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Effect of silicon and nitrogen levels on growth of sorghum (*Sorghum bicolor* L. Moench) crop

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Abstract
A field experiment entitled "Effect of silicon and nitrogen levels on soil nutrient dynamics, yield and quality of sorghum (*Sorghum bicolor* L. Moench) under Inceptisol" was conducted during the *Rabi* season 2019-20, at Soil Science and Agriculture Chemistry, Departmental Research Farm, College of Agriculture, Latur. The experiment was laid out in factorial randomized block design with two factors *viz.*, four levels of Silicon (S0 - control, S0.25 - silicon @ 0.25% foliar spray, S0.5 - silicon @ 0.5% foliar spray and S1.0 - silicon @ 1% foliar spray) and four levels of nitrogen (N0 - control, N40 - nitrogen @ 40 kg ha^{-1}, N80-nitrogen @ 80 kg ha^{-1} and N120 - nitrogen @ 120 kg ha^{-1}) with three replications and SPV-2407 as test crop. Growth parameters *viz.* plant height; number of functional leaves, number of internodes, stem girth, length of ear head and final plant count of sorghum at different stages were increased significantly with application of silicon @ 1% foliar spray in combination with soil application of nitrogen @ 120 kg ha^{-1} over rest of the treatments. Thus, it can be concluded that the combined application of silicon and nitrogen was found to be superior in increasing growth parameters of sorghum over separate application of silicon and nitrogen.

Keywords: Jowar (*Sorghum bicolor* (L.) Moench), *Gramineae, soil nutrient dynamics*

Introduction
Jowar (*Sorghum bicolor* (L.) Moench) is the fourth most important cereal following wheat, rice and maize in the world. Sorghum word is derived from Latin word "Sargo" means rising above *i.e.*, growing taller than other crops in the field. Sorghum is an important grain and fodder crop of rainfed or dry land areas, providing food for human beings, fodder for cattle and feed for birds. Sorghum belongs to the family *Gramineae*. In Maharashtra, it is truly the poor man's "bread". Marathwada and Western Maharashtra regions of the state of Maharashtra are known as the "Sorghum Bowl of India". Sorghum is a leading tropical crop having larger genomes and more genes like sugarcane which is most promising crop of world's most efficient biomass-production and the leading biofuel source in the world (Paterson *et al.*, 2009) [17]. The appropriate timing of N application is reported to have a higher effect on plant growth rate (Tsialtas and Maslaris, 2005) [22] and yield than the total amount of N applied. Silicon (Si) is the second most abundant element in soil. In soil solution, Si occurs mainly as monosilicic acid (H4SiO4) at concentrations ranging from 0.1 to 0.6 mm and is taken up by plants in this form (Epstein 1994 [6]; Ma and Takahashi 2002 [15]). Silicon can remove the negative effects of abiotic stresses including physical stresses (high temperature, freezing, drought, lodging, radiation, irradiation, UV) and chemical stresses (salt, nutrient imbalance, metal toxicity) in *Borago officinalis* L. (Shahnaz *et al.*, 2011) [20]. It has been reported that adding silicon to monocots, especially Gramineae plants, not only promote growth and development but also promote photosynthesis, reduces pest infestation, maintain the shoot in an erect position and alleviates salt stress (Ahmad *et al.*, 1992 [1], Epstein, 1999 [7], Korndorfer and Lepsch, 2001 [13]). Nitrogen (N) is a key element required for plant growth and is one of the most important yield-limiting nutrients in crop production over the all agro-ecological regions of the world. Higher N levels led to higher leaf chlorophyll index for stay-green sorghum during anthesis (Addy *et al.*, 2010) [2], an important factor in determining not only onset of leaf senescence but also the rate of post anthesis leaf senescence. Increase in leaf photosynthesis rates were observed under higher N levels in grain sorghum hybrids (Cechin, 1998) [5] and hence, keeping this view in mind it is needed to study the effect of silicon and nitrogen in sorghum.

Materials and Methods
Field experiment entitled "Effect of silicon and nitrogen levels on soil nutrient dynamics, yield and quality of sorghum (*Sorghum bicolor* L. Moench) under Inceptisol" was conducted at Soil

Science and Agricultural Chemistry Departmental Research Farm, College of Agriculture, Latur during *Rabi* season 2019 on sorghum variety SPV-2407. The topography of experimental field was uniform and leveled. The experimental soil was slightly alkaline in nature. The total geographical area of Latur district is 7.37 MH. Geographically Latur district comes under Maharashtra state which is located between 180 05 to 180 75 North. The soils of Latur district belongs to order Vertisols, Inceptisol and Entisol derived from Deccan trap. RDF (80:40:40 kg NPK ha^{-1}) supplied through Urea, SSP and MOP.

