Int.J.Curr.Microbiol.App.Sci (2018) *7*(11): 838-844

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 11 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.711.099

Effect of Soil Application of Silicon on Growth and Yield Attributes of Rice (*Oryza sativa* L.)

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Keywords

Silixol granules, Reproductive stage, Rice, Growth, Yield attributes

Article Info

Accepted:
07 October 2018
Available Online:
10 November 2018

A B S T R A C T

A field experiment entitled "Effect of soil application of silicon on growth and yield attributes of rice (*Oryza sativa* L.) was conducted in *Kharif* season 2017-18. Soil application of silixol granules was given at the time of mid-vegetative, mid-reproductive and mid-ripening stages of rice. The experiment was arranged as randomized block design with four treatments which replicated thrice. Various growth parameters like Leaf area, photosynthetic rate, and SPAD values were evaluated at 15 days after silicon application in the target leaf and yield attributes like spikelets per panicle, filled spikelet percentage, test weight and grain yield per panicle were measured at harvest. The results revealed that all growth and yield parameters were influenced positively at mid reproductive stage of silicon application than vegetative and ripening stages.

Introduction

Rice (*Oryza sativa*) is a staple food that accounts for more than 22% of world's population calorie intake (Wailes *et al.*, 1997). China is the world's leading rice producer, while India has the largest rice acreage and ranked second position in production. In 2017, the global rice production reached 502.2 million tons and 83% of it was consumed for food intake (FAOSTAT, 2017). The world population has grown at an exponential rate and increasing awareness on healthy lifestyles, which demands for more gluten-free foods, are intensifying the global consumption of rice (USDA-ARS, 2015). Along with higher consumption of rice, climate changes such as extreme weather, unexpected temperature and rainfall fluctuations have affected crop productivity, and strategies to increase yield have been studied (Georgescu *et al.*, 2011 and Lobell *et al.*, 2011). An effective soil nutrient management is an essential component of crop production, responsible for increasing and sustaining crop yields at high levels (Gruhn *et al.*, 2000).

Interestingly, the only non-essential nutrient that is included in the guidelines for rice fertilization is silicon (Si) (Dobermann and Fairhurst, 2000). Silicon is the eighth most common element by mass and second most abundant element in soil after oxygen. Rice is considered to be a silicon accumulator plant and tends to actively accumulate Si to tissue concentrations of 5% or higher (Epstein, 2002). Reduced amount of silicon in plant produces necrosis, disturbance in leaf photosynthetic efficiency, growth retardation and reduces grain yield in cereals especially rice (Shashidhar *et al.,* 2008).

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 was reported by Lavinsky *et al.,* (2016), who surmised that proper levels of Si in reproductive structures played an unidentified role in increasing the yields of rice.

There were many reports, found that application of silicon during the reproductive growth stage is most important for plant growth and also increased the final yield of rice (Yoshida *et al.,* 1959; Okuda and Takahashi, 1961; Ma *et al.,* 1989 and Lee *et al.,* 1990) and sugarcane (Kaufman, 1979).

Silicon plays an important role in plant growth and development. It increased the photosynthetic rate (Detmann *et al.,* 2012 and Song *et al.,* 2014), leaf area (Gong *et al.,* 2003; Pati *et al.,* 2016; Sarma *et al.,* 2017 and Jan *et al.,* 2018) and chlorophyll content (Ranganathan *et al.,* 2006 and Song *et al.,* 2014). Silicon also has a major role in increasing yield attributing characters like number of spikelets, filled spikelet percentage, test weight and total grain yield (Rani *et al.,* 1997; Ahmad *et al.,* 2013; Jawahar *et al.,* 2015 and Patil *et al.,* 2017) in rice.

Keeping in view the above facts, the present study was designed with the objective to study the effect of silicon on growth and yield attributes of transplanted rice.

