Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(6): 1572-1575
Received: 23-09-2019
Accepted: 24-10-2019

Shridevi
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka, India

NS Hebsur
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka, India

Corresponding Author:
Shridevi
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka, India

Effect of silicon fertilization on growth and yield of soybean [*Glycine max* (L.) Merrill] in a vertisol

Shridevi and NS Hebsur

Abstract
A field experiment was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, to study the effect of silicon fertilization on growth and yield of soybean in a Vertisol during kharif 2018. Experiment was laid out in randomized complete block design with nine treatments replicated thrice. The treatments included were two soil (25 and 50 kg ha-1), two foliar (0.25 and 0.50 %) application rates of silicon and their combinations with one control. The results revealed that soil application of silicon @ 25 kg ha-1 + foliar application of silicon @ 0.25 per cent improved the growth parameters viz., number of leaves (27.47) and chlorophyll content (49.40) plant-1 at 60 DAS (days after sowing) and effective nodules plant-1 (19.73) at 50 DAS and yield parameters viz., number of pods (39.87), pod weight (24.21 g) plant-1 and 100-seed weight (14.97 g). A significant increase in seed (14.84 q ha-1) and haulm (19.72 q ha-1) yields were recorded with soil (25 kg ha-1) + foliar (0.25 %) application of silicon and the lowest seed (12.86 q ha-1) and haulm (17.68 q ha-1) yields were recorded in the control. It can be concluded that combination of soil application of silicon (25 kg ha-1) at the time of sowing and foliar (0.25 %) at 30 DAS along with RPP (recommended package of practice) recorded highest soybean yield in a Vertisol.

Keywords: Silicon, soybean, growth, yield, vertisol

Introduction
Soybean [*Glycine max* (L.) Merrill] is considered a "golden bean" and "miracle crop" of 21st century due to its high yielding potential with high protein (40-42 %) and oil content (18-20 %). Soybean is also rich in minerals (Ca, Mg, P and Fe) and vitamins (A, B and D). Soybean forage and cake are excellent nutritive foods for live stocks and poultry birds. Cultivation of soybean improves soil fertility through fixation of atmospheric nitrogen and addition of leaf residues.

The area under soybean is increasing in recent years due to its high nutritive value but its productivity is declining, as most of the farmers are not applying adequate and balanced dose of fertilizers. Therefore, balanced application of macro and micronutrients will help in augmenting the production and productivity of soybean crop. Among the beneficial nutrients, silicon plays an important role in providing beneficial effects on growth and yield of crops. It helps in alleviating various abiotic stresses like metal toxicity, drought, radiation damage due to high temperature and biotic stresses like pest and disease incidence such as blast in rice, powdery mildew in cucumber etc., Silicon also prevents the lodging in cereal crops besides increasing photosynthesis, improving water economy of plants and strengthening the culm wall which are of great importance in terms of achieving higher yield. Under Si-deficit conditions, soybean plants displayed malformations such as curling of newly developed leaves during flowering, necrotic spots on leaves and low pollen fertility particularly in case of severe Si deficiency.

Studies on Si fertilization particularly in soybean are scarce. Moreover, at present there is no recommendation of silicon nutrient to crops. With this background, the present experiment was initiated to come out with optimum dose, method and time of application of silicon for sustainable soybean production in a Vertisol.

Material and Methods
The experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad. This research station comes under Northern Transitional Zone (Zone 8) of Karnataka. The site was located at 15° 29' N latitude and 74° 59' E longitude with an altitude of 678 m above mean sea level. Experiment was laid out in

