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ORIGINAL ARTICLE

Role of nano-SiO_2 in germination of tomato (*Lycopersicum esculentum* seeds Mill.)

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Abstract Agricultural biotechnology is very familiar with the properties of nanomaterial and their potential uses. Therefore, the present experiment was conducted to test the beneficial effects of nanosilicon dioxide ($nSiO_2$: size- 12 nm) on the seed germination of tomato (*Lycopersicum esculentum* Mill. cv Super Strain B). Application of $nSiO_2$ significantly enhanced the characteristics of seed germination. Among the treatments, 8 $g L^{-1}$ of $nSiO_2$ improved percent seed germination, mean germination time, seed germination index, seed vigour index, seedling fresh weight and dry weight. Therefore, it is very clear that $nSiO_2$ has a significant impact on the seed germination potential. These findings could provide that alternative source for fertilizer that may improve sustainable agriculture.

1. Introduction

Today it has become important to increase crop production to feed the growing world population. To meet this increasing demand, researchers are trying to develop an efficient and eco-friendly production technology based on the innovative techniques to increase seedling vigour and plant establishment through physical seed treatments. Seed germination is an important phenomenon in modern agriculture because it is a thread of life of plants that guarantee its survival.

Silicon still failed to get recognition as an essential nutrient for plant growth and development, while beneficial effects of this element have been established in a wide variety of plants species for their growth, yield, and biotic and abiotic resistance (Ma and Yamaji, 2006; Ma, 2004; Pilon-Smits et al., 2009; Saqib et al., 2008; Pei et al., 2010). It plays an important role as a physicomechanical barrier, and is deposited on the walls of epidermis and vascular tissues of the stem, leaf sheath and hull in most plants especially monocots (Ma and Yamaji, 2006; Currie and Perry, 2007; Parven and Ashraf, 2010), and also regulates physiological activities in plants (Bao-Shan et al., 2004). Furthermore, regulatory effect of the silicon element on plant growth and development under stress conditions is well documented (Matichenkov and Kosobrukhov, 2004; Ma and Yamaji, 2006; Liang et al., 2007; Janislampi, 2012).

Nowadays, there is an increasing interest in the use of *ex vivo* synthesis of nanoparticles (NPs) for diverse purposes,

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such as medical treatments, use in various branches of industry production, and wide incorporation into diverse materials, such as cosmetics or clothes (Rogers, 2005; Lee et al. 2008, 2010). They have a high surface to volume ratio that increases their reactivity and possible biochemical activity (Dubchak et al., 2010). However, the interaction mechanisms at the molecular level between nanoparticles and biological systems are largely unknown (Barrena et al., 2009). Also, a thorough understanding of the role of nano-sized engineered materials on plant physiology at the molecular level is still lacking (Khodakovskaya et al., 2011). Plants, under certain conditions, were reported to be capable of producing natural mineralized nano-materials (NMs) necessary to their growth (Wang et al., 2001). Nano-TiO_2 treatment, in proper concentration, accelerates the germination of the aged seeds of spinach (Zheng et al., 2005) and wheat (Feizi et al., 2012) in comparison to bulk TiO_2. Similarly, carbon nanotubes improve seed germination and root growth by penetrating the thick seed coat of tomato and support water uptake inside seeds (Khodakovskaya et al., 2009). The effect of NPs on plants varies from plant to plant and species to species.

In view of the acclaimed reports on the use of nanotechnology as an emerging discipline in almost all fields of technology, it is an important to understand the course of germination in relation to nanoparticles. The recent advances in nanotechnology and its use in the field of agriculture are astonishingly increasing; therefore, it is tempting to understand the role of nanosilicon dioxide ($nSiO_2$) in the germination of seeds. In view of the available literature, the present experiment was designed to investigate the effect of $nSiO_2$ on the characteristics of germination of tomato (*Lycopersicum esculentum*) seed.

2. Materials and methods

2.1. Preparation of seeds

To test the effect of $nSiO_2$ on seed germination, the present experiment was performed under laboratory conditions using tomato (*L. esculentum* Mill. cv. Super Strain B) purchased from a local market of Riyadh, Saudi Arabia. Healthy seeds were selected and surface sterilized with 10% sodium hypochlorite solution for 10 min then vigourously rinsed with sterilized double-distilled water (DDW) before transferring into Petri dish (Size 12 in) having a double layer of filter paper.

