International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 01-06-2021, Accepted: 16-06-2021, Published: 02-07-2021
Volume 6, Issue 4, 2021, Page No. 09-12

Effect of silicon on vegetative growth and root characteristics of rice

Phurailatpa Pooja Sharma[1], S Jawahar[2*], C Kalaiyarasan[3], MV Sriramachandrasekharan[4]
[1]Ph.D. Scholar, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India
[2]Assistant Professor in Agronomy, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India
[3]Associate Professor in Agronomy, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India
[4] Professor of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India

Abstract
Field experiment was conducted to study the effect of silicon on vegetative growth and root characteristics of rice during Kharif season during (July-Nov2019) at Department of Agronomy, Annamalai University, Tamil Nadu, India. The experiment was laid out in split plot design with two replications. The main plots comprised of M_1- Dry Seeded Rice (DSR), M_2- Wet Seeded Rice (WSR) and M_3- Transplanted Rice (TR) and sub plots are S_1- RDF, S_2 - S_1 + 100 kg Si ha^{-1} through Calcium Silicate + Silicate solubilising bacteria (SSB), S_3 - S_1 + 200 kg Si ha^{-1} through Calcium Silicate + SSB, S_4 - S_1 + 100 kg Si ha^{-1} through Diatomaceous Earth, S_5 - S_1 + 200 kg Si ha^{-1} through Diatomaceous Earth, S_6 – S_1 + 100 kg Si ha^{-1} through Fly ash + SSB and S_7 – S_1 + 200 kg Si ha^{-1} through Fly ash + SSB. Among the methods of rice establishments, transplanted method registered higher vegetative growth (plant height, number of tillers, chlorophyll content, leaf area index and dry matter production) and root characteristics (root length and root volume) of rice, which was followed by wet seeded rice, With respect to silicon sources and its levels, application of 200 kg Si ha^{-1} through Diatomaceous Earth along with RDF recorded higher vegetative growth (plant height, number of tillers hill^{-1}, chlorophyll content, leaf area index and dry matter production) and root characteristics (root length and root volume) of rice. This was closely followed by 100 kg Si ha^{-1} through Diatomaceous Earth along with RDF. The interaction effect between establishment methods and silicon was significant. The treatment combination of Diatomaceous Earth @ 200 kg Si ha^{-1} earth along with RDF and transplanted method registered its superiority over others and recorded higher vegetative growth (plant height, number of tillers hill^{-1}, chlorophyll content, leaf area index and dry matter production) and root characteristics (root length and root volume) of rice. Thus it can be concluded that silicon fertilization through Diatomaceous Earth @200 kg Si ha^{-1} + RDF to transplanted rice holds immense potentially to enhance the vegetative growth of rice.

Keywords: silicon, establishment methods, rice, vegetative growth, root characteristics

Introduction

Globally, rice is being widely cultivated in tropical regions and it is cultivated in an area of 161.28 million hectares with an annual production of 715.75 million tonnes (MoAFW, 2018) [12]. In India, the project production of rice during 2020-2021 is 102.36 million tonnes (Parida *et al*, 2020) [14]. In Tamil Nadu, rice is cultivated in an area of 2.08 million hectares with the production of 6.57 million tonnes (MoA yearbook, 2019) [11]. To meet the growing demand of 130 million tonnes of milled rice the productivity needs to increase by 4.03 tonnes ha^{-1} thereby maintaining the present level of food sufficiency (Soumya *et al*, 2020) [21]. Silicon is the second most abundant element in the earth's crust. (Bhatt and Sharma, 2018) Silicon is absorbed by the plant roots through a passive process regulated by transpiration stream, which occurs via xylem along with water or by inactive process through transporters located in the plasma membrane of root cells. The most noticeable beneficial effect of Si is an enhanced resistance to both biotic and abiotic stresses (Ma & Yamaji, 2006) [10]. Various studies had indicated that Si accumulated in plants exerts several beneficial effects on plant growth (Swain and Rout, 2018). Silicon is especially important in typical Si-accumulating plants, such as rice (Oryza sativa) [14, 18, 21] for healthy growth and high productivity (Epstein & Bloom, 2005) [4]. Role of silicon seemed significantly effecting in plant health and growth has been investigated in silicon accumulating crops (Jinab *et al*, 2010) [5]. Many scientists working on role of silicon in plant growth have concluded that reduced amount of silicon in plant develops necrosis, growth retardation and reduces grain yield in rice crop (Shashidhar [17] *et al*, 2008). Silicon is an important micronutrient for healthy and competitive growth of all cereals including rice in Asia (Singh *et al*, 2020) [18, 23]. Silicon is the only element that does not damage plants with excess accumulation. It has been demonstrated to be necessary for healthy growth and stable production. For this reason, Si has been recognized as an agronomically essential element in Japan and silicate fertilizers have been applied to paddy soils (Malav *et al*, 2018). The positive effects of silicon on rice growth and production, manifested when it was specifically supplied during the reproductive growth stage (panicle initiation to heading) than that of vegetative and ripening stages, which exerted a feed-forward effect on photosynthesis coupled with increased in both stomatal conductance and biochemical capacity to fix CO_2 (carbon dioxide) (Lavinsky *et al*, 2016) [8]. Although silicon has not been considered important for vegetative growth but it aids the plant in healthy development under stresses in different grasses especially in rice (Khan *et al*, 2018) [6]. Plant tissue analysis has revealed that the optimum amount of silicon is necessary for cell development and differentiation (Liang *et al*, 2005) [9]. Therefore, field experiment was conducted to study the effect of silicon on vegetative growth and root characteristics of rice.