The composite soil sample before sowing was taken for their initial values. The soil pH (7.9) and EC (0.32 dSm^{-1}) were analyzed using soil: water suspension (1:2.5) and determined by pH meter method and Conductivity meter method respectively, organic carbon (0.30%) by walkley and black (1934) method, available N (208.24 kg ha-1) determined by alkaline KMnO4 as described by Subbiah and Asija (1956) [21], available P (32.21 kg ha-1) by Olsen's method as described by Jackson (1973) [9], and available K (294.36 kg ha^{-1}) by Flame photometer as described by Piper (1966). The experiment was laid out in factorial randomized block design with two factors *viz.* four levels of Silicon (S0 - control, S0.25 - silicon @ 0.25%, S0.5 - silicon @ 0.5% and S1.0 - silicon @ 1% as foliar spray) and four levels of nitrogen (N0 - control, N40 - nitrogen @ 40 kg ha^{-1}, N80 - nitrogen @ 80 kg ha-1 and N120 - nitrogen @ 120 kg ha^{-1} as soil application) and three replications, respectively.

Results and discussion

Effect of silicon and nitrogen on plant height (cm) of sorghum

The data in respect of plant height (cm) at 30, 60, 90 and 120 DAS of sorghum as influenced by different silicon and nitrogen levels are presented in Table 1. The data showed that the application of various silicon and nitrogen levels significantly influenced plant height of sorghum at all the stages of crop.

It was noticed from the data that the response of application of different silicon levels on plant height ranges between 37.21 to 43.85 cm at 30 DAS, 140.53 to 166.63 cm at 60 DAS, 187.28 to 211.49 cm at 90 DAS and 191.98 to 218.13 at 120 DAS of sorghum. At 30 DAS plant height was not affected significantly due to different levels of silicon. Significantly the higher plant height was recorded due to S1.0 treatment at 120 (218.13 cm) DAS. However, the treatment S0.5 was at par with treatment S1.0 at 60 and 90 DAS. The minimum plant height was recorded due to the treatment S0 at 30, 60, 90 and 120 DAS than the other treatment. The plant height increased by increasing silicon levels. Similar results were also reported by Jawahar *et al.*, (2019) [10]. Increase in plant height might be due to the deposition of silica on plant tissues causing erectness of leaves and stem.

Table 1: Effect of silicon and nitrogen levels on plant height (cm) at 30, 60, 90 and 120 DAS

Plant height (cm)				
Silicon levels %	**At 30 DAS**	**At 60 DAS**	**At 90 DAS**	**At 120 DAS**
S0	37.21	140.53	187.28	191.98
S0.25	38.34	147.05	194.60	198.59
S0.5	39.17	157.92	203.35	207.25
S1	43.85	166.63	211.49	218.13
S.E.	**1.58**	**4.0**	**3.27**	**3.02**
C.D. at 5%	**NS**	**11.55**	**9.459**	**8.74**
Nitrogen levels (kg ha^{-1})				
N0	29.42	99.58	141.88	148.87
N40	39.82	141.73	193.87	197.08
N80	40.83	173.53	219.78	225.20
N120	48.47	197.29	241.18	244.80
S.E.	1.58	4.0	3.27	3.02
C.D. at 5%	4.56	11.55	9.459	8.74
Interaction (S X N)				
S.E.	3.16	8.0	6.55	6.05
C.D. at 5%	NS	NS	NS	NS

The effect of different levels of nitrogen on plant height ranged between 29.42 to 48.47 cm, 99.58 to 197.29 cm, 141.88 to 241.18 cm and 148.87 to 244.80 cm at 30, 60, 90 and 120 DAS, respectively. The treatment N120 recorded significantly higher plant height at 30 (48.47 cm), 60 (197.29 cm), 90 (241.18 cm) and 120 (244.80 cm) DAS than the rest of the treatments. The treatment N40 and N80 were at par with each other at 30 DAS. The treatment N0 recorded significantly lower plant height at 30 (29.42 cm), 60 (99.58 cm), 90 (141.88 cm) and 120 (148.87 cm) DAS than the remaining treatments. The plant height was

increased due to the increasing levels of nitrogen. Similar results were reported by Nirmal *et al.*, (2016) [16]. The increase in the plant height might be due to the positive effect of nitrogen element on plant growth that leads to progressive increase in inter nodal length and consequently plant height.

