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Influence of rice husk ash and bagasse ash as a source of silicon on growth, yield and nutrient uptake of rice

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Abstract
The field experiment was conducted at Division of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur, India, to study the influence of rice husk ash and bagasse ash as a source of silicon on growth, yield and nutrient uptake of rice. The present investigation was carried out in randomized block design. The treatments consist of four levels of silicon (Si) *viz.* 0, 250, 500 and 750 kg Si ha^{-1} which was supplied through rice husk ash (RHA) and bagasse ash (BA) and were replicated four times. The plant height (cm), number of tillers $hill^{-1}$, thousand grains weight and dry matter $hill^{-1}$ (g) of rice increased significantly due to application of silicon. The application of silicon @ 250 kg ha^{-1} through bagasse ash was found optimum for increase in the grain yield (49.66 q ha^{-1}) and straw yield (53.84 q ha^{-1}) of rice. The highest benefit-cost ratio (1.52) was recorded with application of silicon @ 250 kg ha^{-1} through bagasse ash. The silicon uptake of rice increased significantly due to application of silicon either through rice husk ash or bagasse ash at different growth stages. The significantly highest uptake of silicon was recorded with the application of silicon @ 750 kg ha^{-1} through bagasse ash. The uptake of N, P and K increased significantly with application of silicon. The plant available silicon was enhanced at harvest of rice due to silicon application through rice husk ash and bagasse ash.

Keywords: silicon, rice husk ash, bagasse ash, growth, yield, nutrient uptake, rice

Introduction
Rice is known as silicon accumulator plant and benefits much from silicon nutrition (Takahashi, 1995) [17]. Consequently, there is a definite need to consider silicon as an agronomically essential element for increasing and sustaining rice production (Takahashi and Miyake, 1977) [16]. Silica is required for healthy and productive development of the rice plant (Lewin and Reiman, 1969) [7]. This element is absorbed by rice from the soil in large amounts that are several folds greater than those of other macro nutrients. On an average, it is estimated that a rice crop producing a total grain yield of about 5 t ha^{-1} will normally remove 230 to 470 kg Si ha^{-1} from soil (Amarasai and Perera, 1975) [2]. Rice is having the ability to absorb and accumulate silicon metabolically while many upland crop plants seem to lack such ability. A rice crop producing 5 t ha^{-1} grain yield in a lateritic soil of India has been found to remove 468 kg Si ha^{-1} (Sahu, 1990) [12]. Rice and sugarcane are best example of silicon accumulating crops. The advances in physiology, biochemistry and genetics suggest that silicon interacts with other native or applied nutrients and has the potential to induce resistance in the rice plant to biotic (insects, pests and diseases) and abiotic stresses (Al, Fe and Mn toxicity, salt injury, lodging, etc.) (Yoshida, 1975 and Epstein, 1994) [20, 3]. Silicon nutrition has direct and indirect potential benefits on the rice growth. The ideal silicon source must have characteristics such as a relatively high content of silicon, provide sufficient water soluble silicon to meet the needs of the plant, be cost effective, ease in availability, have a physical nature that facilitates application and not contain substances that will contaminate the soil (Gascho, 2001) [5]. The crop residues like rice husk ash and bagasse ash are used as silicon source. The rice husk ash is already being used in rice nurseries and main fields in different parts of southern India. Likewise bagasse ash which is one of the organic wastes obtained from sugar industries may be used as silicon source. The use of silica fertilizers in the form of either soluble silicates or calcium silicate slag is still very restricted due to higher cost. So the rice husk ash and bagasse ash which are easily available organic sources of silica for cultivation. The current study was undertaken to investigate the effects of influence of rice husk ash and bagasse ash as a source of silicon on growth, yield and nutrient uptake of rice.