Materials and Methods

Field experiment was conducted in the Department of Agronomy, Annamalai University, Cuddalore district during Kharif season (July- Nov2019) to study the effect on vegetative growth and root characteristics of rice. The soil of the experimental field is clay loam in texture with moderate fertility. The experiment was laid out in split plot design with two replications. The main plots comprised of M_1- Dry Seeded Rice (DSR), M_2- Wet Seeded Rice (WSR) and M_3- Transplanted Rice (TR) and sub plots are S_1- RDF, S_2 - S_1 + 100 kg Si ha^{-1} through Calcium Silicate + SSB, S_3 - S_1 + 200 kg Si ha^{-1} through Calcium Silicate + SSB, S_4 - S_1 + 100 kg Si ha^{-1} through Diatomaceous Earth, S_5 - S_1 + 200 kg Si ha^{-1} through Diatomaceous Earth, S_6 – S_1 + 100 kg Si ha^{-1} through Fly ash + SSB and S_7 – S_1 + 200 kg Si ha^{-1} through Fly ash + SSB. Rice variety ASD-16 was used for this study and was fertilized with 120:40:40 kg NPK ha^{-1}. Entire dose of P_2O_5 was applied as basal. N and K were applied in four equal splits at basal, tillering, panicle initiation and heading stages. Silicon sources and SSB were applied as basal as per the treatments. Observations for vegetative growth (plant height, number of tillers $hill^{-1}$, chlorophyll content, leaf area index and dry matter production) and root characteristics (root length and root volume) were recorded at tillering and flowering stages. Statistical analysis was performed using the split plot design as suggested by Gomez and Gomez (1984).

Results and Discussion

Vegetative growth and root characteristics

Vegetative growth (plant height, number of tiller $hill^{-1}$, chlorophyll content, leaf area index and dry matter production) and root characteristics (root length and root volume) of rice was significantly influenced by establishment methods and silicon fertilization (Table 1, 2 and 3). With respect to establishment methods, transplanted rice attained the highest vegetative growth (plant height- 47.78 and 68.65 cm, number of tillers $hill^{-1}$-11.32 and 14.89, chlorophyll content-3.83 and 5.48 mg g^{-1}, leaf area index - 3.51 and 4.45 and dry matter production- 5901 and 7181 kg ha^{-1}) and root characteristics (root length - 19.92 and 22.42 cm and root volume -26.49 and 31.78 cm^3) at tillering and flowering stages over wet and dry seeded rice. This could be due to lower competition in space, sunlight and nutrients in transplanted crop than other establishment methods (Pandey *et al.* 2018) [13]. and also deep penetration of roots resulting in efficient use of water and nutrient uptake (Kumhar *et al*, 2016) [7]. Regarding silicon sources and its levels, application of silicon through diatomaceous earth @ 200 kg ha^{-1} increased the vegetative growth (plant height- 50.26 and 70.23 cm, number of tillers $hill^{-1}$- 11.73 and 15.59), chlorophyll content- 5.21 and 3.63 mg g^{-1}), leaf area index- 3.62 and 4.57), dry matter production- 6055 and 7544 kg ha^{-1}) and root characteristics (root length- 18.08 and 20.98 cm and root volume - 25.38 and 30.77cm^3) at tillering and flowering stages. Tallest plant height could be due to deposition of silicon in leaf tissues and maintained leaf in erected position (Lakshmi *et al.* 2020). Maximum number of tillers $hill^{-1}$ is recorded due to production of expanding auxiliary buds which clearly depend upon the nutritional condition of mother clump because tillers receive nutrients from mother clump at early growth stages so that silicon improves the nutritional condition of mother clump automatically, mother clump produces more number of tillers $hill^{-1}$ (Singh *et al*, 2006) [18, 23]. Highest chlorophyll content by the application of silicon could be the possible reason for increasing SPAD readings due to maintenance of high photosynthetic activity, higher utilization of light and translocation of assimilated product to sink (Sivaranjani *et al*, 2020) [19]. Si treatments to plants induces accumulation of enzymes involved in photosynthesis and detoxification of reactive oxygen species (Schmidst *et al*, 1999) Higher leaf area index may be due to higher nutrient uptake by the plants (Soumya *et al*, 2020) [21]. Vasudevan *et al.* (2019) [22] reported that higher leaf area index could be due to higher leaf number $plant^{-1}$, erectness of leaves and also improves high interception of light by keeping leaves erect thereby stimulated canopy photosynthesis in rice. Dry matter production increases with increased levels of silicon. This might be due to the efficient utilization of sun light by making plant leaves more erect. Such ideal crop stand enhanced photosynthetic activity and translocation of assimilated product from source to sink. This ultimately resulted in higher dry matter accumulation (Patil *et al*, 2017) [15]. Increase in root length and root volume of rice might be due to the optimization of Si nutrition increases mass and volume of roots. Silicon addition increase the erectness of leaf of rice, it strengthens air canal, leading to more efficient oxygen supply to roots and limited loss of water. It plays an important role in the root formation of secondary and tertiary cells which is controlled by monosilicic acid in soil solution (Aravinthkumar, 2019) [1].

