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Effect of potassium silicate in enhancement of seed germination and establishment of rice seedlings (*Oryza sativa* L.)

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ABSTRACT

Uniformity and synchronization of seed germination area are the utmost aspects and important indicatorsand well-established healthy seedlings make the foundation of high crop yield. The present study has been done to document the effects on seed germination and seedling growth parameters in response to silicon (Potassium silicate) application. The effects of different concentrations (0, 2.5, 4.5, 7.5, 9.5, and 12 mg/ 100 ml) of Si have been studied on seeds of rice (Oryza sativa L.) varieties PB 1121 and Karan bhog-521. In this study, Si treatments have been found quite effective at all the parameters and decrease in 28.54% in MGT and a rise of 39.39% in germination %, 34.52% in MGR, 77.98 % in GI, and 71.62% in G value than control has been observed in Variety PB 1121 and decrease in 4.43 and 6.65% in MGT and rise of 27.76% in germination percent, 6.83% in MGR, 26.54 % in GI and 89.84% in G value in the concentration 12 mg than control has been observed in Karan bhog-521. Similarly, a significant rise in CVt, CVG, MDG and peak value has been observed than control in Variety PB 1121and Karan bhog-521. The present study suggested that Si can be used as a stimulating agent for the seed germination and can enhance the growth of rice seedlings, laying a solid foundation for subsequent rice crop growth.

Keywords: *Rice, Silicon fertilizer, Seed germination parameters, Potassium silicate.*

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INTRODUCTION

Seed germination process plays a significant role in the foundation for the quality and final yield of the crop. It involves various physiological and biochemical changes prior to the activation of the embryo. The rapid germination after the sowing of seeds can lead to homogenous and synchronised growth of the seedlings. Silicon 'the second most abundant element and covering 25% of earth's crust' constitute a main portion of most soils ranging from 50-400 g/ Kg of soil and is present in the form of silicon dioxide, silica gel, silicic acid etc. [1].It has been considered as non-essential element for higher plant species, although its application in the form of fertilizer has been found beneficial and aids plants to tolerate abiotic and biotic stress conditions [2] and classify silicon as a beneficial element [3].Despite of high occurrence in the soil, most of its compound are insoluble and are not available for plants uptake. The plant available concentration of silicon is very low ranging from 0.1-0.6 mM/L [4].Although several studies documents that treatment of seeds with silicon can promote the plant growth. Rice (*Oryza sativa* L.), the crop of Poaceae family, is the staple and chief food of many developing countries of the world. India, is the world's second-largest producer of paddy, with around 44 million hectares of rice-growing land andUttar Pradesh, Punjab and, West Bengal are the chief paddy- producing states of India [5].The present study has been done to study the impact of various concentrations of silicon (potassium silicate) on the seed germination indices and parameters of seedling growth of rice(Variety PB 1121 and Variety Karan bhog-521).

MATERIAL AND METHODS

Geographical position of the study site: The current research was carried out at Baba Mastnath University, Asthalbohar in Haryana, India, between April and May 2021. The village Asthalbohar is located in the district Rohtak, Haryana, and has an area of about 1668 square kilometres. It is located between 28°40'30" N and 29°05'35" N latitude and 76°13'22"E and 76° 51'20"E longitude. This region's climate is arid to semi-arid, and the soil is loamy in nature. In this area, several rabi and kharif crops are farmed and sugarcane, wheat, bajra, and paddy being the most important kharif crops [6].

Experimental Design

Procurement of the Rice seeds and Potassium silicate

The seeds of two varieties of rice,(*Oryza sativa* L.)(Variety PB 1121 and Variety Karan bhog-521), were purchased from "The Haryana State Seed Certification Agency", Rohtak, India. Potassium silicate K_2O_3Si (molecular weight: 154.28gmol^{-1}) was purchased from Akshar Chem. private limited, Mumbai. Five concentrations of potassium silicate viz. 2.5 mg, 4.5mg.7.5 mg.9.5 mg and 12 mg/100 ml. were prepared with distilled water for use.

