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Effects of Titanium and Silicon Nanoparticles and Super Absorbent Polymer on Morphological and Functional Traits of Cumin Plant under Drought Stress

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Abstract

This study was performed to investigate the effects of using titanium and silicon nanoparticles (Si and TiO_2 NPs) and super absorbent polymer (SAP) on morphological and functional traits of cumin plant under drought stress conditions. An experiment was conducted as a factorial split-plot in a randomized complete block design with three replications. Water availability was considered as the main factor at three levels of 50 (control), 100, and 150 (drought stress) ml evaporation from a Class A evaporation pan. Foliar application levels of Si and TiO_2 NPs and SAP were regarded as the secondary factor. The main factor (drought stress) and the secondary factor, viz. different levels of Si and TiO_2 NPs and SAP were each applied at two levels. Plant height, stem diameter, number of umbels per plant, number of seeds per umbel, 1000-seed weight, biological yield, and grain yield were investigated in this study. Overall, the highest plant height, stem diameter, and shoot dry weight were obtained in the drought stress treatment of 50 mm evaporation from the pan with foliar application of Si and TiO_2 NPs and the use of SAP. The highest grain yield, biological yield, shoot fresh weight (SFW), number of seeds per umbel, and number of umbels per plant were recorded in the treatment of 50 mm evaporation from the pan. centage of essential oil in irrigation stress treatment was obtained after 150 mm evaporationTherefore,foliar application of Si and TiO_2 NPs and the use of SAP are recommended to improve plant height, stem diameter, and shoot dry weight under drought stress.

Keywords; Titanium oxide, Grain yield, Biological yield, Drought stress.

Introduction

The global interest in the use of herbal medicines has increased the attention of most countries to the identification and therapeutic use of medicinal plants as therapeutics, which can play a substantial role in the economic growth and entrepreneurship depending on the potential and climatic diversity of a country in this sector (Morales et al., 2017). Medicinal plants have properties that are of special importance in terms of both disease treatment and prevention as well as in the health of communities. According to the statistics of the World Health Organization, over 80% of the world population, particularly in developing countries and poor areas, provide their main health needs from medicinal plants (Naseri et al., 2019). Cumin, (*Cuminum cyminu*) from the Umbelliferae family, is one of the important export products produced in limited regions of the world due to special ecological conditions required for its cultivation. India, Iran, Indonesia, and Lebanon are the main exporters of cumin, but such countries as Turkey, Egypt, Syria, China, Cyprus, Argentina, and Mexico are also other exporters of cumin. In Iran, the export of cumin started many years ago and the present export rate is about 20-40% (Abu Ali et al., 2019).

Cumin is considered an important medicinal plant with a high economic value, which is cultivated in such countries as Iran and has so far been the only cumin in Iran. Cumin is used in the treatment of various diseases as anticonvulsant, an anti-epileptic, stomach strengthening, diuretic, anti-flatulence, indigestion, and sweating stimulant, and also accelerates the onset of menstruation in each period (Haghir-o-Sadat et al., 2011). It also has beneficial effects in acute and chronic colds of the bronchi, bloating due to indigestion, treatment of gynecological secretions, and cessation of menstruation in young women. Cumin is also beneficial for diabetics, in addition to its diuretic and milk-boosting effects. Cumin contains 2-5% of essential oil, most of which is para-cymene, alpha and beta-pinene, comic alcohol, comic aldehyde, alpha and beta flandren, eugenol, perilaldehyde, alpha-terpineol, and myrcene. Cumin also contains 7.7% oil, 13.5% resin, 8% gum and mucilage, and 15.50% protein (Taheri et al., 2018).

Water shortage in Iran has always been considered as a limiting factor in the cultivation of crops and medicinal plants. Drought stress limits the yield at different stages of growth, in particular at flowering and seedling stages (Selmar et al., 2017). Plants encounter various environmental stresses during their growth, each of which can have different effects on their growth and performance depending on the sensitivity and growth stage of the plant species. Drought stress, particularly in arid and semiarid regions of the world, is one of the most important environmental factors in the reduction of growth and yield of many crops. Decreased photosynthetic rate due to stomatal closure, reduced plant growth, lack of photosynthates required for grain filling and reduction of the grain filling period duration are the most important effects of drought on plants (Babaian et al., 2010). The quality and quantity of medicinal plants are particularly influenced by genetics, environmental factors, and their interactions (Abdullah and Al-Koushiban, 2007). The occurrence of dehydration stress at different developmental stages, in particular the reproductive stage, is due to the reduction of the photosynthetic period and the transfer of current photosynthates to the seed, resulting from premature leaf aging, reduced leaf area, and decreased contribution of retransferring reserved material to the stem, leading to declined yield due to a reduction in the seed weight (Ramroudi et al., 2011). Various minerals, including silicon (Si) and titanium (Ti), are used to improve different traits of plants under stress conditions such as drought stress. Pereira et al. (2013) studied the effect of silicon application on water deficit stress conditions in pepper plant and reported an increase in proline synthesis. Lee et al. (2007) investigated the effects of drought stress and silicon on maize under greenhouse conditions and found that silicone treatment increased the growth and yield under drought stress conditions. Moaveni et al. (2011) sprayed titanium dioxide nanoparticles (TiO_2 NPs) on wheat and observed that the grain yield and biological yield of this plant increased under the influence of nanoparticles compared to the control. Given the negative effects of drought stress and the positive effect of nanoparticles on plant traits, it is expected that Si and TiO_2 NPs and SAP to improve plant morphological traits. Therefore, the present study was conducted to investigate the effects of using titanium and silicon nanoparticles and SAP on the morphological traits of cumin under drought stress conditions.