Combined effect between establishment methods and silicon fertilization, transplanted method of rice cultivation applied with silicon through diatomaceous earth @ 200 kg Si ha^{-1} recorded increased vegetative growth and root characteristics of rice. This could be due to seedlings planted in well puddled soil condition favoured the crop growth and adequate supply of plant available silicon to the crop during critical stages of crop growth.

Table 1: Effect of silicon on plant height, number of tillers hill^{-1}, chlorophyll content, leaf area index and dry matter production of rice at tillering stage

Main Plot / Sub Plot	Plant height (cm)				Number of tillers hill^{-1}				Chlorophyll content (mg g^{-1})				Leaf area index				Dry matter production (kg ha^{-1})			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	M_1	M_1	M_2	M_3	Mean
S_1	31.99	38.88	41.24	37.37	9.12	9.87	10.32	9.77	2.74	3.44	3.64	3.27	2.15	3.04	2.92	2.70	4906	5306	5473	5228
S_2	33.63	40.43	43.99	39.35	9.39	10.12	10.60	10.04	2.80	3.51	3.72	3.34	2.63	3.24	3.41	3.09	5046	5433	5613	5364
S_3	38.79	44.88	47.71	43.79	10.08	10.77	11.29	10.71	2.92	3.61	3.83	3.45	2.85	3.35	3.53	3.24	5313	5713	5906	5644
S_4	46.19	48.27	51.41	48.62	10.64	11.37	12.01	11.34	3.02	3.72	3.94	3.56	3.12	3.57	3.70	3.46	5579	5979	6179	5913
S_5	45.11	51.71	53.97	50.26	10.97	11.81	12.40	11.73	3.08	3.78	4.05	3.63	3.32	3.65	3.90	3.62	5719	6119	6326	6055
S_6	37.59	43.68	46.51	42.59	9.96	10.65	11.17	10.59	2.9	3.59	3.81	3.43	2.73	3.32	3.51	3.19	5233	5633	5819	5562
S_7	40.04	46.72	49.60	45.45	10.25	10.94	11.46	10.88	2.96	3.65	3.87	3.49	2.92	3.40	3.58	3.30	5400	5799	5993	5731
MEAN	39.05	44.94	47.78		10.06	10.79	11.32		2.91	3.61	3.83		2.82	3.37	3.51		5314	5712	5901	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.40	0.59	1.86	0.83	0.23	0.06	0.37	0.22	0.10	0.01	0.21	0.04	0.06	0.03	0.15	0.09	93	42	136	74
CD (p = 0.05)	2.83	1.20	3.75	1.68	0.46	0.13	0.75	0.45	0.21	0.03	0.43	0.08	0.13	0.07	0.31	0.18	187	84	275	149

Table 2: Effect of silicon on plant height, number of tillers hill^{-1}, chlorophyll content, leaf area index and dry matter production of rice at flowering stage

