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Investigation the effects of nano TiO_2 and TiO_2 spraying on the oil yield of Safflower (*Carthamus tinctorius* L.)

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ABSTRACT: An experiment was performed in order to study the effects nano TiO_2 and TiO_2 (bulk) spraying on the oil yield of safflower (*Carthamus tinctorius* L.) in RCBD design at one farm, Grmsar, Iran. This experiment consisted of four treatments, T1: no-foliar application, T2: foliar application of TiO_2 (bulk) at concentration of 0.04%, T3: foliar application with nano-TiO_2 at concentration of 0.02% and T4: concentration of 0.04%. Results indicated the significant effect of nano TiO_2 and bulk concentrations on the traits of height, grain yield, oil percentage and oil yield of safflower, but its effect was not significant on the 1000 grain weight of this plant. Results showed that spraying of safflower plants by nano TiO_2 increased oil yield and other measured traits in comparison with the non-nano TiO_2 (bulk) and control treatments. Maximum oil yield of this plant was achieved with application of 0.04% nano TiO_2 and minimum amount of this trait was obtained by control treatment. Therefore, in accordance to the production of oil and importance of the safflower as an oily plant, application of nano TiO_2 can be used to increase oil yield of this plant.

Keywords: Nano TiO_2, Safflower, Oil yield, Grain yield, Height

INTRODUCTION

Plant of safflower, (*Carthamus tinctorius* L.), is a member of the family composite, cultivated mainly for its seed, which is used as edible oil and as birdseed (Weiss, 2000). Safflower is currently grown mostly for edible oil, considered as one of the best for human consumption due to high quantities (70 -75%) of poly-unsaturated (Linoleic acid) or monounsaturated fatty acid (Oleic acid) (Nimbkar and Singh, 2005). Historically, the crop is restricted to the middle east, parts of Asia and Africa and over time it has been adapted to the semi-arid climatic condition of western United States (Lartey *et al.,* 2005). Safflower is a tap-rooted multipurpose crop which can tolerate environmental stresses including salinity and water stress (Soheilikhah *et al.,* 2005). In addition, spring and fall types make safflower suitable choice for production of edible oil. For the sake of the shorter period of cultivation, spring type is preferred to fall type (Sanoie *et al.,* 2013). Manufactured nanoparticles have received a particular attention for their positive impact in improving many consumer products, and are increasingly used for a wide range of industrial applications. Nanoparticles are atomic or molecular aggregates with at least one dimension between 1 and 100 nm, that can drastically modify their physico-chemical properties compared with the bulk material. Manufactured nanoparticles can be made from various bulk materials and they behave differently depending on both the chemical composition and on the size and/or shape of the particles (Kim *et al.,* 2011). In according to the large surface area and unique physicochemical properties, nano and ultra fine particles have drawn much attention in recent years for their roles in adsorption/desorption of contaminants in environment. Nano TiO_2 has been widely used in industry at present and has a rapidly increasing exposure to environment, especially under the driving force of nanotechnology. Nano-anatase TiO_2 can affect the spinach microenvironment of PSII and increase the visible-light absorption of leaves, thereby improving the energy transport capacity (Su *et al.,* 2007).

Galbraith (2007) and Torney *et al.* (2007) revealed that engineered nanoparticles was able to inter into plants cells and leaves, and also can transport DNA and chemicals into plant cells. This area of research offers new possibilities in plant biotechnology to target specific gene's manipulation and expression in the specific cells of the plants. Nano particle of titanium dioxide promotes chlorophyll formation and aged seeds' vigor and increase activity of Ribulose 1, 5-bisphosphate carboxylase enzyme and photosynthesis, also increases growth of plant and development also this nano particle increases the transport and conversion of the light energy, the photosynthetic time of the chloroplasts, light absorbance and protects chloroplast of plants from aging (Yang *et al.,* 2006). TiO_2 act as the most suitable photocatalytic catalyst, which upon exposure to ultraviolet light mineralizes organic chemicals in solution to water and carbon dioxide, and may have potential in destruction of microorganisms (CETAC 2000; Frazer 2001).