Materials and methods

Time and location of the research

This research was conducted in two research farms in Pariz and Chahar Gonbad region, Sirjan city, during the cropping year of 2018-19. The Pariz region is located at 49° 40′ E and 29° and 35′ N at an altitude of 1937 m above sea level. Chahar Gonbad region is located in the geographical coordinates of 56° 11′ E and 29° 18′ N at an altitude of 2050 m above sea level. These areas have a milder climate than other semi-desert cities in Iran.

Experimental design

The effects of Si and TiO_2 NPs and SAP on the quantitative and qualitative traits of cumin under drought stress in Pariz and Chahar Gonbad were investigated in a factorial split-plot experiment based on a randomized complete block design with three replications. Water availability at three levels of 50 (control), 100, and 150 (drought stress) mm evaporation from a Class A evaporation pan was considered as the main factor. Foliar application levels of Si and TiO_2 NPs and SAP were regarded as the secondary factor. The main factor (drought stress) and the secondary factor, viz. different levels of Si and TiO_2 NPs and SAP each were applied at two levels.

Experimental traits

Plant height

Prior to harvest in the physiological maturity stage, the heights of six plants were measured randomly from the crown to the end of the tallest umbel and the average was recorded as plant height (PH) in each plot.

Stem diameter

Prior to harvest in the physiological maturation stage, the diameters of six plants were measured randomly from the crown by a caliper, and the mean was taken as the stem diameter (SD) in each plot.

Number of umbel per plant

At the harvest, the number of umbel was counted in six plants selected randomly from the middle rows of each experimental unit. Then, the mean was recorded as the number of umbel per plant (UPP) for each treatment.

Number of seeds per umbel

Six plants were selected randomly from the middle rows of each experimental unit, and the seeds were counted in six umbel from each plant. Then, the average number of seeds in these umbel was recorded as the number of seeds per umbel (SPU).

Thousand seed weight

To calculate thousand seed weight (TSW), 1000 seeds were counted by a seed counter in each plot and weighed with a digital scale with an accuracy of 0.01 g.

Biological yield

To determine the biological yield (BY), freshly harvested plants from 1.0 m^2 were weighed using a digital scale with an accuracy of 0.01 g and generalized to hectares.

Grain yield

Cumin was harvested to calculate the grain yield (GY) at the grain ripening stage. To this end, plants were sampled from five middle rows in each plot, followed by the elimination of marginal effects. Plants were harvested from an area of 1.5 m^2 to calculate GY (Sartip and Sirus Mehr, 2017).

Statistical analysis

Quantitative and qualitative data were organized by Excel software. Statistical calculations were performed using SAS 9.3 software. Mean values were compared by Duncan's multiple range test at 5% probability level.

Results and discussion

Plant height

ANOVA results indicated that the simple and interaction effects of experimental treatments were significant on cumin PH at levels of 1% and 5%, respectively (Table 1). A comparison of means showed that the highest PH (25.34 cm) was obtained in the drought stress treatment of 50 mm evaporation from the pan with foliar application of Si and TiO_2 NPs and the use of SAP (Fig. 1). Reduction of plant stem length in drought stress conditions is probably due to decreased cell division and expansion. Cell volume, cell division, cell wall formation, overall plant size, and plant fresh and dry weights as general growth criteria are often reduced as a result of water shortage. One of the first signs of water deficiency is a decrease in turgescence and consequently declined cell growth and development, particularly in the stem and leaves. Cell growth is the most sensitive process affected by drought stress. Organ size is limited with reduced cell growth, which is therefore used to detect the first noticeable effect of water deficit on plants through smaller leaf size or PH (Hessia, 2013). Moaveni et al. (2011) also observed that wheat PH increased in response to various treatments of TiO_2 NPs. Jaberzadeh et al. (2010) reported that the highest wheat PH was obtained under drought stress treatment with TiO_2 NPs. Titanium as a beneficial element improves and stimulates plant growth and can also induce the absorption of some elements such as nitrogen, phosphorus, calcium, magnesium, iron, manganese, and zinc. The application of titanium in nutrient solution or foliar application on plant leaves was found to increase the biomass and growth of various plant species including pepper and corn (Carvajal and Alkaraz, 1998). In general, titanium at higher concentrations and nano-titanium, with tiny particle size and easier penetration into the roots, could affect some growth and photosynthetic traits of tomatoes (Haghighi and Daneshmand, 2013).

Table 1: Results of ANOVA for some traits of cumin under experimental treatments

		MS			
Sources of variation	df	PH	SD	PFW	PDW
Replication	2	12.94	0.11	47.9	0.13
Irrigation level	2	285.69**	1.23**	344.6**	2.17**
Main error	4	2.42	0.034	69.26	0.014
Fertilizer	7	16.03**	0.05*	48.41**	1.62**
Irrigation level × Fertilizer	14	3.03*	0.049	4.88^{ns}	0.016^{ns}
Secondary error	42	1.49	0.019	6.72	0.106
CV%	-	6.11	7.28	8.63	10.19

*, **, and ns are significant at 5%, 1%, and no significant difference, respectively.

