Journal of Agriculture and Veterinary Science
ISSN: 2959-1198 (Print), 2959-1201 (Online)

Check for updates

OPEN ACCESS

Research Article

Effect of Zinc Nanoparticles on Seed Priming, Growth and Production of Cucumber

Samia Nisar[1], Imran Hassan[1], Syed Zia ul Hasan[1,2*], Ishrat Batool[1], Adnan Saleem[1], Riffat Bibi[3], Safia Naureen Malik[3], Rizwan Rafique[4], Asif Ur Rehman[5]

[1] *Department of Horticulture, PMAS-Arid Agriculture University, Rawalpindi, Pakistan.*
[2] *Hill Fruit Research Station Sunny Bank Murree, Pakistan.*
[3] *Soil and Water Conservation Research Institute Chakwal, Pakistan.*
[4] *Agriculture Extension Department Chakwal, Pakistan.*
[5] *Horticultural Research Station Sahiwal, Pakistan.*
*Correspondence: ziawish1@hotmail.com

Article History
Received: August 13, 2022
Accepted: September 19, 2022
Published: September 30, 2022

Abstract

Cucumber (*Cucumis sativus* L.) is an important vegetable and its demand remains around the year. High quality and yield are desired quality for both grower and consumers. Therefore, influence of seed priming and foliar application of zinc nano particles was checked on yield and quality of cucumber. ZnO nano particles are non-toxic and recently listed as "Generally Recognized as Safe (GRAS)" safe material by food and drug administration and use as food additive. Due to interaction of nano particles with plant, many physiological and morphological changes take place depending on the characteristic of Nanoparticles. By the exploitation of new application of nanotechnology crop yield can be increased. In plants, nano particles as a zinc fertilizer with small size and large surface area are predicted to be an ideal material to use. Zinc is one of the vital nutrients required for plant growth Result indicate that zinc nano particles at 20 ppm concentration increased seed germination as well as physical parameters plant height, number of leaves, leaf area, number of flower, yield, fruit weight, fruit length, fruit diameter, average single fruit weight, fruit firmness and fruit color was increased. Furthermore, chemical parameters like total soluble solids, ascorbic acid and titratable acidity was increased at 20 ppm zinc nano particles as compared to control and other treatments. Present research proves that seed priming and foliar application of zinc nano particles are effective for improving fruit physical and chemical characteristics. The finding of this research work will be helpful in future research on utilization of nano particles for vegetable crops.

Keywords: Cucumber; Seed priming; Nanoparticles.

Introduction

Cucumber (*Cucumis sativus*) belongs to the cucurbitaceae family and commercially cultivated worldwide as a seasonal crop (Kirkbride, 1993; Gupta *et al.*, 2022). In Pakistan, it is being cultivated on 3367 hectares' area, yielding 52,766 tons per annum. In Punjab cucumber is grown on 1805 hectares' area with the complete production of 68664 tons (Food vegetable and condiments statistics of Pakistan 2019). Different parts of the plant

like leaf, fruit and seeds have important medicinal value they are extensively used for several skin problems like sunburn and swelling under the eyes. It promotes refreshing, cooling, therapeutic, calming and anti-burning effect to irritated skin (Franco *et al.*, 2002). In plants, nano particles as a zinc fertilizer with small size and large surface area are predicted to be an ideal material to use.

Seed production in cucumbers is inefficient due to a higher production of underdeveloped seeds with poor quality (Gupta *et al.*, 2021a; Gupta *et al.*, 2021b; Gupta *et al.*, 2022). Amongst the various constraints, improper pollination, source-sink limitation (Gupta *et al.*, 2021a) and nutrient deficiency (Campos *et al.*, 2021; Hernández-Apaolaza *et al.*, 2020) have been attributed to the formation of immature and inferior quality seeds. Zinc is one of the vital nutrients required for plant growth. It has important function in the synthesis of auxin or indole acetic acid (IAA) as well as in biochemical reaction required for formation of chlorophyll and carbohydrates (Jamali *et al.*, 2011). Although it is required in trace amount but, if it is not available in required amount, it affects enzyme activities, creates physiological imbalances and other metabolic processes (Baybordi, 2006). By the exploitation of new application of nanotechnology crop yield can be increased. Because of many factors, such as hydrolysis, leakage, decomposition and degradation by photolysis most of the applied fertilizer become unavailable hence, it is essential to lessen the nutrient losses.

