Evaluation of the Effects of Silver and Zinc-Oxide Nanoparticles on the Germination of *Lycopersicum esculentum*

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Abstract
Nanotechnology is one of the new area of research and use of engineered nanoparticles (NPs) has increased as a result of their positive roles in many fields including agriculture. The aim of present study was to investigate the effects of silver nanoparticles (Ag-NPs) and zinc oxide nanoparticles (ZnO-NPs) on germination index, vigor index and seed germination rate of tomato (*Lycopersicon esculentum*). The experiment was performed in petriplates under controlled conditions. Different concentrations (10, 50, 100 and 200 ppm) of both Ag-NPs and ZnO-NPs were prepared and used for the treatment of tomato seeds to study the aforesaid parameters. The results indicate that out of the above four concentration 10 ppm proved best irrespective of NPs used and enhanced the vigor index, germination index and seed germination rate over the control. Whereas, ZnO-NPs was more effective as compared to Ag-NPs.
Keywords: Agriculture, germination index; nanotechnology.

Introduction

Nanotechnology has revolutionized many aspects of modern society through widespread applications in various fields (Ying-qing *et al*., 2014). Nano particles (NPs) are tiny material having nanoscale dimensions in the range of 1-100 nm and used in the areas of textiles, electronics, medical devices, cosmetics, and environmental treatment processes etc. (Stampoulis *et al*., 2009; Santhoshkumar, 2017). NPs are generally classified into carbon-based, metal based, composite materials etc. (Lin and Xing, 2008). Ag-NPs are one of the most important engineered NPs used in various fields (Quadros and Marr, 2010). Ag-NPs enhanced seed germination and growth of various crop plants (Savithramma *et al*., 2012; Sharma *et al*., 2012). Zinc being an essential micronutrient plays an important role in many integral metabolic processes (Rout and Das, 2003). Important optoelectrical, physical and antimicrobial activities of ZnO-NPs offers great potential to enhance the productivity of crop (Hussain *et al*., 2016). ZnO-NPs enhanced seed germination, protein content and activity of antioxidant system in plants (Singh *et al*., 2013). Plant growth begins with seed germination and is the most critical stage in plant life. Successful germination in seeds depends upon the ability of the plant embryo to gain its metabolic processes (Rajjou *et al*., 2012). In this experiment, we examined the effects of Ag-NPs and ZnO-NPs on the germination index, vigor index and seed germination rate of tomato seeds.

Material and Methods

Seeds

The seeds of *Lycopersicon esculentum* variety PKM-1 were procured from National Seed Corporation Ltd., Indian Agricultural Research Institute, Pusa, New Delhi, India. Prior to start of experiment, these seeds were surface sterilized with 1% sodium hypochlorite solution for 10 minutes, followed by rinsing with double distilled water (DDW) thrice to remove the traces of sodium hypochlorite, adhered to the seed surface.

Sources of nanoparticles

Ag-NPs and ZnO-NPs were purchased directly from the Sigma-Aldrich, New Delhi. Required concentrations (10, 50, 100 and 200 ppm) of both Ag-NPs and ZnO-NPs were dissolved in 10 ml of double distilled water (DDW) in a 100 ml volumetric flask and final volume was made upto the mark with the help of DDW.

Treatment pattern and experimental design

This experiment was performed under the controlled conditions (Temperature 28 ± 2^{o}C, dark). The surface sterilized seeds of the tomato cv. PKM-1 were transferred on the filter papers placed in the petriplates. The treatments of Ag-NPs and ZnO-NPs were applied as follows, control, 10 ppm, 50 ppm, 100 ppm or 200 ppm for Ag-NPs, and 10 ppm, 50 ppm, 100 ppm and 200 ppm for ZnO-NPs. After the treatment, plates were sealed with paraffin tape, and placed in the dark in an incubator at 28 ± 2^{o}C. The number of germinated seeds was counted every day. At the end of 8thday (d), germination was assessed in terms of % seed germination, germination index and vigor index.

Germination index

Germination index was calculated with the formula given by Tao and Zheng (1990).

$$Germination\ index = \frac{\%\ germination}{days\ of\ germination}$$

Vigor index

Vigor index was calculated with the help of following formula as used by Zhu and Hong (2008).

Vigor index = % germination × mean of seedling length (root + shoot)

Seed germination rate

The seed germination rate was recorded every day from 2 to 8 days. 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.

Results

Germination index

It is observed from **figure 1A** that germination index increased with the increasing concentration of both the NPs upto a 50 ppm. The maximum increased was recorded when the seeds received 10 ppm of ZnO-NPs and it was about 31% more over the control whereas increased by 10 ppm of Ag-NPs was about 17%. Germination index was decreased as the concentration of both the NPs increased beyond 50 ppm.

Vigor index

The data presented in **figure 1B** indicate that seed vigor index was significantly affected by the application of both the NPs in a concentration dependent manner. Out of the different concentrations, 10 ppm of ZnO-NPs proved best and increased the vigor index by 315% over the control. Whereas, 10 ppm of Ag-NPs enhanced the vigor index by 209% over the control. The other two concentrations (100 and 200 ppm) of Ag-NPs and ZnO-NPs proved to be inhibitory.