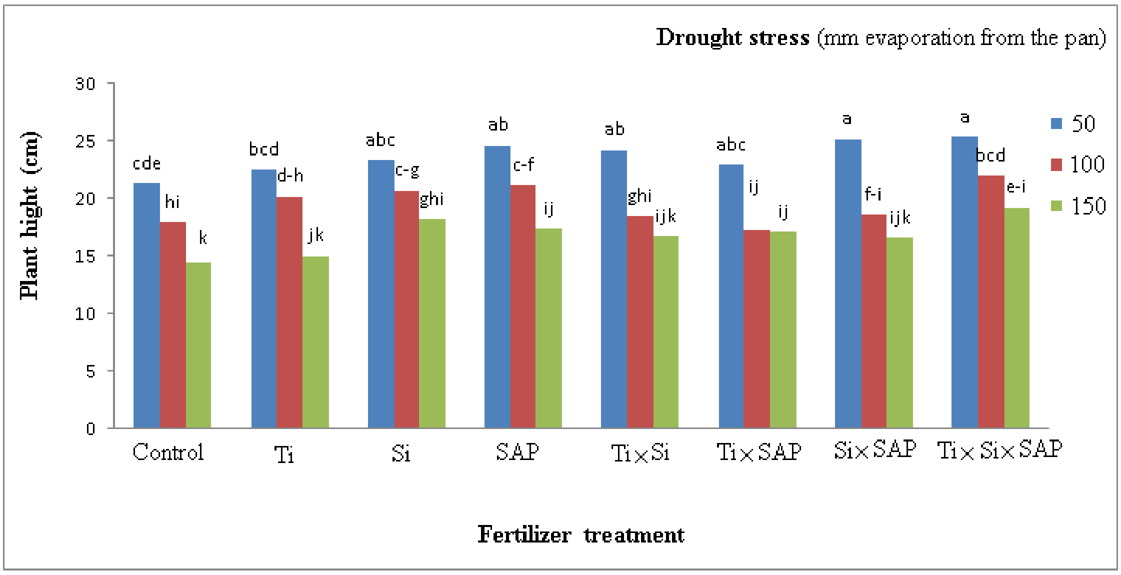

Fig. 1. Interaction of drought stress and fertilizer treatments on cumin plant height

Stem diameter

According to results of ANOVA, the simple and interaction effects of different experimental treatments were significant on cumin SD (Table 1). A comparison of means revealed that the highest SD (2.3 mm) was obtained in the drought stress treatment of 50 mm evaporation from the pan with foliar application of Si and TiO_2 NPs. SD was lowermost (1.53 mm) in drought stress treatment of 150 mm evaporation from the pan by spraying TiO_2 NPs, which together with the drought stress treatment of 150 mm evaporation from the pan and control treatment were placed in a common statistical group (Fig. 2).

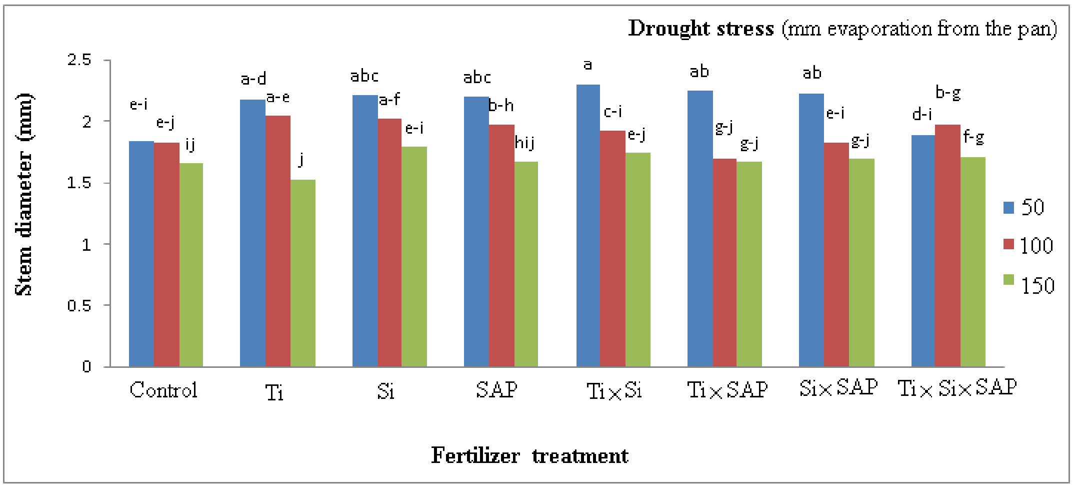

Fig. 2. Interaction of drought stress and fertilizer treatments on cumin stem diameter

Shoot fresh weight

The SFW of cumin shoots was significantly affected by the drought stress (Table 1). A comparison of means indicated that the highest SFW (33.72 g) was obtained in the 50 mm evaporation treatment from the pan, which was not different significantly with the treatment with 100 mm evaporation from the pan. The treatment with 150 mm evaporation from the pan presented the lowest (26.15 g) SFW of cumin (Fig. 3). Results of ANOVA showed that the SFW of cumin was affected significantly by fertilizer treatments (Table 1). A comparison of means revealed that the highest SFW (33.03 g) belonged to the treatment of Si and TiO_2 NPs with and the use of SAP (Fig. 4). Photosynthesis directly affects dry matter production and yield levels, hence an increase in photosynthesis with the use of titanium for its role in nitrogen assimilation and photosynthesis can affect the yield under drought stress conditions. Jaberzadeh et al. (2010) reported that foliar application of TiO_2 NPs increased the height, spike weight, and GY of wheat under drought stress. Titanium improves plant growth by increasing ammonium content, the activity of nitrate reductase, and enzymes involved in ammonium assimilation (Yang et al., 2006). TiO_2 NPs have an incremental effect on photosynthetic rate and increase plant growth (Yang et al., 2006). In their experiment, therefore, the application of titanium treatment as foliar application on cumin foliage stimulated the growth of shoots in common purslane. The highest height and fresh and dry weights of purslane were obtained from an optimal irrigation interaction (50 mm evaporation from the pan) and a treatment with nitrogen biological and chemical fertilizer. TiO_2 NPs enhance nitrogen uptake and metabolism and nitrate reductase activity, thereby increasing the ammonium content in the plant. Additionally, these NPs elevate the assimilation rate of ammonium and the involved enzymes and cause ammonium to be rapidly converted into organic nitrogen such as proteins, amino acids, and chlorophyll (Yang et al., 2006). In these conditions, water availability for the plant can be effective in the synthesis of these molecules and explain an increase in plant biomass and dry weight. Saber et al. (2013) reported that TiO_2 increased the synthesis of amino acids, proteins, chlorophyll, and photosynthesis through accelerating the activity of nitrate reductase, thereby improving the growth and dry and fresh weight of spinach.

