Journal of Experimental Agriculture International

Volume 46, Issue 8, Page 757-761, 2024; Article no.JEAI.121705
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Seed Germination and Subsequent Seedling Growth as Influenced by Silica Nanoparticles Invigoration in Soybean (*Glycine max* (L.) Merrill.)

Parul Singh [a++*], Birendra Prasad [a#], Mukesh Kumar Karnwal [a#], Omvati Verma [b#], Subhash Chandra [b#], Kumari Manikarnika [a] and Kumari Renu [a†]

[a] Department of Genetics and Plant Breeding, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar-263145, India.
[b] Department of Agronomy, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar-263145, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i82758

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121705

Original Research Article

Received: 06/06/2024
Accepted: 08/08/2024
Published: 10/08/2024

[++] *Ph. D. Genetics and Plant Breeding;*
[#] *Professor;*
[†] *Master Student;*
**Corresponding author: E-mail: parulsingh2456@gmail.com;*

Cite as: *Singh, Parul, Birendra Prasad, Mukesh Kumar Karnwal, Omvati Verma, Subhash Chandra, Kumari Manikarnika, and Kumari Renu. 2024. "Seed Germination and Subsequent Seedling Growth As Influenced by Silica Nanoparticles Invigoration in Soybean (Glycine Max (L.) Merrill.)". Journal of Experimental Agriculture International 46 (8):757-61. https://doi.org/10.9734/jeai/2024/v46i82758.*

ABSTRACT

Soybean is a miracle crop, contains 40% protein and 20% oil. The quality of soybean seeds is very sensitive and prone to adverse environment from harvesting to poor storage conditions (at room temperature), that leads to poor longevity and viability. Therefore, to obtain proper germination of crop, seed treatment is imperative. The investigation was aimed to evaluate the effect of silica nanoparticles (seed vitalizer) on seed germination and seedling growth. Silica nanoparticles have 10-20 nm particle size characterized on the basis of 99.5% trace metal. In the present study, seeds of five cultivars viz; Bhatt, Kalitoor (landraces) and improved varieties- PS-26, PS-1225, PS-1347 were taken and treated with different concentration of silica nanoparticles viz; 800, 1000 and 1500 ppm. The study was conducted under controlled conditions using Complete Randomised Design design. Among different cultivars, land race Kalitoor showed the highest germination percentage followed by PS-26 whereas among different concentration, 1000 ppm of silica nanoparticles treated seed was most effective and achieved the maximum germination percentage, root length, shoot length, seedling length, fresh mass, dry mass, and also the seedling vigor index-I and seedling vigor index-II. Further increase in silica dose showed adverse impact on seedling parameters. The finding of present investigation revealed that landrace Kalitoor has better germination ability and nano-silica @1000 ppm was the most appropriate dose to achieve higher germination and seedling growth of soybean.

Keywords: Soybean; nano-silica; seed germination; vigor.

1. INTRODUCTION

Quality of seed plays an essential role in increasing crop productivity. Quality seeds establish earlier and perform well in the field, even in the sub-optimal conditions. Soybean, in particular, is known to have poor storage capabilities, with seeds becoming unsuitable for planting within six to seven months of storage, making farmers hesitant to rely on their own stored seeds for the next season's sowing. Seed longevity in soybean is negatively impacted by mechanical damage and exposure to field weathering. Mechanical injuries often occur during harvesting, drying, and seed conditioning, resulting in cracks or breaks in the seed coat, damage to cotyledons, rupture of the hypocotyl-radicle axis, or complete seed breakage, rendering the seed unusable. Therefore, various seed enhancement techniques such as energy treatments, seed priming, seed pelleting etc. are taken into consideration to enhance the seed quality. Seed invigoration is one of the physiochemical ways that can enhance the seed performance and synchronous germination. This process involves soaking of seeds in water or salt solution for a certain amount of time and after that re-drying them immediately just before the radical development [1]. It is very tedious job to dry seeds on large scale; therefore, nano-priming seems to be very effective ex vivo synthesis of seed. Germination test is a measure of potential of seed lot to emerge under field conditions. This is crucial for crops like soybean, corn and sorghum, where factors such as temperature, rain and frost directly impact seed viability. Among several metals and non-metals silica nanoparticles have been reported to enhance plant tolerance to biotic and abiotic stress, reducing the negative effects [2]. Despite the established beneficial effects of silicon on various aspects of plant growth, yield, and resistance to both biotic and abiotic stresses across a wide range of plant species, it still lacks recognition as an essential nutrient for plant growth and development [3-7]. Silica nanoparticles (SiNPs) offer a promising solution in agriculture by reducing reliance on environmentally harmful inputs and costly fertilizers. They are produced using eco-friendly methods, mitigating the adverse effects of chemical fungicides. With their executive features such as large surface area and small dimensions, SiNPs show potential in agriculture by effectively dispersing within plant tissues [8]. SiNPs can be applied directly to roots or on plants as pesticides, herbicides and fertilizers [9] and serves as carriers for transporting various compounds like proteins, nucleotides and might be used in farming to enhance the water holding capacity of soil [10]. With nanotechnology gaining widespread recognition and permeating various technological fields, it becomes imperative to explore its impact on seed germination in relation to nanoparticles. With nanotechnology making significant strides, especially in agriculture, there is a growing curiosity surrounding the role of nanosilicon dioxide (nSiO2) in seed germination, particularly in soybean (*Glycine max*) seeds.