Main Plot / Sub Plot	Plant height (cm)				Number of tillers hill^{-1}				Chlorophyll content (mg g^{-1})				Leaf area index				Dry matter production (kg ha^{-1})			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	50.75	58.50	62.20	57.15	12.29	12.99	13.44	12.91	4.09	4.79	5.14	4.67	2.54	3.49	3.79	3.27	5513	6233	6406	6051
S_2	52.88	60.65	64.65	59.39	12.72	13.40	13.88	13.33	4.3	5.01	5.39	4.9	2.74	3.69	4.00	3.48	5773	6433	6639	6282
S_3	60.63	64.32	68.54	64.50	13.78	14.44	14.97	14.40	4.39	5.12	5.50	5.0	3.09	4.04	4.39	3.84	6339	6953	7179	6824
S_4	64.61	68.86	73.30	68.92	14.39	15.15	15.70	15.08	4.52	5.24	5.64	5.13	3.48	4.43	4.92	4.28	6706	7333	7693	7244
S_5	65.95	70.11	74.64	70.23	14.90	15.59	16.29	15.59	4.6	5.32	5.72	5.21	3.78	4.73	5.21	4.57	6926	7739	7966	7544
S_6	59.18	63.03	67.09	63.10	13.52	14.18	14.71	14.14	4.35	5.08	5.46	4.96	2.94	3.89	4.24	3.69	6239	6786	7046	6690
S_7	62.15	65.87	70.14	66.05	14.08	14.74	15.27	14.70	4.45	5.17	5.56	5.06	3.28	4.23	4.59	4.03	6473	7106	7339	6973
MEAN	59.45	64.48	68.65		13.67	14.36	14.89		4.38	5.10	5.48		3.12	4.07	4.45		6282	6940	7181	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	2.04	0.74	2.20	0.67	0.21	0.13	0.36	0.27	0.18	0.02	0.26	0.04	0.18	0.08	0.33	0.15	118	67	210	153
CD (p = 0.05)	4.12	1.49	4.45	1.35	0.43	0.27	0.72	0.54	0.37	0.05	0.52	0.09	0.36	0.16	0.66	0.30	239	135	425	310

Table 3: Effect of silicon on root length and root volume of rice at tillering and flowering stages

Main Plot / Sub Plot	Root length (cm)								Root volume (cm^3)							
	tillering				floweing				Tillering				flowering			
	M_1	M_2	M_3	M_1	M_1	M_1	M_3	Mean	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	Mean
S_1	10.64	16.05	18.05	14.91	12.86	18.06	20.21	17.04	15.19	20.98	23.43	19.87	18.25	25.61	27.71	23.86
S_2	11.10	16.57	18.71	15.46	13.52	18.94	21.22	17.89	15.87	21.82	24.43	20.71	19.32	26.96	29.28	25.19
S_3	11.94	17.67	19.94	16.52	14.36	19.91	22.36	18.88	17.22	23.49	26.26	22.32	21.05	29.12	31.58	27.25
S_4	12.82	18.62	21.07	17.50	15.66	21.13	23.69	20.16	18.94	25.78	28.82	24.51	22.87	31.99	34.68	29.85
S_5	13.40	19.20	21.64	18.08	16.14	22.07	24.74	20.98	19.61	26.68	29.84	25.38	23.60	32.96	35.75	30.77
S_6	11.65	17.38	19.65	16.23	14.07	19.62	22.07	18.59	16.61	22.87	25.58	21.69	20.37	28.52	30.90	26.60
S_7	12.36	18.09	20.36	16.94	14.65	20.63	22.68	19.32	17.93	24.20	27.09	23.07	21.91	30.06	32.56	28.18
MEAN	11.99	17.65	19.92		14.47	20.05	22.42		17.34	23.69	26.49		21.05	29.32	31.78	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.11	0.16	1.77	0.32	1.11	0.16	1.87	0.42	1.33	0.32	2.22	0.45	1.20	0.33	2.49	0.53
CD (p = 0.05)	2.25	0.32	3.58	0.65	2.25	0.32	3.78	0.85	2.68	0.65	4.48	0.91	2.42	0.67	5.03	1.07