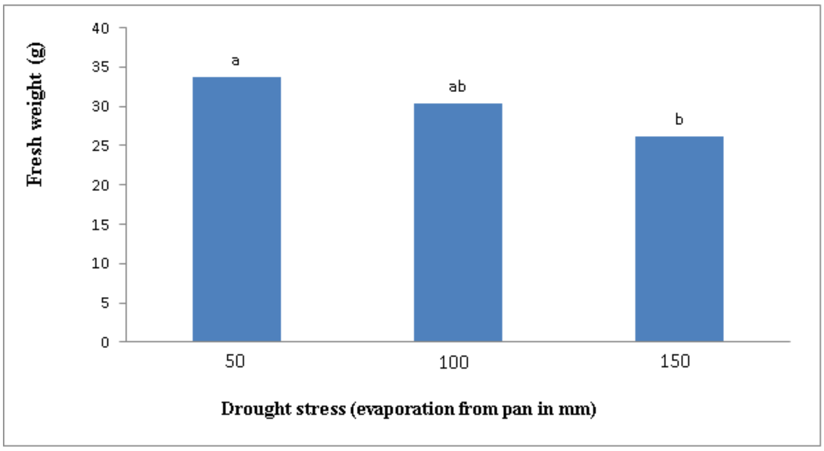

Fig. 3. Simple effect of drought stress on fresh weight of cumin shoots

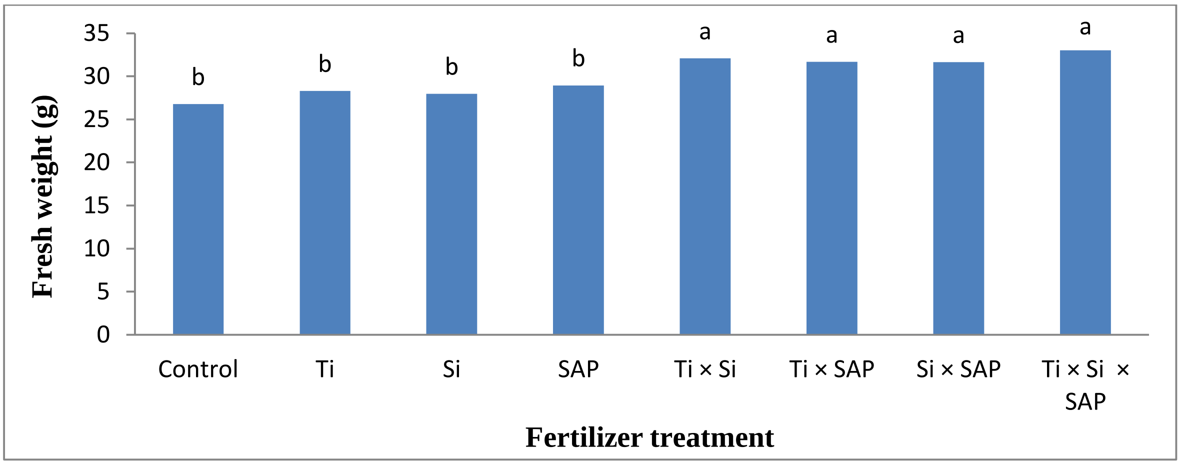

Fig. 4. Simple effect of fertilizer treatments on fresh weight of cumin shoots

Shoot dry weight

Results of ANOVA for the data revealed that shoot dry weight (SDW) of cumin was influenced significantly by drought stress (Table 1). A comparison of means indicated that the highest SDW of cumin (3.43 g) was related to the irrigation treatment of 50 mm evaporation from the pan, which differed significantly with the other irrigation treatments. The treatment of 150 mm evaporation from the pan had the lowest (2.86 g) SDW of cumin (Fig. 5). ANOVA results also showed that the SDW was affected by the fertilizer treatments at a probability level of 1% (Table 1).

Based on the comparison of average data, the highest (3.78 g) and the lowest levels of SDW were recorded in the foliar application of TiO_2 and Si NPs and the use of SAP and in the control, respectively (Fig. 6). In fact, salinity reduced the plant growth and production of organic matter by affecting the reduction of photosynthesis and elements. Low growth has been suggested to be an adaptation for plant survival under stress conditions, because it directs the plant, nutrients, and energy to stress- retentive molecules instead of being used for shoot growth. Lebaschi and Sharifi Ashurabadi (2004) examined different levels of drought stress on flea wort, yarrow, common sage, marigold, and chamomile plants, and reported that increasing drought stress led to decreased shoot weight and plant height in all studied plants.