Results of many studies showed that negative and positive effects of nano particles on growth and development on crop plants related to the physical and chemical properties, concentration, size and composition of engineered nanoparticles and plant species (Ma *et al.,* 2010). Kužel *et al.* (2003) applied Ti with different levels of Mg in nutrient solution and found that Ti increased the Mg content of oat leaves. Haghighi *et al.,* (2012) in one experiment showed that spraying of tomato plants by nano particle of TiO_2, increased root and shoot dry weight, flower number and shoot diameter of this plant. Zheng *et al.,* (2005) examined the effect of nano particle of TiO_2 and TiO_2 (bulk) on traits of spinach plant, they concluded that traits of ribulose bisphosphate carboxylase/oxygenase activity, chlorophyll content, photosynthetic rate, plant dry weight, vigor indexes, germination rate in treatment of nano TiO_2 was higher than the treatment of TiO_2 (bulk) they declared that positive effects of nano TiO_2 in comparison with the TiO_2 (bulk), is because of smaller size of nano particle that lets to the nano particle for penetration into the seeds of spinach. Similar shoot dry matter, seedling dry matter and root dry matter increasing by nano TiO_2 in comparison with the type of bulk, were reported by Feizi *et al.,* (2011) in wheat plant. Also Moaveni and Kheiri (2011) reported increasing of maize yield by nano TiO_2. Therefore, based on the importance of TiO_2 nano particle in increasing of growth and yield of plants, the objective of this study was to determine the effects of nano TiO2 and TiO_2 spraying on the oil yield of safflower (*Carthamus tinctorius* L.)

MATERIAL AND METHODS

This study was conducted during the growing seasons of 2013 and 2014. This research was done as a RCBD experiment with four replications at the one personal farm, at Garmsar, Iran. This experiment consisted of four treatments, T1: no-foliar application, T2: foliar application of TiO_2 (bulk) at concentration of 0.04%, T3: foliar application with nano-TiO_2 at concentration of 0.02% and T4: concentration of 0.04%. The size of the TiO_2 nanoparticles and TiO_2 (bulk) were determined by scanning electron microscopy (SEM) at the Rezaei laboratory at Tehran, Iran. Nanosized TiO_2 with average particle size of 44.17 nm (Fig. 1) and TiO_2 (bulk) with average particle size of 132.16 nm (Fig. 2). Each experimental plot consisted of 4 rows, 3 m long with 50 cm spaced between rows and 10 cm distance between plants on the rows. Seeds were sown on October 17th, 2013. 1/3 of nitrogen fertilizer was applied before sowing and the remaining of N fertilizer was applied during the vegetative growth and p fertilizer was applied at a rate of 150 kg P_2O_5 in the form of superphosphate triple in the soil before sowing. Titanium dioxide nanoparticles and Titanium dioxide (bulk) were sprayed by a portable spray machine on the safflower plants at vegetative and reproductive stages of plant. Plant height was measured at time of 50% flowering stage. After harvesting, branches were dried in the shade and 1000 grain weight, and grain yield was measured using a carriage scale using standard moisture at 14%. Seed oil percentage content was determined by Nuclear Magnetic Resonance Spectroscopy, according to Ios (1992) and the oil yield per hectare were calculated by the following formula

Oil yield (kg/ha) = oil percentage (%) × grain yield (kg/ha)

The analysis of variance of data was done by sas software, and duncan' multiple range test was used to compare treatment means.

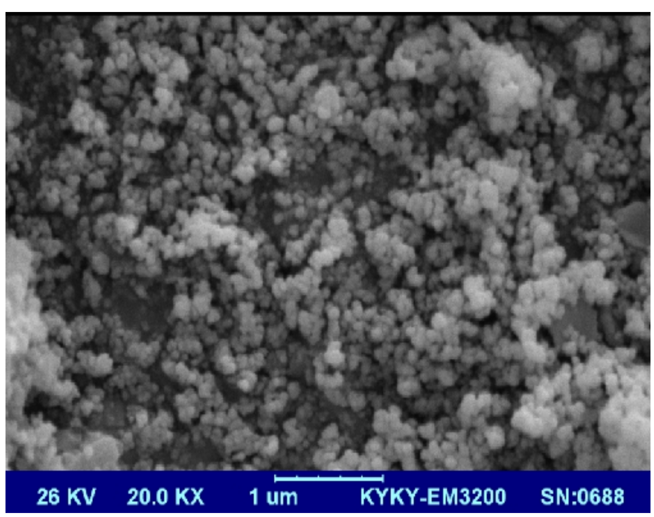

Fig. 1. Image of nano TiO_2 by scanning electron microscopy (SEM).

