The Andhra Agric. J 65 (4): 908-912, 2018

Effect of Silicon Nutrition on Photosynthetic Attributes of Rice (*Oryza Sativa* .L)

L Anand, B Sreekanth, K Jayalalitha and D P B Jyothula
Department of Crop Physiology, Agricultural College, Bapatla, A.P.

ABSTRACT

A field experiment on "Effect of silicon nutrition on photosynthetic attributes of rice (*Oryza sativa* .L)" was conducted during *kharif* season 2017-18 at Agricultural college farm, Bapatla. The experiment was laid out in a Randomized Block Design with eight treatments, each replicated thrice. Of these, four treatments are soil application with silixol granules and other four are foliar application with 1 % sodium silicate including both controls (without silicon and foliar application with water). The results revealed that, at all the three sampling times silicon application either through soil or foliar modes increased the photosynthetic rate, stomatal conductance, leaf area and SPAD value of rice leaves, and this increase was more with soil application. Among the stages, except SPAD value photosynthetic rate, stomatal conductance and leaf area were highest in mid-reproductive stage, irrespective of time and form of silicon application. But in the same manner transpiration rate of rice leaf was decreased with silicon application either through soil or foliar forms and this decrease was more in soil application.

Key words: *Photosynthetic attributes, Rice, Silicon nutrition*

Rice is most widely consumed staple food crop of about two third of the world human population especially in Asia. India has the largest rice acreage and ranked second position in production. In India, rice is grown in an area of 44.1 Mha with a production of 105.48 Mt and productivity of 2391 Kg ha^{-1}. In Andhra Pradesh, it is grown in an area of 2.39 Mha with a production of 7.24 Mt and productivity of 3022 Kg ha^{-1} (Annual report, 2017). Silicon (Si) is the second most abundant element of the earth's crust and plays a significant role in imparting biotic, abiotic stress resistance and crop productivity (Savant *et al*., 1997). Rice is a silicon (Si) accumulating plant. Silica is required for healthy and productive development of the rice plant (Yoshida, 1975). Effect of silicon on yield are related to the deposition of the element under the leaf epidermis which results a physical mechanism of defence, reduces lodging, increases photosynthesis capacity and decreases transpiration losses (Korndorfer *et al*., 2004). Hence, the study was planned to understand the effect of silicon nutrition on photosynthetic attributes of rice.

MATERIAL AND METHODS

A field experiment was conducted at Field No. 49, Southern Block, Agricultural College Farm, Bapatla during *kharif* season 2017-18 and was laid out in a Randomized Block Design with eight treatments, of these, four are soil application (NSi -control; SVeg- Soil application of silicon at mid vegetative stage; SRep- Soil application of silicon at mid reproductive stage; SRip- Soil application of silicon at mid ripening stage) with silixol granules (37.5 kg ha^{-1}) and other four are foliar application (FW- Foliar application of water; FVeg- Foliar application of silicon at mid vegetative stage; FRep- Foliar application of silicon at mid reproductive stage; FRip- Foliar application of silicon at mid ripening stage) with sodium silicate (1 %). Silicon nutrition was applied either through soil or foliar modes at three different stages of rice *cv* BPT-5204 *viz*., mid-vegetative stage (20 DAT), mid-reproductive stage (55 DAT) and mid-ripening stage (85 DAT). Leaf photosynthetic attributes were measured at 15 days after silicon application. Photosynthetic rate, stomatal conductance and transpiration rate were measured in the target leaf, between 10:00 AM to 12:00 noon by using a portable infra red gas analyser (TPS-2, PP Systems). Leaf area was measured by using an electronic leaf area meter (Model No. 211, Systronics). SPAD Chlorophyll Meter Reading (SCMR) values were measured by using a SPAD meter (SPAD-502) in the third leaf from the top, in the main culm of tagged hills. The data generated from present experiment was statistically analyzed by methods suggested by Panse and Sukhathme (1978).