2. MATERIALS AND METHODS

$$\text{Germination\%} = \frac{\text{Number of normal seedlings germinated}}{\textit{Total number of seeds}} \times 100 \qquad [11]$$

The The experiment was conducted under laboratory conditions using five cultivars of soybean viz; PS-26, Kalitoor, PS-1347, Bhatt and PS-1225. The carry-over seed lot was taken for the experiment and surface sterilized with 5% sodium hypochlorite for 10 minutes then vigorously rinsed with sterilized distilled water. The sterilized seeds were soaked for four hours in different concentrations of $nSiO_2$ viz; 0, 800, 1000 and 1500 ppm. Two layers of moistened paper towel were soaked in RO water for overnight and surplus water was drained from the tray. Four hundred seeds were taken randomly from each variety and replicated forth with hundred seeds in each replication. The seeds were then covered with another sheet of moistened paper towel and a sheet of butter paper and were rolled up. The, seeds were then kept in an incubator at 27 ± 3 °C and 85 ± 3 % relative humidity. The number of seeds germinated was counted at the 5^{th} day for first count and the second and final counting was done on day 8^{th}. On the 8^{th} day the potential of seed germination was assessed in terms of percent seed germination, seedling vigor index (SVI), fresh seedling mass and dry seedling mass. The experimental data were analyzed statistically as per the method described by [12] for two factorial Completely Randomized Design. The number of germinated seeds was noted daily for eight days. Seeds were considered germinated when their radicle showed at least 2 mm length [13]. On the 8^{th} day, ten seedlings were randomly selected to measure fresh mass of seedlings. Samples were then placed in a hot air oven at 60°C for 48 hours until the mass of the seedlings became constant. The data were expressed as means standard error, and analyzed statistically with OPSTAT (Operations and Statistics) software [14].

Seedling vigor index was calculated by two different methods [15].

Seedling vigor index I (SVI - I) = Standard germination % × mean of seedling length (root length + shoot length)

Seedling vigor index II (SVI – II) = standard germination % × seedling dry mass (g).

3. RESULTS AND DISCUSSION

In this experiment, the application of nSiO2 enhanced seed quality potential by increasing the characteristics of seed germination and subsequent seedling vigor. Seed germination as well as seed quality parameters in terms of seed vigor were increased as the $nSiO_2$ concentration increased upto 1000 ppm. However, these parameters decreased at 1500 ppm (Table 1). Among all the treatments (0, 800, 1000, 1500 ppm), the application of 1000 ppm of silica nanoparticles was found superior for highest

Table 1. Effect of silica nanoparticles on seed germination and seedling vigor of soybean cultivars

Treatments	Germination (%)	Root Length (cm)	Shoot length (cm)	Seedling Length (cm)	Fresh Mass (g)	Dry Mass (g)	SVI - I	SVI - II
Control	72.13	5.2	2.90	8.23	3.35	0.32	579.48	23.49
800 ppm	72.80	6.97	6.29	13.25	4.13	0.39	965.57	28.49
1000 ppm	79.53	14.27	11.89	26.16	6.99	0.66	2101.09	51.30
1500 ppm	55.67	3.65	2.92	6.57	3.17	0.30	371.49	21.68
SE ± (m)	0.71	0.06	0.06	0.09	0.09	0.01	6.50	0.24
CD (5%)	2.05	0.18	0.18	0.27	0.18	0.00	18.66	0.68
Varieties								
PS 26	72.08	7.64	6.77	14.49	4.96	0.47	1102.09	41.04
Kalitoor	79.00	7.96	6.18	14.14	3.06	0.29	1163.86	23.96
PS 1347	64.50	7.48	5.50	13.00	5.36	0.51	844.70	33.11
Bhatt	65.91	7.05	5.93	12.97	3.49	0.33	971.63	23.41
PS 1225	68.67	7.50	5.64	13.15	5.16	0.49	940.59	34.67

Treatments	Germination (%)	Root Length (cm)	Shoot length (cm)	Seedling Length (cm)	Fresh Mass (g)	Dry Mass (g)	SVI - I	SVI - II
SE ± (m)	0.80	0.07	0.07	0.10	0.10	0.01	7.27	0.27
CD (5%)	2.29	0.20	0.21	0.30	0.20	0.00	20.86	0.76

values for percent seed germination (79.5%), root length (14.27 cm), shoot length (11.89 cm), seedling length (26.16 cm), fresh and dry mass of 10 seedlings (6.99 g and 0.66 g, respectively), seedling vigor index- I (2101.09) and seedling vigor index-II (51.30). The application of 800 ppm of $nSiO_2$ resulted in the second best values for measured characteristics: Germination percentage (72.8%), root length (6.97cm), shoot length (6.29 cm), seedling length (13.25 cm), fresh and dry mass (4.13g, 0.39g respectively), seedling vigor index-I (965.07) and seedling vigor index- II (28.89).

