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EFFECT OF DIFFERENT SOURCES AND LEVELS OF SILICON APPLICATION ON GROWTH, YIELD ATTRIBUTES AND YIELD OF RICE (*Oryza sativa* L.)

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ABSTRACT

A field experiment was conducted to study the effect of different sources and levels of silicon fertilization on growth, yield and yield attributes of rice during *kharif* and *rabi* season of 2018 at College Farm, College of Agriculture, Rajendranagar. Experiment was laid out in randomized block design with fourteen treatments and three replications consisting of four silica sources and three levels of silicon fertilizers along with one RDF(100:40:40 NPK) and one absolute control. Results showed that application of silica through different sources with different levels significantly increased grain and straw yield as well as yield attributing parameters such as plant height, number of panicles hill^{-1}, length of panicle (cm), number of filled grains panicle^{-1} and 1000 grain weight (g). The application of RDF + FYM + 450 kg silicon per hectare through diatomaceous earth recorded significantly higher grain and straw yield of 8547 kg ha^{-1}and 10204 kg ha^{-1} respectively.Higher grain and straw yield under this particular treatment was mainly attributed to higher growth and yield parameters like higher plant height (87.50 cm), number of panicles hill^{-1} (19.44), length of panicle (23.47 cm), number of grains panicle^{-1} (269.30), and 1000 grain weight (13.67 g) at harvest.

Rice is an important staple food crop for more than two-thirds of the population of India and plays a vital role in national food security and a means of livelihood for millions of people. Population in our country is expected to reach 1.4 and 1.6 billion by 2025 and 2050,requiring annually 380 and 450 million tonnes of food grains respectively (Pati *et al.*,2016).Continuous paddy growing regions showing evidence of soil nutrient depletion, imbalances and low nutrient use efficiency necessitating improvement in the production and productivity of crops in a sustainable manner. Hence improving the yields of crops without deteriorating the environment and soil health is a big challenge to the farmers and scientists. Therefore, adequate nutrient management is essential to enhance productivity of rice as it is an exhaustive feeder crop (Thind *et al.*, 2012).

Si is the second most abundant element in soils after oxygen and is available to plants in the form of silicic acid (H_4SiO_4). Although Si is abundant in the earth's crust, its availability in soil is very low because of its low solubility from soil source. Monocotyledons in general and Poaceae species such as rice in particular are clearly favored due to an enhanced supply of Si (Epstein 1999; Ma *et al.,*2007). In modern agriculture, silicon has already been recognized as a functional nutrient for a number of crops, particularly rice, maize and sugarcane, and plays an important role in the growth and development of crops, especially Gramineae crops. Plants vary in their ability to absorb silicon. Plants that can absorb and accumulate silicon in their tissues are known as silicon accumulators. Rice exhibits the greatest uptake of silicic acid in the grass family. Information on the importance of Si in Indian rice farming system is limited (Prakash *et al.*, 2011). Since yield responses of rice to Si application are related to available Si in soils and the Si content of rice plants. This is evident from the fact that most of the traditional rice fields of the world are low in plant available Si and addition of Si is reported to improve the rice yield. Rice being a largest silicon accumulator, information on use of different sources of silicon, extent of their usage, standard dosages of Si, their effects on growth and yield of wetland paddy is limited. A rice crop producing 5 t ha^{-1} grain yields in soils of India has been found to remove 300 - 450 kg Si ha^{-1} (Korndorfer*et al.*, 2001). In this view a suitable field which was low in soil available silicon status was selected for the field

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experiment to evaluate various indigenous sources of silicon *viz* rice husk ash (RHA), fly ash (FA) along with diatomaceous earth (DE) and silica gel (SG) with low, medium and high silicon doses. With this background the present investigation was undertaken to know the effect of sources and levels of silica application on performance of low land rice.

MATERIAL AND METHODS

A field experiment was carried out at College Farm, College of agriculture, Rajendranagar during *kharif* and *rabi* season of 2018 in same field. It is located between 17^0 21' N latitude and 78^0 25' E longitude and 543.2 meters above mean sea level. The soil was sandy loam in texture with slightly alkaline reaction (pH = 7.64), electrical conductivity was 1.36 dSm^{-1} and organic carbon content was medium (0.63%). The soil was medium in available nitrogen (422.1 kg ha^{-1}), high in available phosphorus (93 kg ha^{-1}), and high in exchangeable potassium (320.6.4 kg ha^{-1}), with high available sulphur (48.12 mg kg^{-1}) and low available silicon content (91 kg ha^{-1}/ 40.62 ppm). The available silicon content in the soil was estimated by 0.5 M acetic acid method and availability ranges of silica is < 50 ppm for sandy soils having < 15 % clay, 65 ppm for soils having 16 to 35% of clay and < 100 ppm for clay soils having > 35% clay as per Korndorfer*et al.*, (2001).