RESULTS AND DISCUSSION

Rate of photosynthesis

Significant differences were observed in photosynthetic rate of rice leaves under silicon nutrition when it was applied at mid-vegetative stage, mid-reproductive stage and mid-ripening stages (Table 1). During the last sampling time, soil application of silicon at mid-reproductive stage recorded higher photosynthetic rate (25.95 mmol CO_2 m^{-2} s^{-1}) than mid-vegetative (23.06 mmol CO_2 m^{-2} s^{-1}) and mid-ripening

Table 1. Effect of silicon on photosynthetic attributes of rice leaves

S. No	Treatments	At mid Vegetative stage			At mid Reproductive stage			At mid Ripening stage		
		Rate of photosynthesis	Rate of Stomatal conductance	Transpiration rate	Rate of photosynthesis	Rate of Stomatal conductance	Transpiration rate	Rate of photosynthesis	Rate of Stomatal conductance	Transpiration rate
		(m mol CO_2 $m^{-2} s^{-1}$)	(m mol $m^{-2}s^{-1}$)	(m mol $m^{-2}s^{-1}$)	(m mol CO_2 $m^{-2} s^{-1}$)	(m mol $m^{-2}s^{-1}$)	(m mol $m^{-2}s^{-1}$)	(m mol CO_2 $m^{-2} s^{-1}$)	(m mol $m^{-2}s^{-1}$)	(m mol $m^{-2}s^{-1}$)
1	NSi	15.10	521.57	6.82	25.29	533.25	11.51	19.56	516.44	6.48
2	SVeg	20.75	544.44	5.37	34.26	536.67	10.38	23.06	523.83	5.54
3	SRep	15.26	515.82	6.83	38.24	565.55	9.68	25.95	528.85	5.22
4	SRip	15.80	520.39	6.61	27.04	530.70	11.29	21.95	526.01	5.45
5	FW	16.60	517.64	6.75	27.25	532.79	11.12	19.30	513.41	6.77
6	FVeg	19.41	537.75	6.16	33.82	538.27	10.46	22.42	522.24	5.34
7	FRep	14.84	522.54	6.77	36.74	553.34	10.11	24.66	527.42	5.21
8	FRip	16.10	519.62	6.89	28.15	532.81	11.05	21.07	525.08	5.27
	SEm	0.6	5.11	0.21	2.03	6.07	0.29	0.85	5.16	0.14
	CD (0.05)	1.83	15.5	0.64	6.17	18.43	0.88	2.6	15.66	0.43
	CV (%)	6.24	1.68	5.68	11.24	1.94	4.72	6.68	1.71	4.4

Table 2. Effect of silicon on photosynthetic attributes of rice leaves

S. No	Treatments	At mid Vegetative stage		At mid Reproductive stage		At mid Ripening stage	
		Leaf area (cm^2 $plant^{-1}$)	SPAD value	Leaf area (cm^2 $plant^{-1}$)	SPAD value	Leaf area (cm^2 $plant^{-1}$)	SPAD value
1	NSi	414.19	31.58	771.19	36.31	609.46	37.88
2	SVeg	494.55	38.57	864.71	37.45	736.49	37.84
3	SRep	430.43	32.51	980.87	40.60	776.83	42.42
4	SRip	433.71	32.15	814.13	36.22	698.01	36.84
5	FW	410.13	31.39	757.25	36.76	597.47	36.26
6	FVeg	481.37	35.35	847.91	37.09	726.54	37.15
7	FRep	424.48	30.69	961.33	37.31	744.10	38.89
8	FRip	418.40	31.45	755.03	36.84	667.14	36.07
	SEm	6.23	1.27	13.9	0.69	10.53	0.87
	CD (0.05)	18.9	3.87	42.18	2.1	31.96	2.64
	CV (%)	2.46	6.71	2.85	3.22	2.62	3.98

stages (21.95 mmol CO_2 m^{-2} s^{-1}). Similarly in case of foliar application of silicon at mid-reproductive stage noted higher rates of photosynthesis (24.66 mmol CO_2 m^{-2} s^{-1}) than mid-vegetative (22.42 mmol CO_2 m^{-2} s^{-1}) and mid-ripening stages (21.07 mmol CO_2 m^{-2} s^{-1}). There were no significant differences between the treatments i.e. without any silicon application (NSi) and foliar application of water (FW) with regards to the rate of photosynthesis. Based on the above results, silicon application either through soil or foliar mode increased the rate of photosynthesis of rice leaves, and this increase was more with soil application. These results are in conformity with Abed-Ashtiani *et al.* (2012) who observed better growth parameters with soil application over foliar application of silicon in rice. Photosynthetic rate was highest in mid-reproductive stage, irrespective of time and form of silicon application. These are in agreement with the findings of Detmann *et al.* (2012) and Lavinsky *et al.* (2016) in rice, and Kaufman (1979) in sugarcane. This might be due to Si fertilization improved the resistance to lodging and also increases the erectness of leaves and leaf blades; which allow better light transmittance through plant canopies and thus indirectly improve whole-plant photosynthesis in rice (Savant *et al.,* 1997).