2.2. Characterization and preparation of nanoparticle suspension for treatment

Nanoparticle of (SiO_2) was purchased from the Evonik Industries, Germany. The hydrophilic fumed silica commercially known as Aerosil 200 (Evonik Industries) and was used in the present study. It has an average primary particle size of 12 nm with a corresponding surface area of 200 m^2/g. The characteristics of nanoparticles were subjected to identification and morphology that are given in Fig. 1. The morphological study of this nanoparticles was done by scanning electron microscope (SEM). The solution was sonicated for 30 min using Sonic's Vibra-Cell (Model VCX 750) in order to obtain a homogeneous mixture.

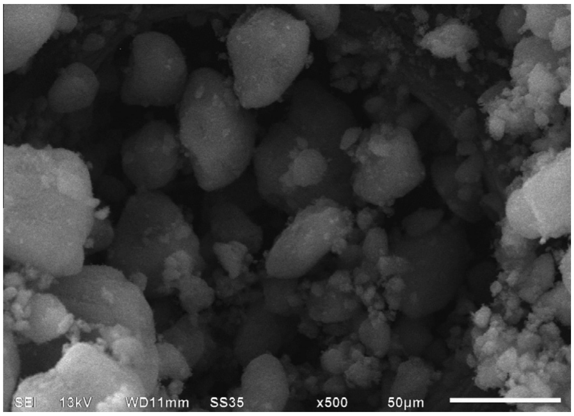

Figure 1 Scanning electron microscopy image of $nSiO_2$ equal distribution.

2.3. Seeds treatments and germination

The sterilized seeds were transferred onto the two sheets of sterilized filter papers inside the Petri dishes. Hundred seeds were put into each dish. The dishes were arranged in a simple randomized design with single factor and five replicates. The treatments of $nSiO_2$ were applied as follows (the concentration (in g L^{-1} for $nSiO_2$ is indicated as a subscript)) (1) SiO_0 (control), (2) SiO_2 (3) SiO_4, (4) SiO_6, (5) SiO_8 and (6) SiO_{10}, (7) SiO_{12} (8) SiO_{14}. After treatment, the dishes were sealed with paraffin tape, and placed in the dark in an incubator at 28 ± 3 °C. The number of seeds germinated was counted every day. After every 2 d, germinated seedlings were transferred onto the sterile filter paper in new sterile dishes containing same concentrations and volume of treatments. At the end of the 10d, the potential of seed germination was assessed in terms of percent seed germination, mean germination time (MGT), germination index (GI), vigour index (VI), fresh weight $seedling^{-1}$ and dry weight $seedling^{-1}$.

2.4. Determination of growth characteristics

The seed germination percentage was recorded every day from 2 to 10 d. The number of germinated seed was noted daily for 8 d. Seeds were considered as germinated when their radicle showed at least 2-mm length. Mean germination time was

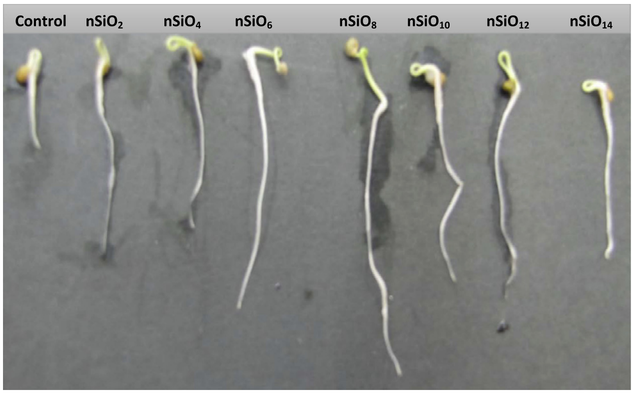

Figure 2 Effect of $nSiO_2$ on seeding growth of tomato.

calculated according to the following formula Matthews and Khajeh-Hosseini (2007).

$$\text{Mean germination time} = \Sigma PF. \times /\Sigma F$$

where F is the number of seeds newly germinated at the time of X, and X is the number of days from sowing.

Seedling vigour index (V) was calculated by the following formula (Vashisth and Nagarajan, 2010).

$$\text{Vigour index} = \text{germination\%} \times \text{meanof seedling length(root} + \text{shoot)}$$

Germination index was calculated according to the formula given by Tao and Zheng, 1990.

$$\text{Germination index}(GI) = \Sigma Gt/Dt$$

where Gt is percent germination and Dt represents germination days

At the end of the 10 d, after taking seedling fresh weight, samples were then placed in an oven run at 60 °C for 48 h for dry weight of seedling.

Each Petri dish was treated as one replicate and all the treatments were repeated five times. The data were expressed as means ± standard error, and analysed statistically with SPSS v17 statistical software (SPSS Inc., Chicago, IL, USA). Means were statistically compared by Duncan's multiple-range test (DMRT) at the $p < 0.05$ % level.

