Arab Journal of Nuclear Science and Applications, 48(4), (187-194) 2015

Effect of Titanium Nanoparticles (TiO_2) on Growth, Yield and Chemical Constituents of Coriander Plants

Mohamed S. khater
National Institute of Laser Enhanced Science (NILES) Cairo University, Egypt.

Received: 5/9/2014 **Accepted: 10/11/2014**

ABSTRACT

An investigation was initiated to examine the effects of nanoscale titanium dioxide nano particles on some growth parameters and chemical constitutes of Coriander. Coriander plants were sprayed twice with different concentrations of titanium dioxide 2, 4 and 6 ppm, first one after 30 days from cultivation and the second one was after 60 days .The results indicate that titanium dioxide (TiO_2) nanoparticles (NPs) lead to a significant increase in plant height, fruit yield and number of branches. It also caused an increase in amino acids, total sugars, total phenols, total indols and pigments.

Key word: Laser, Titanium nanoparticles, chemical constituents, coriander.

INTRODACTION

Coriander (*Coriandrum Sativum* L.), is an annual herb of the Apiaceae family and native of the Mediterranean region, and it has been cultivated since human antiquity [(1)]. The seeds are popular as a spice and the finely ground seed is a major ingredient of curry powder. It contains essential oil and linalool is the main component [(2)]. Coriander is economically important since it has been used as a flavouring agent in food products, perfumes and cosmetics. They are used medically as a drug for indigestion, against worms, rheumatism and pain in joints [(3)]. Titanium compounds enhance the yield of various crops, by improving some essential elements content in the plant tissues and increases the peroxidase, catalase, and nitrate reductase activities in plant tissues. TiO_2 nanoparticles encourage spinach (*Spinacia oleracea*) seed germination and plant growth[(4)]. TiO_2 NPs can promote plant photosynthesis and nitrogen metabolism and then greatly improve growth of spinach at a suitable concentration [(4-6)].

These nanoparticles improved light absorbance and accelerated spinach growth [(4,7)]. Nano-TiO_2 improves plant growth by enhancing nitrogen metabolism [(6)] that promotes the absorption of nitrate in spinach and accelerating conversion of inorganic nitrogen into organic nitrogen, thereby increasing the fresh and dry weights. Effects of nano- TiO_2 on the content of light harvesting complex II (LHC II) on thylakoid membranes of spinach increases LHC II content [(5,8)]. These promote energy transfer and oxygen evolution in photosystem II (PS II) of spinach [(8)]. It was found that nano-anatase TiO_2 promotes antioxidant stress by decreasing the accumulation of superoxide radicals, hydrogen peroxide, malonyldialdehyde content and enhances the activities of superoxide dismutase, catalase, ascorbate peroxidase, guaiacol peroxidase and thereby increases the evolution oxygen rate in spinach chloroplasts under UV-B radiation [(7)]. The ability of nano-anatase TiO_2 to improve the light harvesting complex content of plants is highly comparable with the use of TiO_2-quantum dot (QD) assembly for the conversion of solar energy. Uptake and distribution of QD through plant cells can be exploited for efficient and increased solar energy trapping which might improve the photosynthetic efficiency of plants and the photoluminescence property of quantum dots that can be used for cell imaging too [(9)].

The present study aims to investigate the effect of TiO_2 nanoparticles on growth, physiological parameters and chemical constituents of coriander.

Author E-mail: saskhater@hotmail.com mobile:+201111606111

MATERIAL AND METHOD

Field Experiment

Experiments were carried out at a Farm in Sakara, Giza , Egypt . During two successive seasons, 2011/2012 and 2012/2013. Seeds were bought from the National Research Centre, Doki, Giza, Egypt. The experimental plot area was 2 m x 4m The planting distance was 30 cm apart and it was 50 cm between lines.

The soil chemical properties were determined according to [10,11] (Table 1).

