As for average number of tubers/plant, there were no significant differences among Se treatments in both seasons. The increase in total yield (ton) were about 0.670 and 0.723 for Se at 5 mg /l, 1.240 and 1.514 for Se at 10 mg /l and 1.506 and 2.472 for Se at 15 mg /l over the control treatment in the 1st and 2nd seasons, respectively.

Table (6). Effect of spraying with titanium and selenium on yield and its components of potato plants during 2023 and 2024 seasons.

Treatments	Average tuber weight (g)		Average number of tuber/plant		Tuber weight/plant (g)		Total yield (ton/fed.)	
	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season
Effect of titanium								
Control	143.02 d	142.84d	4.24 a	4.24 a	607.71d	607.78d	12.109 d	11.929 d
5 mg/l	148.69c	148.98 c	4.33 a	4.33 a	643.82 c	646.17c	12.635c	12.645c
10 mg/l	152.78 b	153.83 b	4.50 a	4.58 a	688.28 b	705.72 b	13.527 b	13.904 b
15 mg/l	160.09a	158.90a	4.91 a	4.99 a	787.12a	794.56a	15.504a	15.319a
Effect of selenium								
Control	147.10 c	146.94b	4.33 a	4.24 a	638.33c	625.62d	12.590c	12.272d
5 mg/l	149.29c	149.54 b	4.49 a	4.41 a	673.16b	661.95 c	13.260b	12.995 c
10 mg/l	152.32 b	152.60 a	4.58 a	4.66 a	699.67 a	714.13 b	13.830 a	13.786b
15 mg/l	155.88a	155.47a	4.58 a	4.83a	715.77 a	752.54 a	14.096 a	14.744 a

Control: spraying with water

Selenium also has a positive impact on carbohydrate accumulation in potatoes and potentially on yield formation (Poggi, et al., 2000). In this concern, selenium can alter antioxidant levels in plants and detoxify superoxide radicals, consequently preventing oxidative damage and protecting the membranes and enzymes (Habibi, 2013). All the beneficial effects of added selenium were positively reflected on plant growth, nutrient contents, and yield of potato plants. In this regard, tuber diameter, tuber size, average tuber weight and tuber yield /feddan, were the best when spraying potato plants with 20 g /fed. (Yassen et al., 2011). Also, Ibrahim and Ibrahim (2016) found that foliar application of Se at (10 µM), produced the maximum tuber weight/plant and total yield than Se at high concentration (100 µM). In addition, El-Ghamry et al. (2024) indicated that, average tuber weight number of tubers/ plant and total yield of potato as well as tuber quality significantly increased with selenium at 20.0 mg /L as compared to unsprayed plan

Effect of the interaction:

The interaction between foliar spray with Ti at 15 mg/l and Se at 10 or 15 mg/l increased average tuber weight, tuber weight/plant and total yield/fed **(Table 7).** As for average number of tubers/plant, there were no significant differences among the interaction between Ti and Se treatments in both seasons. Under different levels of Ti (0, 5, 10 and 15 mg l), spraying with Se at 5, 10 and 15 mg/l were the best treatments for enhancing tuber weight, tuber yield/plant and total yield/fed., compared to control (0 Se) under the same treatments of Ti in both seasons. For the forgoing results, it could be concluded that the interaction between Ti at 15 mg/l and Se at 10 or 15 mg/l increased plant growth, total chlorophyll, P and K contents in shoots, average tuber weight, tuber weight/plant and total yield/fed of potato during summer plantations.

Table (7). Effect of the interaction between spraying with titanium and selenium on yield and its components of potato plants during 2023 and 2024 seasons.

