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ORIGINAL ARTICLE

Yield and Nutrient Content of Rice as Influenced by Silicon and Nitrogen Application

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ABSTRACT
In order to investigate the effect of silicon and nitrogen application on yield and nutrient contents in rice, a field experiment was carried out in randomized block design with three replications during kharif 2014 and 2015. The experiment encompassed four levels of silicon (0, 200, 400 and 600 kg Si ha^{-1}) from calcium silicate and four levels of nitrogen (0, 75, 100 and 125 kg N ha^{-1}) from ammonium sulphate. The highest grain and straw yields (6163 and 8536 kg ha^{-1}, respectively) of rice were recorded with application of 600 kg Si ha^{-1} whereas, application of 125 kg N ha^{-1} produced 6445 and 8658 kg ha^{-1}, grain and straw yields, respectively. Silicon application had increased grain and straw yield by 8 and 17% over check, respectively; similarly, nitrogen application increased the grain and straw yield by 23 and 24% over control, respectively. Nitrogen, P, K, S and Si content in grain increased by 25, 11, 11, 12, and 51% over control with increase in Si application, respectively. Application of nitrogen also recorded significant increase in the N, P, K and Si contents in rice grain by 12, 2, 5 and 13% over control, respectively. The effect of N and Si and their interaction found to be significant for N, P, S and silicon contents in rice gain and straw.
Keywords: *Rice, silicon, nitrogen, yield, nutrient contents*

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INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food grain crop. It is well documented that judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice. Fertilizer is very important input for intensive rice production and the profitability of rice production systems. Silicon is the most important for sustainable production of Basmati rice. Though the solubility of silicate minerals vary under different soil and environmental conditions, however, its concentrations in soil solutions usually range from 0.1 to 0.6 mM [1]. Its concentrations in different plants range from 0.1% (similar to P and S) to more than 10% of whole plant dry matter. Hydrated amorphous silicon compounds are likely to be deposited in different cellular parts such as cell lumens, cell walls and intercellular spaces, its deposition below and above of the cuticle layer has also been reported. Silicon is an important micronutrient for healthy and competitive growth of all cereals including rice in Asia [2]. Role of silicon in plant health and growth has been investigated in silicon accumulating crops and it seemed significantly effecting [3]. Silicon uptake by plants reduces the susceptibility to chewing insects such as stem borer; it might be by rendering plant tissue less digestible or by damaging greatly to the mandibles of feeding insects. Silicon deficiency in plants makes them more susceptible to insect feeding, fungal diseases, microorganisms attack and abiotic stresses that adversely affect crop yield and quality. Therefore, the present study was conducted to explore the effect of silicon and nitrogen application on yield and nutrient contents in rice.

MATERIALS AND METHODS

A field experiment was conducted during the *Kharif* season 2014 and 2015 at Agriculture Research Station, Anand Agricultural University, Jabugam, Gujarat. Geographically, Jabugam is situated at 22^{0}17'37.70" north latitude, 73^{0}46'41.02" east longitude with an elevation of 92 meters above mean sea level. The climate of Jabugam region is semi-arid and sub-tropical with hot summer and cold winter. In this region, generally monsoon commences in the month of June and retreats from the end of September. Most of the rainfall is received from south-west monsoon currents. July and August are the months of heavy showers. The total rainfall of the region is about 800-1000 mm. Average minimum and maximum temperature of both the year of study was 19.6°C and 33.3°C, respectively. The soil was loamy sand, with a sand, fine sand, silt and clay composition of 49.8, 26.6, 10.0 and 12.1%, respectively. The soil had pH at 6.3 available N 313 kg ha^{-1}, Si 190.8 kg ha^{-1}, P_2O_5 88 kg ha^{-1}, K_2O 221 kg ha^{-1}, organic carbon 6.3 g kg^{-1} and EC 0.43 dSm^{-1}.

The experiment was laid out in randomized block design with factorial concept encompassing three replications and sixteen combined treatments. The plot size was 5.0 m × 3.6 m. GAR 13 (Gujarat Anand Rice 13) variety was used as test crop. The entire dose of phosphorus as per recommendation was applied through single superphosphate. Four levels (0, 75, 100 and 125 kg ha^{-1}) of N were applied through ammonium sulphate in 3 equal splits (1/3 basal, 1/3 at active tillering stage and 1/3 at panicle initiation stage) and four levels (0, 200, 400 and 600 kg ha^{-1}) of Si were applied through calcium silicate at the time of sowing.