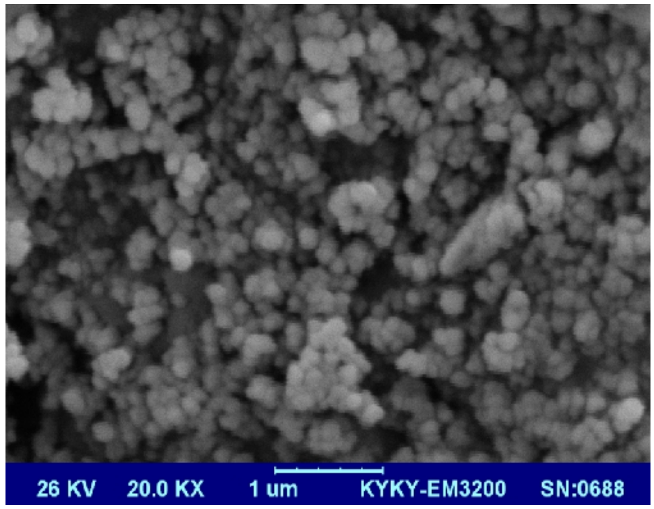

Fig. 2. Image of TiO_2 (Bulk) by scanning electron microscopy (SEM).

RESULTS

A. Height

Effects of nanoparticle of titanium dioxide and titanium dioxide concentration on the height trait was significant at P ≤0.05 (Table 1). In according to the results of the means comparison (Fig. 3), concentration of 0.04% of nano TiO_2 (with the amount of 59.98 cm), had the maximum amount of height. No-application of nano TiO_2, had the least amount of plant height, also spraying of safflower with application of 0.02% of nano TiO_2 (with the amount of 59.77 cm) and TiO_2 (bulk) (with the amount of 50.18 cm) were placed between the maximum and minimum values of plant height.

B. 1000 grain weight

On the basis of the results of analysis of variance (Table 1), use of all concentration of TiO_2 (nano and bulk), had not been significant with together and were placed in the same statistically group. However, concentrations of 0.04% of nano TiO_2 (42.11 gr) had the highest weight of 1000 grain and control treatment (40.76 gr), had the least amount of this trait (Fig. 4).

C. Grain yield

According to the results of analysis of variance (Table 1), spraying with nano TiO_2 and TiO_2 had a significant difference (P ≤0.01) on the grain yield of this plant. Results of means comparison (Fig. 5) showed that spraying of safflower with nano TiO_2 at concentration of 0.04% with yield of 2430.08 $kg.ha^{-1}$, nano TiO_2 at concentration of 0.02% with yield of 2315.54 $kg.ha^{-1}$, bulk treatment with yiled of 2260.50 $kg.ha^{-1}$ and control treatment with yield of 2200.06 $kg.ha^{-1}$ respectively showed the least yield.

Table 1: Analysis of variance results of the safflower (*Carthamus tinctorius L.*) traits under different concentrations of TiO_2 (nano and bulk).

		Means squares				
Sources of variation	**Df**	**Height**	**1000 grain weight**	**Grain yield**	**Oil percentage**	**Oil yield**
Replication	3	31.77^{ns}	17.09^{ns}	13943.05^{ns}	0.16^{ns}	539.39^{ns}
NanoTiO_2 and TiO2 (bulk) spraying	3	275.77^{*}	1.58^{ns}	38270.26^{**}	4.83^{**}	16116.63^{**}
Error	9	85.80	18.37	7280.04	0.16	1389.08

* and **: Significant at 5 and 1% levels respectively

D. Oil percentage

The results of analysis of variance (Table 1) showed that different concentrations of nanoparticles of titanium dioxide and titanium dioxide (bulk) on the characteristic of the oil percentage had a significant effect on the level P ≤0.01. Highest oil percent (28.20%), was related to the application of 0.04% concentration of nano TiO_2 and the least amount of this trait (25.60%) was belonged to the control treatment (Fig.6).