Treatments		Average tuber weight (g)		Average number of tubers / plant		Tuber weight/plant (g)		Total yield (ton /fed.)	
Titanium (mg/l)	Selenium (mg/l)	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season
Control	Control	140.22g	138.35h	4.00 a	4.00 a	560.88f	553.40 g	11.162g	10.957i
	5	141.18fg	142.17gh	4.33 a	4.00 a	611.31e	568.68g	12.165f	11.146 i
	10	143.26efg	144.50fg	4.33 a	4.33 a	620.32de	625.68ef	12.406 ef	12.013gh
	15	147.42de	146.33fg	4.33 a	4.66 a	638.33de	683.36cd	12.703def	13.599cd
10	Control	144.50efg	145.87fg	4.33 a	4.00 a	625.68de	583.48fg	12.326ef	11.436hi
	5	146.27def	146.18fg	4.33 a	4.33 a	633.35de	632.96de	12.350ef	12.343fg
	10	150.50cd	149.36def	4.33 a	4.33 a	651.67de	646.73de	12.838de	12.805ef
	15	153.48bc	154.50bcd	4.33 a	4.67 a	664.57 d	721.52c	13.026d	13.997bc
10	Control	146.50de	148.31efg	4.33 a	4.33 a	634.35de	642.18de	12.370ef	12.587efg
	5	150.13cd	153.51cde	4.33 a	4.33 a	650.06de	664.70de	12.806de	13.095de
	10	154.00bc	156.00bc	4.67 a	4.67 a	719.18c	728.52c	14.168c	14.498 b
	15	160.50 a	157.50abc	4.67 a	5.00 a	749.53bc	787.50 b	14.766b	15.435 a
15	Control	157.17ab	155.24bcd	4.66 a	4.66 a	732.41 c	723.42c	14.502bc	14.107bc
	5	159.58 a	156.29bc	5.00 a	5.00 a	797.90ab	781.45b	15.719 a	15.395 a
	10	161.50 a	160.52ab	5.00 a	5.33 a	807.50 a	855.57 a	15.908 a	15.828 a
	15	162.13 a	163.56 a	5.00 a	5.00	810.65 a	817.80ab	15.889 a	15.947 a

Control: spraying with water

4. Tuber quality:-

Effect of Ti concentration:

Spraying potato plants with Ti at 15 mg /l scored the highest values of dry matter (21.27 and 21.59 %), specific gravity (1.166 and 1.54 g/cm^3), TSS (7.14 and 7.31 brix), vitamin C (18.98 and 19.10 mg/100 g FW) (Table 8), total protein (9.24 and 8.94 %), total sugars (5.51 and 5.48 %), starch (17.51 and 17.77 %) and Se contents (2.10 and 2.13 (µg/ g DW) in the 1st and 2nd seasons, respectively (Table 9). These results align with the findings of Al-Khafaji et al. (2024) showed that the highest dry matter percent in potato tuber was obtained by plants which sprayed with titanium dioxide compared to the lowest in non-spraying (T0).

Effect of Se concentration:

Dry matter, specific gravity, TSS, vitamin C, total protein, total sugars, starch and Se contents in tuber significantly increased with increasing Se at 15 mg/l in both seasons **(Tables 8 and 9**). This means that Se at 15 mg /l gave the highest values of dry matter (20.85 and 21.02 %), specific gravity (1.087 and 1.081 g/cm^3), TSS (7.35 and 7.37 brix), vitamin C (18.44 and 18.54 mg/100 g FW) (Table, 8), total protein (8.93 and 8.73 %), total sugars (7.96 and 4.96%), starch (16.68 and 16.81 %) and Se contents (2.37 and 43 "µg/ g DW") in the 1st and 2nd seasons, respectively (Table 9). Selenium also has a positive impact on carbohydrate accumulation in potatoes; spraying Se has been employed to enhance the selenium content in potatoes (Poggi, et al., 2000). These results are harmony with those reported with (Yassen et al., 2011) showed that spraying potato plants with 20 g /fed. gave an increase tuber quality traits such as specific gravity, total protein, starch and total carbohydrates contents in tuber . Also, Belal (2020) indicated that spraying tomato plants with the moderate concentration 20 ppm significantly increased TSS in fruits as compared to 0 or 40 ppm. In addition, El-Ghamry et al. (2024) indicated that tuber quality significantly increased with selenium at 20.0 mg /L as compared to unsprayed plant.

Table (8). Effect of spraying with titanium and selenium on in potato tuber quality at harvest time during 2023 and 2024 seasons.