RESULTS AND DISCUSSION

Grain and straw yield

The results (Table 1) illustrated that the rice grain and straw yield was significantly influenced by silicon application and significantly higher grain (6163 kg ha^{-1}) and straw (8536 kg ha^{-1}) yields were recorded at 600 kg Si ha^{-1} and lowest grain (5693 kg ha^{-1}) and straw (7319) yields under control. Application of 600 kg Si ha^{-1} gave significantly higher grain and straw yields over the control and 200 kg Si ha^{-1}; which was at par with 400 kg Si ha^{-1}. The increase in rice yield might be due to increased availability of silicon. The lower yield in the control compared to silicon fertilized plots, might be due to leaching and fixation loss of native silicon in submerged conditions which is inadequate in meeting the Si requirement by the crop for producing higher grain yield. The increase in yield with Si application could be due to beneficial effects *viz.,* decreasing mutual shading by improving leaf erectness, decreasing susceptibility to lodging, decreasing the incidence of infections with root parasites and pathogens, leaf pathogens and preventing manganese and iron toxicity or both. Increased water use efficiency observed with the application of Si, probably might be due to prevention of excessive transpiration. During the reproductive stage, silicon is preferentially transported into the flag leaves, and interruption of silicon supply at this stage is detrimental for spikelet fertility [4]. Silicon application increased grain yield by increase of spikelet number, filled spikelet percentage and 1000-seed weight [5].

Application of nitrogen had significant effect on grain yield of rice. Maximum grain (6445 kg ha^{-1}) and straw (8658 kg ha^{-1}) yields was recorded with 125 kg N ha^{-1} and the lowest grain (5241 kg ha^{-1}) and straw (6961 kg ha^{-1}) under control. The increase in yield as a result of nitrogen application could be due to marginal nitrogen content of soil, improvement in root development and vegetative growth as well. The improvement in yield attributing traits may be ascribed to the improved vegetative growth due to N fertilization, facilitating photosynthesis, thereby increasing translocation of organic food materials towards the reproductive organs; which enhanced the formation of panicles with fertile grains. Nitrogen fertilizer has played an important role in increasing rice yields, and total consumption of N for rice production has increased gradually worldwide [6]. Sudhakar also observed 16.7 per cent increase in grain yield with application of N at 160 kg ha^{-1} as compared to 80 kg N ha^{-1} [7]. The improvement in yield components due to increased N levels have also been reported by [8] [9].

Nutrient contents

The N content was significantly influenced by various levels of nitrogen and silicon and their interaction (Table 1). The maximum nitrogen contents in grain (2.50) and straw (1.23%) were renowned at 100 and 125 kg N ha^{-1}. On the other hand the maximum nitrogen content in grain (2.59%) and straw (1.23%) was recorded at 600 kg Si ha^{-1}; which was at par with 400 kg Si ha^{-1}. Also revealed that the significantly highest N content in grain (2.82%) was observed with the application of 100 kg N ha^{-1} coupled with Si at 600 kg ha^{-1} and in straw (1.34%) at 125 kg N ha^{-1} combined with 200 kg Si ha^{-1} (Table 2). Malidareh reported an increase in grain nitrogen content with increase in nitrogen fertilizer application at particular levels [10]. At higher levels of N (120 and 160 kg ha^{-1}) integration with Si could regulate the absorption and mobility of N in the plant and maintains optimum level of N and hence Si fertilization increases N use efficiency [11] [12].

Silicon concentration in rice grain was significantly influenced by the application of N. The maximum silicon content in grain 1.80% and straw 6.58% was recorded with 125 kg N ha^{-1}; which was at par with 100 kg N ha^{-1}. The maximum silicon content in grain (2.01%) and straw (6.95%) was recorded at 600 kg Si ha^{-1}; which was at par with 400 kg Si ha^{-1} (Table 1). Significantly the highest Si content in grain (2.23%) was observed with the application of 100 kg N ha^{-1} coupled with Si at 600 kg ha^{-1} (Table 3). The application of N and silicon fertilizers showed greater accumulation of Si in rice plants. This could be due the release of inorganic N from the applied source over time and higher removal at panicle initiation stage. Higher Si content in the straw than in the grain suggests that Si is linked in shoot and straw and Si content in the straw increased with increase in Si application [10]. The accumulation of Si in the straw may be related to a number of factors such as transpiration, growth duration, growth rate etc.

The P, K and S contents were significantly influenced by various levels of nitrogen and silicon and their interaction. The maximum P and K contents in grain and straw were observed with the individual application of N @ 100 kg ha^{-1} and Si @ 600 kg ha^{-1}. The interaction effect between N and Si was found significant with respect to P contents in grain and straw (Table 2). Increased P in grain and straw can be attributed to enhanced translocation of P from roots to shoots due to Si application. The beneficial effect of Si when available P is low can be explained as a partial substitution of Si for P [13]. Increase in Si levels ultimately increases the absorption of K and CO_2 content thus it block the hatches and improve the photosynthesis [14].