Experiment in disposable thermocol glasses

The rice seeds of inferior quality were discarded by floating in the tap water. After washing thoroughly to remove dirt and dust, these were surface sterilized with sodium hypochlorite solution for 5 min and were repeatedly washed and were soaked in wet gunny bags for 2-3 days. The treatments consist of three replicas per treatment and control. Hundred gram field soil of pH, 8.06; organic matter, 44.50 g, total nitrogen, 2.48 g, total phosphorus 1.12 g, total potassium 142.3 mg and Silicon 75.4mg/kg was filled in each disposable thermocol glass and five seeds were placed in each and were irrigated with treatment concentrations of sodium silicate and plain water respectively. These containers were placed in laboratory under natural conditions of 20.3/35.6^{0}C average day and night temperature and photoperiod of about 16 hours and were watered with distilled water whenever required. On daily basis, observations were recorded till 20 days. Seeds were considered germinated when radicle was of about 2mm length and the seedling length was measured at the end of 25days [7].

Determination of seed germination and seedling growth parameters

To measure the seed germination indices and parameters of seedling growth of two varieties of rice (*Oryza sativa* L.), following [8], [9] and **S**cott *et al*., [10] methodology and equations were followed [6]:

- The Germination Percentage (GP percent) is defined as the number of seeds germinated divided by the total number of seeds multiplied by 100.
- Mean Germination Time (MGT) = Gx/G, where G is the number of seeds germinated on day X and G is the number of seeds germinated on day G.
- CVG = X1+X2+.X3.....+ /100 x X1T1+...+XiTi; where X is the number of seeds germinated per day and T is the number of days from seeding corresponding to X.
- The mean germination rate (MGR) is calculated as Coefficient velocity/100 = 1/T, where T is the mean germination time.
- Germination Rate Index (GRI) was calculated by using the formula:X1/1+X2/2+ X3/3.... +Xi/i; where X1 is the percentage germination at day 1, X2 is at day 2 and X3 at day 3 and so on.
- Germination index (GI) = (15xX1) +(14xX2) + ... +(1xX15)
- Germination (G) was calculated by the formula: Number of seeds germinated / Days of first count + + + …number of seeds germinated/Days of final count (seed day-1)
- Mean Daily Germination (MDG) was calculated according to the formula

  MDG = GP/D
- Peak value (PV): The maximum quotient derived from all of the cumulative full-seed germination percentages on any day/ number of days to reach that percentages.

Seedling, root and stem length

The rice seedlings were taken with their roots intact and were rinsed with tap and distilled water to determine seedling growth. The roots and shoots of these seedlings were separated and length was measured by using ruler. [11].

Vigour index

The Vigour index of rice seedlings was estimated by the formula proposed by Abdul - Baki and Anderson, 1973. Vigour index (VI) = Total seedling length x germination percentage

Statistical analysis

Data were statistically analysed using analysis of variance (ANOVA) in Excel. The treatment means were analysed by Turkey HSD Test at p value<0.05.

RESULTS AND DISCUSSION

Effects of Silicon on seed germination parameters: Silicon had been found effective in promoting the germination of rice seeds and resulted in significant increase in values of GP, GR, GRI, MDG, MGT etc. on both the varieties than control. Markedly decrease in 24.5 and 28.54% in MGT and rise of 36.36% and 39.39% in germination percent, 30.37 and 34.52% in MGR, 66.4 and 77.98 % in GI and 49.03 and 71.62% in G value than control has been observed in Variety PB 1121(table 1) has been observed in PB1121 at the concentration of Si 9.5and 12 mg respectively. Markedly decrease in 4.43 and 6.65% in MGT and rise of 17.56 and 27.76% in germination percent, 4.23 and 6.83% in MGR, 15.4 and 26.54 % in GI and 64.66 and 89.84% in G value than control (table 2) has been observed in Karan bhog-521 at the concentration of

Si 9.5and 12 mg respectively. Similarly significant rise of 30.01and 39.55 in CVt, 30.58 and 37.22% in CVG, 36.79 and41.46 % in MDG and 31.59 and 47.49 % in P value than control in Variety PB 1121(table 3) and rise of 34.85 and 41.92 in CVt, 4.57 and 7.01%
in CVG, 14.13 and 23.42 % in MDG and 41.97 and 53.6 % in P value than control has been observed in Karan bhog-521at the concentration of Si 9.5and 12 mg respectively (table 4).