Materials and Methods

The field experiment was conducted at the Agronomy Farm, College of Agriculture, Kolhapur, India. The experiment was conducted on soil order Inceptisol by adopting randomized block design and was replicated four times. The treatments consisted of four levels of silicon (Si) *viz*., 0, 250, 500 and 750 kg Si ha^{-1} which was supplied through rice husk ash (RHA) (34.20% Si) and bagasse ash (BA) (27.90% Si). The site was selected on the basis of suitability of soil for raising direct seeded rice and having low available silicon (94 ppm). The experimental soil had pH 7.50, EC 0.20 dS m^{-1}, organic carbon 0.80%, available nutrients *viz*., N, P, K and Si (272, 20.82, 212.41 and 210.56 kg ha^{-1}, respectively) and DTPA extractable micronutrients *viz*., Fe, Mn, Zn and Cu (4.62, 1.46, 1.62 and 1.48 ppm, respectively). The test crop as rice (*Cv*. Indrayani) was cultivated by adopting recommended package of practices. The plant available silicon (PAS) from soil samples was extracted and estimated as per methods given by Fox *et al*. (1967) [4] and Korndorfer *et al.* (2001) [5, 6], respectively. The digestion of rice plant samples and estimation of silicon from them was done as per procedure given by Nayar *et al.* (1975) [8]. The experimental data were analyzed statistically by applying the technique of analysis of variance and significance was tested by variance ratio *i.e.* F value at 5 per cent level of significance as described by Panse and Sukhatme (1967) [9]. The standard error of mean (SE) and critical difference (CD) was worked out to evaluate differences between treatment means. The cost of cultivation of crop under individual treatment was worked out by taking into account the cost of all inputs. The net monetary returns were worked out by subtracting cost of cultivation from gross monetary of individual treatment and the benefit-cost (B:C) ratio was worked out as follow.

$$\text{B:C ratio} = \frac{\text{Gross monetary returns ha}^{-1}}{\text{Cost of cultivation ha}^{-1}}$$

Results and Discussion

Growth and yield of rice

The plant height, total number of tillers $hill^{-1}$, thousand grains weight and dry matter $hill^{-1}$ of rice were increased significantly due to silicon application through different sources; however the differences between different sources and levels of silicon were not significant (Table 1). The results revealed that the application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) recorded significantly highest plant height (76.82 cm) but it was at par with T_4, T_5, T_6. The application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) recorded significantly highest total number of tillers $hill^{-1}$ (12.35), but it was at par with all other treatments except control (T_1). The thousand grains weight was significantly increased with application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7). However, it was at par with all treatments except T_1 and T_2. The dry matter $hill^{-1}$ at harvest was significantly increased with application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) (24.68 g), but it was at par with application of silicon @ 500 through bagasse ash (T_6). The grain and straw yields of rice was increased significantly with silicon application. However, the differences between silicon sources and levels were not significant. The application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) recorded significantly highest grain yield (49.82 q ha^{-1}) and straw yield (54.20 q ha^{-1}). However, it was at par with all the treatments (up to lowest dose of silicon @ 250 kg ha^{-1} through rice husk ash and bagasse ash) except control (T_1). The highest benefit-cost ratio (B:C) (1.52) was recorded with application of silicon @ 250 kg ha^{-1} through bagasse ash (T_5). These results are in confirmative with those reported by Singh *et al.* (2005) [13], Singh *et al.* (2007) [15], Wader *et al.* (2013) [18], Aarekar (2014) [1], Patil *et al.* (2015) [11] and Patil *et al.* (2017) [10].