Treatments	Dry matter (%)		Specific gravity (g/cm^3)		TSS (%)		Vitamin C mg/100g FW	
	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season
				Effect of titanium				
Control	17.39 d	17.50 d	0.988 d	0.992 c	6.67 c	6.70 c	16.29 c	16.03 c
5 mg/l	19.28 c	19.34 c	1.033 c	1.036 b	6.95 b	7.03 b	16.70 c	16.78 c
10 mg/l	20.14 b	20.42 b	1.070 b	1.050 b	7.20 a	7.21 a	17.85 b	17.96 b
15 mg/l	21.27 a	21.59a	1.166 a	1.154 a	7.14 a	7.31 a	18.98 a	19.10 a
				Effect of selenium				
Control	17.44 d	17.69 c	1.032 c	1.031 c	6.42 d	6.38 c	15.60 c	15.58 c
5 mg/l	19.64 c	19.89 b	1.059 b	1.049 b	6.96 c	7.21 b	17.74 b	17.71 b
10 mg/l	20.13 b	20.24 b	1.080a	1.072 a	7.23 b	7.29 ab	18.05 ab	18.04ab
15 mg/l	20.85 a	21.02 a	1.087a	1.081 a	7.35 a	7.37 a	18.44 a	18.54a

Control: spraying with water

Table (9). Effect of spraying with titanium and selenium on tubers quality at harvest time during 2023 and 2024 seasons.

Treatments	Total protein (%)		Total sugars (%)		Starch (%)		Se (µg/g DW)	
	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season
Effect of titanium								
Control	7.10 d	7.00 c	3.96 d	3.92 d	13.91 d	14.00	2.11 b	2.12 b
5 mg/l	7.93 c	8.10 b	4.44 c	4.41 c	15.32 c	15.47 c	2.11 b	2.10 b
10 mg/l	8.51 b	8.62 a	4.79 b	4.94 b	16.11 b	16.34 b	2.16 a	2.18 a
15 mg/l	9.24a	8.94 a	5.51a	5.48a	17.51a	17.77 a	2.10 b	2.13 ab
effect of selenium								
Control	7.53 c	7.61 c	4.37 d	4.38 d	14.45 d	14.65 c	1.71 d	1.67 d
5 mg/l	7.86 c	7.92 c	4.61 c	4.61 c	15.61 c	15.91 b	2.13 c	2.16 c
10 mg/l	8.46 b	8.39 b	4.77 b	4.79 b	16.10 b	16.19 b	2.26 b	2.27 b
15 mg/l	8.93 a	8.73 a	4.96 a	4.96 a	16.68a	16.81 a	2.37a	2.43 a

Control: spraying with water

Effect of the interaction:

In general, the interaction between foliar spray with Ti at 15 mg and Se at 10 or 15 mg/l increased tuber quality (dry matter, specific gravity, TSS, vitamin C, total protein, total sugars, starch and Se contents in tuber) as shown in **Tables (10 and 11).** For all the interaction treatments, dry matter were around from 16.26 and 16.89 % to 23.38 and 23.24 % and starch were around from 13.00 and 13.51 % to 18.70 and 18.59 % in both seasons.

Table (10). Effect of the interaction between spraying with titanium and selenium on tuber quality in potato at harvest time during 2023 and 2024 seasons.

