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Yield attributes and yields of Rice (*Oryza sativa* L.) Under Lateritic Soil of Jharkhand in Response to Silicon Sources and Levels

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ABSTRACT

Diverse silicon (Si) sources have been reported in terms of their efficacy to improve rice yield. Besides, it is critical to apprehend the efficiency of different silicon sources and their levels for judicious plant uptake and its performances in different types of soils. In this point of view, field experiments were conducted during kharif season of 2017-18 and 2018-19 to assess the effect of different silicon sources and levels on yield attributes and yields of rice (Oryza sativa L.) under lateritic soil of Jharkhand. Silica was applied at the rate of 0, 50 and 100 kg Si ha^{-1} through Calcium Silicate, Fly Ash and Paddy Straw. The results indicated that the yield attributes and yields were significantly affected by the sources and levels of Silicon. Application of calcium silicate @ 150 kg Si ha^{-1}was found most effective followed by Paddy Straw @ 150 kg Si ha^{-1} followed by Fly Ash @ 150 kg Si ha^{-1} compared to control (RDF). The highest yield attributes and grain and straw yield were found with calcium silicate @ 150 kg Si ha^{-1} in combination with RDF. Accordingly different treatments could be arranged in the order $T_4>T_{10}>T_7>T_3>T_9> T_6>T_2>T_8>T_5>T_1$.Si application at the level 150 kg Si ha^{-1} along with RDF would help in the sustainable production of rice in the lateritic soil of Jharkhand.

Keywords: *Rice, Silicon, Yield attributes, Yields*

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INTRODUCTION

With around 154 million hectares of area, rice is one of thevital cereal crops in the world. Rice is the key source of calorie intake and primary food for more than three billion persons in the world [1, 2]. Need for rice is gradually increasing due to rise in population of the world. Asian nations are the leading consumer of rice where more than 1.3 billion people consider rice as staple food [3].

Rice is consider as silicon (Si) accumulating plant, and application of Si fertilizers rise the straw and grain yield through increasing photosynthesis and plant growth [4]. Si is also recognized for its importance in alleviating the adverse stress effects on various plant species [3].Silica is one of the common elements in the earth's crust and plant's ash [5] and is second most abundant element in soil, being exist in the form of silicate or aluminum silicate [6]. It may be easily absorbed into root system from soil solution, where it is found in the form of monomeric or monosilicic acid (H_4SiO_4) [7, 8].Soils of tropical and subtropical areas are generally low in plant available Si [9] and Si content in red soils (highly weathered soil) of tropical zone may be less than 1% because of immensely active desilification and fersialitization processes[10]. In various countries Si fertilizer has been used for improving yield of rice [11]. About 20 kg/ha^2 SiO_2 is being removed from soil to yield each 100 kg brown rice [3]. Various farmers disseminate Si from fields through eliminating straw residues with harvest and exogenous application of Si in rice cultivation is often overlooked. This recommends that Si may become a yield-limiting element for rice production; hence, addition of Si fertilizer might be crucial for economic and sustainable rice production system [12].There are various Si sources for agricultural use, which range from natural minerals to chemical products and by-products of steel and iron industries. All these products are shown to be effective in improving crop growth and yield [10].

However numerous sources of Si are reported to be effective, for field application an ideal Si source should possess attributes such as easily available in locality, a relatively high content of silicon, cost-effectiveness, provide sufficient water-soluble silicon, easy to handle, have a physical nature that facilitates storage as well as application, improve plant-available Si and not contain ingredients that pollute the soil with improving crop growth and yield [4]. However, only a few sources meet all of these requirements. Crop residues mostly of high silicon-accumulating plant like rice are used as silicon sources either deliberately or inadvertently. In view of the above facts, the present investigation have been taken under the effects of indigenous sources of silicon; Paddy straw and Fly Ash and calcium silicate at different levels on effect on yield attributes and yields of rice (*Oryza sativa* L.) under lateritic soil of Jharkhand.