Table (1): The soil chemical analysis for the two seasons.

measurements	Season 2011-2012				Season 2012-2013			
Soil depth (Cm)	0-60				0-60			
pH (1:2.5)	7.2				7.5			
E.C. (mmhos/Cm)	1.37				0.6			
Calcium Carbonates (%)	7.1				7.4			
Soluble cations (meq/L)	K^+	Na^+	Mg^{+2}	Ca^{+2}	K^+	Na^+	Mg^{+2}	Ca^{+2}
	0.97	2. 2	2.8	2.0	0.42	2.43	0.8	4.8
Soluble anions (meq/L)	SO_4^{-2}	Cl^-	HCO_3^-	CO_3^{-2}	SO_4^{-2}	Cl^-	HCO_3^-	CO_3^{-2}
	4.77	1. 1	1.2	–	3.21	1.25	2.8	–

Preparation of TiO_2 Nanoparticles

Titanium nanoparticles (TiO_2) were prepared by laser ablation of a titanium plate (99.9% purity) in 10 ml deionized water . Q-switched Nd: YAG (Quantel) pulse laser generating 8 ns pulses at the wavelength of 1064 nm with a repetition rate of 10 Hz and the focused energy density was 400 mJ cm^{-2}, using a 100 mm focal length lens on the metal plate immersed in water according to [12].

Characterization of TiO_2 Nanoparticles

Physicochemical properties of TiO_2 nanoparticles were characterized via TEM imaging Fig. (1). The images of the synthesized TiO_2 nanoparticles reveal a spherical shape and an average particle size of 19.5 to 20 nm.

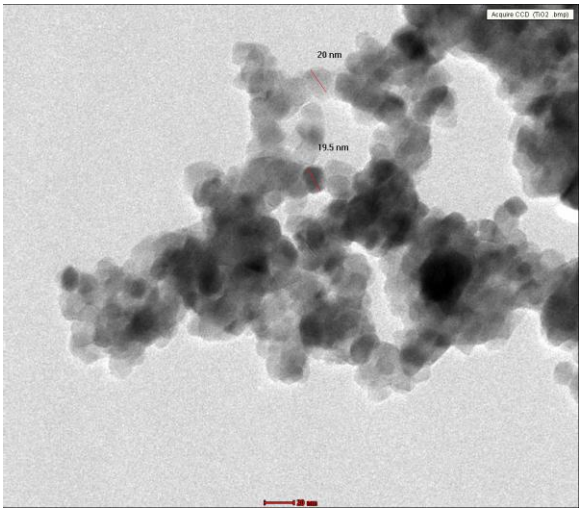

Fig (1): TEM imaging of the prepared TiO_2 nanoparticles revealed a spherical shape of the particles, with an average size of 20 ±2.0 nm (inset shows electron diffraction pattern).

Chemical Analysis

Total soluble sugars were measured by using phenol-sulfuric acid assay [13]. The absorption was then determined by spectrophotometry at 490 nm.

Total soluble amino acids were measured by using the nine-hydride color metric method, as described by Rosen [14] and modified by Seliem et al [15].

Total soluble phenols were determined by using Ciocaltue colorimetric methods and Folin by spectrophotometry at 730 nm wavelength [16].

Total soluble indoles were described by Larsen et al [17] and modified by Seliem et al [15] .It was estimated colormetrically at 350 nm.

N, P , K and crude protein contents were determined according to Jackson [10].

Chlorophyll a (Chla), Chlorophyll b (Chlb) and Carotenoids contents were determined according to the method described by Wettstein [18].

The absorbance of extract was determined spectrophotometrically at wavelengths 660 nm, 640 nm and 440 nm for Chla, Chlb and Carotene respectively.

Statistical Analyses

All statistical analyses were carried out by SAS version 9 software for all data R- Squared values (R^2) are considered significant (p-values <0.05) for the analysis of variance test (ANOVA).