Nano-nutrients and nano-fertilizer has the property of controlled release of chemical fertilizer and released the nutrients on demand which regulate growth of plant and increase target activity (DeRosa *et al.*, 2010). Nanoparticles have exceptional physiochemical properties and ability to increase the plant metabolism (Giraldo *et al.*, 2014). Due to interaction of nanoparticles with plant, many physiological and morphological changes take place depending on the characteristic of nanoparticles. When materials are altered tonano scale they change their chemical, physical and biological characteristic as well as catalytic activities hence increased the biological and chemical activities (Mazaherinia *et al.*, 2010). Efficiency of nano particles is determined by the dose at whichthey are effective, chemical structure, size, covering of surface and reactivity (Khodakovskaya *et al.*, 2012). ZnO nanoparticles are non-toxic and recently listed as "Generally Recognized as Safe (GRAS)" safe material by food and drug administration and use as food additive. Due to vast application among metal nanoparticles ZnO nanoparticles have their own importance (Huang *et al.*, 2001). Keeping in view the effectiveness of zinc nanoparticles in fruits and vegetables, this study was conducted to evaluate the efficiency of these nanoparticles to enhance the yield and quality of cucumber.

Methodology

The present study was carried out at Postharvest laboratory and field area of horticulture department at Arid Agriculture University, Rawalpindi during 2017-18. Effect of different concentrations of zinc nanoparticles (10, 20 and 30 ppm) were checked on the seed germination rate, growth and yield of cucumber.

Seed priming

Seed priming was done at postharvest laboratory of horticulture department. Seeds were sterilized by dipping seeds for 10 minutes in 10 % sodium hypochlorite. Then they were rinsed with distilled water and leave for drying at room temperature. Different volume i.e. 10, 20 and 30 ppm nanoparticles solutions were prepared and seeds were dipped in nanoparticles solutions for 10 minutes and they were transferred in petri dishes containing filter paper which was sprinkled by water. After treatment petri dishes were

sealed with paraffin tape and placed at room temperature. Four treatments were given and each treatment containing 4 replications (Siddiqui and Al-Whaibi, 2014).

Foliar spray

Different concentrations of zinc nanoparticles were sprayed to the plant leaves and fruits with sprayer. First foliar spray of Zn nanoparticles was done at two to three true leaves then two times at an interval of 15 days. The number of sprays per plant were kept constant, with each plant receiving approximately 40 ml solution. The solution was sprayed on the abaxial and adaxial surfaces of leaves and fruits in such a way to obtain complete coverage of plant. Four treatments were given to plants. Each treatment had 4 replications and each replication contained 4 plants. Effect of all treatments were compared with control which received no treatment.

Preparation of Nanoparticles

Nanoparticles were prepared by sol-gel method with little modification and they were used in solution form for foliar spray (Hasnidawani *et al.*, 2016).

Plant physical characteristics

Seed germination rate was recorded in laboratory. Plant height was recorded at the day of harvest with the help of measuring tape. Number of leaves, number of flowers and yield were recorded from the day of transplanting to harvesting and onwards. Leaf area was recorded with the help of leaf area meter (LI-3100C).

Fruit physical quality characteristics

Sample of 10 mature fruits were taken for measuring the physical quality parameters like weight (gm), length (cm), diameter (cm), fruit firmness. While color of fruit was determined with chromameter.

Fruit chemical quality characteristics

The same fruits used to determine the physical characteristics were sliced and fruit juice was extracted for analysis of total soluble solids, ascorbic acids and titratable acidity. Total soluble solids (TSS) were measured according to Huang *et al.* (2001) using hand refractometer. Ascorbic acid was measured according to the method described by Hans (1992).