RCBD design with nine treatments viz., T1: Control; T2: Soil application of silicon @ 25 kg ha-1; T3: Soil application of silicon @ 50 kg ha-1; T4: Foliar application of silicon @ 0.25 %; T5: Foliar application of silicon @ 0.50 %; T6: Soil (25 kg ha-1) + Foliar (0.25 %) application of silicon; T7: Soil (25 kg ha-1) + Foliar (0.50 %) application of silicon; T8: Soil (50 kg ha-1) + Foliar (0.25 %) application of silicon; T9: Soil (50 kg ha-1) + Foliar (0.50 %) application of silicon with three replications. Recommended fertilizers as per package (N: P2O5: K2O @ 40: 80: 25: kg + ZnSO4.7H2O @ 12.5 kg + Gypsum @ 100 kg ha-1) were applied to all the treatments at the time of sowing. Calcium silicate and monosilicic acid were the sources of silicon used for soil application at the time of sowing and foliar application at 30 DAS, respectively. Initial properties of experimental soil were determined by standard procedure and values were presented in Table 1.

Crop was raised by following recommended cultural practices and was harvested at maturity. Growth parameters viz., plant height, number of leaves, number of branches and chlorophyll content per plant were recorded at different growth stages of crop. Total and effective nodules were counted by uprooting the plant at 50 DAS. While yield parameters (Number of pods plant-1, pod weight plant-1 and 100 seed weight) and yield were recorded at maturity.

Statistical analysis

The statistical analysis and interpretation of data was done using the Fischer's method of analysis of variance technique as described by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was P=0.05. Critical differences were calculated wherever 'F' test was significant and treatment means were compared by applying Duncan's multiple range test (DMRT).

Results and Discussion

Effect of silicon on growth parameters

Perusal of data presented in Tables 2, 3 and 4 revealed that there was a variation in the growth parameters of soybean due to application of silicon through soil and foliar. Critical examination of the data revealed that, the application of silicon either through soil and/or foliar resulted in favorable effects on growth parameters. Further, the combined application of silicon resulted in greater growth parameters compared to only either soil or foliar application.

There was no significant difference on plant height and number of branches but there was a significant increase in number of leaves (27.47), chlorophyll content (49.40) at 60

Table 1: Initial physical and chemical properties of the experimental soil

Sl. No.	Particulars	Value
I	Physical properties	
1.	Partical size analysis	
	Sand (%)	16.00
	Silt (%)	23.84
	Clay (%)	60.16
	Textural class	Clay
II.	Chemical properties	
1.	Soil reaction (1:2.5 soil: water suspension)	7.69
2.	Electrical conductivity (1:2.5 soil: water extract) (dS m-1)	0.22
3.	Organic carbon (g kg-1)	7.40
4.	Available macronutrients (kg ha-1)	
	Nitrogen (N)	141.24
	Phosphorous (P2O5)	44.80
	Potassium (K2O)	250.33
5.	Available micronutrients (mg kg-1)	
	Zinc (Zn)	0.64
	Iron (Fe)	4.86
	Copper (Cu)	0.89
	Manganese (Mn)	7.99
6.	Available silicon (mg kg-1)	318.56

Table 2: Effect of soil and foliar application of silicon on plant height and number of branches of soybean at different growth stages

Treatments	Plant height (cm)				Number of branches per plant			
	30 DAS	45 DAS	60 DAS	Harvest	30 DAS	45 DAS	60 DAS	Harvest
T1 : Control	16.87 a	37.33 a	39.93 a	40.40 a	1.53 a	6.80 a	7.40 a	7.40 a
T2 : Soil application of silicon @ 25 kg ha-1	16.80 a	36.47 a	39.60 a	41.40 a	1.60 a	7.13 a	7.67 a	7.93 a
T3 : Soil application of silicon @ 50 kg ha-1	15.87 a	34.67 a	37.47 a	40.80 a	1.60 a	7.13 a	7.60 a	7.87 a
T4 : Foliar application of silicon @ 0.25 %	18.60 a	37.73 a	40.47 a	41.80 a	1.53 a	7.33 a	7.87 a	8.07 a
T5 : Foliar application of silicon @ 0.50 %	17.53 a	37.47 a	40.13 a	41.60 a	1.47 a	7.20 a	7.93 a	8.07 a
T6 : Soil (25 kg ha-1) + Foliar (0.25 %) application of silicon	17.00 a	36.47 a	38.87 a	42.07 a	1.53 a	7.60 a	7.93 a	8.20 a
T7 : Soil (25 kg ha-1) + Foliar (0.50 %) application of silicon	17.60 a	38.40 a	40.40 a	41.80 a	1.47 a	7.20 a	7.67 a	7.87 a
T8 : Soil (50 kg ha-1) + Foliar (0.25 %) application of silicon	17.20 a	35.53 a	38.20 a	41.07 a	1.40 a	7.40 a	7.87 a	8.07 a
T9 : Soil (50 kg ha-1) + Foliar (0.50 %) application of silicon	15.40 a	36.73 a	39.07 a	41.80 a	1.47 a	7.13 a	7.67 a	7.87 a
LSD	NS	NS	NS	NS	NS	NS	NS	NS

