بررسی اثرات غلظت‌های مختلف ذرات نانو و غیر نانو دی اکسید تیتانیوم بر جوانه زنی بذر و رشد گیاهچه رازیانه

حسن فیضی [1*]، مریم کمالی [2]، پرویز رضوانی مقدم [3]، سعید جاهدی پور [4]، حسین صحابی [1]

1- عضو هئیت علمی دانشکده کشاورزی و منابع طبیعی، دانشگاه تربت حیدریه. 2- دانشجوی دکتری باغبانی، دانشکده کشاورزی دانشگاه فردوسی مشهد. 3- استاد گروه زراعت و اصلاح نباتات دانشکده کشاورزی، دانشگاه فردوسی مشهد. 4- دانشجوی دکتری بوم شناسی زراعی (اگرواکولوژی)، دانشکده کشاورزی دانشگاه فردوسی مشهد و مدرس دانشگاه پیام نور مشهد.

Email: hasanfeizi@yahoo.com

چکیده:

هدف از آزمایش حاضر بررسی غلظتهای 0، 20، 40، 60 و 80 میلی گرم بر لیتر ذرات نانو و غیر نانو دی اکسید تیتانیوم بر جوانه زنی و رشد گیاهچه رازیانه بود. آزمایش به صورت طرح کاملا تصادفی در آزمایشگاه دانشگاه فردوسی مشهد انجام شد. پس از 14 روز، درصد جوانه زنی بذرها به صورت معنی داری در تیمار کاربرد غلظت 60 میلی گرم بر لیتر ذرات نانو دی اکسید تیتانیوم (76 درصد) نسبت به سایر تیمارها و شاهد (54 درصد) افزایش یافت. این افزایش در وزن خشک ساقه و سرعت جوانه زنی بذرها نیز مشاهده شد. کاربرد ذرات غیر نانو وزن خشک ساقه را تا 50 درصد نسبت به شاهد کاهش داد. متوسط زمان جوانه زنی در اثر کاربرد نانو ذرات با غلظت 40 میلی گرم بر لیتر نسبت به شاهد حدود 31 درصد بهبود یافت در صورتی که ذرات غیر نانو متوسط زمان جوانه زنی را فقط 21 درصد بهبود داد. همچنین کاربرد ذرات نانو با غلظت کم و متوسط باعث بهبود شاخصهایی نظیر ارزش جوانه زنی، شاخص بنیه و میانگین جوانه زنی روزانه شد. به طور کلی کاربرد نانو ذرات دی اکسید تیتانیوم به عنوان یک گزینه جهت بذرهایی که دارای مشکل جوانه زنی هستند و درصد جوانه زنی کمی دارند می تواند مورد استفاده قرار گیرد.

کلمات کلیدی: نانو ذرات، گیاهان دارویی، جوانه زنی بذر.

Effect of bulk and nano Titanium dioxide particle concentrations on fennel (Foeniculum vulgare Mill)

Hassan Feizi۱*, Maryam Kamali۲, Parviz Rezvani Moghaddam۳, Saeed Jahedi pour٤, Hossein Sahabi۱

۱Member of Scientific Board, Faculty of Agriculture and Natural Resources, University of Torbat-e- Heydarieh Torbat Heydarieh, IRAN.

۲Ph.D. student, Horticulture Sciences Department, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, IRAN.

۳Ph.D. Wales Professor, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, IRAN.

٤Ph.D Student in Agroecology, Faculty of Agriculture, Ferdowsi University of Mashhad & Educator of Payame Noor University of Mashhad, Mashhad, IRAN.

E-mail: hasanfeizi@yahoo.com

Abstract:

The aim of this study was to compare concentrations of nanosized TiO_2 at ۰, ٥, ۲۰, ٤۰, ٦۰ and ۸۰ mg L^{-1} with bulk TiO_2 for phytotoxic and stimulatory effects on fennel seed germination and early growth stage. After ١٤ days of seed incubation, germination percentage highly improved following exposure to ٦۰ ppm nanosized TiO_2. Similar positive effects occurred in terms of shoot dry weight and germination rate. Application of bulk TiO_2 particles in ٤۰ ppm concentration greatly decreased shoot biomass up to ٥۰٪ compared to the control. Application of ٤۰ ppm nanosized TiO_2 treatment improved mean germination time by ۳۱٫۸٪ in comparison to the untreated control. In addition, low and intermediate concentrations of nanosized TiO_2 enhanced indices such as germination value, vigor index and mean daily germination. In general, there was a considerable response by fennel seed to nanosized TiO_2 presenting the possibility of a new approach to overcome problems with seed germination in some plant species, particularly medicinal plants.

Keywords: Nanosized TiO_2, Phytotoxicity, Medicinal plant, Seed improvement.