Result and Discussion

Plant physical characteristics

Significant increased seed germination was recorded in seeds treated with 20 ppm zinc nanoparticles. Similarly, plant height, number of leaves, leaf area, number of flowers and yield was increased in plants treated with foliar spray of 20 ppm zinc nanoparticles. Maximum plant height (162.37 cm) was recorded in plants treated with 20 ppm Zn nanoparticles followed by 10 ppm and 30 ppm Zn nanoparticles having plant height (147.42 cm) and (126.41 cm) respectively. While minimum plant height (110.78 cm) was recorded in untreated plants. The result for number of leaves shows same trend having number of leaves (49) while minimum number of leaves (25.33) were recorded in untreated plants.

Data regarding leaf area is presented in Table 1. Maximum leaf area was recorded in plants treated with 20 ppm Zn nanoparticles having leaf area (177.97 cm^2) while decreased leaf area was recorded in control plants with leaf area (101.12 cm^2).The maximum number of flowers (16) were recorded in plants treated with 20 ppm Zn nanoparticles while lowest number of flowers (8) were recorded in plants which were kept control as evident from the data presented in Table 1. Similarly, Table 1 shows that treatment of 20 ppm zinc nanoparticles were effective in increasing the yield compared to untreated plants. Maximum fruit yield (1.77 kg/plant) were recorded in plants treated

https://doi.org/10.55627/Javs.01.2.0252

with 20 ppm zinc nanoparticles while minimum fruit yield (0.44kg/plant) were recorded in untreated plants.

Fruit physical quality characteristics

Average fruit weight, fruit diameter and fruit length were significantly increased by the foliar application of 20 ppm zinc nanoparticles (Table 2). Highest average fruit weight (128gm) was recorded in the plants sprayed with 20 ppm zinc nanoparticles while lowest weight (82.75gm) was observed in the plant which was kept untreated. Similar trend was observed in fruit diameter. Highest fruit diameter (4.57cm) was recorded in plants received 20 ppm zinc nanoparticles treatment while minimum fruit diameter (2.57) was recorded in control plants. A substantial increase was observed in fruit length (19cm) by the treatment of 20 ppm zinc nanoparticles while minimum fruit length (11.75cm) was recorded in control plants.

Fruit firmness was also significantly high in the plants treated with 20 ppm zinc nanoparticles having fruit firmness 7.87 kg while minimum firmness (4.8 kg) was observed in control (untreated) plants. Data regarding fruit color presented in Table 1 reveals that all the treatments had significant effect on L* value of color in comparison to control. Maximum L*, a* and b* value was noted in the fruits treated with pre-harvest foliar application of 20 ppm Zn nanoparticles having L* value (32.91), a* value (-3.89) and b* value (8.42) while minimum values of L*, a* and b* was recorded in control plants having values (29.84), (-7.76) and (5.32) respectively.

Fruit chemical characteristics

Figures shown in table 2 reveals that total soluble solids (TSS) contents were increased significantly by the treatment of 20 ppm zinc nanoparticles. The highest amount of total soluble solids values were recorded in fruits treated with pre-harvest foliar application of zinc nanoparticles having values 3.87 while minimum values (2.5) were recorded in untreated fruits. The data of ascorbic acid show that it was also significantly increased by sprays of 20 ppm zinc nanoparticles solution.

Effect of 20 ppm zinc nanoparticles were more promising than all other treatments in enhancing ascorbic acid contents.20 ppm zinc nanoparticles proved to be the best treatment in increasing ascorbic acid contents of cucumber having value 3.07 while lowest value of ascorbic acid (1.49) was observed in untreated fruits. Maximum titratable acidity (0.66 %) was found by foliar spray of 20 ppm Zn nanoparticles. While minimum titratable acidity (0.34 %) was observed in control treatment. 20 ppm zinc nanoparticles proved statistically superior than other treatments.