Stomatal conductance

Soil application of silicon at mid-reproductive stage recorded higher stomatal conductance (528.85 mmol $m^{-2}s^{-1}$) than mid-vegetative (523.83 mmol $m^{-2}s^{-1}$) and mid-ripening stages (526.01 mmol $m^{-2}s^{-1}$) at last sampling time. Similarly, foliar application of silicon at mid-reproductive stage noted higher stomatal conductance (527.42 mmol $m^{-2}s^{-1}$) than mid-vegetative (522.24 mmol $m^{-2}s^{-1}$) and mid-ripening stages (525.08 mmol $m^{-2}s^{-1}$). Silicon application either through soil or foliar forms increased the stomatal conductance of rice leaves, and this increase was more with soil application (Table 1). These results are in conformity with Abed-Ashtiani *et al.* (2012) who observed better growth parameters with soil application over foliar application of silicon in rice. Among the stages, stomatal conductance was highest in mid-reproductive stage, irrespective of time and form of silicon application. These are in agreement with the findings of Detmann *et al.* (2012) and Lavinsky *et al.* (2016) who demonstrated that Si played important role in enhancing the sink size and strength, which, in turn, exerted a feed-forward effect on photosynthesis that was coupled with increased stomatal conductance and biochemical capacity to fix CO_2,when Si is specifically supplied during the reproductive growth stage (panicle initiation to heading) of rice.

Transpiration rate

Results presented in the Table 1 showed significant differences in transpiration rate of rice leaves by silicon nutrition which was applied at mid-vegetative, mid-reproductive and mid-ripening stages. There were no significant differences between the treatments *i.e.*without any silicon application (NSi) and foliar application of water (FW) pertaining to transpiration rate. During the last sampling time, soil application of silicon at mid-reproductive stage recorded lower transpiration rate (5.22 m mol $m^{-2}s^{-1}$) than mid-vegetative (5.54 m mol $m^{-2}s^{-1}$) and mid-ripening stages (5.45 m mol $m^{-2}s^{-1}$). Similarly, foliar application of silicon at mid-reproductive stage recorded lower transpiration rate (5.21 m mol $m^{-2}s^{-1}$) than mid-vegetative (5.34 m mol $m^{-2}s^{-1}$) and mid-ripening stages (5.27 m mol $m^{-2}s^{-1}$). Silicon application either through soil or foliar modes decreased the rate of transpiration, and this decrease was more with soil application. Decrease in transpiration rate by silicon application over control was reported earlier in rice (Rani *et al.,* 1997), barley (Kudinova, 1974) and sorghum (Ahmed *et al*., 2011). This decrease in transpiration rate by silicon nutrition could be due to deposition of silica between the cuticle and epidermal cells (Yoshida *et al*., 1962a).

Leaf area

Significant differences were observed in leaf area of rice with silicon nutrition at different stages (Table 2). Soil application of silicon at mid-reproductive stage gives higher leaf area (776.83 sq.cm plant^{-1}) than mid-vegetative stage (736.49 sq.cm plant^{-1}) and mid-ripening stage (698.01 sq.cm plant^{-1}) at last sampling time. Likewise, foliar application of silicon at mid-reproductive stage noted higher leaf area (744.10 sq.cm plant^{-1}) than mid-vegetative (726.54 sq.cm plant^{-1}) and mid-ripening stages (667.14 sq.cm plant^{-1}). Silicon application either through soil or foliar forms increased the leaf area of rice leaves, and this increase was more with soil application. This was in conformity with the results of Abed-Ashtiani *et al.* (2012) who observed better growth parameters with soil application over foliar application of silicon in rice. Increase in leaf area in rice by silicon application over control was reported earlier in rice (Rani *et a*l., 1997 and Pati *et al*., 2016), wheat (Chen *et al.*, 2011) and sorghum (Ahmed *et al.,* 2011). Silicon nutrition increased the source and sink strength and might have provided resistance against disease and insects, through which leaf became healthier and increased the leaf area (Chen *et al.,* 2011).