Refrences

1. Aravinthkumar. Response of rice to dual application of nitrogen and silicon in Typic Ustifluvent soil (Padugai series). M.Sc. (Ag.) Thesis, Annamalai University, Annamalai nagar, Chidambaram, Tamil Nadu, India, 2019.
2. Bhagya Lakshmi M, Latha M, Sujani Rao Ch, Sree Rekha M. Effect of different sources and methods of silicon application on direct sown rice. Journal of Pharmacognosy and Phytochemistry,2020:9(5):461-465.
3. Divya Bhatt, Geeta Sharma. Role of silicon in counteracting abiotic and biotic plant stresses. International Journal of Chemical Studies, 2018:6(2):1434-1442
4. Epstein E, Bloom AJ Mineral nutrition of plants: principles and perspectives, 2nd edn. Sinauer Associates, Sunderland, 2005.
5. Jinab H, Solond M, Varietel M Functional food product development. Pub Smith & Charter, 2010.
6. Khan FH, M Adil, S Jahan, M Iqbal, MM Mozumder, A Sultana *et al*. Consequence of foliar application of silicon on yield and quality of rice in T Aman season of Bangladesh. Eco-friendly Agril J, 2018:11 (09):88-92.
7. Kumhar BL, Chavan VG, Rajemahadik VA, Kanade VM, Dhopavkar RV, Tilekar RN. Effect of Different Rice Establishment Methods on Growth, Yield and Different Varieties During Kharif Season Department of Agronomy, College of Agriculture, Dapoli. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli – 415 712, Distt. Ratnagiri. International Journal of Plant, Animal and Environment Sciences,2016:6(2),127–132.
8. Lavinsky AO, Detmann KC, Josimar VR, Avila RT, Sanglard ML, Pereira LF, *et al*. Silicon improves rice grain yield and photosynthesis specifically when supplied during the reproductive growth stage. Journal of Plant Physiology,2016:206:125-132.
9. Liang YC, Sun WC, Si J, Römheld V. Effects of foliar- and rootapplied silicon on the enhancement of induced

resistance to powdery mildew in Cucumis sativus. Plant Pathology,2005:54:678–685.
10. Ma JF, Yamaji N. Silicon uptake and accumulation in higher plants. Trends in Plant Science,2006:11:392-397.
11. MoA. Policy Note, Demand No.5- Agriculture. Government of Tamil Nadu, India, 2019.
12. MoAFW. Area production and yield of principal crops, 2018 Agricultural Statistics at a Glance, (Publ.) Ministry of Agricukture and Farmers Welfare, Government of India, New Delhi, 2018.
13. Mukesh Kumar Pandey, Ajay Verma, Aditya Sirmaur Ajay Dwivedi. Journal of pharmacognosy and phytochemistry,2018:7(1):501-505.
14. Parida, P, Behera, B, Behera SD. Weed management in rice (Oryza sativa L.) fallow for enhancement in productivity and profitability of rice-zero till toria (Brassica campestris) system. Indian J. Agro,2020:65(1):10-16.
15. Patil AA, AG Durgude, AL Pharande, AD Kadlag, CA Nimbalkar. Effect of calcium silicate as a silicon source on growth and yield of rice plants. International Journal of Chemical Studies,2017:5(6):545-549
16. Rinny Swain, Gyana Ranjan Rout. Effect of silicon interaction with nutrients in rice. Journal of Experimental Biology and Agricultural Sciences,2018:6(4):717 – 731.
17. Shashidhar HE, N Chandrashekhar, C Narayanaswamy, AC Mahendra, NB Prakash. Calcium silicate as silicon source and its interaction with nitrogen in aerobic rice. Paper presented in 4th International conference on silicon in agriculture, held at University of Kwa Zulu-Natal, South Africa, 2008, 93.
18. Singh K, Singh R, Singh JP, Singh Y, Singh KK. Effect of level and time of silicon application on growth, yield and its uptake by rice (Oryza sativa). Indian Journal of Agricultural Sciences,2006:76(7):410-413.
19. Sivaranjani C, Chithra M Baskar, R Thamiz Vendan, K Subrahmaniyan. Influence of silicon and nitrogen on chlorophyll content of rice var. TKM-13 in Entisol. Journal of pharmacognosy and phytochemistry, 2020:9(1):2245-2249.
20. Schmidt RE, Zhang X, Chalmerus DR. Response of photosynthesis and superoxide dismute to silica apply to creeping bentgrass grown under to fertility levels. Journal plant nutrition,1999:22:1763-1773
21. Soumya K, Girijesh GK, Veeranna HK, Dushyanthkumar BM, Sarvajna B Salimath. Effect of Nano Zinc and Silicon on crop growth and yield of rice (oryza sativa L). Int.J.Curr. Microbial. App.Sci, 2020:9(10):1112-1120.
22. Vasudevan S, Muthukumararaja MV, Srirama chandrasekharan. Efficacy of calcium silicate on morphological and yield of rice in salt affected soil. International Journal of Multidisciplinary Research and Development,2019:6(9):159-163.
23. Veer Singh, Virendra Singh, Satybhan Singh, Richa Khanna. 2020. Effect of Zinc and Silicon on Growth and Yield of Aromatic Rice (Oryza Sativa) in North-Western Plains of India. Journal of Rice Research and Developments,2020:3(1)82-86.