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Effect of foliar application of sodium silicate on yield and grain quality of rice

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Abstract
A field study was conducted to investigate the "Effect of foliar application of sodium silicate on yield and grain quality of rice (*Oryza sativa* L.)" at agricultural college farm, Bapatla during kharif season 2017-18. The research was designed as randomized block design (RBD) which replicated thrice. The treatments were foliar application of silicon at mid-vegetative (20 DAT), mid-reproductive stage (55 DAT) and mid-ripening stage (85 DAT) including control. Sodium silicate (1%) was used as a source of silicon. Fertilizers like nitrogen, phosphorus and potassium were applied as per general recommendations and all other agronomic practices were kept constant for all the treatments. The yield components like number of primary and secondary branches per panicle, panicle length, spikelet length, test weight, harvest index and grain yield; quality parameters like starch content and protein content in grains were evaluated at maturity stage. All the above parameters were positively influenced with foliar application of silicon and this influence was more in reproductive stage of silicon application.

Keywords: Sodium silicate, foliar application, rice, quality, silicon

Introduction

Rice is the most widely consumed staple food crop of about two third of the world human population especially in Asia. It ranks third in worldwide production after sugarcane and maize. India has the largest rice acreage and ranked second in production while china occupied first position. Rice contributes 42% of total food grains production and 45% of the cereal production. It is the most important crop with respect to nutrition and calorie intake, providing more than one fifth of the total calories consumed by human population (Li *et al.*, 2014) [14].
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) [9, 16]. 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) [10]. Interestingly, the only non-essential nutrient that is included in the guidelines for rice fertilization is silicon (Si) (Dobermann and Fairhurst, 2000) [6].

Silicon is known as the second most abundant element in earth crust. Silicon concentrations in plants range from 0.1% (similar to Phosphorous and Sulfur) to more than 10% of whole plant dry matter (Epstein, 1999) [8]. Rice plant accumulates about 10% silicon in shoot which helps rice plant to fight against biotic and abiotic stresses. Silicon has been found accumulating in shoots in the form of monosilicic acid (H_4SiO_4). Low silicon uptake has been proved to increase the susceptibility of rice to diseases such as rice blast, leaf blight of rice, brown spot, stem rot and grain discoloration (Akhtar *et al.*, 2003 and Massey and Hartley, 2006) [5, 19]. It is general consideration among the growers that role of Si in plant growth is non-obligatory. Silicon effects on yield are related to the deposition of the element under the leaf epidermis which results a physical mechanism of defense, production of phenols which stimulates phytoalexin production, reduces lodging, decreases transpiration losses and increases photosynthesis capacity of crop plants. Plant tissue analysis has revealed the optimum amount of silicon is necessary for plant development (Liang *et al.*, 2006) [15].

Major nutrients like nitrogen, phosphorus and potassium are already in practice at maximum level but still a yield gap is present in rice. So, recent research is needed to following the micronutrients like silicon (Si) in rice production. In the light of above contest, current study was planned with the objective to study the effect of foliar application of silicon on yield and quality of rice.

Materials and Methods

A field research was conducted to study the effect of foliar application of silicon on rice yield and quality, at agricultural college farm, Bapatla, ANGRAU, India during 2017-18 in rice cv BPT-5204. The experiment was laid out in randomized block design (RBD) having three replications. Treatments included in the experiment were as following, FW= Foliar application with water, FVeg= Foliar application of silicon at mid-vegetative stage (20 DAT), FRep= Foliar application of silicon at mid-reproductive stage (55 DAT), FRip= Foliar application of silicon at mid-ripening stage (85 DAT). 1 % Sodium silicate was applied at above specified stages of rice. Recommended package of practices for cultivation and management of rice were followed during the experimental crop growth period.