The experiment was laid out in Randomized Block Design (RBD) with fourteen treatments and three replications. The treatment combinations consisting of four sources of silicon fertilizers (*viz.* diatomaceous earth, rice husk ash, flyash and silica gel) and three levels of silicon (150, 300 and 450 kg silicon ha^{-1}) from each source along with one absolute control and recommended dose of fertilizers. Here 150, 300 and 450 kg silicon ha^{-1} was fixed mainly because for the production of 5 t ha^{-1} of grain yield of rice it is estimated to remove about 300-450 kg elemental silicon from soil, depending upon soil and plant factors (Korndorfer*et al.*, 2001) and based on this one low, medium and high levels of silicon was taken in the experiment. Recommended quantity of FYM at the rate of 10 t ha^{-1} was applied for both the seasons and mixed into the soil two weeks before transplanting. As per the treatments fifty percent of nitrogen was applied as basal dose and entire quantity of phosphorus (DAP), potassium (MOP), and silicon were supplied at the time of transplanting as a basal dose to each plot and remaining fifty percent of nitrogen was applied as top dress at 30 days after transplanting.

Table 1. Characteristics of the Si sources used in experiment analyzed by XRD and XRF (CSIR-Indian Institute of Chemical Technology, Hyderabad)

S.No.	Parameter	Diatomaceous earth	Rice husk	Fly ash	Silica gel
1.	Solubility (1:10)	Easily soluble	Fairly	Slightly good	Good
2.	Forms of silica	Amorphous	Amorphous	Crystalline	Amorphous
3.	SiO_2 (%)	72	34.4	30.02	99.01
4.	pH (1:2.5)	8.02	7.14	8.94	7.81
5.	EC (dS m^{-1})	0.74	0.05	1.84	0.14
6.	Al_2O_3 (%)	16.4	0.34	20.23	0.12
7.	CaO (%)	2.25	0.18	2.64	1.16
8.	Fe_2O_3 (%)	4.2	0.10	4.80	0.42
9.	K_2O (%)	0.4	0.10	0.20	0.10
10.	MgO (%)	2.8	0.19	3.60	0.24
11.	MnO (%)	00	0.10	0.12	0.10
12.	Na_2O (%)	1.1	0.14	1.36	0.21
13.	P_2O_5 (%)	0.1	0.1	0.23	0.10
14.	SO_3	0.43	0.12	0.62	0.20

The quantity of bioavailable silicon contributed from the each source (Table.1) was estimated by UV visible spectrophotometry using aminonaphthol sulphonic acid (ANSA) as reducing agent (Ma and Takahashi.,2002) prior to their applications in the main field. As per the treatment wise 150 kg, 300 kg and 450 kg of silicon levels were maintained by weighing accurately from the required known quantity of silica sources. These silicon sources with different levels are then mixed thoroughly with the other NPK (100:40:40 kg N: P: K respectively per hectare) fertilizers at the time of transplanting and applied entire silica to the root zone of the transplanted rice. Soluble silicon concentration available for plant (PAS) was determined by soil extraction using 0.5 M acetic acid and Si was measured using UV visible spectrophotometry.

The mineralogical composition and forms of silica sources were determined by X-ray diffraction (XRD) on powdered samples using a Philips MPD 3710 (Co anti–cathode) X-ray diffractometer. The oxides of minerals present in different silica sources was quantified by energy-dispersive X-ray diffractometer spectroscopy (EDS- Quantax) with a Si-Li detector (Table.1). Twenty one days old seedlings was transplanted with spacing of 30 cm × 10 cm as inter and intra row spacing. Irrigation was given as per requirement. Usually every 4 to 5 days once irrigation was given based on the moisture prevailing in the field and two hand weeding was done to keep the plots free from weeds at 25 and 45 DAT. The plant growth and yield parameters *viz.* number of panicles hill^{-1}, length of panicle (cm), number of filled grains panicle^{-1} and 1000 grain weight were recorded. Biomass yields of straw and grain were also recorded at harvest from each plot in both the seasons and mean of data is presented.

RESULTS AND DISCUSSION

Plant height is a direct index to measure the growth and vigour of the plant. Plant height was significantly influenced by various levels and sources of silicon application. Among the different treatments RDF + FYM + 450 kg silicon per hectare through diatomaceous earth (T_5 treatment) recorded higher plant height of 87.50 cm compare to other treatments, however absolute control recorded lower plant height of 71.80 cm. The superiority of diatomaceous earth could be attributed to agronomic efficiency of fertilizer, where plants were able to utilize maximum nutrients. These results were in harmony with Pati *et al.* (2016) with diatomaceous earth.