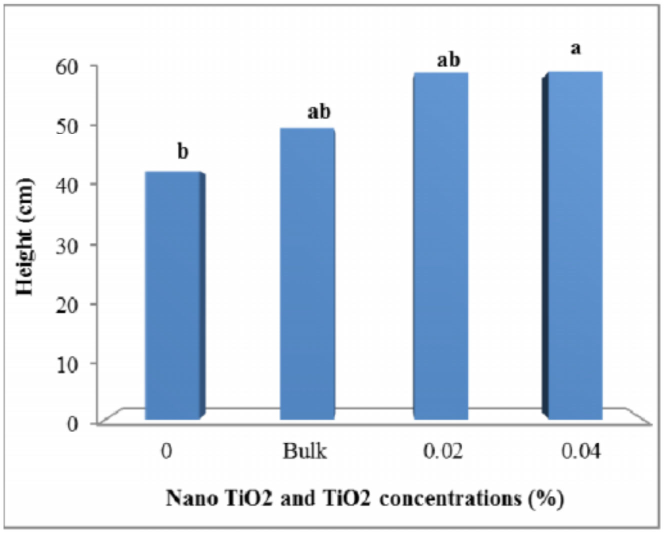

Fig 3. Effect of TiO_2 (nano and bulk) concentrations on height of safflower.

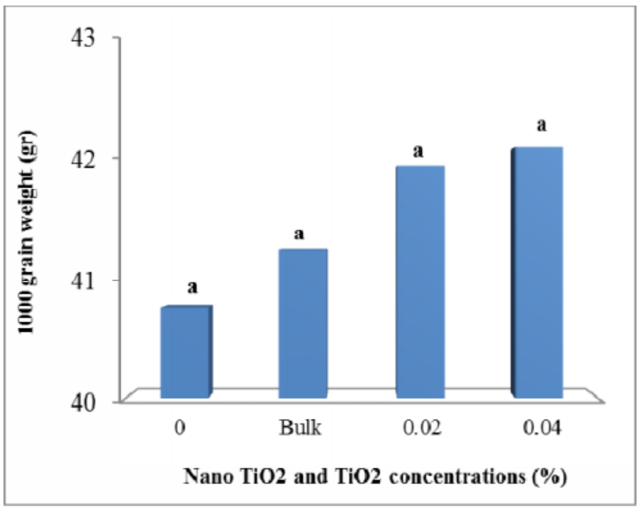

Fig 4. Effect of TiO_2 (nano and bulk) concentrations on 1000 grain weight of safflower.

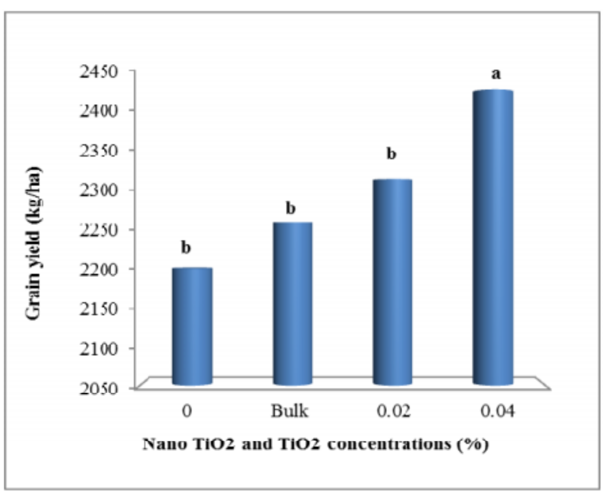

Fig 5. Effect of TiO_2 (nano and bulk) concentrations on grain yield.

E. Oil yield

Based on the results of analysis of variance (Table 1) different concentrations of nano TiO_2 and TiO_2 on the oil yield trait of safflower had a significant difference effect (P ≤0.01). The minimum and maximum amounts of oil yield, respectively was related to the use of nano TiO_2 at concentration of 0.04% (685.28 $kg.ha^{-1}$) and control treatment (563.30 $kg.ha^{-1}$) but concentration of 0.02% of nano TiO_2 (635.15$kg.ha^{-1}$) and bulk (TiO_2) treatment (604. 59 $kg.ha^{-1}$) were placed between treatments of 0.04% nano TiO_2 and control (Fig. 7).