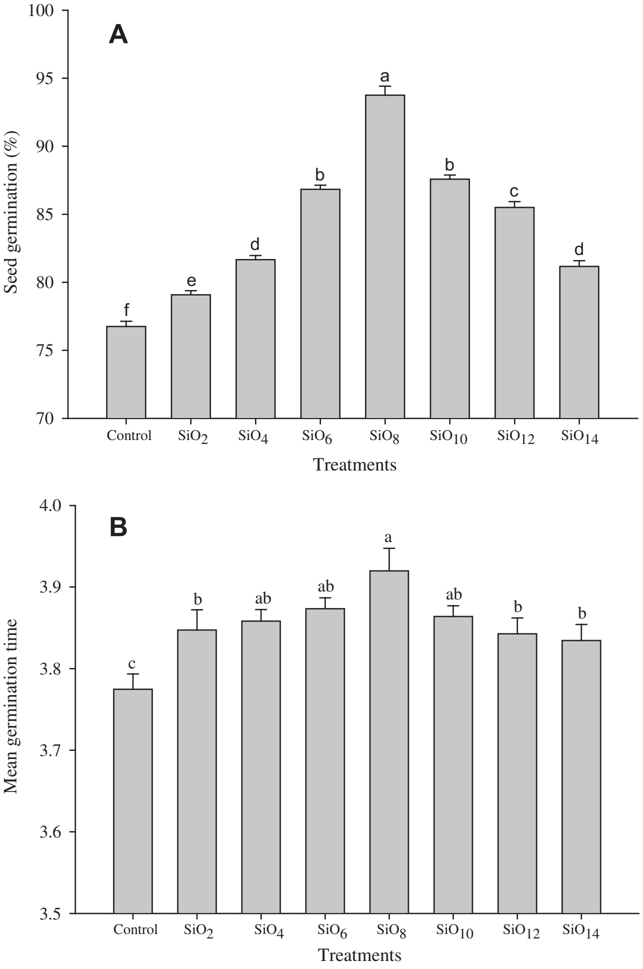

Figure 3 Effect of $nSiO_2$ on seed germination percentage (A) and Mean germination time (MGT) of tomato.

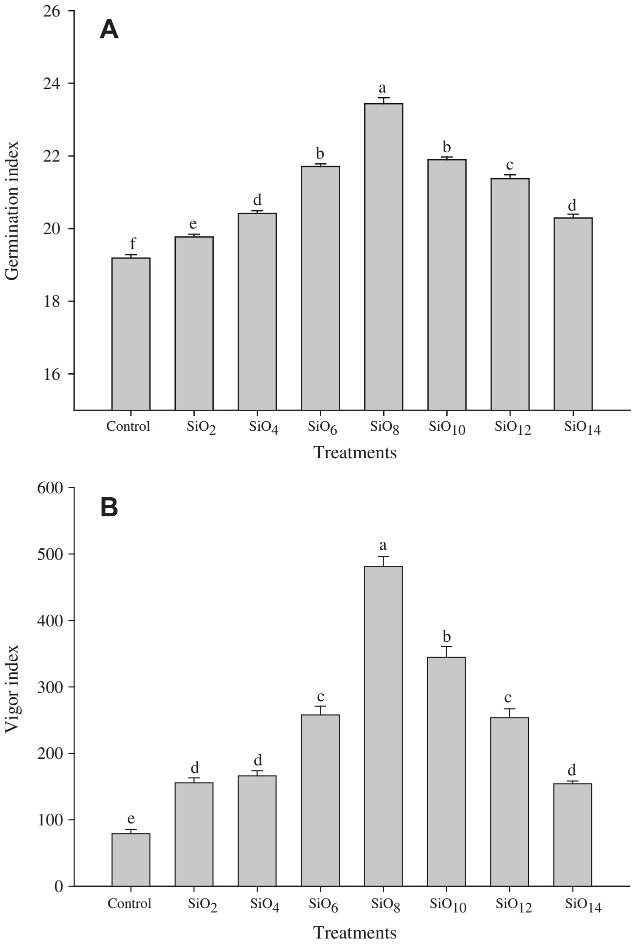

Figure 4 Effect of $nSiO_2$ on seed germination index (A) and seed vigour index (B) of tomato.