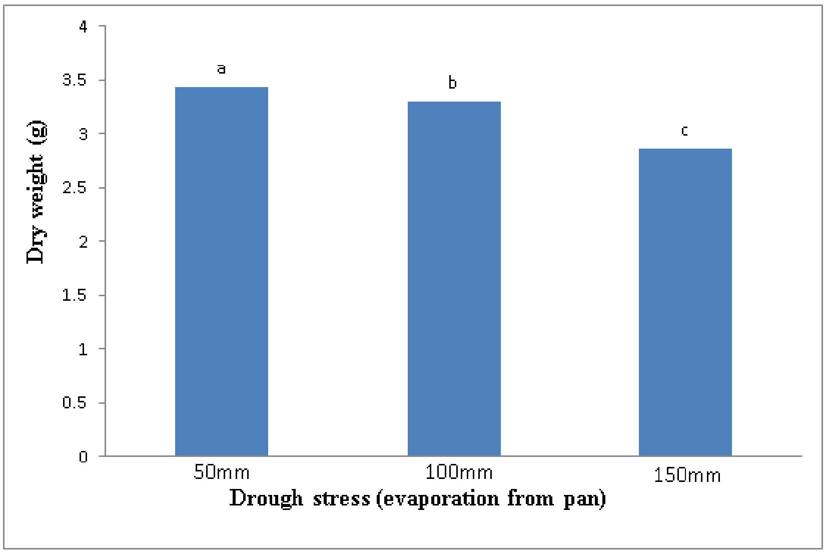

Fig. 5. Simple effect of drought stress on the dry weight of cumin shoots

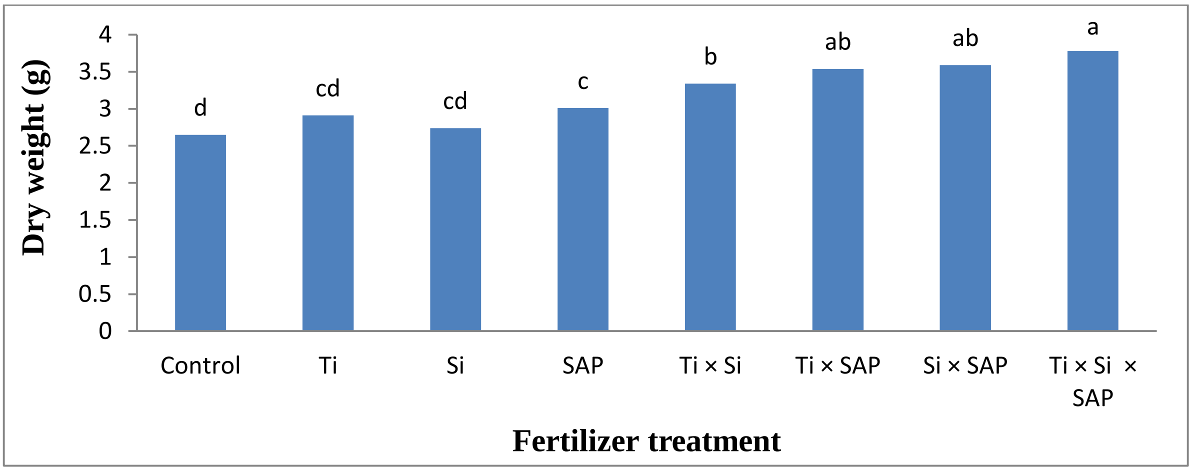

Fig. 6. Simple effect of fertilizer treatments on the dry weight of cumin shoots

Number of umbel per plant

The effect of drought stress on the number of UPP was significant at a probability level of 1%, while the effect of fertilizer treatments and the interaction of experimental treatments were not significant on this trait (Table 2). The highest number of UPP (17.29) belonged to the treatment of 50 mm evaporation from the pan, which was significantly different from the other irrigation treatments. Also, the lowest number of umbrellas per plant (13.79) was obtained in the irrigation treatment of 150 mm evaporation from the pan, which were placed in a common statistical group with the irrigation treatment of 100 mm evaporation from the pan (Fig. 7).

Table 2: Analysis of variance of some cumin traits under experimental treatments

		MS		
Sources of variation	df	No. of UPP	No. of SPU	No. of SPP
Replication	2	3.38	1.88	21428
Irrigation level	2	74.47**	597.45*	1268980**

Main error	4	5.97	866.28	207119
Fertilizer	7	2.95^{ns}	182.66^{ns}	70030^{ns}
Irrigation level × Fertilizer	14	2.78^{ns}	128.05^{ns}	63233^{ns}
Secondary error	42	1.59	150.76	56605.89
CV%	-	8.2	13.41	16.79

*, **, and ns are significant at 5%, 1%, and no significant difference, respectively.

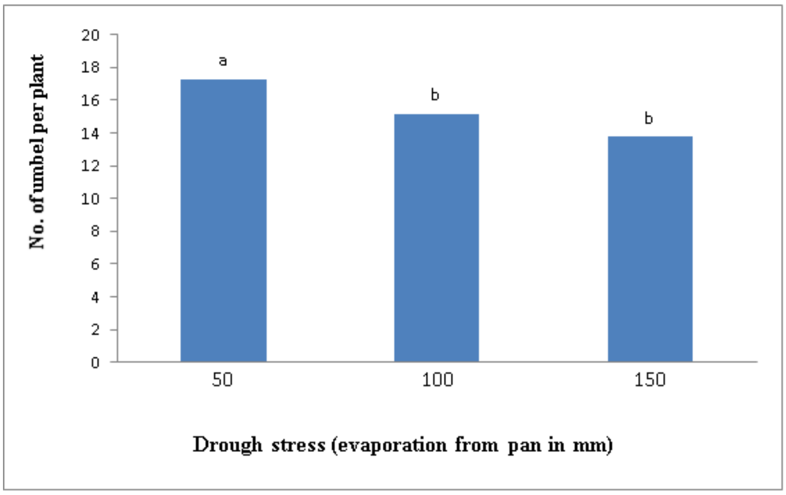

Fig. 7. Simple effect of drought stress on the number of umbels per cumin plant

Number of seeds per umbel

The effect of drought stress treatment on the number of SPU was significant at 5% probability level (Table 3). A comparison of means showed that the highest number of cumin SPU (95.57) was obtained in the 50 mm evaporation treatment from the pan, which together with the 100 mm evaporation treatment were placed in one statistical group and differed significantly with the irrigation treatment of 150 mm evaporation from the pan (Fig. 8).

Table 3. Results of ANOVA for some cumin traits under experimental treatments

		MS			
Sources of variation	df	TSW	BY	GY	Essential oil (%)
Replication	2	0.03	167516	111.92	0.014
Irrigation level	2	0.02^{ns}	1498593**	3650.1**	0.119**
Main error	4	0.2	2.2835	68.77	0.002
Fertilizer	7	0.18^{ns}	132929**	173.33**	0.173**
Irrigation level × Fertilizer	14	0.11^{ns}	27678^{ns}	34.72*	0.0903*
Secondary error	42	0.15	28622	17.71	0.0005
CV%	-	11.85	8.96	6.37	4.71

*, **, and ns are significant at 5%, 1%, and no significant difference, respectively.