Table 1. Effect of potassium silicate treatment on G%, MGT, MGR, GI and G value on seed germination indices of rice (*Oryza sativa* L.) Variety PB 1121

Groups	G %	MGT	MGR	GI	G Value
Control	$70.6^{d}\pm0.6$	$6.822^{f}\pm0.02$	$0.1464^{ab}\pm0.00$	$3.506^{e}\pm0.01$	$38.166^{f}\pm0.4$
2.5mg Si	$72.2^{d}\pm0.5$	$6.518^{e}\pm0.02$	$0.1532^{a}\pm0.00$	$3.526^{e}\pm0.01$	$42.276^{e}\pm0.4$
4.5mg Si	$72.8^{d}\pm0.7$	$6.55^{de}\pm0.02$	$0.1526^{a}\pm0.00$	$3.61^{de}\pm0.02$	$40.788^{de}\pm0.4$
7.5mg Si	$80.4^{c}\pm0.5$	$6.626^{cde}\pm0.02$	$0.1534^{a}\pm0.00$	$3.87^{c}\pm0.02$	$50.58^{c}\pm0.6$
9.5mg Si	$83^{bc}\pm0.7$ (17.56%)^{x}	$6.52^{bcde}\pm0.02$ (4.43%)^{x}	$0.1526^{a}\pm0.00$ (4.23%)^{x}	$4.046^{b}\pm0.01$ (15.4%)^{x}	$62.844^{b}\pm0.4$ (64.66%)^{x}
12mg Si	$90.2^{a}\pm0.8$ (27.76%)^{x}	$6.368^{a}\pm0.03$ (6.65%)^{x}	$0.1564^{a}\pm0.00$ (6.83%)^{x}	$4.37^{a}\pm0.02$ (24.64%)^{x}	$72.454^{a}\pm0.6$ (89.84%)^{x}

*Stimulation percentage over control. The data in table are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at $P < 0.05$

Table 2. Effect of potassium silicate treatment on G%, MGT, MGR, GI and G value on seed germination indices of rice (*Oryza sativa* L.) Karan bhog-521

Groups	G %	MGT	MGR	GI	G Value
Control	$66^{e}\pm0.7$	$7.462^{f}\pm0.05$	$0.135^{e}\pm0.0021$	$3.042^{f}\pm0.0166$	$51.254^{f}\pm0.3963$
2.5mg Si	$80.2^{d}\pm0.5$	$5.976^{e}\pm0.04$	$0.1626^{d}\pm0.0019$	$4.248^{e}\pm0.0198$	$54.592^{e}\pm0.7881$
4.5mg Si	$82.2^{cd}\pm0.5$	$6.09^{de}\pm0.03$	$0.1606^{cd}\pm0.0027$	$4.384^{d}\pm0.0242$	$62.882^{d}\pm0.4262$
7.5mg Si	$83^{bcd}\pm0.7$	$5.824^{ce}\pm0.06$	$0.1714^{bd}\pm0.0012$	$4.52^{c}\pm0.0228$	$63.278^{cd}\pm0.3871$
9.5mg Si	90a±0.7 (36.36%)^{x}	$5.634^{bc}\pm0.09$ (24.5%)^{x}	$0.176^{ab}\pm0.0016$ (30.37%)^{x}	$5.062^{b}\pm0.0208$ (66.4%)^{x}	$76.382^{b}\pm0.3593$ (49.03%)^{x}
12mg Si	$92^{a}\pm0.7$ (39.39%)^{x}	$5.332^{ab}\pm0.1$ (28.54%)^{x}	$0.1816^{ab}\pm0.0023$ (34.52%)^{x}	$5.414^{a}\pm0.0277$ (77.98%)^{x}	$87.964^{a}\pm0.5963$ (71.62%)^{x}