3. Results and discussion

Nanotechnology has emerged as a new discipline, and nanoparticles have become a centre of attraction for researchers because of its unique physico-chemical properties compared to their bulk particles (Monica and Cermonini, 2009). Silica nanoparticle acts as a delivering agent that delivers DNA and chemicals into plants as well as animals cell and tissue (Torney et al., 2007). However, the mode of action of nanoparticles on plant growth and development is still too scarce. As we know seed germination provides a suitable foundation for plant growth, development and yield. In the present experiment application of $nSiO_2$ enhanced seed potential by increasing the characteristics of seed germination (Figs. 3A, B and 4A, B). Parameters of seed germination were increased with increasing levels of $nSiO_2$ up to 8 g L^{-1}. Among the treatments, application of 8 g L^{-1} of $nSiO_2$ proved best by giving the highest values for percent seed germination, germination mean time, seedling vigour index and seed germination index. Application of 8 g L^{-1} of $nSiO_2$ increased percent seed

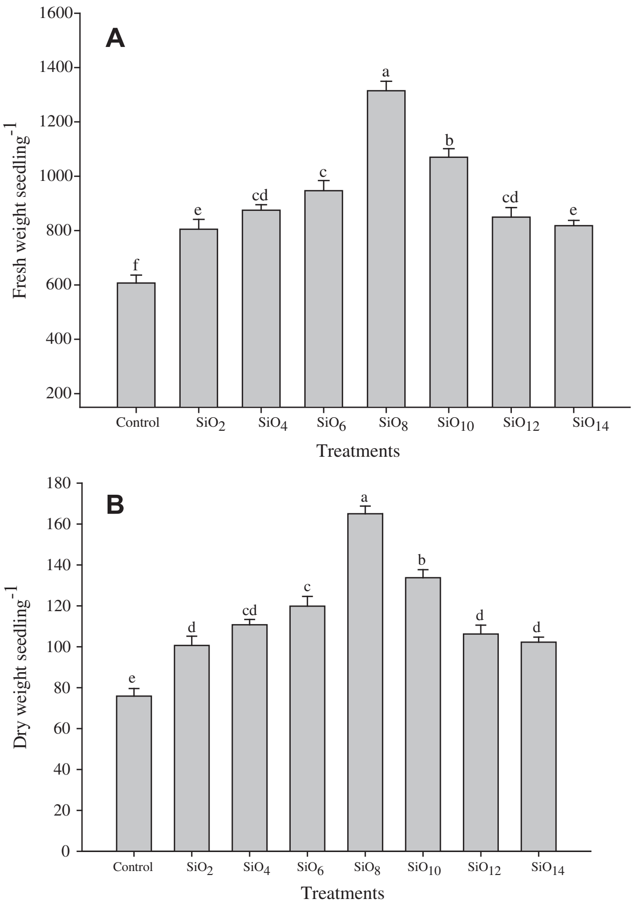

Figure 5 Effect of $nSiO_2$ on seedling fresh weight (A) and seedling dry weight (B) of tomato.

germination by 22.16%, germination mean time by 3.98%, seedling vigour index by 507.82% and seed germination index by 22.15% over the respective controls. These results agree with the findings of Nair et al. (2011). They observed better germination of seeds of rice in the presence of FITC-labelled silica nanoparticles. Also, the improvement in germination characteristics of seed as a result of $nSiO_2$ demonstrated that it may act like a bulk particle of silica, which calls for more research on its involvement into the mechanisms of seed germination. An increase in germination may be due to the absorption and utilization of $nSiO_2$ by seeds (Suriyaprabha et al., 2012a). Data presented in Fig. 5A and B reveal that the application of $nSiO_2$ had a significant effect on seedling fresh weight and dry weight. Seedling fresh weight and dry weight increased with increasing levels of $nSiO_2$ up to $8\,g\,L^{-1}$. Application of $8\,g\,L^{-1}$ of $nSiO_2$ increased seedling fresh weight by 116.58% and seedling dry weight by 117.46% over the respective controls. Suriyaprabha et al. (2012b) reported that $nSiO_2$ significantly enhanced plant dry weight, and also observed enhanced levels of organic compounds such as proteins, chlorophyll and phenols in maize plants treated with nanosilica. Thus, on the basis of the roles played by $nSiO_2$, we could easily visualize their direct and indirect involvement in the root and shoot growth (Fig. 2) by better improvement in seed germination characteristics (Figs. 3A, B and 4A, B).

4. Conclusion

In conclusion, these results of the current study reveal that the application of $nSiO_2$ significantly enhanced seed germination potential. Application of $nSiO_2$ improved percent seed germination, mean germination time, seed germination index, seed vigour index, seedling fresh weight and dry weight. An increase in germination parameters by the application of $nSiO_2$ may be effective for the growth and yield of crops. However, the present experiment invites researchers to find out the interaction mechanism between nanosilica and plants which estabilishes that $nSiO_2$ could be used as a fertilizer for the crop improvement.

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