In the present study plant physical characteristics like seed germination, plant height, number of leaves, leaf area, number of flowers and yield were increased by the foliar application of 20 ppm zinc nanoparticles. ZnO nanoparticles have a good effect on seed germination of *Cicer Aurantium* (Pandey *et al.*, 2010). Seed germination in peanuts was increased due to the application of ZnO nanoparticles (Prasad *et al.*, 2012). Application of ZnO nanoparticles has positive effect on seed germination in cucumber as compared to alfalfa and tomato (de la Rosa *et al.*, 2013). ZnO nanoparticles maximize the level of IAA in the roots which results in higher growth rate (Pandey *et al.*, 2010).

dehydrogenase) leading to higher rate of seed germination. As evident from previous studies zinc is involved in some catalytic activities that result in activation of some plant enzymes and improve the alteration level in the plant ultimately favored the plant physiological process thus increasing the plant height (Puzina, 2004). Present study confirmed the findings of Ahmed *et al.* (2011) who stated that the increased number of leaves might be due to additional zinc provision to the plants, as well as higher levels of zinc application, might be also reason for increased number of leaves as they have important role in accelerating the vegetative growth in plantlets.

https://doi.org/10.55627/Javs.01.2.0252

Table 1. Data regarding different parameters as effected by pre-harvest spray of Znnp.

Treatments	No of leaves	Plant height (cm)	No of flowers	Leaf area (cm^2)	Yield (kg)	Fruit color			Fruit length (cm)
						L*	a*	b*	
Control	25.33c	110.78 d	8c	101.12d	0.443c	29.84c	-7.76c	5.32c	11.75c
10ppm ZnOnps	33.0b	147.42 b	12b	116.20c	1.083b	31.96ab	-7.15c	6.44b	16.70ab
20ppm ZnOnps	49.0a	162.37 a	16a	177.97a	1.776a	32.91a	-3.89a	82.7a	19.0a
30ppm Znonps	36.0b	126.41 c	11b	145.26b	1.116b	31.75b	-5.72b	7.96a	13.87bc

Means** within columns sharing same letters are statistically significant at $p \leq 0.05$

Table 2: Data regarding different parameters as effected by pre-harvest spray of Znnps

Treatments	Fruit weight(gm)	Fruit Diameter(cm)	Fruit Firmness(kg)	Total soluble solids(°Brix)	Titratable acidity (%)	Ascorbic acids (mg/100ml)
Control	82.75c	2.575c	4.876d	2.500c	0.347d	1.490c
10ppm ZnOnps	110.0b	3.750b	7.576b	3.100b	0.465c	2.777a
20ppm Znonps	128.0a	4.575a	8.500a	3.875a	0.662a	3.070a
30ppm ZnOnps	100.0b	4.075b	6.700c	3.550a	0.565b	2.260b

Means** within columns sharing same letters are statistically significant at $p \leq 0.05$

Zinc is an important constituent of enzymes (i.e proteinase, peptides, and Zinc has an important role in carrying out some of the metabolic activities which promote the formation of chlorophyll and carotenoids that are beneficial during photosynthesis (Aravind and Prasad, 2005; Aravind and Prasad, 2004). Zinc play role in some activities of enzymes and have a role in the formation of tryptophan which is a precursor for auxin production (Swietlik, 1999) which might be the reason for greater leaf area.

Zinc deficiency resulted in decreased number of flowers, therefore, the appropriate amount of zinc is required for increasing number of flowers as zinc has an important role in the formation of auxin and cell division as well as sustaining the structure and function of the membrane (Sharma *et al.*, 1987; Marschner, 1995). The increase in yield may be due to the improvement of physiological processes like IAA hormone and chlorophyll content by correcting efficiency of enzymes through foliar application of zinc.