*Stimulation percentage over control. The data in table are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at $P < 0.05$

Table 3. Effect of potassium silicate treatment on CVt, CVG, MDG and P value of seed germination indices of rice (*Oryza sativa* L.) Variety PB 1121

Groups	CV_t	CVG	MDG	P Value
Control	$33.514^{f}\pm0.01$	$13.514^{f}\pm0.0$	$4.708^{f}\pm0.01$	$9.042^{f}\pm0.01$
2.5mg Si	$26.944^{e}\pm0.02$	$16.5532^{e}\pm0.0$	$5.7^{e}\pm0.01$	$9.56^{e}\pm0.01$
4.5mg Si	$25.06^{d}\pm0.02$	$16.4466^{d}\pm0.0$	$5.942^{d}\pm0.0$	$10.416^{d}\pm0.01$
7.5mg Si	$23.538^{c}\pm0.02$	$17.1242^{c}\pm0.0$	$5.936^{cd}\pm0.01$	$10.426^{cd}\pm0.01$
9.5mg Si	$23.456^{bc}\pm0.01$ (30.01%)*	$17.647^{b}\pm0.0$ (30.58%)^{x}	$6.44^{b}\pm0.02$ (36.79%)^{x}	$11.898^{b}\pm0.01$ (31.59%)^{x}
12mg Si	$20.26^{a}\pm0.22$ (39.55%)^{x}	$18.5434^{a}\pm0.0$ (37.22%)^{x}	$6.66^{a}\pm0.01$ (41.46%)^{x}	$13.336^{a}\pm0.01$ (47.49%)^{x}

*Stimulation percentage over control. The data in table are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at $P < 0.05$

Table 4. Effect of potassium silicate treatment on CVt, CVG, MDG and P value of seed germination indices of rice (*Oryza sativa* L.) Karan bhog-521

Groups	CV_t	CVG	MDG	P Value
Control	$31.254^{f}\pm0.02$	$14.6662^{f}\pm0.5$	$5.21^{d}\pm0.01$	$7.324^{f}\pm0.02$
2.5mg Si	$22.94^{e}\pm0.02$	$15.2774^{e}\pm0.0$	$5.238^{d}\pm0.01$	$8.108^{e}\pm0.01$
4.5mg Si	$27.916^{d}\pm0.02$	$15.1754^{d}\pm0.0$	$5.252^{d}\pm0.01$	$7.768^{d}\pm0.01$
7.5mg Si	$25.104^{c}\pm0.01$	$15.091^{c}\pm0.00$	$5.714^{c}\pm0.01$	$8.892^{c}\pm0.02$
9.5mg Si	$20.362^{b}\pm0.03$ (34.85%)^{x}	$15.3366^{b}\pm0.0$ (4.57%)^{x}	$5.946^{b}\pm0.01$ (14.13%)^{x}	$10.398^{b}\pm0.01$ (41.97%)^{x}
12mg Si	$18.152^{a}\pm0.1$ (41.92%)^{x}	$15.695^{a}\pm0.00$ (7.01%)^{x}	$6.43^{a}\pm0.01$ (23.42%)^{x}	$11.25^{a}\pm0.01$ (53.6%)^{x}

*Stimulation percentage over control. The data in table are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at P < 0.05

Effect of silicon on Seedling growth parameters

Stem length, root length and seedling length: The effect of various concentrations of silicon on stem length, root length and seedling length has been shown in fig.1 and 2. All the concentrations of silicon were found effectiveand significant rise of 20.52 % and 40.83 % in stem length, 53 and 64.06 %in root length and 26.51 and 29.16 % in seedling length and similarly significant rise of 11.8 and 14.87 % in stem length, 54 and 65.38 % in root length and 22 and 28.21 % in seedling length was observed in Karan bhog-521as comparison to controlwas observed in Variety PB 1121 in the silicon concentration of 9.5 mg and 12 mg/100ml respectively.