Introduction:

Nanotechnology has many applications in agricultural research, such as in reproductive science and technology, the transfer of agricultural and food waste to energy and other helpful by-products through enzymatic nanobioprocessing, disease prevention and various other plant treatments using nanocides (Carmen et al. ۲۰۰۳). An important effect of titanium compounds on plants used for various crops is improvement of yield (about ۱۰–۲۰٪). Other effects of titanium on plants are increased contents of some essential elements in plant tissue; an

increase in enzyme activity such as peroxidase, catalase, and nitrate reductase activities in plant tissue and research has shown increased chlorophyll in paprika (Capsicum anuum L.) and green alga (Chlorella pyrenoidosa) (Hruby et al. ۲۰۰۲). Nanosized TiO۲ is a frequently used nanoparticle, consequently there has been an exponential increase in data collection on the effects of TiO۲ nanoparticles on different species but there is much less information on the effects of nanoparticles on plants compared to animals. Studies of effects of TiO۲ nanoparticles on plants provide information about the positive and stimulating effects as well as any negative impact (Klancnik et al. ۲۰۱۱).

Foeniculum vulgare commonly known as fennel is a well known and important medicinal and aromatic plant widely used to treat carminative, digestive, lactagogue, diuretic, respiratory and gastrointestinal disorders (Manzoor et al. ۲۰۱۲). Efficient seed germination and early seedling establishment are important processes in commercial agriculture. Rapid and uniform seedling emergence leads to successful plant establishment, as a deep root system is formed before the upper layers of the soil dry out, harden, or reach supra-optimal temperatures (Chen and Arora, ۲۰۱۲). This study was therefore done to investigate possible phytotoxicity and/or beneficial stimulatory effects of nanosized TiO۲ concentrations compared to bulk TiO۲ particles on fennel seed and seedling growth.

Materials and Methods:

Tests were done to assess the effect of different concentrations of bulk and nanosized TiO۲ on fennel seed germination in a completely randomized design with four replications. The treatments in the experiment were five concentrations (۵, ۲۰, ٤۰, ٦۰ and ۸۰ ppm) of bulk and five concentrations (۵, ۲۰, ٤۰, ٦۰ and ۸۰ ppm) of nanosized TiO۲ and an untreated control (without any TiO۲ types). The Experiment was performed in a germinator with an average temperature of ۲۵ ±۱°C at the College of Agriculture, Ferdowsi University of Mashhad, Iran in ۲۰۱۲. Seeds of similar size were randomly selected and sterilized using ClONa (۵٪) for ۳ minutes and then carefully washed with distilled water three times. In order to obtain properly dispersed and stable TiO۲ suspensions of each concentration, an ultra-sonication treatment was applied to bulk and nanoparticles TiO۲ powders dispersed in water for ۱۵ minutes. The seeds were placed on paper in four groups of ۲۵ seeds in Petri dishes, and after that ۳ ml of each concentration treatments was added to each. For the control, only distilled water was added to the Petri dishes. Germination tests were performed according to the rule issued by the International Seed Testing Association (ISTA, ۲۰۰۹). All concentrations of TiO۲ and the control were tested at the same time to ensure uniform conditions of light and temperature across all tests. Number of germinated seeds was noted daily for ۱٤ days. Seeds were considered germinated when the radicle showed at least ۲ mm in length (ISTA, ۲۰۰۹).

A one-way analysis of variance (ANOVA) was performed between treatment samples in a completely randomized design in four replications. Data were analyzed using MSTAT-C software. Significant levels of difference for all measured traits were calculated and means were compared by the multiple range Duncan test at ۵٪ level.

Results and Discussion:

Results demonstrated that treatments applied in this experiment had significant affects on most studied traits. Use of TiO۲ nanoparticles extraordinarily enhanced fennel seed germination, while seed germination percentages decreased from exposure to concentrations of bulk TiO۲ particles compared to the control group (Table ۱). Final seed germination percentage showed the most value (۷٦٪) in ٦۰ ppm TiO۲ nanoparticles, whereas the lowest value (٤۱٪) was in ٦۰ ppm bulk TiO۲ particles. However, fennel seeds exposed to TiO۲ nanoparticles improved germination percentage ۳۹,۵٪ compared to the unexposed control group and was ۸۳٪ more than those concentrations of bulk particles. The key reason for this increased growth rate could have been the photo-sterilization and photo-generation of “active oxygen like superoxide and hydroxide anions” by nano-TiO۲ that enhanced seed stress resistance and encouraged capsule penetration for intakes of water and oxygen needed for quick germination (Khot et al. ۲۰۱۲).