Note:

- Recommended package of practice (RPP) is common to all treatments
- Soil and foliar application of silicon at the time of sowing and 30 DAS (Days after sowing), respectively
- Calcium silicate and monosilicic acid were used for soil and foliar application, respectively
- In a column, mean values followed by the common letter are not significantly different at P = 0.05 level (DMRT at 5 % level).

Table 3: Effect of soil and foliar application of silicon on number of leaves and nodules of soybean at different growth stages

Treatments	Number of leaves			Number of nodules 50 DAS	
	30 DAS	45 DAS	60 DAS	Total nodules	Effective nodules
T1 : Control	7.33 b	22.53 b	23.80 d	20.27 d	9.80 d
T2 : Soil application of silicon @ 25 kg ha-1	6.80 a	23.73 ab	25.47 a-d	24.60 bc	14.27 c
T3 : Soil application of silicon @ 50 kg ha-1	7.47 ab	22.87 ab	23.93 cd	22.53 cd	12.80 cd
T4 : Foliar application of silicon @ 0.25%	7.40 ab	23.27 ab	26.80 ab	29.13 a	18.47 a
T5 : Foliar application of silicon @ 0.50 %	7.67 ab	24.33 ab	26.00 a-c	26.40 ab	14.73 bc
T6 : Soil (25 kg ha-1) + Foliar (0.25 %) application of silicon	7.00 ab	23.20 ab	27.47 a	29.27 a	19.73 a

T7 : Soil (25 kg ha-1) + Foliar (0.50 %) application of silicon	8.13 a	24.87 a	26.07 a-c	27.33 ab	18.13 ab
T8 : Soil (50 kg ha-1) + Foliar (0.25 %) application of silicon	7.33 ab	23.87 ab	25.33 a-d	23.33 cd	13.13 cd
T9 : Soil (50 kg ha-1) + Foliar (0.50 %) application of silicon	6.80 b	22.73 ab	24.93 b-d	22.60 cd	13.00 cd
LSD	1.07	2.03	1.92	2.91	3.51

Note:

- Recommended package of practice (RPP) is common to all treatments
- Soil and foliar application of silicon at the time of sowing and 30 DAS (Days after sowing), respectively
- Calcium silicate and monosilicic acid were used for soil and foliar application, respectively
- In a column, mean values followed by the common letter are not significantly different at P = 0.05 level (DMRT at 5 % level).

Table 4: Effect of soil and foliar application of silicon on chlorophyll content and dry matter production of soybean