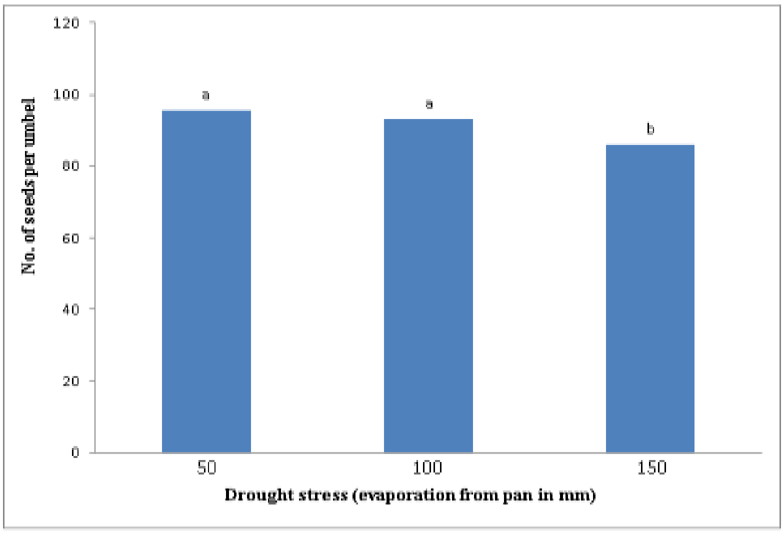

Fig. 8. Simple effect of drought stress on the number of seeds per umbel in cumin

Number of umbel per plant

Based on ANOVA results of data, the effect of drought stress was significant on number of SPP at a probability level of 1%, while the effect of fertilizer treatments and the interaction of experimental treatments were not significant on this trait (Table 2). A comparison of means showed that the highest (1644) and the lowest (1184) numbers of SPP belonged to the irrigation treatments of 50 and 150 mm evaporation from the pan, respectively, which were placed in one statistical group with the irrigation treatment of 100 mm evaporation from the pan (Fig. 9).

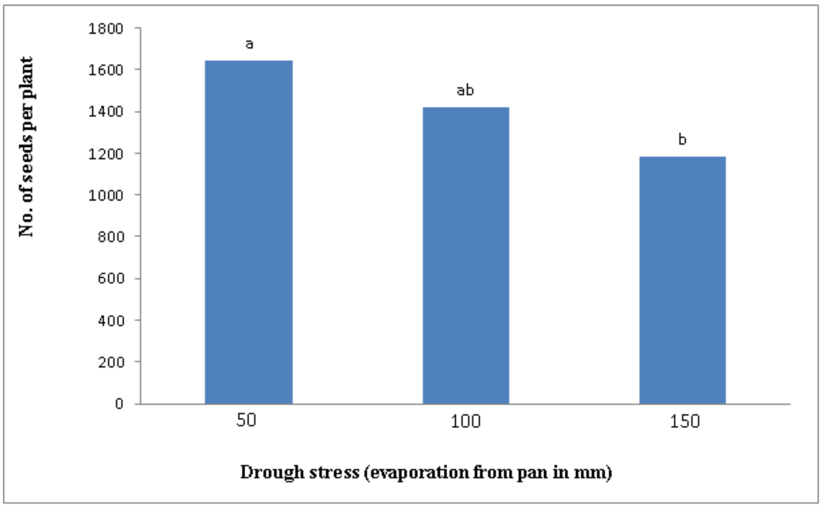

Fig. 9. Simple effect of drought stress on the number of seeds per cumin plant

Thousand seed weight

According to the results of ANOVA, there are no significant differences between the experimental treatments in terms of TSW (Table 3). A comparison of means indicated that most of the treatments were in one statistical group with no significant differences. TSW is one of the most stable components of plant yield that has a high heritability and is less influenced by environmental factors. Rezvani Moghadam et al. (2008) investigated on castor and found that the TSW of this plant was not affected by organic and chemical fertilizer treatments. In general, it can be concluded that the use of nanofertilizers and SAP in the form of foliar and soil application is effective in the improvement of yield components even in TSW, which was not significant in this experiment, and can meet part of fertilizer needs of cumin plants with low fertilizer requirements.

Biological yield

The results of ANAVA revealed that the BY of cumin was affected significantly by the drought stress (Table 3). A comparison of means showed that the highest BY (2117.5) was obtained in the irrigation treatment of 50 mm evaporation from the pan, which did not differ significantly with the irrigation treatment of 100 mm evaporation from the pan. The treatment of 150 mm evaporation from the pan yielded the lowest BY of cumin (1621.5) (Figure 10). As indicated by the results of ANOVA, BY was affected by the fertilizer treatments at a probability level of 1% (Table 3). Based on a comparison of means, the highest (2042) and the lowest (1742) BY were observed in the foliar application of TiO_2 and Si NPs and in the control, respectively (Fig. 11).