RESULTS AND DISCUSSION

Growth and Yield

Generally, all growth and yield characters such as plant height, number of branches and fruit yield were increased as a result of foliar spray with TiO_2 nanoparticles (Table 2). The highest values of plant growth and yield were obtained from the concentration of 6 ppm TiO_2 nanoparticles 105.2 , 106.5 cm and 31.5 , 26.96 g for first and second season, respectively. These results are respectively in a agreement with those obtained by Zygmunt [19] who found that TiO_2 nanoparticles had significant and consistent effect on the growth of apple and sour cherry.

Raskar et al [20] showed that TiO_2 nanoparticles at the concentrations ranging from 10 to 40 ppm enhanced seed germination, promptness index, and seedling growth. Results indicated that lower concentrations were not harmful to the seed germination and early seedlings growth. However, concentrations that are higher than 50µg mL-1 could inhibit seed germination and seedling growth in onion.

Moaveni et al [21] found that the most yields perceived in some quality like (weight of spicules, number of spicules and grain per m^2) resulted from TiO_2 nanoparticles at 0.03% concentration on Barley.

Table (2): Effect of different concentrations of TiO_2 NPs foliar spray on growth and yield (g/pl.) of coriander during 2012 and 2013**.**

Treatment	Plant height (cm)		Number of branches(Branch/Plant)		Fruit yield (g/pl.)	
	2011/ 2012	2012/2013	2011/ 2012	2012/2013	2011/ 2012	2012/2013
Control	69.13	75.3	4.8	5.2	16.38	19.11
2 ppm	82.6	87.2	5.5	5.8	19.95	22.8
4 ppm	100.4	103.3	6.7	6.6	23.23	26.88
6 ppm	105.2	106.5	6.9	7.4	31.5	26.96
R^2	0.94	0.95	0.94	0.99	0.94	0.90

Pigment Content

The contents of chlorophyll-a, chlorophyll-b and carotenoids were significantly increased with foliar application on coriander (Table 3) with varying TiO_2 nanoparticles concentrations (2, 4 and 6 mg/L).Giving highly significant results at 6mg/L which resulted in 2.812n,2.229,n1.270 mg/g for the first season and 2.833, 2.25, 1.287 mg/g for the second season for chlorophyll-a, chlorophyll-b and carotenoids contents , respectively as compared with the untreated plants.

These results agreed with Moaveni et al [21] who reported that, TiO_2 nanoparticles could gain the amount of pigments and ease photosynthesis matter transportation by recovery in chlorophyll structure and light sorption. Nanoparticles were prolonged the photosynthesis mechanism by transforming light energy to active electrons and chemical activity, in chloroplast. This procedure increases photosynthesis efficiency, motivates Rubisco activase complex and gains carbon photosynthesis in Barley.

Table (3): Effect of different concentrations of TiO_2 nanoparticles on chl.a, chl.b and carotenoids of coriander plants during 2012 and 2013.

Treatment	Chlorophyll a		Chlorophyll b		Carotenoids	
	2011/ 2012	2012/2013	2011/ 2012	2012/2013	2011/ 2012	2012/2013
Control	2.690	2.750	2.040	2.137	0.952	1.023
2 ppm	2.714	2.758	2.080	2.156	0.973	1.084
4 ppm	2.768	2.798	2.147	2.185	1.131	1.186
6 ppm	2.812	2.833	2.229	2.25	1.270	1.287
R^2	0.97	0.94	0.97	0.92	0.92	0.98

Total Amino Acids and Total Sugars Content

The foliar application of coriander with TiO_2 nanoparticles at 2, 4 and 6 mg/L had a significantly increased with Total amino acids and total sugars content as compared with control ones (Table 4).