Materials and Methods

The field experiment was carried out at agricultural college farm, Bapatla (ANGRAU), Andhra Pradesh, India during *kharif* season 2017 in rice *cv* BPT-5204. The treatments comprised of soil application of silicon at mid-vegetative stage (SVeg), soil application of silicon at mid-reproductive stage (SRep), soil application of silicon at mid-ripening stage (SRip) and control. Treatments were applied at mid-vegetative (Veg), mid-reproductive (Rep) and mid-ripening (Rip) phases of the crop corresponding to the crop age 20, 55 and 85 DAT, respectively. Silixol granules (0.4 % Ortho Silicic Acid) were applied @ 37.5 kg ha^{-1} at target stages as specified above. The photosynthetic rate was 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. Spikelets or grains arising from the pedicels of panicle (primary and secondary branches) are separated carefully and counted to get number of spikelets per panicle. Filled and unfilled/partially filled spikelets were separated and filled spikelet percentage was calculated as below.

$$\text{Filled spikelet percentage} = \frac{\text{Number of filled spikelets per panicle}}{\text{Total number of spikelets per panicle}} \times 100$$

One thousand filled dried grains were separated from a random composite sample in each treatment and weighed to get test weight (g 1000 $grains^{-1}$). Grains from each panicle are separated carefully and weighed obtain grain yield per panicle (g).

Results and Discussion

Silixol Granules significantly influenced the growth and yield of rice. Photosynthetic (PS) rate as affected by different treatments of silicon in rice leaves when it was applied at mid-vegetative stage, mid-reproductive stage and mid-ripening stage (Table 1).

At all the three sampling times, silicon application increased the PS rate and this increase was highest in mid-reproductive stage. These are in agreement with the findings of Detmann *et al.,* (2012) and Lavinsky *et al.,* (2016) who demonstrated that Si played important functions in enhancing the sink size and strength, which, in turn, exerted a feed-forward effect on photosynthesis that was coupled with increased in both 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.

This might be due to Si fertilization improving 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; Tamai and Ma, 2008).

Leaf area is an important parameter which influences the growth and yield of a crop and is mainly responsible for photosynthetic activity of the plant. Data presented in Table 1 indicated that leaf area of rice increased with silicon application than control and this increase was more prominent during reproductive growth stage.

Increased leaf area in rice by silicon application over control was reported earlier in rice (Rani *et al.,* 1997 and Pati *et al.,* 2016), wheat (Chen *et al.,* 2011), sorghum (Ahmed *et al.,* 2011). Silicon nutrition increased the source and sink strength and might have possible to provide resistant against disease and insects, through which leaf become healthier and increased the leaf area (Chen *et al.,* 2011).

Among all the three sampling times silicon application increased the SPAD value of rice leaves than control (Table 1), and this increase was more during reproductive growth stage than vegetative and ripening. Increase in SPAD value/chlorophyll content by silicon application over control was reported earlier by Ranganathan *et al.,* (2006) and song *et al.,* (2014) in rice, Barbosa *et al.,* (2015) in maize, Maghsoudi *et al.,* (2016) in wheat and Hosseini *et al.,* (2017) in barley.

The increased in SPAD value of all rice plants under silicic acid treatment also indicated that silicon is required for normal development of the photosynthetic apparatus and for chlorophyll synthesis in the leaf and stem, which is involved in growth and yield.

Yield attributes *viz.,* spikelets per panicle, filled spikelet percentage, test weight and grain yield per panicle were significantly affected by silixol application in rice (Table 2). Silicon application increased the number of spikelets per panicle of rice particularly when it was applied during reproductive stage.

These are in agreement with the findings of Lavinsky *et al.,* (2016). Increase in number of spikelets per panicle in rice by silicon over control was reported earlier by Patil *et al.,* 2017 and Jan *et al.,* 2018.

This might be due to increased synthesis of carbohydrates and that might have increased the sink size and capacity. Silicon fertilizer, that may significantly reduce empty spikelet's number in rice and increase fertility, increased spikelets per panicle that ultimately increased crop yield.