The interaction effect of different silicon and nitrogen levels on plant height at 30, 60, 90 and 120 DAS not reached to the level of significance.

Number of functional leaves plant 1

The data in respect of number of functional leaves at 30, 60, 90 and 120 DAS of sorghum as influenced by different silicon and nitrogen levels was presented in Table 2. The data showed that the application of various silicon and nitrogen levels significantly influenced number of functional leaves of sorghum at 30, 60, 90 and 120 DAS.

It was observed from the data that effect of different silicon levels on number of functional leaves ranged between 4.43 to 4.83 at 30 DAS, 6.61 to 7.68 at 60 DAS, 6.92 to 7.84 at 90 and 7.58 to 8.66 at 120 DAS of sorghum. The treatment S1.0 recorded significantly the highest number of functional leaves

7.84 and 8.66 at 90 and 120 DAS respectively over all remaining treatments. Silicon showed non-significant effect on number of leaves at 30 DAS. However, the treatment S0.5 was at par with treatment S1.0 at 60 DAS. The treatment S0 recorded significantly lower number of functional leaves plant^{-1} at 90 (6.92) and 120 (7.58) DAS than rest of the treatments. The numbers of functional leaves were increased by increasing of silicon levels. Similar results were also reported by Paul *et al.* (2018) [18]. Increasing growth attributes such as number of leaves might be due to increasing cell division, elongation and expansion caused by silicon.

Table 2: Effect of silicon and nitrogen levels on number of functional leaves plant^{-1} of sorghum at 30, 60, 90 and 120 DAS

Number of functional leaves plant 1				
Silicon levels %	**At 30 DAS**	**At 60 DAS**	**At 90 DAS**	**At 120 DAS**
S0	4.43	6.61	6.92	7.58
S0.25	4.51	6.96	7.18	7.97
S0.5	4.63	7.30	7.42	8.06
S1	4.83	7.68	7.84	8.66
S.E.	**0.06**	**0.15**	**0.05**	**0.08**
C.D. at 5%	**NS**	**0.43**	**0.15**	**0.24**
Nitrogen levels (kg ha^{-1})				
N0	3.81	5.35	5.95	6.43
N40	4.45	6.55	6.77	7.40
N80	4.84	7.77	7.73	8.72
N80	40.83	173.53	219.78	225.20
N120	48.47	197.29	241.18	244.80
S.E.	**1.58**	**4.0**	**3.27**	**3.02**
C.D. at 5%	**4.56**	**11.55**	**9.459**	**8.74**
Interaction (S X N)				
S.E.	**3.16**	**8.0**	**6.55**	**6.05**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**

The response of application of different levels of nitrogen on number of functional leaves ranges between 3.81 to 5.3, 5.35 to 8.88, 5.95 to 8.94 and 6.43 to 9.73 at 30, 60, 90 and 120 DAS, respectively. The treatment N120 recorded significantly highest number of functional leaves at 30 (5.30), 60 (8.88), 90 (8.94) and 120 (9.73) DAS than the rest of the treatments. However, all the treatments recorded significantly superior over their lower levels of nitrogen. The treatment N0 recorded significantly lower number of functional leaves plant-1 than rest of the treatments. Increase in number of leaves plant-1 in sorghum with application of nitrogen has also been reported by Nirmal *et al.*, (2016) [16] and Afzal *et al.*, (2012) [3]. The number of leaves increased by increasing nitrogen levels might be due to improved nutrients availability and increased translocation of carbohydrates from source to growing points in well-fertilized plots.

Whereas the interaction effect of different silicon and nitrogen levels on number of functional leaves at 30, 60, 90 and 120 DAS was found to be non-significant.

Stem girth (cm)

The data in respect to stem girth (cm) at 30, 60, 90 and 120 DAS of sorghum as influenced by different silicon and nitrogen levels are presented in Table 3. The effect of different levels of nitrogen on stem girth ranges between 3.24 to 5.29, 3.24 to 5.45, 3.54 to 5.55 and 3.79 to 5.69 at 30, 60, 90 and 120 DAS respectively.

Significantly the higher stem girth was recorded due to the treatment N120 at 30 (5.29 cm), 60 (5.45 cm), 90 (5.55 cm) and 120 (5.69 cm) DAS over rest of the treatments. However, all the treatments were significantly superior over its lower level. The treatment N0 recorded significantly lower stem girth 3.24, 3.24, 3.54 and 3.79 cm at 30, 60, 90 and 120 DAS than the rest of the treatments. Similar results were also reported by Arshewar *et al.*, (2018) [4]. Increase in stem girth due to application of nitrogen levels attributed might because of adequate supply of nutrition and favorable condition.