Table 1: Effect of silicon sources and levels of silicon on growth and yield of rice

Treatments	Plant height (cm)	Total no. of tillers $hill^{-1}$	1000 grains wt. (g)	Dry matter $hill^{-1}$ (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	B:C ratio
T_1 (Control)	68.14	10.96	20.50	22.01	41.21	46.25	1.40
T_2 (RHA @ 250)	73.12	11.82	21.21	23.68	47.43	51.50	1.49
T_3 (RHA @ 500)	73.24	12.27	22.15	23.52	48.66	52.50	1.46
T_4 (RHA @ 750)	75.23	12.30	22.50	23.59	49.12	53.60	1.48
T_5 (BA @ 250)	75.39	11.86	22.20	23.91	49.66	53.84	1.52
T_6 (BA @ 500)	75.84	12.23	22.47	24.53	49.56	53.60	1.50
T_7 (BA @ 750)	76.82	12.35	22.60	24.68	49.82	54.20	1.51
S.E. $\pm$	0.90	0.32	0.40	0.25	1.42	1.68	-
C.D. (P=0.05)	2.60	0.98	1.28	0.75	4.23	5.04	-

Silicon uptake at different growth stages by rice

The uptake of silicon by rice at critical growth stages increased significantly due to silicon application through rice husk ash as well as bagasse ash (Table 2). At tillering stage, the application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) recorded highest silicon uptake (81.14 kg ha^{-1}) which was at par with application of silicon @ 250 kg ha^{-1} through bagasse ash (T_5) (77.40 kg ha^{-1}). At panicle initiation stage, significantly highest silicon uptake was recorded in the application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) (145.73 kg ha^{-1}). However, it was at par with application of silicon @ 500 kg ha^{-1} through bagasse ash (T_6) (136.52 kg ha^{-1}). Similar trend of silicon uptake was observed at flowering stage of rice. The uptake of silicon at harvest increased significantly with levels of silicon. The highest uptake of silicon at harvest was recorded in application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) (262.40 kg ha^{-1}) and it was at par with application of silicon @ 500 kg ha^{-1} through bagasse ash (T_6) (251.20 kg ha^{-1}). The increase in uptake of silicon might be due to increase availability of silicon with supply of silicon through both the sources of silicon and its luxury consumption. The similar findings were also reported by Singh *et al*. (2006) [14], Wader *et al*. (2013) [18], Aarekar (2014) [1] and Patil *et al.* (2015) [11].

Table 2: Effect of silicon sources and levels of silicon on silicon uptake by rice

Treatments	Silicon uptake (kg ha^{-1})			
	Tillering (65 DAS)	Panicle initiation(95 DAS)	Flowering (115 DAS)	At harvest (145 DAS)
T_1 (Control)	51.53	94.34	160.77	179.42
T_2 (RHA @ 250)	63.87	104.49	176.17	198.74
T_3 (RHA @ 500)	71.85	111.96	196.77	210.38
T_4 (RHA @ 750)	74.31	128.76	216.69	224.00
T_5 (BA @ 250)	77.40	119.65	214.45	227.62
T_6 (BA @ 500)	75.18	136.52	225.12	251.20
T_7 (BA @ 750)	81.14	145.73	231.71	262.40
S.E. ±	1.32	3.24	3.81	3.86
C.D. (P=0.05)	3.92	9.62	11.34	11.48

(Note: DAS-Days after sowing)

Nitrogen, Phosphorus and Potassium uptake by rice

The uptake of nitrogen increased significantly due to the application of silicon in both the sources of silicon *viz*., rice husk ash and bagasse ash (Table 3). The significantly highest uptake of nitrogen was recorded in application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) (83.75 kg ha^{-1}) and it was at par with treatment T_6. The uptake of phosphorus increased significantly due to silicon application. The significantly highest total uptake of phosphorus was found with application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) (20.83 kg ha^{-1}) and it was at par with treatment T_6. The highest uptake of potassium was found in application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) (83.49 kg ha^{-1}), however it was at par with other treatments except control (T_1). The increase in uptake of nitrogen, phosphorus and potassium due to application of silicon were reported by. The uptake of micronutrients (Fe, Mn, Zn and Cu) was not significantly affected due to application of silicon through different sources and levels of silicon. These results corroborate with those obtained by Singh *et al.* (2006) [14], Wader *et al*. (2013) [18] and Aarekar (2014) [1].