Table.1 Effect of soil application of silixol granules on growth of rice

S. No	Treatments	At mid-vegetative stage			At mid-reproductive stage			At mid-ripening stage		
		Photosynthetic rate (mmol CO_2 m^{-2} s^{-1})	Leaf area (cm^2 $plant^{-1}$)	SPAD value	Photosynthetic rate (mmol CO_2 m^{-2} s^{-1})	Leaf area (cm^2 $plant^{-1}$)	SPAD value	Photosynthetic rate (mmol CO_2 m^{-2} s^{-1})	Leaf area (cm^2 $plant^{-1}$)	SPAD value
1	NSi	15.103	414.190	31.587	25.297	771.190	36.313	19.563	609.460	37.880
2	SVeg	20.753	494.557	38.573	34.263	864.710	37.450	23.067	736.490	37.847
3	SRep	15.260	430.433	32.517	38.240	980.877	40.603	25.957	776.830	42.427
4	SRip	15.800	433.717	32.157	27.043	814.133	36.220	21.953	698.010	36.840
	SEm	**0.344**	**5.660**	**1.088**	**1.675**	**14.807**	**0.587**	**0.602**	**6.798**	**0.608**
	CD (0.05)	**1.044**	**16.882**	**3.303**	**5.081**	**44.913**	**1.783**	**1.825**	**20.620**	**1.844**
	CV (%)	**7.132**	**4.350**	**11.189**	**18.593**	**5.980**	**5.409**	**9.212**	**3.339**	**5.436**

(**NSi** –No Silicon ; **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)

Table.2 Effect of soil application of Silixol granules on yield attributes of rice

S. No.	Treatments	Number of spikelets/ panicle	Filled spikelet percentage (%)	Test weight (g)	Grain yield per panicle (g)
1	NSi	168.663	93.147	15.200	3.500
2	SVeg	193.220	95.283	16.133	3.733
3	SRep	230.663	98.000	17.000	4.100
4	SRip	189.887	94.057	16.100	3.667
	SEm	**7.545**	**1.422**	**0.609**	**0.095**
	CD (0.05)	**22.885**	**4.313**	**1.848**	**0.289**
	CV (%)	**13.361**	**5.178**	**13.106**	**8.825**

Filled spikelet percentage of rice was increased by silicon application particularly when it was applied during reproductive phase. These results agree with the findings of Ma *et al.*, (1989) and Lavinsky *et al.,* (2016) who reported that the effect of silicon was most prominent during the reproductive stage and it increased the percentage of filled spikelets in rice. This higher percentage of filled spikelets by silicon fertilizer was through the increased current photosynthetic rate and decreases fungal diseases (Ma, 2009). The contribution of carbohydrates from photosynthetic activity for longer period might have resulted in efficient translocation of food material into the sink (grain) thereby increased the number of filled grains percentage.

Soil application of silicon increased the 1000 grain weight of rice and this increase was more prominent during reproductive stage. These findings are in agreement with the reports of Ma *et al.*, (1989) and Lavinsky *et al.,* (2016). The enhancement in 1000 grain weight by silicon application was due to improved and enhanced the photosynthetic activity, density of grain by improving the translocation and accumulation of carbohydrates and other macro and micro molecules also increased in number of filled grains and influenced the biomass of grains, and ultimately grain weight increased.

Grain yield per panicle of rice also increased by silicon than controls (without silicon). Similar results were observed earlier by Jawahar *et al.,* (2015). It was reported that silicon is responsible to control stomatal activity, photosynthesis and water use efficiency which ultimately results in better vegetative and reproductive growth which ultimately increased the panicle weight.

In the overall conclusion, soil application of silicon with silixol granules influences growth and yield parameters of rice and this influence is more when silicon application at reproductive stage of crop than vegetative and ripening stages.

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How to cite this article:

Anand Lokadal and Sreekanth, B. 2018. Effect of Soil Application of Silicon on Growth and Yield Attributes of Rice (*Oryza sativa* L.). *Int.J.Curr.Microbiol.App.Sci.* 7(11): 838-844.
doi: https://doi.org/10.20546/ijcmas.2018.711.099