Length of panicle was taken as the length (cm) between the neck node of the panicle to the top most spikelet. Primary and secondary branches of the panicle were separated and counted as per Mohapatra *et al*. (2011) [20]; branches arising from the central axis (rachis) of the panicle were considered as primary branches and branches similarly arising from primary branches are considered as secondary branches. Spikelets or grains from the panicle are separated carefully and measured by using a calliper or simple laboratory scale to obtain length of spikelet (mm). 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}). The harvest index was calculated separately for each treatment by the adopting the following formula,

$$Harvest\ index = (Economic\ yield)/(Biological\ yield) \text{ x } 100,$$

Where, Economic yield is dry weight of grains per hill and Biological yield is above ground shoot dry weight of plants per hill.

The crop harvested from each treatmental plot was bundled separately and sun dried and later manually threshed. After threshing, grain was cleaned and sun dried to a constant weight, grain yield per treatment plot was determined. Grain yields from the tagged hills were also added to the corresponding plot yield and final yield was calculated that expressed as ton ha^{-1}.

Starch content of grains was estimated by the anthrone method of Hodge and Hofreiter (1962) [11] as given by Thimmaiah (1999) [29]. Protein content in the grains was estimated by the method of Lowry *et al.* (1951) [17]. The data generated from present experiment was statistically analyzed by methods suggested by Panse and Sukhatme (1978) [22].

Results and discussion

Yield attributes of rice under silicon

Panicle length

The panicle length was significantly influenced by foliar application of silicon (Table 1). Among the foliar application treatments, FRep showed significantly higher panicle length than other treatments (FVeg, FRip and control). The current results were agreed with the findings of Ahmad *et al*. (2013) [2], El-Temsah (2017) [7], Patil *et al*. (2017) [24] and Jan *et al.* (2018) [12] while contradicted to the results of Abro *et al.* (2009) [1]. The increased panicle length with silicon application might be due to deposition of silicon at cellular levels makes plant parts more elongated and erect.

Number of primary and secondary branches

The number of primary branches per panicle was significantly influenced by foliar application of sodium silicate in rice (Table 1). Among the foliar application treatments, FRep showed significantly higher number of primary branches per panicle than other treatments (FRep, FRip and control). Similar results were obtained by Ahmad *et al*. (2013) [2] who recorded that foliar applications of sodium silicate increased the branches per panicle in rice. Ahmad *et al*. (2007) [4] and Shahidhar *et al*. (2008) [27] also reported similar results in rice.

Number of secondary branches per panicle was also significantly influenced by foliar application of sodium silicate in rice (Table 1). Even, among the foliar application treatments, FRep showed significantly higher secondary branches than other treatments (FVeg, FRip and control). This enhanced effect of silicon was reviewed in rice by Seo and Ota (1983) [26] who reported that increased number of secondary branches of panicle with application of potassium silicate during spikelet differentiation. Subramanian and Gopalaswamy (1991) [28] also suggested that soil application with potassium silicate during spikelet differentiation of rice increased the number of secondary branches per panicle.

Spikelet length

The data pertaining to spikelet length showed significant differences with foliar application of silicon in rice (Table 1). In between the foliar application treatments, FRep showed significantly higher spikelet length than other treatments. To summarize, foliar application of silicon increased the spikelet length of rice particularly when it was applied during the reproductive stage. These are in agreement with the findings of Lavinsky *et al*. (2016) [13]. Increase in spikelet length in rice by silicon over control was reported earlier by Seo and Ota (1983) [26] and Ahmad *et al*. (2013) [2] in rice.

Test weight

The test weight was significantly influenced by foliar silicon application (Table 1). Even, among the foliar application treatments, FRep showed significantly higher test weight than other treatments like FVeg, FRip and control. To summarize the effects of various treatments of foliar silicon application increased the 1000 grain weight of rice particularly when it is applied during reproductive stage. These results are supported by the reports of Ma *et al*. (1989) [18] and Lavinsky *et al*. (2016) [13]. The increased 1000 grain weight with silicon application over control was also recorded by Pati *et al*. (2016) [23], El-Temsah, (2017) [7], Sarma *et al*. (2017) and Patil *et al*. (2017) [24]. The enhancement in 1000 grain weight due to the silicon treatment, 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.