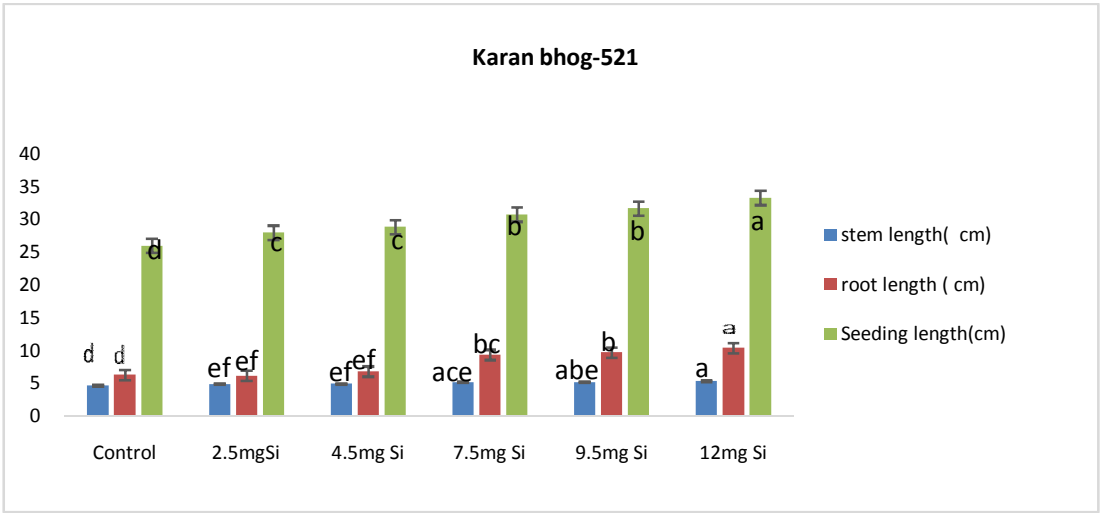

Figure 1. Effect of potassium silicate treatment on stem length, root length and seedling length of rice seedlings (*Oryza sativa* L.) Karan bhog-521.The data in fig. are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at P < 0.05.