Treatments	Chlorophyll content (SPAD)			Dry matter production (g plant-1)			
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	Harvest
T1 : Control	18.66 c	35.53 e	46.19 d	1.99 a	7.09 g	15.99 d	33.91 d
T2 : Soil application of silicon @ 25 kg ha-1	20.69 a	38.99 c	47.05 c	2.10 a	9.45 c-e	18.94 b	35.63 bc
T3 : Soil application of silicon @ 50 kg ha-1	19.61 b	37.04 d	46.78 c	2.09 a	7.67 fg	16.99 c	34.95 cd
T4 : Foliar application of silicon @ 0.25%	18.60 c	41.37 a	48.27 b	2.31 a	11.07 ab	20.15 a	36.74 ab
T5 : Foliar application of silicon @ 0.50 %	18.59 c	39.45 c	47.86 b	2.00 a	9.85 cd	18.96 b	36.60 ab
T6 : Soil (25 kg ha-1) + Foliar (0.25 %) application of silicon	20.56 a	41.84 a	49.40 a	2.29 a	11.65 a	20.67 a	37.50 a
T7 : Soil (25 kg ha-1) + Foliar (0.50 %) application of silicon	20.61 a	40.68 b	47.97 b	2.29 a	10.35 bc	19.15 b	36.65 ab
T8 : Soil (50 kg ha-1) + Foliar (0.25 %) application of silicon	19.86 b	38.86 c	47.04 c	2.06 a	8.78 de	17.51 c	35.37 b-d
T9 : Soil (50 kg ha-1) + Foliar (0.50 %) application of silicon	19.97 b	37.67 d	46.83 c	2.13 a	8.69 ef	17.23 c	35.36 b-d
LSD	0.33	1.04	0.97	1.49	1.04	0.97	1.49

Note:

- Recommended package of practice (RPP) is common to all treatments
- Soil and foliar application of silicon at the time of sowing and 30 DAS (Days after sowing), respectively
- Calcium silicate and monosilicic acid were used for soil and foliar application, respectively
- In a column, mean values followed by the common letter are not significantly different at P = 0.05 level (DMRT at 5 % level).

DAS, number of effective nodules (19.73) at 50 DAS and dry matter production (37.50 g) per plant at harvest with the soil application of silicon @ 25 kg ha-1 + foliar @ 0.25 per cent (T6). This might be due to supply of silicon both from the soil and also from the foliar. Silicon plays a major role in increasing the photosynthesis. Si gets deposited in the plant tissue causing erectness of leaves and stem which makes efficient utilization of sunlight. Lee *et al*. (2010) [6] reported that application of silicon as sodium silicate to hydroponically grown soybean improved plant height and biomass. Hamayun *et al*. (2010) [3] reported that application of silicic acid enhanced the plant growth under control condition to soybean. Further, the shoot fresh weight and dry weight attributes also significantly improved when Si applied alone under salt stress. Miao *et al*. (2010) [11] also observed enhanced root and shoot growth of soybean seedlings with the application of silicon in K-deficient medium.

Manju *et al*. (2008) [9] recorded maximum relative nodule number, nodule fresh and dry weights with the application of silicon @ 100 µg g-1. Nelwamondo and Dakora (1999) [14] also reported promotary effects of silicon on formation of more number of effective nodules and greater symbiotic N fixation by cowpea. Similarly, increased total biomass, root length and root mass were also observed by Miyake and Takahashi (1985) [12], Paul *et al*. (2018) [15] in soybean and Mali and Aery (2009) [8] in cowpea. In view of these, the results of present study are in conformity with the findings of earlier workers.

Effect of silicon on yield and yield parameters of soybean

There was a significant effect of soil and foliar application of silicon on yield and yield parameters of soybean (Table 5). The number of pods per plant, pod weight per plant, 100-seed weight, haulm yield and seed yield of soybean were greatly influenced by either individual soil and/or foliar application of silicon. The highest number of pods (39.87) and pod weight per plant (24.21g) were recorded with soil application @ 25 kg ha-1 + foliar @ 1.25 per cent (T6) closely followed by T4 (only foliar 0.25 %), T5 (only foliar 0.50 %) and T7 (soil @ 25 kg ha-1 + foliar @ 0.50 % Si). The highest 100-seed weight (14.97) was also recorded in the same treatment T6. However, all other treatments barring T1 and T3 were on par with T6 as seed weight is a genetic character of a crop.