The highest values for total amino acids and total sugars were determined for the plants treated with 6 mg/L 0.645, 1.254 and 0.734 1.206 as compared with 0.095 and 0.176 for amino acid 0.720 and 0.750 mg/g for sugars for control plants in the first and the second seasons respectively. These finding agreed with those of Lopez et al [22] who found that Sprays containing Ca^{2+}, Mg^{2+} or Ti^{4+} on peach tree in several combinations, and that containing titanium increased tree performance (branch elongation, flowering and fruit set intensities) and fruit size, fruits from Ti-treated trees showed better behavior in the Total amino acids and total sugars content. Titanium application significantly increased iron, copper and zinc concentrations in the peel and calcium concentration in the peel and flesh.

Table (4): Effect of different concentrations of TiO_2 nanoparticles on amino acids contents and sugars contents of coriander plants during 2012 and 2013.

Treatment	Amino acid		Sugars	
	2011/ 2012	2012/2013	2011/ 2012	2012/2013
Control	0.095	0.176	0.720	0.750
2 ppm	0.252	0.274	0.916	0.970
4 ppm	0.370	0.446	1.156	1.108
6 ppm	0.645	0.734	1.254	1.206
R^2	0.96	0.94	0.97	0.96

Total Phenols and Total Indoles

In case of total phenols, the highest values were 1.90 and 2.03 mg followed by 1.838 and 1.96 for 6 and 4 mg/L TiO_2 nanoparticles as compared with 1.60 and 1.67 for control treatment , in the first and the second seasons respectively (Table 5).

Concerning indoles content, similar trend had been obtained by getting the highest values 2.20 and 2.24 my followed by 2.10 and 2.15 mg for 6 and 4 mg/L TiO_2 nanoparticles as compared with 1.87 and 1.76 mg for control treatment in the first and the second seasons respectively (Table 5).

Generally , the contents increased as the concentration of TiO_2 nanoparticles has been raised. These results are in accordance with that reported by Zheng et al [4] who found that nanosized TiO_2 contributed to water absorption by spinach seeds and as result accelerated seed germination. An earlier study of Feizi et al [23] showed the highest germination of wheat seed percentage (98%) in 2 mg L-1 of nano sized TiO_2 concentrations. The results of Mahmoodzadeh et al[24] found that Higher concentrations of TiO_2 (2000 ppm) improve the germination and root growth for Canola seeds.

Table (5): Effect of different concentrations of TiO_2 nanoparticles on phenols and indoles of coriander contents plants during 2012 and 2013.

Treatment	Phenols		Indoles	
	2011/ 2012	2012/2013	2011/ 2012	2012/2013
Control	1.604	1.668	1.870	1.758
2 ppm	1.785	1.867	2.033	1.99
4 ppm	1.838	1.96	2.104	2.149
6 ppm	1.901	2.03	2.2	2.242
R^2	0.90	0.93	0.96	0.96

Nitrogen Content

Application of 4 mg/L of TiO_2 nanoparticles on coriander exhibited the highest content of nitrogen 2.5% and 2.75% for the first and the second seasons respectively as shown in (Table 6). The control treatment resulted in the lowest nitrogen content 1.54% and 1.69% for the first and the second

seasons respectively as compared to other treatments during both seasons. These findings are in accordance with the observations of Yang et al [6].

Phosphorus Content

Data in (Table 6) showed that, the highest content of phosphorus 0.546 and 0.6006% for the the first and the second seasons respectively, resulted from application of 6 mg/L of TiO_2 nanoparticles. While control treatment resulted in the lowest phosphorus content 0.414 and 0.455 % in the two successive seasons, respectively, These results are in accordance with those reported by Bieleski et al[25] who found that the titanium treated plants have higher concentrations of P, Fe, Cu, Mn, and Zn in the leaves as compared to the control plants.

Potassium Content

The data in (Table 6) cleared that, among different exposure treatments on coriander, exhibited the lowest content of potassium, 4.8, 5.28 % for control .However, exposure to 6 mg/L gave the highest potassium content 6.7 and 7.37 % as compared to the other treatments for the first and the second seasons respectively.