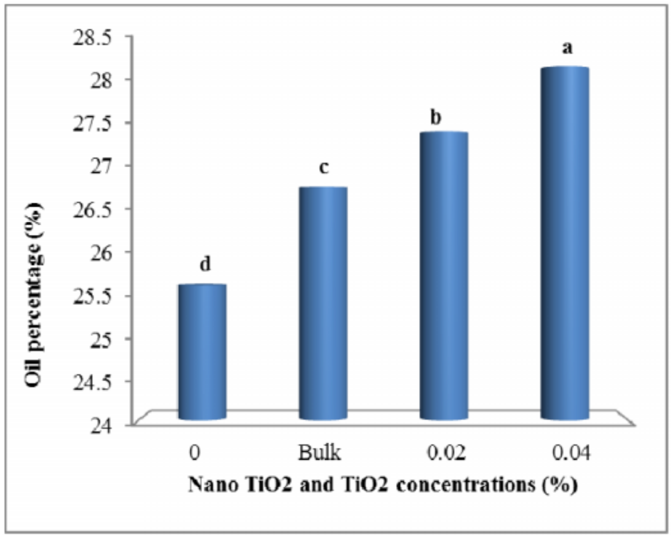

Fig. 6. Effect of TiO_2 (nano and bulk) concentrations on oil percentage of safflower.

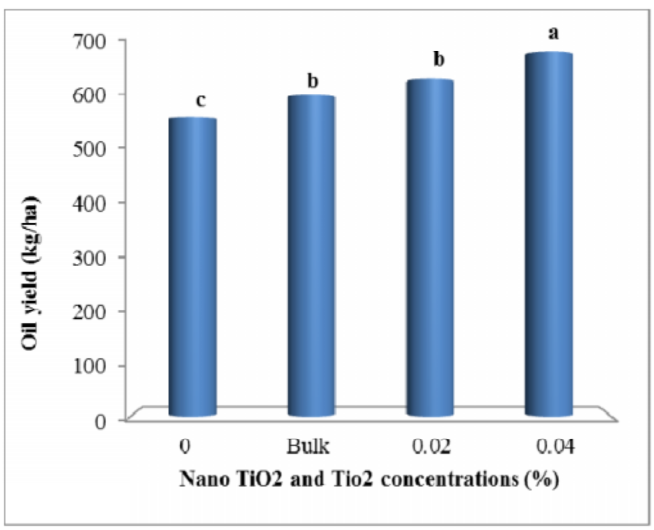

Fig. 7. Effect of TiO_2 (nano and bulk) concentrations on oil yield of safflower.

DISCUSSION

According to the results for this experiment, spraying of safflower by nano TiO_2, increased traits of plant height, 1000 grain weight, oil percentage, grain and oil yield in comparison with the TiO_2 (Bulk) and control treatments. Probably, increase of these traits with application of nano TiO_2 is because of the role of this nano particle in light absorption increasing, enhanced photosynthetic system of plants by strengthening of Rubisco enzyme and obviously increase the activities of nitrate reductase, glutamate dehydrogenase, glutamine synthase, and glutamic-pyruvic transaminase (Yang *et al.*, 2006), Hill's reaction, reduction of iron cytochrome in chloroplast and thus, increase the production of chlorophyll and photo assimilate in comparison with the TiO_2 (bulk) and control treatments. In fact, nanoparticles of TiO_2 in comparison with the bulk type, have photocatalytic properties and because of specific surface and very low diameter can easily pass through the membrane of plant tissue and can do more and faster reactions.

In accordance to these results, Lei *et al.,* (2007) declared yield of spinach treated by nano TiO_2 increased, because nano TiO_2 entered the Chl and was transferred in the photosynthetic electron transport chain to create NADP+, was reduced to NADPH, and coupled to photophosphorylation and transformed electron energy to ATP. So, greatly increased whole chain electron transport, photoreduction in photosystem II, O_2 evolution and photophosphorylation. Therefore, the probability of absorption of nanoparticles by spraying of the leaves and aerial parts of the plant is very high. In this test, the highest amount of height and seed yield is related to the use of TiO_2 nanoparticle and this shows that there is close relationship between height and grain yield. The results for other research by Haghighi *et al.,* (2012) and Moaveni and Kheiri, (2011) confirm the results of this experiment in that they report that application of nano TiO_2 increased yield and component of plants yield. As a result, use of nano TiO_2 compared to the TiO_2 (bulk type), and control treatments caused an increasing in oil and seed yield due to increased absorption of solar radiation, CGR, LAI, plant height, number of nodes, leaf and shoot dry weight.

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