The highest seed (14.84 q ha-1) and haulm (19.72 q ha-1) yields were recorded with soil application of silicon @ 25 kg ha-1 + foliar @ 0.25 per cent (T6). However, treatments T4, T5 and T7 were on par with T6 with respect to seed yield and treatments T4 and T7 were on par with T6 with respect to haulm yield. The lowest seed (12.86 q ha-1) and haulm yield (17.68 q ha-1) was recorded in the control which did not receive silicon. However, the soil application.

Table 5: Effect of soil and foliar application of silicon on yield and yield parameters of soybean

Treatments	Number of pods plant-1	Pod weight plant-1(g)	100-seed weight (g)	Seed yield (q ha-1)	Haulm yield (q ha-1)
T1 : Control	31.20 e	20.90 e	13.80 b	12.86 e	17.68 d
T2 : Soil application of silicon @ 25 kg ha-1	36.87 b-d	22.49 b-d	14.48 ab	13.81 b-d	18.41 cd
T3 : Soil application of silicon @ 50 kg ha-1	34.20 d	21.77 de	13.82 b	13.43 de	17.98 d
T4 : Foliar application of silicon @ 0.25 %	39.07 ab	23.79 ab	14.90 a	14.55 ab	19.54 ab
T5 : Foliar application of silicon @ 0.50 %	37.60 a-c	23.37 a-c	14.58 ab	14.21 a-c	18.52 b-d
T6 : Soil (25 kg ha-1) + Foliar (0.25 %) application of silicon	39.87 a	24.21 a	14.97 a	14.84 a	19.72 a
T7 : Soil (25 kg ha-1) + Foliar (0.50 %)	38.20 a-c	23.62 ab	14.79 a	14.23 a-c	19.11 a-c

application of silicon					
T8 : Soil (50 kg ha-1) + Foliar (0.25 %) application of silicon	36.40 b-d	22.17 c-e	14.40 ab	13.61c-e	18.36 cd
T9 : Soil (50 kg ha-1) + Foliar (0.50 %) application of silicon	35.93 cd	22.05 c-e	14.39 ab	13.57 c-e	18.30 cd
LSD	2.53	1.26	0.79	0.69	1.00

Note:

- Recommended package of practice (RPP) is common to all treatments
- Soil and foliar application of silicon at the time of sowing and 30 DAS (Days after sowing), respectively
- Calcium silicate and monosilicic acid were used for soil and foliar application, respectively
- In a column, mean values followed by the common letter are not significantly different at P = 0.05 level (DMRT at 5 % level).

of silicon (50 kg ha-1) and foliar application (0.25 % and 0.50 %) and their combination did not increase seed and haulm yields.

In the present investigation, application of silicon had promotary effects on soybean growth parameters consequently increased the yield and yield parameters and also dry matter production. This might be due to efficient partitioning of photosynthates and better utilization of absorbed nutrients with the application of silicon. One of the most important role of Si is to stimulate the plants defense abilities against abiotic and biotic stresses. Si deposited on the leaf tissue surface has been found to be responsible for the protective effect of silicon against biotic stresses. Paul *et al*. (2018) [15] recorded increase in yield parameters of soybean with foliar application of Si up to 125 ppm. Shwethakumari (2017) [16] also noticed enhanced seed yield and pod yield over control with the application of silicic acid @ 2 ml L-1 for three times. Malav *et al*. (2018) [7], Patil *et al*. (2017), Prakash *et al*. (2011), Dhamapurkar *et al*. (2011) [1] and Nagula *et al*. (2016) [13] reported that individual application of silicon produced the highest grain and straw yield in rice. Hongwen *et al*. (2016) [4] and Meena *et al*. (2016) reported that application of silicon enhanced net photosynthetic rate and grain yield in maize. Similar results were also observed by Talashilkar *et al*. (2001) [17] and Jadhav *et al*. (2000) [5] in sugarcane.