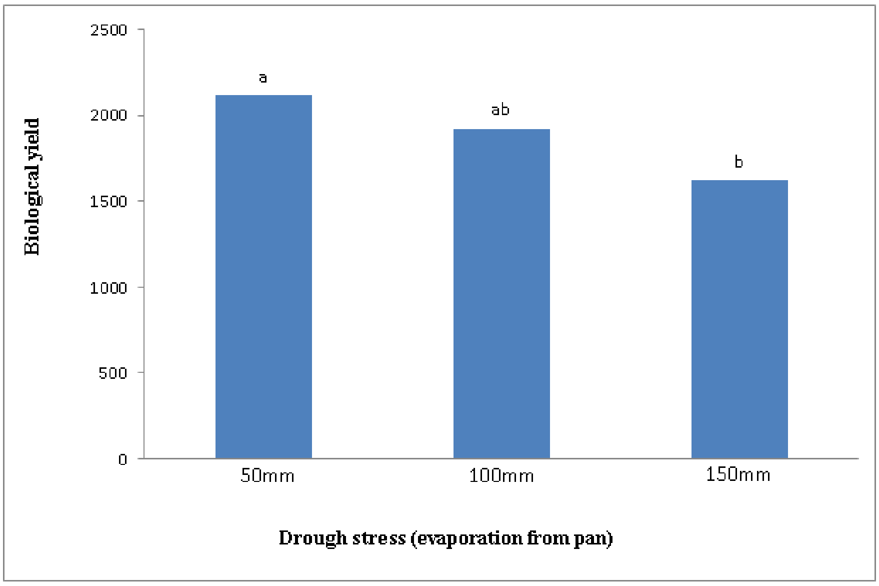

Fig. 10. Simple effect of drought stress on the biological yield of cumin

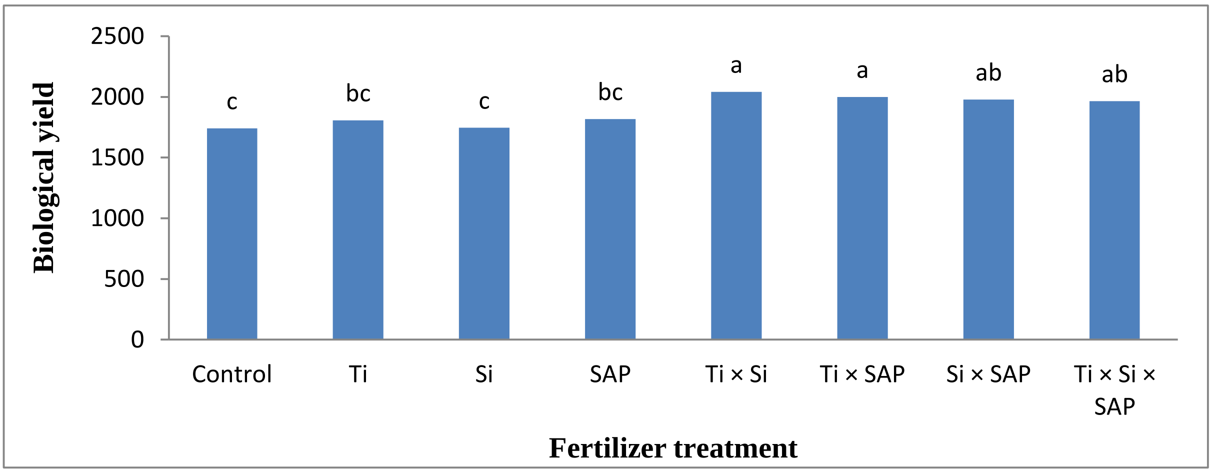

Figure 11 Simple effect of fertilizer treatments on the biological yield of cumin

Grain yield

According to the results of ANOVA, the simple and interaction effects of different experimental treatments were significant on cumin GY (Table 3). Based on a comparison of means, cumin GY was uppermost (89.2 g/m^2) in the drought stress treatment of 50 mm evaporation from the pan with foliar application of TiO_2 and Si NPs and the use of SAP. The drought stress treatment of 150 mm evaporation from the pan along with the control gained the lowest (47.67 g/m^2) cumin GY (Fig. 12).

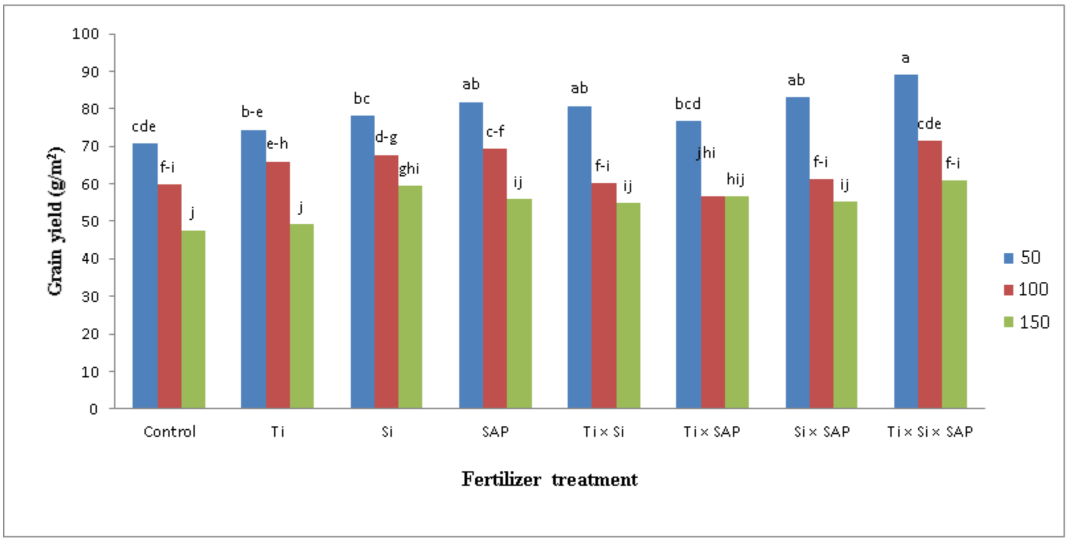

Figure 12 Interaction of drought stress and fertilizer treatments on cumin grain yield

Percentage of essential oils

The results showed that the interaction of water availability at different levels of titanium had a significant effect on the percentage of essential oil at a probability level of 5% (Table 3). The highest percentages of essential oil were obtained in the treatment of irrigation stress with 150 mm of evaporation from the pan and in the control treatment. Arzmjoo et al. (2010) stated that the application of stress led to an increase in the essential oil content in chamomile. In a study on anise, Salmasi (2001) reported that the essential oil content in anise seeds was inversely related to the amount of consumed water. Similar findings on increased percentage of essential oil under the influence of drought stress were reported by Ahmadian et al. (2010) in cumin, Hassani et al. (2002) in basil, and Safikhani and Omid Beigi (2007) in the medicinal plant Moldavian dragonhead.