Treatments		Dry matter (%)		Specific gravity (g/cm^3)		TSS (%)		Vitamin C mg/100g FW	
Titanium (mg/l)	Selenium (mg/l)	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season
Control	**Control**	16.26 h	16.89i	0.943i	0.965g	6.46 f	6.39 ij	15.16 g	14.19 h
	5	17.20g	17.05 i	0.978hi	0.989fg	6.59 f	6.72gh	16.72ef	16.72e-g
	10	17.87fg	17.74hi	1.016fg	1.001ef	6.49 f	6.79gh	16.83ef	16.79d-g
	15	18.24 f	18.32 gh	1.018fg	1.013 ef	6.17 g	6.92fg	16.47fg	16.42e-g
5	**Control**	17.71 fg	17.60 hi	1.007 gh	1.011ef	6.52 f	6.49 hi	15.09 g	15.49gh
	5	19.57e	19.21fg	1.035e-g	1.014ef	6.88 e	7.16ef	17.16d-f	17.16d-f
	10	19.62e	19.95 ef	1.038e-g	1.057cd	6.83 e	7.22d-f	17.23d-f	17.22d-f
	15	20.22 de	20.61de	1.053d-f	1.065cd	6.87 e	7.28 de	17.33d-f	17.28d-f
10	**Control**	17.93 fg	17.75 hi	1.040e-g	1.033 de	7.25cd	6.53hi	15.99fg	16.53e-g
	5	20.15de	21.30 cd	1.069c-e	1.035 de	7.21cd	7.35 c-e	17.95c-e	17.85c-e
	10	20.90cd	20.73 de	1.082cd	1.062 cd	7.03de	7.47b-d	18.44b-d	18.47b-d
	15	21.59 bc	21.92bc	1.092 c	1.071 c	7.54 ab	7.52 a-d	19.04bc	19.02 bc
15	**Control**	17.89 fg	18.54 gh	1.138 b	1.115 b	7.52 ab	6.13 j	16.17 fg	16.14 fg
	5	21.66bc	22.03 bc	1.156 ab	1.158a	7.33 bc	7.63 a-c	19.14 bc	19.13 bc
	10	22.16 b	22.57 ab	1.185 a	1.169a	7.54 ab	7.70 ab	19.72 ab	19.70 b
	15	23.38 a	23.24 a	1.186 a	1.177a	7.66 a	7.78 a	20.92 a	21.44 a

Control: spraying with water

Table (11). Effect of the interaction between spraying with titanium and selenium on tubers quality at harvest time during 2023 and 2024 seasons.

Treatments		Total protein (%)		Total sugars (%)		Starch (%)		Se (µg/g DW)	
Titanium (mg/l)	Selenium (mg/l)	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season	2023 season	2024 season
Control	Control	6.38h	6.09 h	3.85 g	3.69f	13.00 i	13.51i	1.75f	1.65 f
	5	6.94gh	6.30 h	3.90fg	3.88 ef	13.76 h	13.64hi	2.15d	2.15de
	10	7.52fg	7.75 fg	3.94e-g	4.01de	14.29g	14.19gh	2.20d	2.25cd
	15	7.58fg	7.86e-g	4.18ef	4.10de	14.59g	14.66g	2.35 bc	2.45 ab
5	Control	7.02gh	7.59g	4.20 ef	4.16 de	14.16gh	14.08g-i	1.75f	1.65 f
	5	7.28 g	8.06d-g	4.22 e	4.18 d	15.25 f	15.36 f	2.20 d	2.25 cd
	10	8.13ef	8.19 d-g	4.64 cd	4.61 c	15.69 ef	15.96ef	2.20 d	2.15 de
	15	9.30a-c	8.56 bcd	4.70 cd	4.69 bc	16.18de	16.48de	2.30 c	2.35 bc
10	Control	8.19 ef	8.47c-e	4.54 d	4.74 bc	14.34 g	14.20gh	1.80f	1.75 f
	5	8.24d-f	8.61b-d	4.60 cd	4.76 bc	16.12 de	17.04cd	2.15	2.20 d
	10	8.53 c-e	8.42 c-f	4.78 cd	4.89 bc	16.72 c	16.58de	2.30 c	2.35 bc
	15	9.11abc	8.99 a-c	5.26 b	5.39 a	17.27 b	17.54 bc	2.40 ab	2.45 ab
15	Control	8.56cde	8.31d-f	4.89 c	4.96 b	16.31cd	16.83 d	1.55 g	1.65f
	5	8.99 b-d	8.71b-d	5.74 a	5.62 a	17.32 b	17.62 bc	2.05 e	2.05 e
	10	9.66ab	9.21 ab	5.72 a	5.66 a	17.73 b	18.05ab	2.35 bc	2.35 bc
	15	9.75a	9.53 a	5.71 a	5.68 a	18.70a	18.59a	2.45 a	2.50 a

Control: spraying with water

CONCLUSION

Finally, it can be recommended to spray potato plants grown in the summer season with titanium and selenium together at a concentration of 15 mg/L each four times (20, 40, 60 and 80 days after planting) in order to obtain the best increase in plant growth, productivity and tuber quality, as this treatment was better than spraying with the same elements individually or without titanium and without selenium under the same conditions similar to the one used for this work.