Conclusion

Based on the response of soybean in terms of growth and yield, a combination of soil application of silicon @ 25 kg ha-1 at the time of sowing and foliar application of silicon @ 0.25 per cent at 30 DAS was found beneficial in a Vertisol.

References

1. Dhamapurkar VB, Talashilkar SC, Sonar KR. Effect of calcium silicate slag on yield and silica uptake by rice. In proceeding of the 5th International Conference on Silicon in Agriculture, 2011, 40.
2. Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research. John Willy and Sons, New York, 1984, 1-680.
3. Hamayun M, Sohn E, Sumera AK, Zabta KS, Abdul LK, Lee I. Silicon alleviates the adverse effects of salinity and drought stress on growth and endogenous plant growth hormones of soybean. Pakistan J. Bot., 2010; 40(3):1713-1722.
4. Hongwen X, Yan L, Zhiming X. Effects of silicon on maize photosynthesis and grain yield in black soils. Emirates J. Food Agric. 2016; 28(11):779-785.
5. Jadhav MB, Jagtap SM, Savant NK, Pawar AM. Influence of soil application of calcium silicate on growth, yield and quality of sugarcane. Deccan Sugar Technologists Association, 2000, 76-81.
6. Lee SK, Sohn EY, Hamayun M, Yoon JY, Lee IJ. Effect of silicon on growth and salinity stress of soybean plant grown under hydroponic system. Agro for. Syst. 2010; 80(3):333-340.
7. Malav JK, Ramani VP, Patel JK, Pavaya RP, Patel BB, Patel IM *et al*. Rice yield and available nutrients status of loamy sand soil as influenced by different levels of silicon and nitrogen. Int. J. Curr. Microbiol. App. Sci. 2018; 7(2):619-632.
8. Mali M, Aery NC. Effect of silicon on growth, biochemical constituents and mineral nutrition of cowpea. Comms. Soil Sci. Plant Anal. 2009; 40(7):1041-1052.
9. Manju M, Naresh CA. Silicon effects on nodule growth, dry matter production and mineral nutrition of cowpea. J. Plant Nutr. Soil Sci. 2008; 171(6):835-840.
10. Meena OP, Patel KC, Malav JK. Effect of silicon and phosphorus on available Si, P, Fe and Mn content and nutrient ratio of P-stressed maize (*Zea Mays* L.). Res. J. Chem. Environ. 2018; 20(2):18-21.
11. Miao BH, Han XG, Zhang WH. The ameliorative effect of silicon on soybean seedlings grown in potassium-deficient medium. Ann. Bot. 2010; 105(6):967-973.
12. Miyake Y, Takahashi E. Effect of silicon on the growth of soybean plants in a solution culture. Soil Sci. Plant Nutr. 1985; 31(4):625-636.
13. Nagula S, Joseph B, Gladis R. Silicon nutrition to rice (*Oryza sativa* L.) alleviates Fe, Mn and Al toxicity in laterite derived rice soils. J. Indian Soc. Soil Sci. 2016; 64(3):297-301.
14. Nelwamondo A, Dakora FD. Silicon promotes nodule formation and nodule function in symbiotic cowpea (*Vigna unguiculata*). New Phytol. 1999; 140(3):463-467.
15. Paul BT, Agustiansyuah, Ermawati, Suci A. The effects of foliar boron and silica through the leaves on soybean growth and yield. J. Agric. Stud. 2018; 6(3):34-46.
16. Shwethakumari U. Effect of foliar silicic acid on growth, yield and nutrient uptake by soybean [*Glycine max* (L.)]. M.Sc (Agri.) Thesis, Univ. Agric. Sci., Bengaluru, Karnataka (India), 2017.
17. Talashilkar SC, Jadhav MB, Savant NK. Effect of calcium silicate slag on plant growth, nutrient uptake and yield of sugarcane on two soils of Maharashtra state, India. Silicon Agric. 2001, 383-384.