MATERIAL AND METHODS

Field experiments were conducted during *kharif* season of 2017-18 and 2018-19 at the Agricultural Research Farm of KrishiVigyan Kendra, Gumla, VikasBharti, Bishunpur (Jharkhand). Three doses of silica were applied at the rate of 0, 50 and 100 kg Si ha^{-1} through Calcium Silicate, Fly Ash and Paddy Straw. The experiment was arranged in randomized complete block design (RCBD) having 10 treatments *viz*., T_1: Control (RDF), T_2: RDF + 50 Kg Si ha^{-1} by Calcium Silicate, T_3: RDF + 100 Kg Si ha^{-1} by Calcium Silicate, T_4: RDF +150 Kg Si ha^{-1} by Calcium Silicate, T_5 : RDF + 50 Kg Si ha^{-1} by Fly ash, T_6: RDF + 100 Kg Si ha^{-1} by Fly ash, T_7: RDF +150 Kg Si ha^{-1} by Fly ash, T_8: RDF + 50 Kg Si ha^{-1} by paddy straw, T_9: RDF + 100 Kg Si ha^{-1} by Paddy straw, T_{10}: RDF + 150 Kg Si ha^{-1} by Paddy straw. Different silicon sources such as Calcium Silicate, Fly Ash, and Paddy Straw were applied as basal dose at effective root zone,30 days prior to transplanting. The recommended fertilizers dose of 120: 60 : 40; N: P_2O_5: K_2O kg$ha^{-1}$was applied. A basal dose of 40: 60: 40; N: P_2O_5: K_2O kg$ha^{-1}$was applied at the time of transplanting through urea, DAP and muriate of potash in all treatments including control. The second split dose of nitrogen i.e.40 kgN$ha^{-1}$was applied at tillering stage (30days after transplanting) and thirdsplitdoseofnitrogeni.e.40kgN$ha^{-1}$was applied at panicle initiation stage (60days after transplanting) through urea. The important biometric characters such as Panicle length (cm), Filled grains $panicle^{-1}$, Panicle weight (g), 1000 grains weight or test weight (g), Grain yield (g/pot), Straw yield (g/pot) and harvest index (%) were recorded.

For defining the significance between treatment means and to get a valid interpretation, statistical analysis was made. The difference of the treatments mean was tested using critical difference (CD) at 5% level of probability [13]by following the Randomized Complete Block Design (RCBD) to draw the valid differences among the treatments.

RESULT AND DISCUSSION

Effect of sources and levels of silicon on yield attributes and yields of rice

Number of productive tillers/m^2

The data obtained in respect of number of productive tiller/m^{-2} of rice crop under various treatments of silicon have been exhibited in table 1.Productive tillers/m^{-2} increased with increasing silicon levels during both the years at all growth stage and with all sources. Application of 150 Kg Si ha^{-1} by calcium silicate (T_4) registered significantly maximum productive tillers as compared to control (0% Si) and 50 to 150 kg Si ha^{-1} by different sources as fly ash and paddy straw of silicon during both the years. The effect of various treatments on number of productive tiller/m^{-2} of rice crop could be arranged in order of $T_4>T_{10}>T_7>T_3>T_9> T_6>T_2>T_8>T_5>T_1$.

Panicle length (cm)

The data related to panicle length as affected by sources and levels of silicon are presented in table 1.The panicle length (cm) increased significantly with increasing silicon levels during both the years and application of 150 Kg Si ha^{-1} by Calcium Silicate produced significantly longer panicle length as compared to other treatments. The treatment 150 kg Si ha^{-1} through Fly ash and Paddy straw gave significantly longer panicle length over the control and 50 kg Si ha^{-1}; which was at par with 100 kg Si ha^{-1}. As evident from the results, panicle length (cm) variation among similar level of silicon through fly ash & paddy straw was at par at all the growth stages during both years. The effect of various Si treatments on panicle length of rice was found in the order $T_4>T_{10}>T_7>T_3>T_9> T_6>T_2>T_8>T_5>T_1$.

Panicle weight (g)

Data regarding panicle weight as affected by different source and levels of silicon have been interpreted in table 2.As evident from results, T_4 treatment (150 Kg Si ha^{-1} by Calcium Silicate) had recorded significantly higher panicle weight against all other treatments during both the years of experimentation.

It was observed that increasing silicon levels increased panicle weight with all sources in both the years. Among the different sources, application of Calcium Silicate found to record significantly higher panicle weight as compared to Fly ash and Paddy straw at all level of silicon and panicle weight in fly ash & paddy straw treatment was observed at par in both years. There was significant increase inpanicle weight with the different sources and levels of silicon over control

Number of filled grains panicle^{-1}

Grains panicle^{-1} as affected by different sources and levels of silicon has been presented in table 2. Significantly higher grain panicle^{-1}was recorded in plot that had received 150 Kg Si ha^{-1} by Calcium Silicate (T_4) as compared to other treatments whereas Fly ash & paddy straw treatment was observed at par during both the years of experimentation. Careful scanning of the data clearly indicated that number of grain penicle^{-1} increased with increasing silicon levels from 0 to 150 kg Si ha^{-1} during the both years and the highest grain penicle^{-1} pooled data (121.67) was recorded with T_4 treatment (150 Kg Si ha^{-1}by Calcium Silicate) followed by T_{10} (RDF + 150 Kg Si ha^{-1}by Paddy straw) and T_7 (RDF +150 Kg Si ha^{-1}by Fly ash).

Grain yield and straw yield (q/ha)

Data pertaining to grain yield as influenced by different source and levels of silicon have been interpreted in table 3.Application of silicon through any source increased grain yield of rice significantly over control. Further, the yield was significantly superior under the use of Calcium Silicate as a source followed by paddy straw and fly ash. It is apparent from table that T_4 (150 Kg Si ha^{-1} by Calcium Silicate) produced significantly higher grain yield than the T2 & T3 (50 & 100 Kg Si ha^{-1} by Calcium Silicate) during the both the years of experimentation.