REFERENCES

Abdalla, Z.F., El-Bassiony, A.E.M., El-Ramady, H.,ElSawy, S. and Shedeed, S. (2023). Broccoli Biofortification Using Biological Nano-and Mineral Fertilizers of Selenium: A Comparative Study under Soil Nutrient Deficiency Stress. Egyptian J. Soil Sci., 63(1):57-66.

Al-Khafaji, A.M., Al-jubouri, K.D.H. and Baktash, F.Y. (2024). Amelioration potato plant performance under drought conditions in Iraq by using titanium dioxide, and biodegrading, biodegradable treatments. Iraqi J. Agric. Sci., 55(6):1885-1893.

Andre, C.M., Ghislain, M., Bertin, P. and Oufir, M. (2007). Andean potato cultivars (*Solanum tuberosum* L.) as a source of antioxidant and mineral micronutrients. J. Agric. Food Chem., 55: 366–378.

Association of Analytical Chemists "AOAC" (2006). Official Methods of Analysis. 18th ed. AOAC International, Gaithersburg, Maryland.

Bacilieri, F.S., Lana, R.M.Q., Oliveira, R.C. and Luz, J.M.Q. (2022). Foliar application of titanium on potato crop. Comunicata Scientiae, 13: 1-8.

Bacilieri, F.S., Vasconcelos, A.C.P., Lana, R.M.Q, Mageste, J.G. and Torres, J.L.R. (2017). Titanium (Ti) in plant nutrition – A review. Aust. J. Crop Sci., 11(4): 382–386.

Belal, H.E.E. (2020). Effect of selenium on growth and yield of tomato plants. Ph.D. Thesis, Fac. Agric. Fayoum University, Egypt .

Dumon, J.C. and Ernst, W.H.O. (1988). Titanium in Plants. Journal of Plant Physiology, 133 (2): 203-209.

Duncan, D.B. (1958). Multiple Range and Multiple F-Test. Biometrics, 11: 1-5.

El-Ghamry, A.M., El-Sherpiny, M.A., Alkharpotly, A.A. and Elghareeb, E.M. (2024). The synergistic effects of organic composts and microelements co-application in enhancing potato productivity in saline soils . Heliyon, 10 (12)*:* 32694.

El-Ramady, H., Abdalla, N., Alshaal, T. and El-Henawy, A. (2015). Selenium and its role in higher plants. In: Lichtfouse E et al. (eds) Pollutants in buildings, water and living organisms, environmental chemistry for a sustainable world, Vol. 7. Springer, Cham, pp: 235–296.

FAO. (2024). Statistical Database. Food and agricultural organization of the united nations. Available at http:\\www.faostat.fao.org

Habibi, G. (2013). Effect of drought stress and selenium spraying on photosynthesis and antioxidant activity of spring barley. Acta Agric. Slov., 101 (1): 31-39.

Ibrahim, M.F.M. and Ibrahim, H.A. (2016). Assessment of selenium role in promoting or inhibiting potato plants under water stress. J. Hort. Sci. Ornamen. Plants, 8 (3): 125-139.

Kalinowski K. and Wadas, W. (2017). Effect of Titanium on the yield and yield components of very early-maturing potato cultivars. J. Central European Agric., 18(2):291-304.

Kleiber, T. and Markiewicz, B. (2013). Application of "Tytanit" in greenhouse tomato growing. Acta ScienTiarum Polonorum Hortorum Cultus, 12: 117–126.

Kumpulainen, J., Raittila, A.M.; Lehto, J. and Koivistoinen, P. (1983). Electro thermal atomic absorption spectrometric determination of selenium in foods and diets. J Assoc. Off Ana Chem., 66:1129-1135.

Picazo A., Rochera, C., Vicente, E., Miracle, M.R. and Camacho, A. (2013). Spectrophotometric methods for the determination of photosynthetic pigments in stratified lakes: a critical analysis based on comparisons with HPLC determinations in a model lake. Limnetica, 32 (1): 139-158.