Significant improvement has been observed by the application of 20 ppm zinc nanoparticles in fruit physical characteristics like fruit color, fruit length, fruit weight, fruit diameter and fruit firmness. By the application of ZnO nanoparticles at concentration of 10mg/L plant biomass was increased in cluster bean as compared to control (Raliya and Tarafdar, 2013). The positive effect of zinc on cell enlargement and elongation was observed in onion (Cakmak, 2000) which might be the reason for increased weight because of Zn nanoparticles as applied before harvest. Nano zinc-oxide

https://doi.org/10.55627/Javs.01.2.0252

in combination with ultrasound maintained flesh firmness in kiwi fruits as compared to control after 10 days of storage (Meng *et al.*, 2014).

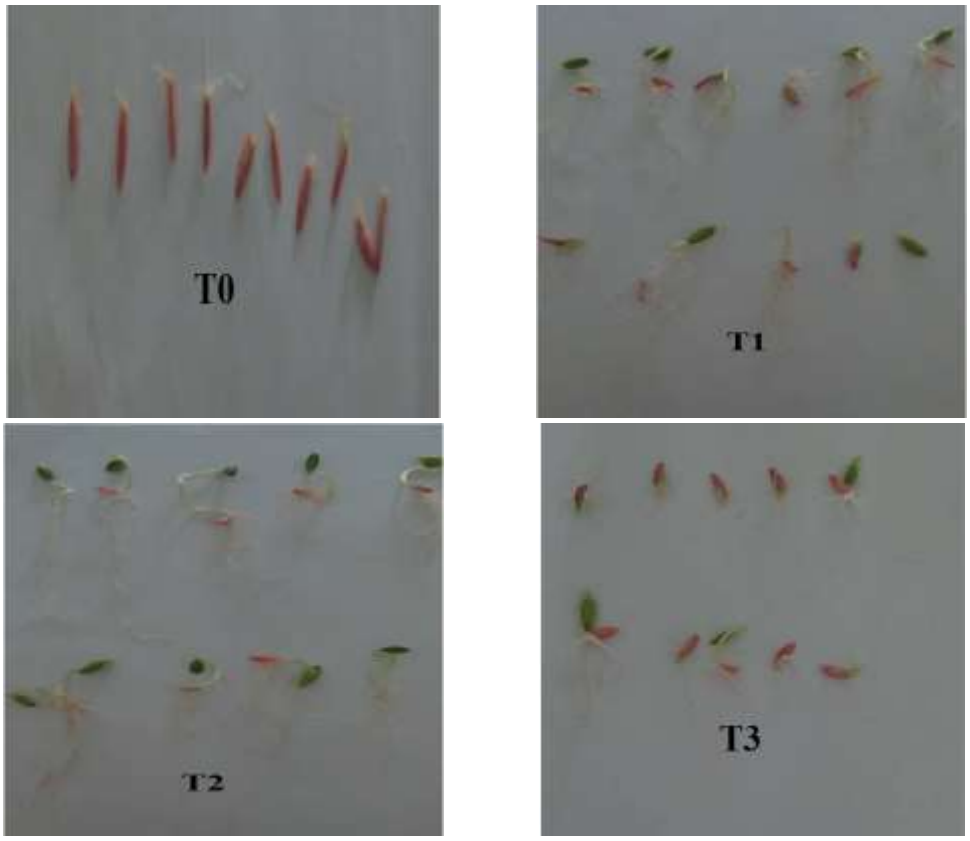

Figure 1. Seed priming treatments of cucumber.

The treatments had significant effects on total soluble solids, ascorbic acid and titratable acidity as well. Zinc plays an important role in the production of auxin in plant species (Alloway, 2008), auxin production increases ascorbic acid content in kinnow Mandarin as reported by Nasir *et al.*, (2016). Similarly, application of zinc sprays has also been reported to increase ascorbic acid contents in Balady mandarin trees. Because of increased levels of bound auxin, the ascorbic acid content of the fruit was increased. Increased level of TSS and TA due to application of Zn might be due to their effect on different enzymes which are involved in the formation of different proteins, acids, and sugars (Srivastava and Singh, 1999).