The yield and yield attributes of rice was significantly influenced by application of different sources and levels of silica. Significantly more number of panicles (19.44 hill^{-1}), higher panicle length (23.47 cm), and higher number of grains per panicle (269.30) was recorded under RDF +FYM+ 450 kg silicon per hectare through diatomaceous earth. However the 1000 grain weight was significantly higher with RDF + FYM+ 450 kg silicon per hectare through diatomaceous earth and it was at par with all other treatments except the absolute control (T_1 treatment) and recommended dose of fertilizers + FYM (T_2 treatment). Application of silica made the leaves to become more erect, thus reducing the leaf shading, increased light penetration, increased number of panicles and increasing the photosynthetic rate which in turn increased their dry matter and grain yield. These results are in accordance with Pati *et al.* (2016); Sandhya *et al.* (2018); Arthanari *et al.* (2007) and Jan *et al.* (2018).

The grain and straw yield of rice as influenced by different sources and levels of silicon is presented in Table 3, significantly higher straw yield (10204 kg ha^{-1}) was recorded with RDF + 450 kg silicon per hectare through diatomaceous earth and was at par with all other treatments except the RDF+FYM+ 150 kg Si ha^{-1} through rice husk ash (T_6), absolute control (T_1) and RDF+FYM (T_2) treatments. However, absolute control recorded the lowest straw yield of 6873 kg ha^{-1}. Grain yield of rice significantly increased with increased doses of silicon treatments, indicating the beneficial role of silica in improving the rice yield. Among the different treatments RDF+FYM+450 kg silicon per hectare through diatomaceous earth recorded significantly higher grain yield (8547 kg ha^{-1}) which is 36.03 % over the control and was at par with RDF+FYM+300 kg Si ha^{-1} (diatomaceous earth), RDF+FYM+450 kg Si ha^{-1} (Silica gel) and RDF+FYM+150 kg Si ha^{-1} (diatomaceous earth) treatments. However lowest grain yield was recorded under absolute control (5467 kg ha^{-1}). Prakash *et al.*(2011) also reported 40 % of increased grain yield by soil application of silicon. The grain and straw yield in any crop is dependent upon the photosynthetic source it can build up. A sound performance in terms

Table 2. Effect of different sources and levels of silicon application on plant growth and yield parameters of rice

Treatments	Plant height (cm)			No of panicles hill^{-1}			Length of panicle (cm)			No of grains panicle^{-1}			Test weight (g)		
	Kharif	***Rabi***	**Mean**	***Kharif***	***Rabi***	**Mean**	***Kharif***	***Rabi***	**Mean**	***Kharif***	***Rabi***	**Mean**	***Kharif***	***Rabi***	**Mean**
Absolute control	75.80	67.80	71.80	11.53	9.20	10.37	18.01	16.22	17.12	249.47	235.53	242.50	12.13	12.00	12.07
RDF+FYM	79.27	71.33	75.30	12.87	11.07	11.97	20.62	18.62	19.62	258.60	244.53	251.57	12.77	12.63	12.70
RDF+FYM +150 kg Si ha^{-1} (DE)	86.53	77.73	82.13	18.07	15.33	16.70	22.51	21.34	21.93	268.67	259.07	263.87	13.43	13.23	13.33
RDF+FYM + 300 kg Si ha^{-1} (DE)	88.87	79.80	84.34	19.47	16.13	17.80	23.08	22.67	22.88	272.60	261.53	267.07	13.53	13.23	13.38
RDF+FYM + 450 kg Si ha^{-1} (DE)	92.07	82.93	87.50	20.67	18.20	19.44	23.51	23.43	23.47	275.07	263.53	269.30	13.73	13.60	13.67
RDF+FYM +150 kg Si ha^{-1} (RHA)	81.27	74.00	77.64	15.47	11.80	13.64	21.15	19.76	20.46	262.00	248.60	255.30	13.13	13.07	13.10
RDF+FYM + 300 kg Si ha^{-1} (RHA)	83.87	77.40	80.64	15.80	12.60	14.20	21.39	19.93	20.66	265.60	251.67	258.64	13.17	13.13	13.15
RDF+FYM + 450 kg Si ha^{-1} (RHA)	85.80	78.60	82.20	17.73	13.80	15.77	22.12	20.78	21.45	266.13	254.13	260.13	13.27	13.20	13.24
RDF+FYM +150 kg Si ha^{-1} (FA)	82.67	75.87	79.27	16.53	12.53	14.53	22.04	20.31	21.18	262.87	249.40	256.14	13.20	13.17	13.19
RDF+FYM + 300 kg Si ha^{-1} (FA)	83.87	76.33	80.10	17.20	12.93	15.07	22.15	20.91	21.53	265.13	251.87	258.50	13.33	13.27	13.30
RDF+FYM + 450 kg Si ha^{-1} (FA)	84.53	77.87	81.20	18.00	13.93	15.97	22.76	21.28	22.02	265.40	254.33	259.87	13.40	13.33	13.37
RDF+FYM + 150 kg Si ha^{-1} (SG)	83.80	76.27	80.04	17.27	14.87	16.07	21.97	20.94	21.46	265.13	252.47	258.80	13.27	13.13	13.20
RDF+FYM + 300 kg Si ha^{-1} (SG)	86.60	77.60	82.10	19.00	15.13	17.07	22.20	21.51	21.86	268.73	257.00	262.87	13.33	13.23	13.28
RDF+FYM + 450 kg Si ha^{-1} (SG)	87.87	79.00	83.44	19.60	15.87	17.74	23.05	21.95	22.50	269.93	259.60	264.77	13.50	13.27	13.39
SEm±	0.38	0.59	0.49	0.28	0.42	0.35	0.25	0.20	0.23	0.72	0.79	0.76	0.28	0.26	0.27
CD (p=0.05)	1.11	1.71	1.41	0.80	1.21	1.01	0.74	0.58	0.66	2.08	2.31	2.20	0.81	0.74	0.78

