

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 **vitaliservitalizer**) 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-silica @1000 ppm was the most appropriate dose to achieve higher germination and seedling growth of soybean.

Key words: Soybean, Nano-silica, Seed germination, Vigor

Comment [A1]: Please refer to the author's guidelines on the journal's website: Different sub-sections should be used.

Comment [A2]: Decide if you are writing in American or British English. If American, vitalizer and characterized. If British, vitaliser and characterise.

Comment [A3]: What does CFR stand for? You have to explain it the first time you use any non-dictionary abbreviation.

Comment [A4]: I think you mean mass. From the internet: Mass is a fundamental measurement of how much matter an object contains. Weight is a measurement of the gravitational force on an object. It not only depends on the object's mass, but also on its location. Therefore, weight is actually a measure of force.

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 frame and after that re-drying them immediately just before the radical development [1]. It is a 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, 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]. 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 serve 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

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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 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 nSiO₂ viz; 0, 800, 1000 and 1500 ppm. Two layers of moistened ~~towel-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 ~~towel~~-paper ~~towel~~ and a sheet of butter paper and were rolled up. Then, seeds were ~~then~~ kept in an incubator at 27 ± 3 °C and 85 ± 3 % relative humidity. The numbers of seeds germinated were counted at ~~the~~ 5th day for ~~the~~ first count and ~~the~~ second and final counting was done ~~at-on-the~~ 8th day. On ~~the~~ 8th day the potential of seed germination was assessed in terms of percent seed germination, seedling vigor index (SVI), fresh ~~seedlingweight~~ ~~mass~~ ~~seedling~~ and dry ~~seedlingweight~~ ~~mass~~ ~~seedling~~. The experimental data were analyzed statistically as per the method described by ~~[11]~~ Cochran and Cox ~~[11]~~ (1992) for two factorial Completely Randomized Design. ~~The seed germination count was recorded everyday from the 1st to the 8th day. The number of germinated seeds was noted daily for eight days.~~ Seeds were considered germinated when their radicle showed at least 2 mm length [12]. On ~~the~~ 8th day, ten seedlings were randomly selected to measure fresh ~~weight~~ ~~mass~~ of seedlings, ~~after that,~~ ~~s~~ Samples were ~~then~~ placed in a hot air oven at 60°C for 48 hours ~~for dry weight of seedling~~ until the ~~weight~~ ~~mass~~ of ~~the seedlings~~ ~~become~~ ~~became~~ constant. The data were expressed as means standard error, and analyzed statistically with OPSTAT ~~software~~.

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

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Comment [A6]: In the abstract you used Kalitoor. Stick to one (the correct) spelling/writing.

Comment [A7]: I see on the internet it can be spelt carryover or carry-over or carry over, but I think here, where you are talking about seed that was kept from the previous season, us a hyphen.

Comment [A8]: OR: on day 8.

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Comment [A9]: You said earlier on in the paragraph: **The number of seeds germinated were counted at the 5th day for the first count and the second and final counting was done on the 8th day.** This is not the same as recording germination every day. Which did you do? Be specific.

Comment [A10]: Maybe easier to say day 1 – 8?

Comment [A11]: These two sentences mean exactly the same, thus you can delete one.

Comment [A12]: You need a reference – where did you get the software? Company name or web link.

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

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

Comment [A13]: If you are going to use the abbreviation SVI-1 you have to give it somewhere. I suggest here.

Seedling vigor index II = standard germination % \times seedling dry ~~weight-mass~~(g).

Comment [A14]: The unit of weight is newton (N).

3. RESULTS AND DISCUSSION

In ~~the present~~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

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quality parameters in terms of seed vigor were increased as ~~increase in the nSiO₂ concentration~~ increased upto 1000 ppm, ~~however~~However, ~~decreased~~ these parameters decreased at 1500 ppm (Table: 1).

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Among all the treatments (0, 800, 1000, 1500 ppm), the application of 1000 ppm of silica nanoparticles was 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-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), ~~followed by~~ The application of 800 ppm of nSiO₂ having resulted in the second best values for measured characteristics: germination percentage (72.8%), root length (6.97cm), shoot length (6.29 cm),

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seedling length (13.25 cm), fresh and dry ~~weight-mass~~ (4.13g, 0.39g respectively), seedling vigor index-I (965.07) and seedling vigor index-II (28.89).

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

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Treatments	Germination (%)	Root Length(cm)	Shoot length (cm)	Seedling length (cm)	Fresh Weight (g)	Dry Weight (g)	SVI-I	SVI-II
control <u>Contro</u>							23.4	
<u>I</u>	72.13	5.2	2.90	8.23	3.35	0.32	579.48	9
							28.4	
800 ppm	72.80	6.97	6.29	13.25	4.13	0.39	965.57	9
1000 ppm	79.53	14.27	11.89	26.16	6.99	0.66	2101.0	51.3

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							9	0
								21.6
1500 ppm	55.67	3.65	2.92	6.57	3.17	0.30	371.49	8
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								
							1102.0	41.0
PS 26	72.08	7.64	6.77	14.49	4.96	0.47	9	4
							1163.8	23.9
Kalitoor	79.00	7.96	6.18	14.14	3.06	0.29	6	6
								33.1
PS 1347	64.50	7.48	5.50	13.00	5.36	0.51	844.70	1
								23.4
Bhatt	65.91	7.05	5.93	12.97	3.49	0.33	971.63	1
								34.6
PS 1225	68.67	7.50	5.64	13.15	5.16	0.49	940.59	7
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, the highest germination percentage was recorded in Kalitoor(79%) which was significantly superior higher to rest of than the other varieties tested, whereas, significantly inferior lower percentage germination was recorded for PS 1347 (64.5%). Among all the seed invigoration treatments, it was observed that, as the concentration reaches increased up to 1000 ppm, it had positive influence on seedling vigor parameters, however, as the concentration of silica nanoparticles reaches reached to 1500 ppm, the had impact became detrimental impact on seed germination and subsequent seedling vigor. (Table1).

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CONCLUSION

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~~ improving percent seed germination, seed vigor index, seedling fresh ~~weight-mass~~ and dry ~~weightmass~~. 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, ~~again-it~~ there is a dire need to find out if the interaction mechanism between silica nanoparticles and seed is persistent enough so ~~-which establish~~ that silica nanoparticles could be utilized as a fertilizer for improving nutritional delivery as well as for better and uniform seedling establishment.

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Comment [A21]: Refer to the journal's guidelines for authors. All journal names should be abbreviated. Journal name abbreviations should be those found in the NCBI databases.

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