Conclusion

In general, the results showed that all the treatments were significantly effective in improving seed germination; yield and production of cucumber as compared to control.20 ppm zinc nanoparticles improved all the physical parameters of plants, physical and chemical parameters of fruits as well. Therefore, it can be concluded that zinc nanoparticles can be used to increase the yield and quality of cucumber.

Conflict of Interest

The authors have not declared any conflict of interest.

Authors Contributions

All the authors have contributed equally to the research and compiling the data as well

https://doi.org/10.55627/Javs.01.2.0252

as editing the manuscript.

References

Ahmed, A., M. Abd El-Baky, M. Zaki and F. S. Abd El-Aal. 2011. Effect of foliar application of active yeast extract and zinc on growth, yield and quality of potato plant (*Solanum tuberosum* L.). Journal of Applied Sciences Research, 7: 2479-88.

Alloway, B. J. 2008. Zinc in soils ad crop nutrition. Second edition, published by IZA and IFA., 1-39.

Aravind, P. and M. Prasad. 2004. Zinc protects chloroplasts and associated photochemical functions in cadmium exposed *Ceratophyllum demersum* L., a freshwater macrophyte. Plant Science, 166: 1321-27.

Aravind, P. and M. N. V. Prasad. 2005. Cadmium-Zinc interactions in a hydroponic system using *Ceratophyllum demersum* L.: adaptive ecophysiology, biochemistry and molecular toxicology. Brazilian Journal of Plant Physiology, 17: 3-20.

Baybordi, A. 2006. Zinc in soils and crop nutritionParivar Press. Tehran, Iran.

Cakmak, I. 2000. Tansley Review No. 111 Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. The New Phytologist, 146: 185-205.

Campos, C. N. S., G. C. M. Teixeira, R. d. M. Prado, G. Caione, G. B. da Silva Júnior, C. H. O. d. David, A. C. Sales, C. G. Roque and P. E. Teodoro. 2021. Macronutrient deficiency in cucumber plants: impacts in nutrition, growth and symptoms. Journal of Plant Nutrition, 44: 2609-26.

de la Rosa, G., M. L. López-Moreno, D. de Haro, C. E. Botez, J. R. Peralta-Videa and J. L. Gardea-Torresdey. 2013. Effects of ZnO nanoparticles in alfalfa, tomato, and cucumber at the germination stage: root development and X-ray absorption spectroscopy studies. Pure and Applied Chemistry, 85: 2161-74.

DeRosa, M. C., C. Monreal, M. Schnitzer, R. Walsh and Y. Sultan. 2010. Nanotechnology in fertilizers. Nature Nanotechnology, 5: 91-91.

Franco, P., S. Vitorria and A. Robert. 2002. Plants in cosmetics. Press-council of Europe.

Giraldo, J. P., M. P. Landry, S. M. Faltermeier, T. P. McNicholas, N. M. Iverson, A. A. Boghossian, N. M. Reuel, A. J. Hilmer, F. Sen, J. A. Brew and M. S. Strano. 2014. Plant nano-bionics approach to augment photosynthesis and biochemical sensing, 13: 400-08.

Gupta, N., S. K. Jain, B. S. Tomar, A. Anand, J. Singh, V. Sagar, R. Kumar, V. Singh, T. Chaubey and K. A. Abd-Elsalam. 2022. Impact of Foliar Application of ZnO and Fe3O4 Nanoparticles on Seed Yield and Physio-Biochemical Parameters of Cucumber (*Cucumis sativus* L.) Seed under Open Field and Protected Environment vis a vis during Seed Germination. Plants, 11: 3211.

Gupta, N., S. K. Jain, B. S. Tomar, A. Anand, J. Singh and A. K. Singh. 2021a. Influence of fruit load per vine on seed quality in cucumber (*Cucumis sativus* L) grown under open field and protected environments. Indian Journal of Horticulture, 78: 93-100.