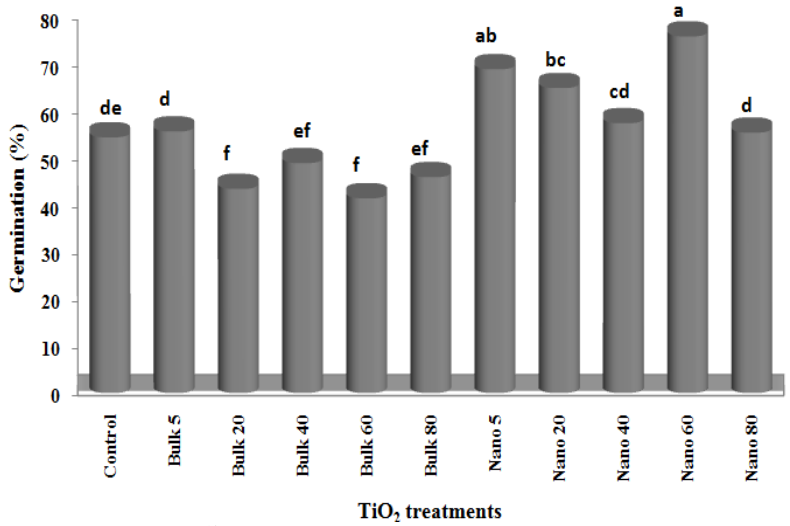

Figure ١. Effect of bulk and nano TiO٢ concentrations on germination percentage of fennel seed.

Shoot, root and seedling elongation were not significantly affected by bulk and nanosized TiO٢ concentrations. Application of bulk TiO٢ particles in ٤٠ ppm concentration greatly decreased shoot biomass up to ٥٠٪ compared to the control seeds but at the concentration of ٤٠ ppm nano-TiO٢ did not demonstrate such reduction in shoot biomass (Table ١). The greatest shoot biomass was found in ٥ ppm bulk particles (١،١٨ mg) and ٨٠ ppm nanoparticles (١،١٦ mg) of titanium dioxide. The highest root biomass was achieved from concentrations of ٢٠ ppm bulk-TiO٢, ٥ and ٢٠ ppm nano-TiO٢ but an increased concentration of bulk particles of ٨٠ ppm significantly reduced root weight. It is probable that increasing the concentration of bulk-TiO٢ induced aggregation of particles and resulted in clogging of root pores that interrupted water uptake by seeds. In addition, application of ٤٠ ppm concentration of bulk and nanosized TiO٢ decreased fennel seedling biomass. It seems that nano TiO٢ could stimulate process of germination similar to water and oxygen uptake by seed result in improves seed germination percentage but in later growth stages of seedling it might be has different effect on plant.

Table ١. Influence of bulk and nanosized TiO٢ concentrations on seed germination, elongation and biomass of fennel seedling.

TiO٢ concentration (ppm)		Shoot length (cm)	Root length (cm)	Seedling length (cm)	Shoot dry weight (mg)	Root dry weight (mg)	Seedling weight (mg)
Control	٠	٤,٠٦a	٥,٨١a	٩,٨٧a	١,٠٧ab	٠,٣٨b	١,٤٦ab
Bulk TiO٢	٥	٣,٧٦a	٥,٢٥a	٩,٠٢a	١,١٨a	٠,٣٦bc	١,٥٥a
	٢٠	٤,١٢a	٦,٢١a	١٠,٣٤a	١,١٢ab	٠,٥٤a	١,٦٦a
	٤٠	٤,٠١a	٥,٥١a	٩,٥٢a	٠,٥٣d	٠,٣٢bcd	٠,٨٥d
	٦٠	٣,٨٩a	٧,٠٠a	١٠,٨٩a	٠,٩٩ab	٠,٣٤bcd	١,٣٣abc
	٨٠	٣,٧٤a	٦,٢٥a	٩,٩٩a	٠,٩٥abc	٠,٢d	١,١٥bcd
Nano TiO٢	٥	٣,٧٩a	٥,٥٥a	٩,٣٤a	١,٠١ab	٠,٤ab	١,٤٢ab
	٢٠	٤,٣٨a	٥,٩٣a	١٠,٣١a	٠,٨bcd	٠,٤ab	١,٢١bc
	٤٠	٤,٠٥a	٦,٦٥a	١٠,٧١a	٠,٦٤cd	٠,٢٢cd	٠,٨٦d
	٦٠	٤,١١a	٥,٩٣a	١٠,٠٥a	٠,٨١bcd	٠,٢٧bcd	١,٠٩cd
	٨٠	٣,٨٧a	٧,٣٩a	١١,٢٧a	١,١٦a	٠,٢٩bcd	١,٤٥ab

*Means, in each column, followed by similar letter are not significantly different at the ٥٪ probability level- using Duncan´s Multiple Range Test.