Protein

Data on protein content as shown in (Table 6) resulted in the highest content of protein 17.215 and 19.28 % for the first and the second seasons respectively, while revealed that application of 6 mg/L TiO_2 nanoparticles on control plants had the lowest protein content 9.63 and 10.59% as compared to the other treatments in the two successive seasons, respectively.

Table (6): The effect of different concentrations of TiO_2 nanoparticles foliar spray on N, P, K (%) and protein of coriander during 2012 and 2013.

treatment	N		P		K		Protein	
	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
Control	1.54	1.694	0.414	0.4554	4.8	5.28	9.63	10.593
2 ppm	2.1	2.31	0.468	0.4642	5.5	6.05	13.13	14.443
4 ppm	2.5	2.75	0.494	0.542	6.3	7.13	15.62	17.18
6 ppm	2.75	3.08	0.546	0.6006	6.7	7.37	17.21	19.28
R^2	0.97	0.98	0.98	0.92	0.98	0.95	0.97	0.98

CONCLUSION

TiO_2 nanoparticles had significant effects on the total chlorophyll-a, chlorophyll-b, carotenoids, sugars, aminoacids, indoles, phenols, nitrogen, potassium, phosphorus, yield and plant growth characteristics of coriander. The results of this work show strong evidence for the high efficiency of this new nanofertilizer on plant growth enhancement. These powerful and inexpensive NPs could replace traditional methods of plant growth enhancement. Further developments in nanotechnology in this sector could have large-scale economic implications and multiple benefits for consumers, producers, and farmers.

REFERENCES

(1) I. Telci, OG. Toncer and S.N. Yield, essential oil content and composition of Coriandrum sativum varieties (var. vulgare Alef and var. microcarpum DC.) grown in two different locations. Journal of Essential Oil Research 18, 189-193. 2006.

(2) R. Omidbaigi, Production and Processing of Medicinal Plants (Vol 2, 3rd Edn), Astan Quds, Tehran, Iran, pp 79-82 ,2005.

(3) H. Wangenesteen, AB. Samuelesen, KE. Malterud Antioxidant activity in extracts from coriander. Food Chemistry 88, 293-297,2004.

(4) L. Zheng, F. Hong, S. Lu, C. Liu Effect of nano-TiO_2 on strength of naturally aged seeds and growth of Spinach. Biological Trace Element Research.;105:83-91. 2005.

(5) F. Hong, J. Zhou, C. Liu, F.Wu.C Yang, L. Zheng Effects of nano- TiO_2 on photochemical reaction of chloroplasts of spinach. Biol Trace Elem Res. ;105:269-279. 2005.

(6) F. Yang, F. Hong, W. You, C. Liu, F. Gao, C. Wu, P. Yang Influence of nano-anatase TiO_2 on the nitrogen metabolism of growing spinach. Biol Trace Elem Res 110(2):179‑190. doi:10.1385/ bter:110:2:179,2006.

(7) Z. Lei, S. Mingyu, W. Xiao, L. Chao, Q. Chunxiang, C. Liang, H. Hao, L. Xiao- qing, H.Fashui Antioxidant stress is promoted by nano-anatase in spinach chloroplasts under UV-B radiation. Biol Trace Elem Res; 121:69–79. 2008.

(8) Z. Lei, MY. Su, W. Xiao, L. Chao, CX. Qu, C. Liang, H. Hao, XQ. Liu and FS. Hong Effects of nano-anatase on spectral characteristics and distribution of LHC II on the thylakoid membranes of spinach, Biol. Trace Elem. Res.120 273–283. 2007.

(9) A. Kongkanand, K. Tvrdy, K. Takechi, M. Kuno, P.V. Kamat, Quantum dot solar cells. Tuning photiresponse through size and shape of CdSe–TiO2 architecture, J. Am. Chem. Soc. 130 4007–4015. 2008.