The maximum sulphur content in grain (0.18%) was recorded due to individual application of 600 kg Si ha^{-1} (Table 1) and the interaction effect between N and Si was found significant in grain content (Table 3). Maximum S contents in rice with Si could be due to increase in S availability in soil and enhanced root system. Combined application of nitrogen and silicon recorded maximum NPKS and Si contents of rice over their individual application. The maximum NPKS and Si contents were noticed with 600 kg Si ha^{-1} and 100 kg N ha^{-1}. This could be due to increased root activity and enhanced the soil nutrient availability. This is in accordance with the reports of [15]. Further, the increased contents with crop growth might be attributed to the increased DMP produced with growth of crop due to the enhanced release and consequent availability of nutrients to the crops.

Table 1: Effect of nitrogen and silicon on yield and nutrient contents in grain and straw at harvest of rice crops (pooled 2 years)

Nitrogen (kg ha^{-1})	Nutrient contents (%)										Yield (kg ha^{-1})	
	N		Si		P		K		S			
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
0	2.23	1.03	1.59	5.77	0.20	0.08	1.08	1.50	0.16	0.18	5241	6961
75	2.39	1.13	1.66	6.05	0.21	0.09	1.11	1.57	0.16	0.18	6040	7982
100	2.50	1.19	1.76	6.32	0.21	0.09	1.14	1.62	0.17	0.19	6163	8541
125	2.37	1.23	1.80	6.58	0.19	0.06	1.02	1.42	0.17	0.17	6445	8658
Silicon (kg ha^{-1})												
0	2.07	1.04	1.33	5.05	0.19	0.07	1.03	1.45	0.16	0.16	5693	7319
200	2.29	1.13	1.55	6.10	0.19	0.07	1.07	1.48	0.16	0.18	5944	7934
400	2.54	1.18	1.91	6.62	0.20	0.08	1.11	1.53	0.17	0.19	6091	8354
600	2.59	1.23	2.01	6.95	0.21	0.09	1.14	1.65	0.18	0.20	6163	8536
S. Em. ±	0.04	0.02	0.03	0.13	0.01	0.01	0.02	0.03	0.01	0.00	78	149
CD (0.05)	0.10	0.07	0.10	0.38	0.01	0.01	0.06	0.09	0.01	0.01	221	422
N x Si	Sig.	Sig.	Sig.	NS	Sig.	Sig.	NS	NS	Sig.	NS	NS	NS
CV %	7.6	9.9	9.7	10.6	9.1	11.5	9.0	9.7	9.9	10.5	6.2	9.5

Table 2: Interaction effect of N x Si on N and P content in grain and straw at harvest

Nitrogen content in grain and straw (%)								
Silicon (kg ha^{-1})	**Nitrogen (kg ha^{-1})**							
	0		**75**		**100**		**125**	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
0	1.86	0.89	2.23	1.06	2.23	1.13	1.95	1.07
200	2.14	1.03	2.16	1.08	2.35	1.08	2.49	1.34
400	2.43	1.06	2.53	1.12	2.58	1.28	2.61	1.24
Si_{600}	2.490	1.150	2.610	1.235	2.822	1.263	2.429	1.290
	Grain				**Straw**			
S. Em ±	0.07				0.05			
CD (0.05)	0.20				0.13			
CV %	7.6				9.9			
Phosphorus content in grain and straw (%)								
Silicon (kg ha^{-1})	**Nitrogen (kg ha^{-1})**							
	0		**75**		**100**		**125**	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
Si_0	0.198	0.068	0.188	0.097	0.188	0.067	0.196	0.048
Si_{200}	0.199	0.066	0.186	0.056	0.222	0.098	0.190	0.072

Si_{400}	0.206	0.076	0.209	0.099	0.223	0.082	0.174	0.070
Si_{600}	0.218	0.115	0.246	0.096	0.210	0.102	0.186	0.074
	Grain				**Straw**			
S. Em ±	0.007				0.004			
CD (0.05)	0.02				0.011			
CV %	9.1				11.5			

Table 3: Interaction effect of N x Si on Si and S content in grain at harvest

Silicon (kg ha^{-1})	**Nitrogen (kg ha^{-1})**							
	0	75	100	125	0	75	100	125
	Silicon (%)				Sulphur (%)			
0	1.40	1.33	1.27	1.33	0.14	0.19	0.15	0.16
200	1.60	1.66	1.36	1.59	0.16	0.16	0.16	0.17
400	1.66	1.69	2.17	2.13	0.17	0.15	0.20	0.17
600	1.71	1.95	2.23	2.14	0.18	0.16	0.19	0.19
S. Em ±	0.07, CD (0.05) - 0.19				0.007, CD (0.05) 0.02			

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