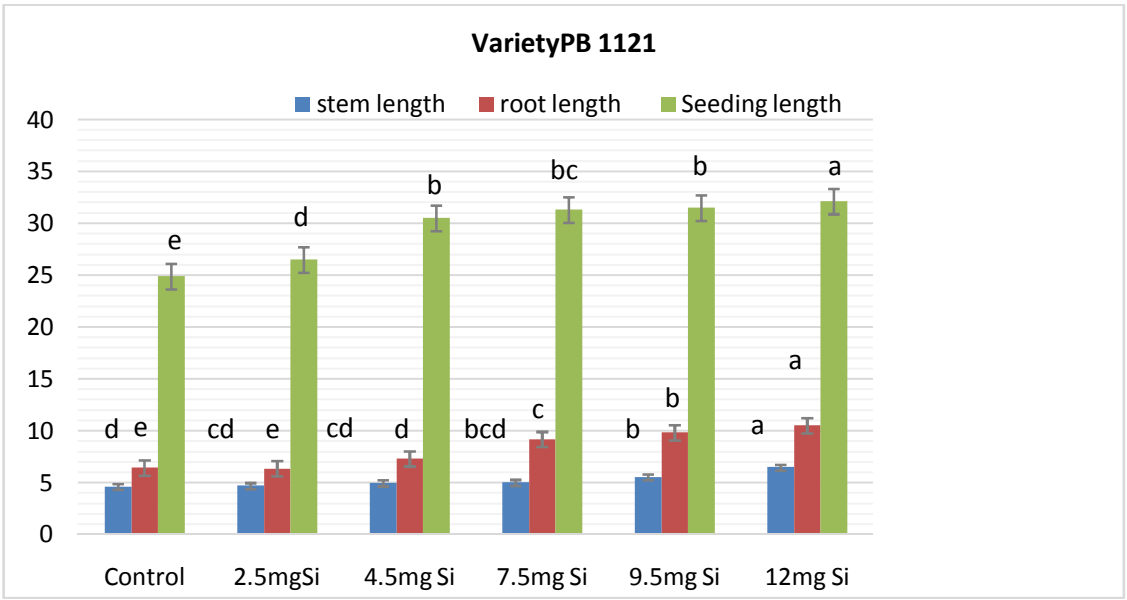

Figure 2. Effect of potassium silicate treatment on stem length, root length and seedling length of rice seedlings (*Oryza sativa* L.) Variety PB 1121. The data in fig. are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at P < 0.05.

Number of leaves and roots

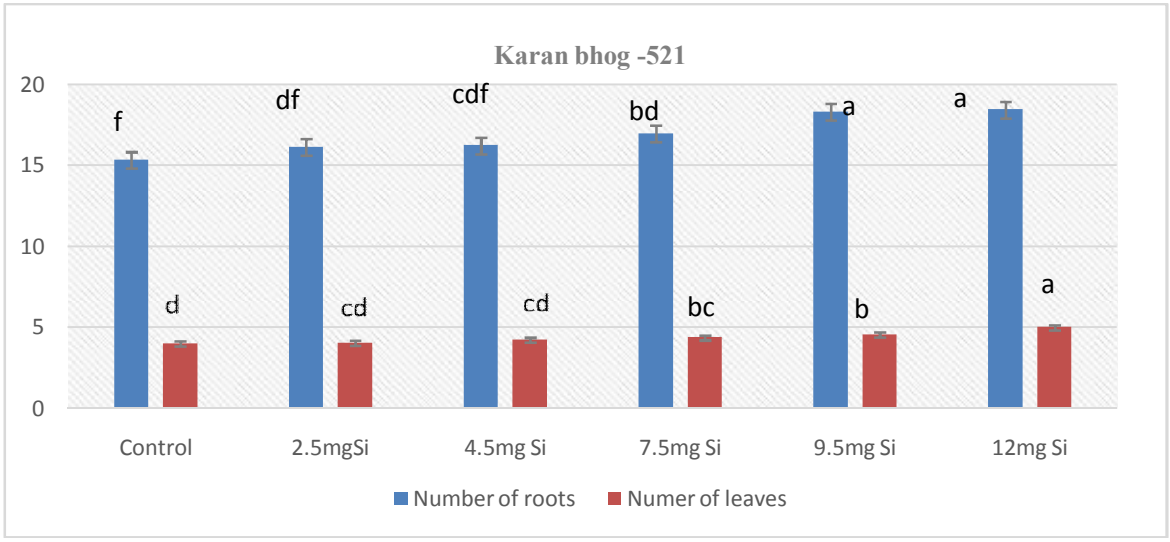

Figure 3. Effect of potassium silicate treatment on number of leaves and roots of rice seedlings (*Oryza sativa* L.) Karan bhog-521. The data in fig. are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at P < 0.05.