Harvest Index

The harvest index was significantly influenced by foliar application of silicon at different stages *i.e.*, mid-vegetative, mid-reproductive and mid-ripening stages (Table 1). Among the four treatments, FRep showed significantly higher harvest index than other treatments. These results were corroborate with the finding of Ahmad *et al.* (2013) [2], Lavinsky *et al.* (2016) [13] and Sarma *et al.* (2017) [25]. The increased Harvest index with Si application indicates that the proportion of biomass contribution to the grain was increased under silicon supply.

Yield and quality parameters
Grain yield
The grain yield was significantly influenced by foliar application of sodium silicate at different stages of rice growth period (Table 2). Among the foliar application treatments, FRep showed significantly higher grain yield than other treatments (FVeg, FRip and control). To summarize the effects of various treatments of silicon on grain yield of rice with foliar application this enhanced the total grain yield of rice particularly when it was applied during reproductive stage. Similar results were also observed by Yoshida *et al*., 1959; Okuda and Takahashi, 1961; and Ma *et al*., 1989 [18], Lavinsky *et al*., 2016 [13] and they conclude that Si nutrition gives more yields in rice when it was specifically applied during reproductive stage (panicle initiation to heading) than at the vegetative and ripening stages of crop growth cycle. This positive effect of silicon on yield over control was reported earlier in rice Ahmad *et al*., 2013 [2]; Sarma *et al*., 2017; [25] El-Temsah *et al*., 2017 [7] and patil *et al*., 2017 [24].
The application of silicon to paddy enhanced the sturdiness in plant and helps to grow erect without lodging. The erectness exposed the plant to sunlight and enhanced the photosynthetic activity and better assimilation of organic constituents (carbohydrates). These assimilates promotes the growth and development of crop, as well as reduce the incidence of pest and disease. The crop grows vigorously and utilized the nutrients and moisture from soil which are turn into the economic yield of paddy. This might be the reason for increasing the grain yield of paddy by silicon.

Starch content
Results showed that foliar application of silicon affected the starch content of rice grains significantly (Table 2). Among the foliar application treatments, FRep showed significantly higher starch content than other treatments. The current results of increased starch content of rice grains by silicon nutrition agree with the reports of Ahmad *et al*. (2012 and 2013) [2, 3] who observed the increased starch content in rice in the production of carbohydrates. This increase in carbohydrates content with the application of silicon might also be due to the enhanced the uptake of K which inturn could help in starch formation.

Protein content
The protein content of rice grains was significantly influenced by foliar application of silicon (Table 2). Among the foliar application treatments, FRep showed significantly higher protein content than other treatments *i.e*., FVeg, FRip and control. From the above results we conclude that foliar application of silicon gives increased protein content in rice grains. The results were agreed with the findings of Ahmad *et al*. (2012) [3] and (2013) [2] who observed the increased protein concentration in rice grain with foliar application of sodium silicate. El-Temsah (2017) [7] also recorded the increased grain crude protein in rice with foliar application of silicon. This might be due to silicon application which directly improved the synthesis of various amino acids and the activity of enzymes in plants.

Table 1: Effect of foliar application of silicon on yield components of rice

S. No.	Treatments	Panicle length (cm)	Number of primary branches	Number of secondary branches	Spikelet length (mm)	Test weight (g)	Harvest index (%)
1	FW	21.76	10.29	40.22	7.33	15.73	37.14
2	FVeg	22.36	10.65	41.22	8.33	16.16	38.05
3	FRep	23.76	11.77	43.00	9.66	16.60	38.39
4	FRip	22.50	10.88	41.46	8.50	16.06	37.86
	SEm	0.10	0.16	0.46	0.29	0.38	0.99
	CD (0.05)	0.32	0.48	1.39	0.87	1.15	3.01
	CV (%)	1.60	5.02	3.83	11.78	8.16	9.02