(10) M.L. Jackson, Soil chemical analysis. Published by prentice Hall Indian Private Limited. M.97, Connght Citrus, New Delhi-1. PP. 200 – 250. 1973.

(11) A. Cottenie, M. Verloo, L. Kiekens, G. Velghe, R. Camerlynck, Chemical analysis of plant and soil. Laboratory of Analytical and Agrochemistry, State Univ., Ghent, Belgium, PP. 100 – 129,1982.

(12) K. Siuzdak, M. Sawczak, M. Klein, G. Nowaczyk, S. Jurga and A. Cenian. Preparation of platinum modified titanium dioxide nanoparticles with the use of laser ablation in water. Royal society of chemistry.6 (2014) .

(13) M. Dubois, K.A. Gilles, J.K. Hamitton, P.A. Rebers and F. Smith, colorimetric for determination of sugar and relateol substances. anal .chem, 28: 350 -356. 1956.

(14) H. Rosen, Amodifiedninhydrin colorimetric analysis for acid Arch. Biochem. Biophys, 67: 10-15. 1957.

(15) H.H. Seliem, M.A. Fayek and A.M. Swedian, reproduction of bricher apple cultivar by layering. annal of Agric. Sci., Moshtohor, 9: 157-166 . 1978.

(16) F.D. Snell and C.T. Snell, Colorimetric Methods of Analysis Including some Turbidimetric and Nephelometric Methods. D.Van Noster and Company Inc. Toronto, New York, London. Vol. III organic, I: 116-117. 1953.

(17) P. Larsen, A. Harbo, D.F. Klungsour and T. Asheim, On the biogenesis of some indole compounds in Acetobacter xylnum. Physiol. Plant., 15: 552-655. 1962.

(18) D. Wettstein, Chlorophyll lethal faktoren under submikro skopoch for mvechsel der plastide Exp. cell. Res.; 12: 427-433. 1957.

(19) Z.S. Grzyb, W. Piotrowski, P. Bielicki, L.S. Paszt and E. Malusà . Effect of different fertilizers and amendments on the growth of apple and sour cherry rootstocks in an organic nursery, Journal of Fruit and Ornamental Plant Research. 20(1) 43-53,2012.

(20) S . Raskar and SL. Laware Effect of titanium dioxide nano particles on seed germination and germination indices in onion. Plant Sciences Feed, 3 (9): 103-107. 2013.

(21) P. Moaveni , A. Talebi , H.A. Farahani and K. Maroufi. Study of Nano Particles TiO_2 Spraying on Some Yield Components in Barley (Hordem Vulgare L.) International Conference on Environmental and Agriculture Engineering IPCBEE vol.15(2011) © (2011) IACSIT Press, Singapore 115-119.

(22) C. Alcaraz-Lopez, M. Botia, C.F. Alcaraz and F.a. Riquelme Effect of foliar sprays containing calcium, magnesium and titanium on peach (Prunus persica L.) fruit quality. J. Sci. Food Agric. 84, 949-954. 2004.

(23) H. Feizi, P.R. Moghaddam, N. Shahtahmassebi and A. Fotovat. Impact of bulk and nanosized titanium dioxide (TiO_2) on wheat seed germination and seedling growth. Biol Trace Elem Res. 146:101–106. 2012.

(24) H. Mahmoodzadeh1, M. Nabavi and H. Kashefi . Effect of Nanoscale Titanium Dioxide Particles on the Germination and Growth of Canola (Brassica napus) Journal of Ornamental and Horticultural Plants, 3 (1): 25-32. 2013.

(25) R.L. Bieleski, I.B. Ferguson, Physiology and Metabolism of Phosphate and its Compounds. In Encyclopedia of Plant Physiology, New Series; A. Lauchli, , R.L. Bieleski, Eds.; Springer-Verlag: Berlin, Germany, Vol. 15A, 422±449. 1983.