Whereas the interaction effects of different silicon and nitrogen levels on plant stem girth at 30, 60, 90 and 120 DAS was found to be non-significant.

Table 3: Effect of silicon and nitrogen levels on stem girth (cm) of sorghum at 30, 60, 90 and 120 DAS

Stem girth (cm)				
Silicon levels %	**At 30 DAS**	**At 60 DAS**	**At 90 DAS**	**At 120 DAS**
S0	3.96	4.13	4.33	4.57
S0.25	4.12	4.25	4.55	4.75
S0.5	4.25	4.49	4.69	4.87
S1	4.61	4.76	4.98	5.13
S.E.	**0.06**	**0.88**	**0.09**	**0.08**
C.D. at 5%	**NS**	**0.25**	**0.27**	**0.23**
Nitrogen levels (kg ha^{-1})				
N0	3.24	3.24	3.54	3.79
N40	3.90	4.28	4.53	4.73
N80	4.51	4.68	4.93	5.10
N120	5.29	5.45	5.55	5.69
S.E.	0.06	0.88	0.09	0.08
C.D. at 5%	0.18	0.25	0.27	0.23
Interaction (S X N)				
S.E.	0.12	0.17	0.18	0.16

Number of internodes plant 1

The data in respect to number of internodes plant-1 at 60, 90 and 120 DAS of sorghum as influenced by different silicon and nitrogen levels are presented in Table 4.

From the above data it was noticed that the effect of different levels of silicon on number of internodes plant-1 ranges between 5.43 to 6.33, 7.30 to 8.11 and 7.85 to 8.58 at 60, 90 and 120 DAS, respectively. The treatment S1.0 recorded significantly higher number of internodes plant^{-1} at 60 (6.33), 90 (8.11) and 120 (8.58) DAS over rest of the treatments except treatment S0.5. However, the treatment S0.5 was at par with treatment S1.0. Lower number of internodes was recorded in treatment S0 at 60 (5.43), 90 (7.30) and 120 (7.85) DAS than the rest of the treatments. The number of internodes plant-1 increased by increasing silicon levels.

Table 4: Effect of silicon and nitrogen levels on number of internodes plant-1 of sorghum at 60, 90 and 120 DAS

Number of internodes plant 1			
Silicon levels %	**At 60 DAS**	**At 90 DAS**	**At 120 DAS**
S0	5.43	7.30	7.85
S0.25	5.72	7.53	8.07
S0.5	6.10	7.90	8.31
S1	6.33	8.11	8.58
S.E.	0.20	0.18	0.12
C.D. at 5%	0.59	0.54	0.36
Nitrogen levels (kg ha 1)			
N0	3.60	5.73	6.51
N40	5.43	7.45	7.91
N80	6.73	8.56	8.85
N120	7.80	9.20	9.53
S.E.	0.20	0.18	0.12
C.D. at 5%	0.59	0.54	0.36

Interaction (S X N)			
S.E.	0.40	0.37	0.24
C.D. at 5%	NS	NS	NS

The response of different levels of nitrogen on number of internodes plant^{-1} ranged between 3.60 to 7.80, 5.73 to 9.20 and 6.51 to 9.53 at 60, 90 and 120 DAS, respectively. The treatment N120 recorded significantly highest number of internodes plant-1 at 60 (7.80), 90 (9.20) and 120 (9.53) DAS over rest of the treatment. All the levels were significantly superior on their lower levels. Significantly the lowest number of internodes at 60 (3.60), 90 (5.73) and 120 (6.51) DAS was recorded in treatment N0. Number of internodes increased due to increasing nitrogen levels. Similar results were also reported by Nirmal *et al*., (2016) [16].

Whereas the interaction effect of different silicon and nitrogen levels on number of internodes plant-1 at 60, 90 and 120 DAS was found to be non-significant.

Chlorophyll content (mg g-1)

The effect of silicon and nitrogen levels on chlorophyll a, chlorophyll b and Total chlorophyll content in leaf at 45 DAS of sorghum was narrated in Table 5. The data showed that the various silicon and nitrogen levels differed significantly with respect to chlorophyll content.