Gupta, N., S. Kumar, S. Jain, B. Tomar, J. Singh and V. Sharma. 2021b. Effects of stage of harvest and post-harvest ripening of fruits on seed yield and quality in cucumber grown under open field and protected environments.

Hasnidawani, J., H. Azlina, H. Norita, N. Bonnia, S. Ratim and E. Ali. 2016. Synthesis of ZnO nanostructures using sol-gel method. Procedia Chemistry, 19: 211-16.

Hernández-Apaolaza, L., L. Escribano, Á. M. Zamarreño, J. M. García-Mina, C. Cano and S. Carrasco-Gil. 2020. Root silicon addition induces Fe deficiency in cucumber plants, but facilitates their recovery after Fe resupply. A comparison with si foliar sprays. Frontiers in Plant Science, 11: 580552.

Huang, M. H., S. Mao, H. Feick, H. Yan, Y. Wu, H. Kind, E. Weber, R. Russo and P. Yang. 2001. Room-temperature ultraviolet nanowire nanolasers. Science, 292: 1897-99.

Jamali, G., S. Enteshari and S. Hosseini. 2011. Study Effect Adjustment drought stress application Potassium and zinc in corn. Iranian Journal of crop ecophysiology, 3: 216-22.

Khodakovskaya, M. V., K. De Silva, A. S. Biris, E. Dervishi and H. Villagarcia. 2012. Carbon nanotubes induce growth enhancement of tobacco cells. ACS Nano, 6: 2128-35.

Kirkbride, J. H. 1993. Biosystematics monograph of the genus *cucumis* (cucurbitacea).

Marschner, H. 1995. Mineral nutrition of higher plants 2nd edn. Institute of Plant Nutrition University of Hohenheim: Germany.

Mazaherinia, S., A. R. Astaraei, A. Fotovat and A. Monshi. 2010. Nano iron oxide particles efficiency on Fe, Mn, Zn and Cu concentrations in wheat plant. World Applied Sciences Journal, 7.

Meng, X., M. Zhang and B. Adhikari. 2014. The effects of ultrasound treatment and nano-zinc oxide coating on the physiological activities of fresh-cut kiwifruit. Food and Bioprocess Technology, 7: 126-32.

Pandey, A. C., S. S. Sanjay and R. S. Yadav. 2010. Application of ZnO nanoparticles in influencing the growth rate of *Cicer arietinum*. Journal of Experimental Nanoscience, 5: 488-97.

Prasad, T., P. Sudhakar, Y. Sreenivasulu, P. Latha, V. Munaswamy, K. R. Reddy, T. Sreeprasad, P. Sajanlal and T. Pradeep. 2012. Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. Journal of Plant Nutrition, 35: 905-27.

Puzina, T. 2004. Effect of zinc sulfate and boric acid on the hormonal status of potato plants in relation to tuberization. Russian Journal of Plant Physiology, 51: 209-15.

Raliya, R. and J. C. Tarafdar. 2013. ZnO nanoparticle biosynthesis and its effect on phosphorous-mobilizing enzyme secretion and gum contents in *Clusterbean (Cyamopsis* tetragonoloba L.). Agricultural Research, 2: 48-57.

Sharma, P. N., C. Chatterjee, C. P. Sharma and S. C. Agarwala. 1987. Zinc deficiency and anther development in maize. Plant and cell physiology, 28: 11-18.

Siddiqui, M. H. and M. H. Al-Whaibi. 2014. Role of nano-SiO2 in germination of tomato (*Lycopersicum esculentum* seeds Mill.). Saudi Journal of Biological Sciences, 21: 13-17.

Srivastava, A. and S. Singh. 1999. Recent trends in citrus production research. Souvenir, International Symposium on Citriculture organised by Indian Society Citriculture, Nagpur, at National Research Centre for Citrus, Nagpur Maharashtra, India (Nov. 23-25, 1999).

Swietlik, D. 1999. Zinc nutrition in horticultural crops. J. Janick. Horti.: 109-18.