SPAD Chlorophyll Meter Reading (SCMR) values

Among all the three sampling times silicon application significantly increased the SPAD values of rice leaves (Table 2). Comparing the results with respect to last sampling time, soil application of silicon at mid-reproductive stage recorded highest SPAD value (42.42) than mid-vegetative (37.84) and mid-ripening stages (36.84). Similarly, foliar application of silicon at mid-reproductive stage recorded higher SPAD value (38.89) than mid-vegetative (37.15) and mid-ripening stages (36.07). Silicon application either through soil or foliar modes increased the SPAD value, and this increase was more with soil application. These results are in conformity with the results of Abed-Ashtiani *et al*. (2012) who observed improved growth parameters with soil application over foliar application of silicon in rice. Increase in SPAD value/chlorophyll content by silicon application over control was reported earlier by song *et al*. (2013) in rice and Ahmed *et al*. (2011) in sorghum. The increase in SPAD value of all rice plants under silicic acid treatment indicated that silicon is required for normal development of the photosynthetic apparatus and for chlorophyll synthesis in the leaf and stem, which improved the growth and yield.

CONCLUSION

It is evident from our results that silicon nutrition in rice increases the photosynthetic attributes like photosynthetic rate, stomatal conductance, leaf area and SPAD value; decreases transpiration rate, which ultimately enhances the final yield of rice. This increase/ decrease of photosynthetic attributes were more with soil application with silixol granules than foliar application with sodium silicate.

LITERATURE CITED

Ahmed M, Hassen F U, Qadeer U and Aslam M A 2011 Silicon application and drought tolerance mechanism of sorghum. *African Journal of Agricultural Research.* 6: 594-607.

Annual Report 2017 Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. 3.

Abed-Ashtiani F A, Kadir J B, Selama, A B, Hanif A H B M and Nasehi A 2012 Effect of foliar and root application of silicon against rice blast fungus in MR219 rice variety. *Plant Pathology Journal*. 28 (2): 164-171.

Chen W, Yao X, Cai K and Chen J 2011 Silicon alleviates drought stress of rice plants by improving plant water status, photosynthesis and mineral nutrient absorption. *Biological Trace Element Research.* 142: 67–76.

Detmann K C, Araujo W L, Martins S C, Sanglard L MV P, Reis JV, Detmann E, Rodrigues, F Á, Nunes-Nesi A, Fernie A R and DaMatta, F M 2012 Silicon nutrition increases grain yield, which, in turn, exerts a feed-forward stimulation of photosynthetic rates via enhanced mesophyll conductance and alters primary metabolism in rice. *New Phytologist*. 196: 752 -762.

Kaufman P B, Takeoka Y and Carlson T J 1979 Studies on silica deposition in sugarcane using scanning electron microscopy. *Phytomorphology*. 29: 185-193.

Korndorfer G H, Pereira H S and Nolla A 2004 Analise de silicio: Solo, planta e fertilizante. Boletim Tecnico n. 2. GPSi/ICIAG/UFU, Uberlândia.

Kudinova L I 1974 The effect of silicon on weight of plant barley. *Sov Soil Science.* 6: 39–41.

Lavinsky A O, Detmann K C, Josimar V R, Avila R T, Sanglard M L, Pereira L F, Sanglard M V P L, Rodrigues A F, Wagner L A and DaMatta F M 2016 Silicon improves rice grain yield and photosynthesis specifically when supplied during the reproductive growth stage. *Journal of Plant Physiology*. 206: 125-132.

Panse M and Sukhatme K 1978 Statistical Methods for Agriculture Workers. *Indian Council of Agriculture Research Publications.* 48-67.

Pati S, Pal B., Badole, S, Hazra G C and Mandal B 2016 Effect of silicon fertilization on growth, yield, and nutrient uptake of rice. *Communications in Soil Science and Plant Analysis*. 47 (3): 284-290.

Rani Y A, Narayanan A, Devi V S and Subbaramamma P 1997 The effect of silicon application on growth and yield of rice plants. *Annals of Plant Physiology*. 11(2): 125-128.

Savant N K, Snyder G H and Datnoff L E 1997 Silicon management and sustainable rice production. *Advances in Agronomy.* 58: 151–199.

Song A, Li P, Fan F, Li Z and Liang Y 2014 The effect of silicon on photosynthesis and expression of its relevant genes in rice (*Oryza sativa* L.) under high-zinc stress. *PLoS ONE* 9 (11): e113782.

Yoshida S 1975 *The physiology of silicon in rice*. Techechnical Bulletin No.25. Food and fertilizer Technical Centre, Taipei, Taiwan. 27.

Yoshida S, Ohnishi Y and Kitagishi K 1962 Histochemistry of silicon in rice plant I. A new method for determining the localization of silicon within plant tissues. *Soil science and Plant Nutrition*. 8 (1): 30-35.

Received on 08.06.2018 and revised on 28.08.2018