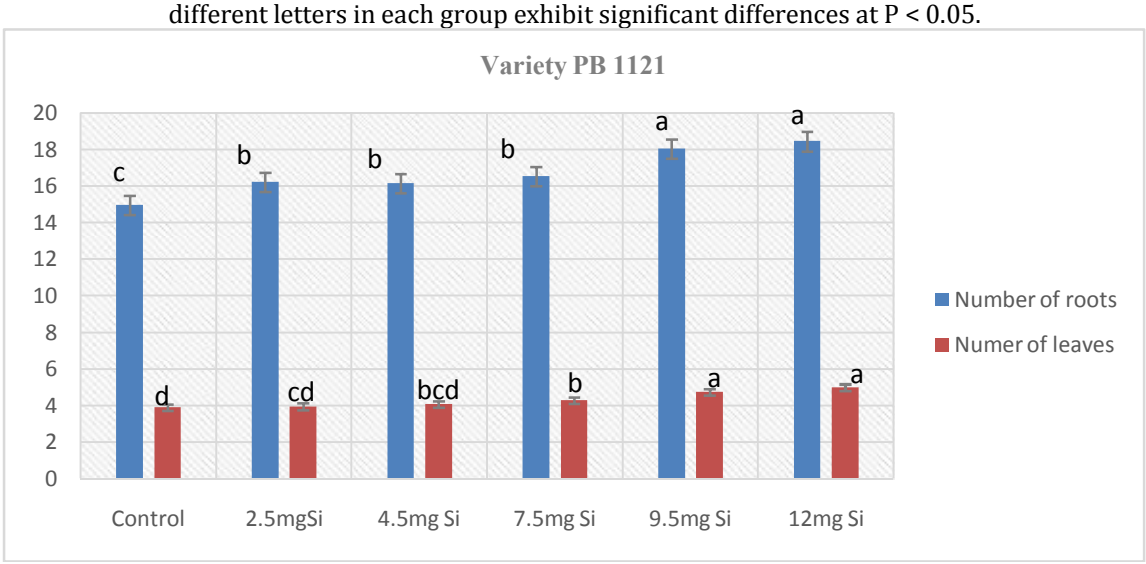

Figure 4. Effect of potassium silicate treatment on number of leaves and roots of rice seedlings (*Oryza sativa* L.) Variety PB 1121.The data in fig. are mean of three replicates and ± SEM. The values with different letters in each group exhibit significant differences at P < 0.05.

Figure 5 & 6. Effect of potassium silicate treatment on Vigour indices of rice seedlings (*Oryza sativa* L.) Variety Karan Bhog 521 and PB 1121. The values represent the mean±SE.

Silicon was found effective at all the concentration and significant rise of 21.79 % and 28.21 % in leaf number and 20.67 and 23.34% in root number was observed in Variety PB 1121and 14and 25 % in leaf number, 19.5 and 20.29 % in root length was observed in variety Karan bhog -521 as comparison to control in the silicon concentration of 9.5 mg and 12 mg/100 ml respectively (Fig. 3&4).

Vigour index: Application of silicon has significantly affected the vigour index and significant rise of 72.55 % and 82.35 % and 50.21 and 62.23 % was observed in Variety PB 1121and Karan bhog-521 respectively as comparison to control (Fig. 5&6).

CONCLUSION

Seed germination, the initial step of the establishment of plants, is a contributory parameter in deciding the total yield and biomass production of any crop. Homogeneity, synchronization and uniformity of seed germination is crucial aspect and important indicator for seed technologist, ecologists and physiologists and determine the ecology of any plant species or variety. Failure of these parameters can lead to poor establishment and loss of overall crop yield [13]. In our studies silicon has been found in significantly improving the germination percentage, Germination index, Vigour index of paddy seeds. This clearly specifies that the suitable concentration of Si can help in breaking the dormancy of rice seeds and has accelerated the process of seed germination and emergence and has been successful in providing the suitable physiological conditions for establishment and growth of seedling. Number and length of roots play significant role in ensuring the sufficient amount of absorption of mineral nutrients and water from the soil and play important role in plant growth by increasing the photosynthesis of plant leaves. In our studies silicon has been in enhancing the characteristics of root system and similar finding documenting the effect of silicon on seed germination and seedling growth parameters of lentil, rice, soybean, maize and barley [14]. Metabolomics, transcriptomic studies also throw light on extraordinary role of silicon in plants. Seed treatment helps to improve germination potential, vigour, and resistance to pests and disease. So, it can be recommended to treat the rice seed with silicon for better productivity of crop.

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