Table 2: Effect of foliar application of silicon on grain yield and grain quality of rice

S. No.	Treatments	Grain yield ha^{-1} (t ha^{-1})	Starch content (mg g^{-1} d.wt.)	Protein content (mg g^{-1} d.wt.)
1	FW	5.66	40.81	13.33
2	FVeg	5.69	43.61	15.43
3	FRep	5.72	48.58	17.18
4	FRip	5.67	44.29	15.65
	SEm	0.06	1.04	0.99
	CD (0.05)	0.18	3.14	3.02
	CV (%)	3.59	8.10	22.37

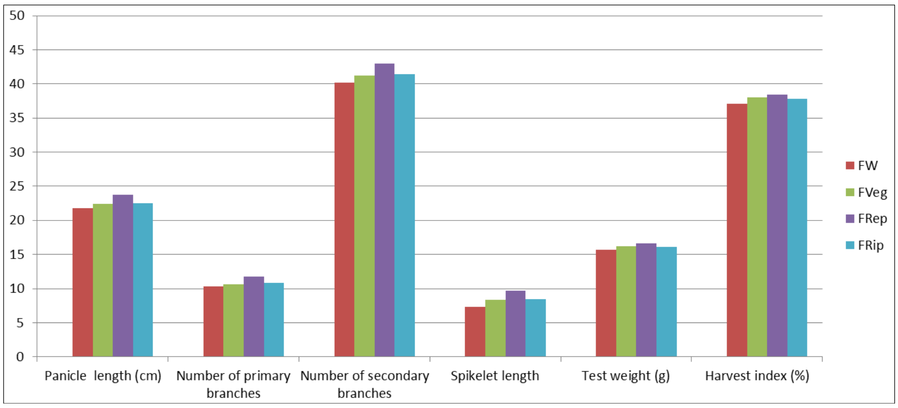

Fig 1: Effect of foliar application of silicon on yield components in rice

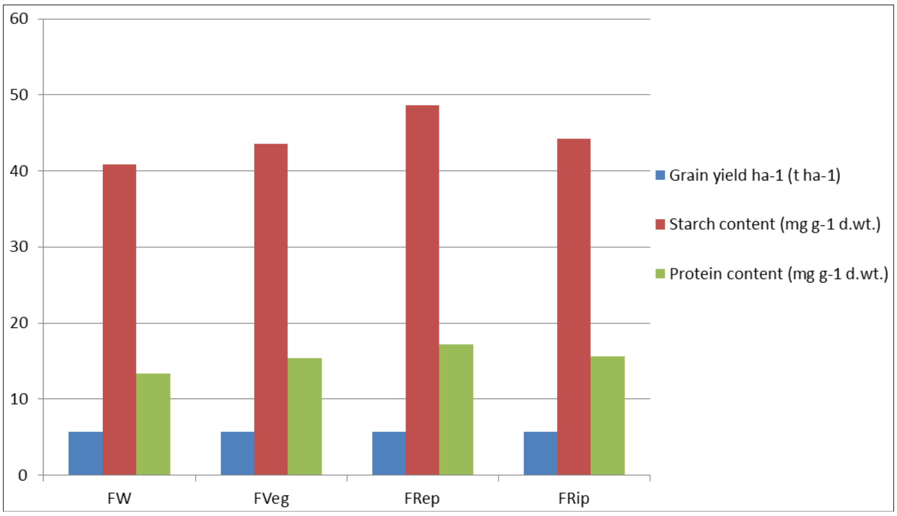

Fig 2: Effect of foliar application of silicon on grain yield and grain quality in rice

Conclusion

From the above results, following conclusions were observed during the research. Yield components like panicle length, spikelet length, number of primary and secondary branches per panicle, test weight, harvest index and grain yield; quality parameters like grain starch and protein contents were increased with foliar application of 1 % sodium silicate in rice. This influence was more when silicon application at reproductive stage of crop than vegetative and ripening stages.

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