Original Research Article

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

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 vitaliser) 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 CRD 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 weight, dry weight, 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-sillica @1000 ppm was the most appropriate dose to achieve higher germination and seedling growth of soybean.

Key words: 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 in 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 timeframe 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 crops like soybean, corn and sorghum, where factors such as temperature, rain, 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].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

The experiment was conducted under laboratory conditions using five cultivars of soybean viz; PS-26, Kali Toor, PS-1347, Bhatt and PS-1225. The carry over seed lot wastaken 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 forfour hours in different concentrations of $nSiO_2$ viz; 0, 800, 1000 and 1500 ppm. Two layers of moistened towel papers 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 towel paper and a sheet of butter paper and were rolled up. Then, seeds were kept in an incubator at 27 ± 3 °C and 85 ± 3 % relative humidity. The numbers of seeds germinated were counted at 5th day for first count and second and final counting was done at 8th day. On 8th day the potential of seed germination was assessed in terms of percent seed germination, seedling vigor index (SVI), fresh weight seedling and dry weight seedling. The experimental data were analyzed statistically as per the method described by [11] **Cochran and Cox (1992)**for two factorial Completely Randomized Design.The seed germination count was recorded everyday from 1st to 8th day.The number of germinated seeds wasnoted daily for eight days. Seeds were considered germinated when their radicle showed at least 2 mm length [12]. On 8th day, ten seedlings were randomly selected to measure fresh weight of seedlings, after that, samples were placed in hot air oven at 60°C for 48 hours for dry weight of seedling until the weight become constant. The data were expressed as means standard error, and analyzed statistically with OPSTAT software.

$$\text{Germination\%} = \frac{\text{Number of normal seedlings germinated}}{\textit{Total number of seeds}} \times 100 [13]$$

The seedling vigor index was calculated by two different methods [14].

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

Seedling vigor index II = standard germination % × seedling dry weight (g).

3. RESULTS AND DISCUSSION

In the present experiment 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 increase in concentration upto 1000 ppm however, decreased these parameters at 1500 ppm (Table: 1). Among all the treatments (0, 800, 1000, 1500 ppm),application of 1000 ppm of silica nanoparticleswas found superior for highest 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 weight of 10 seedlings (6.99 g, 0.66 g, respectively), seedling vigorindex- I (2101.09) and seedling vigor index-II (51.30) followed by 800 ppm havinggermination percentage (72.8%), root length (6.97cm), shoot length (6.29 cm), seedling length (13.25 cm), fresh and dry weight (4.13g, 0.39g respectively), seedling vigor index-I (965.07) and seedling vigor index- II (28.89).

Table1: Effect of silica nanoparticles on seed germination and seed vigor of soybean cultivars

Treatments	Germination (%)	Root Length(cm)	Shoot length (cm)	Seedling Length (cm)	Fresh Weight (g)	Dry Weight (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
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

Among the varieties highest germination percentage was recorded in Kalitoor(79%) which was significantly superior to rest of other varieties whereas, significantly inferior was recorded for PS 1347 (64.5%). Among all the seed invigoration treatments, it was observed that as the concentration reaches up to 1000 ppm had positive influence on seedling vigor parameters, however, as the concentration of silica nanoparticles reaches to 1500 ppm, had detrimental impact on seed germination and subsequent seedlingvigor. (Table1).

These results of the current study revealed that the application of 1000 ppm silica nanoparticles significantly enhanced seed germination potential as well as it also improve percent seed germination, seed vigor index, seedling fresh weight and dry weight. An increase in germination parameters by the application of silica nanoparticles may 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, again it is dire need to find out the interaction mechanism between silica nanoparticles and seed which establish that silica nanoparticles could be utilized as a fertilizer for improving nutritional delivery as well as for better and uniform seedling establishment.

REFERENCES

1 Lu, CM, Zhang, CY, Wen, JQ, Wu, GR, and Tao, MX. Research of the effect of nanometer materials on germinations and growth enhancement of *Glycine max* and its mechanism. Soybean Sci., 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 Plant Sci. 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.Funct. Plant Biol., 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 Adv., 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.

11Cochran, WG and Cox, GM.Completely randomized, randomized block and latin square design. Experimental design. John Wiley and Sons, Inc. USA, 1992; 192; 95-145.

12ISTA. International Rules for Seed Testing. Edition 2007. International Seed Testing Association.Bassersdorf, Switzerland.

13ISTA. International Seed Testing Association International rules for seed testing. ISTA 2004, Zürich, 206

14 Abdul-Baki, AA and Anderson, JD. Viability and leaching of sugars from germinating barley 1. Crop science, 1970; 10(1):31-34.