Seed germination rate

Germination rate was increased with the application of both Ag-NPs and ZnO-NPs **(Figure 1C).** Out of the various concentrations of Ag-NPs and ZnO-NPs, 10 ppm of ZnO-NPs proved best and significantly increased the germination rate by 23%, whereas 10 ppm of Ag-NPs increased the germination rate by 12% over the control. Higher concentrations of both the NPs proved to be inhibitory and decreased the germination rate as compared to control.

Discussion

Nanotechnology has emerged as a new discipline of science and it is considered as one of the most suitable solution to overcome the problems of agriculture. Ag-NPs and ZnO-NPs are comparatively less toxic compared with other metal oxide NPs, which further supports its application potential (Tripathi *et al*., 2017). Seed germination provides the suitable foundation for plant growth, development and yield. Our results indicate that exposure of Ag-NPs and ZnO-NPs had significant effects on seed germination in tomato seeds **(Figure 1C),** which was supported by the results of Hojjat and Hojjat, (2015), Hao *et al*. (2016). Significant difference among NPs treated and water soaked seeds can be attributed to increased mobilization of phyto-metabolites within the seeds or by biochemical changes in the seed, required to start the germination process, such as breaking of dormancy, hydrolysis or metabolization of inhibitors, imbibition and enzyme activation (Ajouri *et al*., 2004; Harris *et al*., 2007; Samad *et al*., 2014; **Figure 2**). Similar findings were also reported by Prasad *et al*. (2012) in groundnut after the treatment of ZnO-NPs and Savithramma *et al*. (2012) in *Boswellia ovailifoliolata* after Ag-NPs treatment. Out of the two NPs used, the response towards ZnO-NPs was more pronounced as compared to Ag-NPs **(Figure 1).** It may be due to the Zn which plays an important role in most of the metabolic processes (Rout and Das, 2003). Zn is also reported to enhance the vigor index by improving the length of shoot and root (Rengel and Graham, 1995; **Figure 2**).

Conclusion

From the present observation it is concluded that out of the two NPs used, ZnO-NPs can be exploited for the better growth of the tomato plants.

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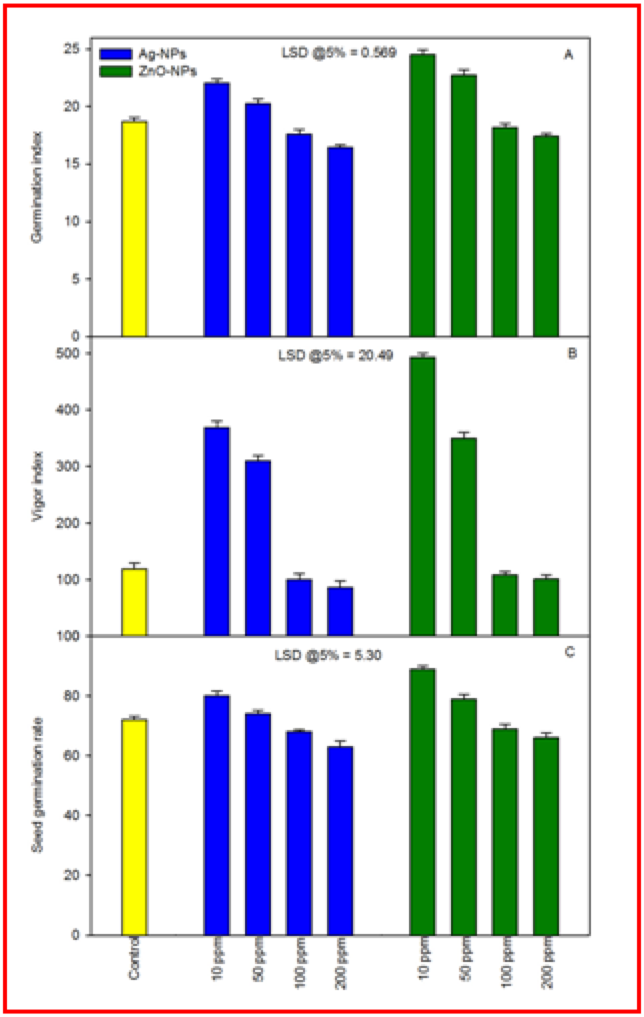

Figure 1: Effect of different concentrations (0, 10, 50, 100 or 200 ppm) of silver nanoparticles (Ag-NPs) and zinc oxide nanoparticles (ZnO-NPs) on germination index (A), vigor index (B) and seed germination rate (C)

Figure 2. Effect of different concentrations (0, 10, 50, 100 or 200 ppm) of silver nanoparticles (Ag-NPs) and zinc oxide nanoparticles (ZnO-NPs) on seedlings growth. Control (A); 10 ppm Ag-NPs (B); 10 ppm ZnO-NPs (C); 50 ppm Ag-NPs (D); 50 ppm ZnO-NPs (E); 100 ppm Ag-NPs (F); 100 ppm ZnO-NPs (G); 200 ppm Ag-NPs (H); 200 ppm ZnO-NPs (I)

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