Among the varieties, the highest germination percentage was recorded in Kalitoor (79%) which was significantly higher than the other varieties tested whereas, significantly lower germination percentage was recorded for PS 1347 (64.5%). Among all the seed invigoration treatments, it was observed that as the concentration increased up to 1000 ppm. It had positive influence on seedling vigor parameters, however, as the concentration of silica nanoparticles reached upto 1500 ppm, the impact became detrimental on seed germination and subsequent seedling vigor. (Table 1).

4. CONCLUSION

These results of the current study revealed that the application of 1000 ppm silica nanoparticles significantly enhanced seed germination potential as well as also improving percent seed germination, seed vigor index, seedling fresh mass and dry mass. An increase in germination parameters by the application of silica nanoparticles may be effective for the growth and seed yield, because high germination of seeds and seedling establishment in the field are critical for soybean production since it determines crop density and eventually affects the seed yield. However, there is a dire need to find out if the interaction mechanism between silica nanoparticles and seed is persistent enough so that silica nanoparticles could be utilized as a fertilizer for improving nutritional delivery as well as for better and uniform seedling establishment.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lu CM, Zhang CY, Wen JQ, Wu GR, Tao MX. Research of the effect of nanometer materials on germinations and growth enhancement of *Glycine max* and its mechanism. Soybean Science.. 2002;21:168-172
2. Khan I, Awan SA, Rizwan M, Ali S, Hassan MJ, Brestic M, Zhang X, Huang L. Effects of silicon on heavy metal uptake at the soil-plant interphase: A review. Ecotoxicology and environmental safety. 2021; 222:112510.
3. Ma JF, Yamaji N. Silicon uptake and accumulation in higher plants. Trends in Plant Science. 2006;11:342-397.
4. Ma JF. Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. Soil science and plant nutrition. 2004;50(1):11-8.
5. Pilon-Smits EA, Quinn CF, Tapken W, Malagoli M, Schiavon M. Physiological functions of beneficial elements. Current opinion in plant biology. 2009;12(3):267-74.
6. Saqib M, Zorb C, Schubert S**.** Silicon-mediated improvement in the salt resistance of wheat (*Triticum aestivum*) results from increased sodium extension exclusion and resistance to oxidative stress. Functional Plant Biology. 2008; 35:633-639.
7. Pei ZF, Ming DF, Liu D, Wan GL, Geng XX, Gong HJ, Zhou WJ. Silicon improves the tolerance to water-deficit stress induced by polyethylene glycol in wheat (*Triticum aestivum* L.) seedlings. Journal of plant growth regulation. 2010;106-15.

8. Bhat JA, Rajora N, Raturi G, Sharma S, Dhiman P, Sanand S, Shivaraj Sonah H, Deshmukh R. Silicon nanoparticles (SiNPs) in sustainable agriculture: Major emphasis on the practically, efficacy and concerns. Nanoscale Advances. 2021;3 (14): 4019-4028.
9. Malik MA, Wani AH, Mir SH, Rehman IU, Tahir I, Ahmad P, Rashid I. Elucidating the role of silicon in drought stress tolerance in plants. Plants Physiology Biochemistry. 2021;165:187-195.
10. Bapat G, Zinjarde S, Tamhane V. Evaluation of silica nanoparticle mediated delivery of protease inhibitor in tomato plants and its effect on insect pest *Helicoverpaarmigera*. Colloids and Surf, B. Biointerfaces. 2020;193:111079.
11. ISTA. International Seed Testing Association International rules for seed testing. ISTA, Zürich. 2004;206.
12. Cochran WG, Cox, GM**.** Completely randomized, randomized block and Latin square design. Experimental design. John Wiley and Sons, Inc. USA. 1992;192:95-145.
13. ISTA. International Rules for Seed Testing. Edition. International Seed Testing Association.Bassersdorf, Switzerland; 2007.
14. Sheoran OP, Tonk DS, Kaushik LS. Statistical Software Package for Agricultural Research Workers: Recent Advances in information theory. Hooda DS, Hasija RC Statistics and Computer Applications, Department of Mathematics Statistics, CCS HAU, Hisar. 1998;139-143.
15. Abdul-Baki AA, Anderson JD. Viability and leaching of sugars from germinating barley 1. Crop Science. 1970;10(1): 31-34.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121705