Table 3: Effect of silicon sources and levels of silicon on nutrient uptake by rice

Treatments	Nutrient uptake (kg ha^{-1})						
	N	P	K	Fe	Mn	Zn	Cu
T_1 (Control)	60.53	13.20	68.80	1.32	0.80	0.72	0.074
T_2 (RHA @ 250)	73.10	16.55	77.68	1.48	0.88	0.82	0.091
T_3 (RHA @ 500)	76.54	18.48	81.97	1.50	0.89	0.79	0.100
T_4 (RHA @ 750)	78.97	19.29	82.77	1.52	0.96	0.78	0.142
T_5 (BA @ 250)	78.33	18.10	83.29	1.50	0.98	0.88	0.097
T_6 (BA @ 500)	81.34	19.77	83.46	1.53	0.97	0.84	0.011
T_7 (BA @ 750)	83.75	20.83	83.49	1.55	0.99	0.82	0.126
S.E. ±	1.46	0.43	2.3	0.11	0.19	0.12	0.007
C.D. (P=0.05)	4.34	1.28	6.9	NS	NS	NS	NS

Chemical properties of soil at harvest of rice

The pH, EC, organic carbon, available N, P, K and DTPA extractable micronutrient (Fe, Mn, Zn and Cu) of soil at harvest of rice were not affected significantly due to application of silicon through different sources and levels of silicon (Table 4). The plant available silicon increased significantly over the control (T_1) due to application of silicon through different sources *viz*., rice husk ash and bagasse ash. The significantly highest plant available silicon was found in application of silicon @ 750 kg ha^{-1} through bagasse ash (T_7) (265 kg ha^{-1}). However, it was at par with application of silicon @ 750 kg ha^{-1} through rice husk ash (T_4) (261 kg ha^{-1}). The increase in available silicon at harvest of rice over control (T_1) might be due to residual effect of silicon which was applied through different silicon sources *viz*., rice husk ash and bagasse ash. The similar residual effects of silicon were also reported by Wader (2012) [19], Aarekar (2014) [1] and Patil *et al.* (2015) [11].

Table 4: Effect of silicon sources and levels of silicon on chemical properties of soil at harvest of rice

Treatments	pH (1:2.5)	EC (dS m^{-1})	Available nutrients (kg ha^{1})				Available micronutrients (ppm)			
			N	P	K	Si	Fe	Mn	Zn	Cu
T_1 (Control)	7.56	0.20	269	21	208	210	4.72	1.36	1.47	1.39
T_2 (RHA @ 250)	7.58	0.21	274	23	242	223	4.68	1.46	1.62	1.43
T_3 (RHA @ 500)	7.59	0.23	274	23	234	243	4.66	1.48	1.70	1.44
T_4 (RHA @ 750)	7.60	0.21	275	24	233	261	4.74	1.43	1.72	1.41
T_5 (BA @ 250)	7.58	0.23	273	23	232	230	4.68	1.39	1.68	1.44
T_6 (BA @ 500)	7.59	0.23	275	23	232	241	4.70	1.42	1.72	1.46
T_7 (BA @ 750)	7.62	0.24	276	24	233	265	4.68	1.43	1.78	1.44
S.E. ±	0.01	0.01	1.54	0.94	4.01	5.50	0.09	0.24	0.14	0.16
C.D. (P=0.05)	NS	NS	NS	NS	NS	16.35	NS	NS	NS	NS

Conclusion

The results of the present investigation indicated that the significant increase in growth, yield contributing characters and yield were recorded due to application of silicon. The application of silicon @ 250 kg ha^{-1} through bagasse ash was found beneficial and optimum for increase in the grain and straw yield of rice. The application of silicon through rice husk ash and bagasse ash significantly enhanced the uptake of N, P, K and Si. The plant available silicon at harvest of rice was increased over initial status due to application of rice husk ash and bagasse ash as a source of silicon.

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