In general, lower mean germination time represents earlier germination. These results revealed that exposure of fennel seeds to ٤٠ ppm nanosized TiO٢ obtained the lowest mean germination time (٣,٩٩ days) but higher concentrations did not improve mean germination time. Thus, ٤٠ ppm concentration of nanosized TiO٢ treatment reduced mean germination time by ٣١,٨٪ in comparison to the untreated control, whereas ٤٠ ppm concentration of bulk TiO٢ contributed to a reduction of mean germination time of about ٢١٪ in comparison with the control (Table ٢). Zheng et al. (٢٠٠٥) stated that the considerable effect of nanosized TiO٢ on spinach germination in tests was probably because of small particle size, which allowed nanoparticles to penetrate the seed during the treatment period, exerting its enhancing functions during growth.

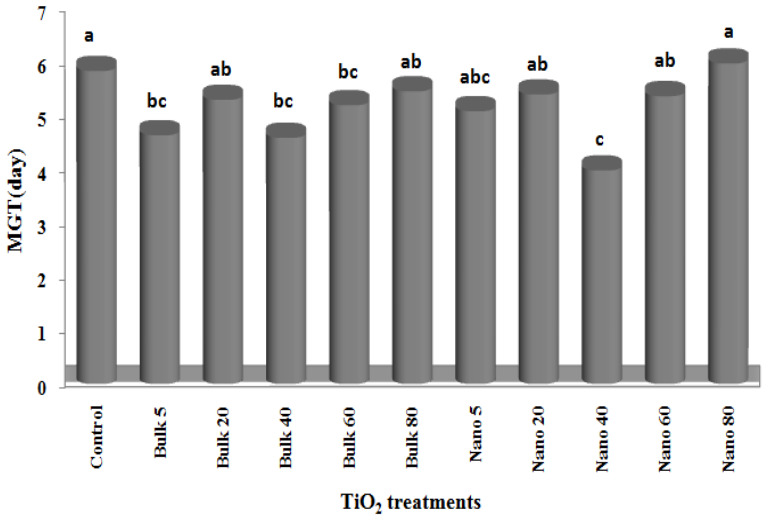

Figure ٢. Effect of bulk and nano TiO٢ concentrations on mean germination time of fennel seed.

The highest germination rate was found in ٥ ppm nano-TiO٢ particles (٦,٣٩ seed day-١) and increasing concentration decreased the germination rate. ٦٠ ppm bulk-TiO٢ treatment showed the lowest germination rate (٢,٤٥ seed day-١). All of bulk TiO٢ particle treatments inhibited germination rates compared to the control.

References:

١.Barrena, R., Casals, E., Colón, J., Font, X., Sánchez, A., Puntes, V. ٢٠٠٩. Evaluation of the ecotoxicity of model nanoparticles. Chemosphere, ٧٥:٨٥٠–٨٥٧.

٢.Carmen, I.U., Chithra, P., Huang, Q., Takhistov, P., Liu, S., Kokini, J.L., ٢٠٠٣. Nanotechnology: a new frontier in food science. Food Technology ٥٧،٢٤–٢٩.

٣.Casals, E., Vazquez-Campos, S. Bastus, N.G., Puntes, V. ٢٠٠٨. Distribution and potential toxicity of engineered inorganic nanoparticles and carbon nanostructures in biological systems. Trends in Analytical Chemistry ٢٧, No. ٨,

٤.Chen, K., Arora, R. ٢٠١٢. Priming memory invokes seed stress-tolerance. Environmental and Experimental Botany. In press.

٥.Chen, F., Bradford, K.J., ٢٠٠٠. Expression of an expansin is associated with endosperm weakening during tomato seed germination. Plant Physiology ١٢٤, ١٢٦٥–١٢٧٤.

٦.Clément, L., Hurel, C., Marmier, N. ٢٠١٢. Toxicity of TiO٢ nanoparticles to cladocerans, algae, rotifers and plants – Effects of size and crystalline structure. Chemosphere, In press.

٧.Feizi, H., Rezvani Moghaddam, P., Shahtahmassebi, N., Fotovat, A. ٢٠١٢. Impact of Bulk and Nanosized Titanium Dioxide (TiO٢) on Wheat Seed Germination and Seedling Growth. Biological Trace Element Research. ١٤٦،١٠١–١٠٦.

٨.Foltete, A.S., Masfaraud, J.F., Bigorgne, E., Nahmani, J., Chaurand P., Botta C., Labille, J., Rose, J., Férard, J.F., Cotelle, S. ٢٠١١. Environmental impact of sunscreen nanomaterials: Ecotoxicity and genotoxicity of altered TiO٢ nanocomposites on Vicia faba. Environmental Pollution ١٥٩, ٢٥١٥-٢٥٢٢.