Poggi, V., Arcioni, A., Filippini, P. and Pifferi, P.G. (2000). Foliar application of selenite and selenate to potato (*Solanum tuberosum*): Effect of a ligand agent on selenium content of tubers. J. Agric. Food Chem., 48: 4749–4751.

Qureshi, A., Singh, D.K. and Dwivedi, S. (2018). Nano-fertilizers: A Novel Way for Enhancing Nutrient Use Efficiency and Crop Productivity. Inter. J. Current Microbiol. Appl. Sci., 7: 3325-3335.

Snedecor, G.W. and Cochran, W.G. (1980). Statistical methods. 7th ed. Iowa State Univ. Press, Ames, Iowa, U.S.A., PP. 507.

Szewczuk, C. (2009). The influence of foliar fertilization on potato tubers yield. Annales Universitatis Mariae Curie-Skłodowska, Sectio E Agricultura, 64 (1): 7-12.

Tlustoš, P., Cígler, M., Hrubý, M., Kužel, J., Szákova, J. and Balik, J. (2005). The role of titanium in biomass production and its influence on essential elements contents

in field growing crops. Plant Soil Environ., 51(1): 19–25.

Wadas, W. and Kalinowski, K. (2017). Effect of titanium on assimilation leaf area and chlorophyll content of very early-maturing potato cultivars. Acta Sci. Pol. Agric.,16(2): 87–98.

Xue, T.L., Hartikainen, H. and Piironen, V. (2001). Antioxidative and growth-promoting effects of selenium on senescing lettuce. Plant Soil, 237: 55-61.

Yassen, A.A., Adam, S.M. and Zaghloul, S.M. (2011). Impact of Nitrogen Fertilizer and Foliar Spray of Selenium on Growth, Yield and Chemical Constituents of Potato plants. Australian J. Basic and Appl. Sci., 5(11): 1296-1303.

الملخص العربي

استجابة نباتات البطاطس للرش بالتيتانيوم والسلينيوم

سامر سمير طه العفيفى[1] مرفت فراج فرج[2] حماده ماهر بديرالمتولى[1]

[1]شعبه بحوث الخضر – معهد بحوث البساتين- مركز البحوث الزراعية- مصر

[2]قسم البساتين- كلية الزراعة- جامعه بنى سويف

أجريت هذه الدراسة في مزرعة خاصة بقرية ميت الكرما، منطقة طلخا، محافظة الدقهلية، مصر خلال موسمى صيف 2023، 2024 وذلك لدراسة تأثير الرش الورقى بكل من التيتانيوم فى صورة ثنائى اكسيد التيتانيوم والسيلينيوم فى صورة سيلينيت الصوديوم بالتركيزات الأتية (0، 5، 10، و15 ملجم/لتر لكل منهما) والتفاعل بينهما على النمو والإنتاجية وجودة درنات البطاطس (صنف سبونتا) النامية فى أرض طينية. وكانت أهم النتائج التى تم الحصول عليها كالتالى:

سجل التفاعل بين رش نباتات البطاطس بكل من التيتانيوم (Ti) والسيلينيوم بتركيز15 ملجم/لتر لكل منهما أربعة مرات عند 20، 40، 60، 80 يوم من الزراعة أفضل القيم لكل من صفات النمو الخضرى متمثلا فى ارتفاع النبات، عدد كل من الأوراق والسيقان للنبات، المساحة الورقية للنبات، الوزن الطازج والجاف لعرش النبات، الصفات الكيمائية للمجموع الهوائى مثل الكلورفيل الكلى فى أنسجه الورقة، محتوى العرش من النيتروجين والفوسفور والبوتاسيوم وذلك بعد 90 من يوم من الزراعة، أيضا أدت هذه المعاملة الى زيادة المحصول ومكوناته (متوسط وزن الدرنة، محصول النبات والفدان، وتحسين صفات الجودة فى الدرنات عند الحصاد متمثلة فى نسبه المادة الجافه، الكثافة النوعية، محتوى الدرنة من المواد الصلبة الذائبة، فيتامين ج، نسبه كل من البروتين والنشا وتركيز السلينيوم مقارنه بباقى المعاملات الأخرى فى كلا موسمى الزراعة.