Table 3. Straw yield and Grain yield of rice as influenced by different sources and levels of silicon application

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	Kharif	***Rabi***	**Mean**	***Kharif***	***Rabi***	**Mean**
Absolute control	5676	5258	5467	7131	6614	6873
RDF+FYM	6622	6173	6397	8077	7614	7846
RDF+FYM +150 kg Si ha^{-1} (DE)	8552	7777	8165	10128	9722	9925
RDF+FYM + 300 kg Si ha^{-1} (DE)	8674	8153	8414	10250	9863	10057
RDF+FYM + 450 kg Si ha^{-1} (DE)	8757	8338	8547	10333	10076	10204
RDF+FYM +150 kg Si ha^{-1} (RHA)	6698	6265	6481	8796	8617	8707
RDF+FYM + 300 kg Si ha^{-1} (RHA)	7206	6936	7071	9304	9104	9204
RDF+FYM + 450 kg Si ha^{-1} (RHA)	7587	7158	7373	10479	9096	9788
RDF+FYM +150 kg Si ha^{-1} (FA)	7250	6909	7080	9336	8906	9121
RDF+FYM + 300 kg Si ha^{-1} (FA)	7641	7207	7424	9726	9069	9398
RDF+FYM + 450 kg Si ha^{-1} (FA)	7825	7453	7639	9401	9169	9285
RDF+FYM +150 kg Si ha^{-1} (SG)	7907	7523	7715	9873	9076	9474
RDF+FYM + 300 kg Si ha^{-1} (SG)	7873	7650	7761	9904	9438	9671
RDF+FYM + 450 kg Si ha^{-1} (SG)	8241	7917	8079	10339	9819	10079
SEm±	207.60	174.41	191.01	457.82	337.93	397.88
CD (p=0.05)	603.49	507.00	555.25	1330.86	982.36	1156.61

DE- Diatomaceous earth; RHA- Rice husk ash; FY- Fly ash; SG- Silica gel

of plant height, number of panicles hill^{-1}, length of panicle, number of grains panicle^{-1} and the 1000 grains weight were logically able to improve the sources and increase the total dry matter and later lead to higher grain yield. In the effect among silicon sources, diatomaceous earth followed by Silica gel had a significant influence and relatively better than other sources. The superiority of diatomaceous earth over the other sources of silicon is mainly due to the agronomic efficiency of the fertilizer *viz.,* Solubility, chemical composition,addition of some micronutrients by diatomaceous earth besides the beneficial effect of silicon to the plant and forms of silica that is present in applied fertilizer. Of all the silicon sources, solubility was in the order of diatomaceous earth > silicagel > fly ash > rice husk Ash. Poor performance of the rice husk ash over the others is due to its solubility nature though it's having plant available forms of silica (amorphous). Ashique, (2014) also reported that diatomaceous earth application will facilitate better plant growth by providing better soil environment, providing additional nutrient supply and increasing plant available silicon in soil, that have resulted in better root growth and thereby nutrient uptake ultimately lead to better yield production. Results of Sandhya *et al.* (2018) and Pati *et al*, (2016) also support for that diatomaceous earth as the most efficient source of silicon to paddy, which outperformed in all growth attributing characters of paddy.

The performance of the silicon fertilization was varied with crop growth periods and it is beneficially good in *kharif* season than over *rabi,* it might be due the favourable climatic factors for crop during *kharif* with good rain fall and sunlight intensity hours. Among the different sources diatomaceous earth is good source for silica supplement followed by silica gel and crop yields increased with increments in silica application.

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