It was noticed from the data that the effect of different levels of silicon on chlorophyll a, chlorophyll b and total chlorophyll content ranged between 1.16 mg g-1 to 1.29 mg g-1 and 0.64 mg g-1 to 0.74 mg g^{-1} and 1.80 to 2.03 mg g-1 respectively at 45 DAS. Significantly higher chlorophyll a (1.29 mg g-1), and total chlorophyll (2.03 mg g-1) content obtained in treatment S1.0 over rest of the treatments. But the treatment S1.0 was recorded significantly higher chlorophyll b (0.74 mg g-1) over rest of the treatment except treatment S0.5. However, the treatment S0.5 was at par with S1.0 in case of chlorophyll b content. The treatment S0 recorded lower chlorophyll a (1.16 mg g-1), chlorophyll b (0.64 mg g-1) and total chlorophyll (1.80 mg g-1) content than rest of the treatments. Similar findings were also reported by Jawahar *et al.*, (2019) [10]. It might be due to Si absorbed by plants accumulated in the epidermis, so it found beneficial for better crop structural changes and better sunlight capture. Increasing the efficiency of sunlight absorption allows the activity of photosynthesis to run smoothly so as to affect the concentration of chlorophyll content in leaf tissue which bring positive impact on chlorophyll content.

Table 5: Effect of silicon and nitrogen levels on chlorophyll a and chlorophyll b content (mg g-1) in leaves at 45 DAS

	Silicon Levels (%)				
Nitrogen Levels (Kg ha 1)	**S0**	**S0.25**	**S0.5**	**S1.0**	**Mean**
Chlorophyll "a"					
N0	0.89	0.96	1.07	1.12	1.01
N40	1.13	1.16	1.19	1.25	1.18
N80	1.26	1.27	1.32	1.34	1.29
N120	1.35	1.36	1.37	1.47	1.38
Mean	1.16	1.19	1.23	1.29	
	Silicon	**Nitrogen**	**S X N**		
S.E ±	0.01	0.01	0.03		
C. D. at 5%	0.04	0.04	0.09		
Chlorophyll "b"					
N0	0.45	0.51	0.56	0.62	0.53
N40	0.63	0.65	0.69	0.70	0.67
N80	0.73	0.74	0.75	0.77	0.74
N120	0.77	0.78	0.79	0.88	0.82
Mean	0.64	0.67	0.69	0.74	
	Silicon	Nitrogen	S X N		
S.E.±	0.02	0.02	0.04		
C. D. at 5%	0.06	0.06	0.13		
Total Chlorophyll (mg g-1)					
N0	1.34	1.47	1.63	1.74	1.54
N40	1.76	1.81	1.88	1.95	1.85
N80	1.99	2.01	2.07	2.11	2.04
N120	2.12	2.14	2.16	2.35	2.19
Mean	1.80	1.85	1.93	2.03	
	Silicon	Nitrogen	S X N		
S.E ±	0.02	0.02	0.04		
C. D. at 5%	0.06	0.06	0.12		

Above data indicated that the effect of different levels of nitrogen on chlorophyll a, chlorophyll b and total chlorophyll content ranged between 1.01 to 1.38, 0.53 to 0.82 and 1.54 to 2.19 mg g-1 respectively at 45 DAS of sorghum. Significantly higher values of chlorophyll a (1.38 mg g-1), chlorophyll b (0.82 mg g-1) and total chlorophyll (2.19 mg g-1) content were obtained under nitrogen application in treatment N120 at 45 DAS over rest of the treatments. All the treatments were significantly superior over their lower levels. Significantly lower values of chlorophyll a (1.01 mg g-1), chlorophyll b (0.53 mg g-1) and total chlorophyll (1.54 mg g-1) content were obtained in treatment N0 than the rest of the treatments at 45 DAS. It was also reported by Khursheed and Mahammad (2015). Chlorophyll content was significantly influenced due to nitrogen levels and was understandable, because nitrogen is a structural element of chlorophyll and protein molecules, and thereby affects formation of chloroplasts and accumulation of chlorophyll in them.

The interaction effect of different silicon and nitrogen levels on chlorophyll content at 45 DAS of sorghum was found to be significant. The treatment S1.0N120 recorded significantly higher chlorophyll a (1.47 mg g-1), chlorophyll b (0.88 mg g-1) and total chlorophyll (2.35 mg g-1) content over rest of the treatments at 45 DAS. Treatment S0N0 recorded lower chlorophyll a (0.89 mg g-1), chlorophyll b (0.45 mg g-1) and total chlorophyll (1.34 mg g-1) content than the rest of the treatments at 45 DAS.

Conclusion

Combined application of silicon and nitrogen significantly increased the growth parameters of sorghum crop than the separate application of silicon and nitrogen. Treatment S1N120 is significantly superior over rest of the treatments in case of growth parameters of sorghum crop.

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