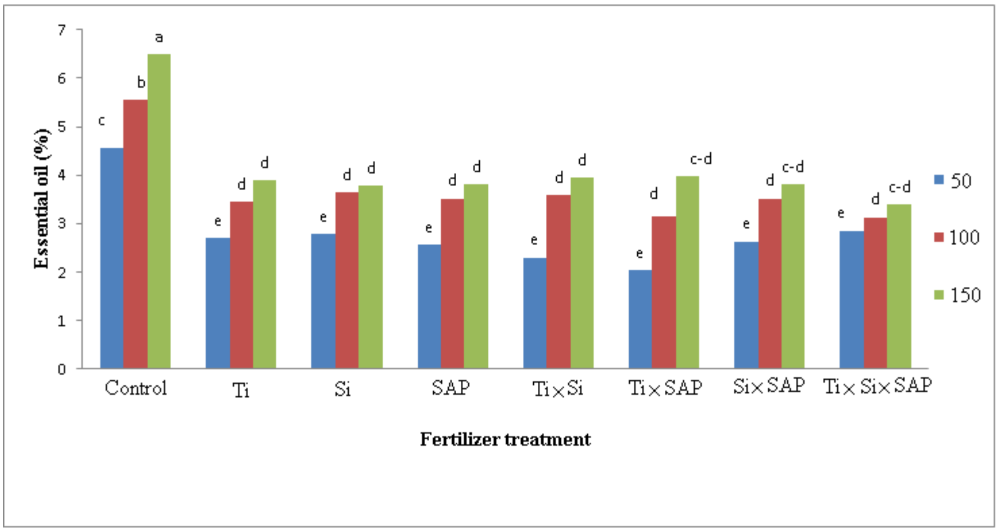

Fig. 13. Interaction of drought stress and fertilizer treatments on cumin essential oil

Conclusion

Overall, the results demonstrated that the highest PH, SD, and SDW were obtained in the drought stress treatment of 50 mm evaporation from the pan with foliar application of TiO_2 and Si NPs and the use of SAP. GY, BY, SFW, number of SPU, and number of UPP were uppermost in treatment of 50 mm evaporation from the pan. centage of essential oil in irrigation stress treatment was obtained after 150 mm evaporationTherefore,foliar application of TiO_2 and Si NPs with the use of SAP is recommended to improve PH, SD, and SDW under drought stress.

Referneces

Abu Ali, Reza, Yousefi, Arshid, Yazdani, Hamid, Khedri, Reza, 2019. A review of the antibacterial effect of cumin (*Cumin cyminum* L.) seed on *Staphylococcus aureus*. Eighth International Green Gold Conference, Rasaish Institute.

Babaian, M., Heidari, M. and Ghanbari, A. 2010. Effects of drought stress and foliar application of trace elements on physiological traits and nutrient uptake in sunflower (*Helianthos annus* L.). Iranian Journal of Crop Sciences, 12 (4): 377-391.

Haghir-o-Sadat Bibi Fatemeh, Vahidi Alireza, Sabur Mohammad Hussein, Azimzadeh Mostafa, Kalantar Seyed Mehdi, Sharaf-o-Dini Maryam. Evaluation of effective compounds and antioxidant properties of *Cumin Cyminum* L. essential oil endemic to Yazd Province. Scientific Research Journal of Shahid Sadoughi University of Medical Sciences, Yazd; 19 (4): 472-481.

Haghighi, M. and B. Daneshmand 2013. Comparison of the effect of titanium and nano-titanium on the growth and photosynthetic changes of tomatoes in a hydroponic system. Science and technology of greenhouse crops 13, 4: 73-79.

Jaberzadeh, A., P. Moaveni, H. Towhidi Moghaddam aand A. Moradi 2010. The effect of foliar application of titanium dioxide nanoparticles on the removal of some agronomic properties in wheat under drought stress. Quarterly Journal of Crop Plant Ecophysiology. 2, 4: 295-301.

Rezvani Moghadam, P. and Moradi, R. 2012. A study on planting date, biological fertilizer, and intercropping on the yield and quantity of cumin and fenugreek essential oil. Iranian Journal of Crop Sciences, 43 (2): 217-230.

Ramroudi, M., Kikhajaleh, M., Golvi, M., Theghat-ol-Eslami, M. and Baradaran, R. 2011. Effects of foliar application of micronutrients and irrigation regimes on quantitative and qualitative yield of the medicinal plant flea wort. Journal of Agricultural Ecology, 3(2): 219-226.

Sartip, H. and Sirus Mehr, A. 2017. Effects of salicylic acid consumption on the growth, yield, and some biochemical properties of cumin (*Cuminum cyminum* L.) under three different irrigation regimes. 10 (4): 547-558.

Saber, S., Z. Ghasimi Hagh and Sh. Mostafavi 2013. The mechanism effect of titanium nanoxide on the physiological processes of spinach (*Spinacia oleracea*). Second National Conference on Sustainable Development of Agriculture and Healthy Environment. 1-16.

Lebaschi, M. and Sharifi Ashurabadi, A. 2004. Growth indices of some medicinal plants under different drought stress conditions. Iranian Journal of Medicinal and Aromatic Plants Research, 20(3): 241-269.

Naseri, Leila; Akbari Bazm, Mohsen; Khazaei, Muzaffar 2019. A review of the therapeutic effects of *Tribulus terrestris*. Quarterly Journal of Medicinal Plants. 4 (72): 1-22.