Careful perusing of the data clearly indicated that grain yield increased with increasing silicon levels from control (0% Si) to 150 kg Si ha^{-1} by any source and significantly higher grain yield was recorded with T4 treatment (150 Kg Si ha^{-1}by Calcium Silicate) as compared to other treatments in both the years . Application of 150 Kg Si ha^{-1} by Calcium Silicate had increased 23% higher grain yield than control. Grain yield in fly ash and paddy straw applied plots was remained at par during both year. According to results, the superiority of the treatments could be arranged as $T_4 > T_{10} > T_7 > T_3 > T_9 > T_6 > T_2 > T_8 > T_5$ and T_1.

The result obtained in respect of the effect of silicon sources and levels on straw yield have been exhibited in table 3. The results presented in Table 4.11 illustrate that the rice straw yield was significantly influenced by silicon application. The significantly higher straw (63.35 q ha^{-1}) yield per plot was recorded due to silicon application at 150 Kg Si ha^{-1} by Calcium Silicate; while the lowest straw (48.10q ha^{-1}) yield per plot was recorded under control. The application 150 Kg Si ha^{-1} gave significantly higher straw yields over the control and 50 kg Si ha^{-1}; which was at par with 100 kg Si ha^{-1} with all sources. At same level of silicon, Straw yield in fly ash and paddy straw treatments was observed at par during both the years of experimentation. The straw yield of rice crop was higher under calcium silicate followed by paddy straw and fly ash.

Harvest index (%)

Data on harvest index (%) as influenced by different source and levels of silicon have been presented in table 4. From the results it was found that harvest index (%)varied depending upon the variation of Si application as well as sources and their magnitude was greater with higher dose of silicon (150 Kg Si ha^{-1}) along with the RDF. Data envisaged that significantly higher harvest index was recorded with application of higher dose (150 Kg Si ha^{-1}) over lower doses (50 and 150 Kg Si ha^{-1})under Calcium Silicate and followed the same trend under fly ash and paddy straw. Alike, grain and straw yield, application of Calcium Silicate as a source had recorded significantly higher harvest index as compared to other sources such aspaddy straw and fly ash while differences between paddy straw and fly ash treatments were non-significant at same level of silicon. On the basis of data, the superiority of the treatments could be arranged as $T_4 > T_{10} > T_7 > T_3 > T_9 > T_6 > T_2 > T_8 > T_5$ and T_1.

1000 grains weight (g) or test weight

Test weight as affected by different sources and levels of silicon has been presented in table 4. The significantly higher test weight was observed with the application of 150 Kg Si ha^{-1} by Calcium Silicate over other treatments during both the years of experimentation. In general, 150 Kg Si ha^{-1} applied plots by fly ash and paddy straw have recorded significantly higher test weight as compared to 50 Kg Si ha^{-1} while it was remained at par with 100 Kg Si ha^{-1} applied plots. In the present study among the different sources, application of fly ash and paddy straw found to be on par with each other in their test weight. On the basis of data, the superiority of the treatments could be arranged as $T_4 > T_{10} > T_7 > T_3 > T_9 > T_6 > T_2 > T_8 > T_5$ and T_1.

The increase in yields of rice might be attributed due to increased availability of phosphorus and other beneficial effect of silicon on growth of paddy. These results are in confirmative with those reported earlier [14, 15, 16]who also reported increase in growth and dry matter of paddy due to silicon application through different organic and inorganic sources. Xue *et al*. [17] revealed significant increase in growth and yield parameters due to application of different sources of silicon. Sandhya and Prakash [4] reported that application of silicon sources significantly increased the panicle number and its length compared to control.

Application of three Si sources significantly increased the yield of rice [18]compared to control but the performance of each source varied which may be due to the reactivity rather than total Si content [4, 19].Si nutrition enhances growth, development and weight of roots resulting in improvement in absorption at the end. These results are in assertion with Alsaeedi *et al*. [20].Si supplementation applied in soil or leaves improved diameter of rose stems and flower bud length and presented better outcomes for other biometric parameter [6].The beneficial effects of Si on plant growth and yield have also been demonstrated by other authors [21].

Table 1: Effect of Silicon Sources and levels on No. of productive tillers/m^2 and panicle length (cm)

Treatments	Productive tillers/m^2			Panicle length (cm)		
	2017-18	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**
T1 : Control (RDF)	290.56	294.22	292.39	15.83	16.00	15.92
T2 : RDF + 50 Kg Si ha^{-1} by Calcium Silicate	314.11	317.56	315.84	16.50	17.00	16.75
T3 : RDF + 100 Kg Si ha^{-1} by Calcium Silicate	326.78	330.11	328.45	17.83	18.17	18.00
T4 : RDF +150 Kg Si ha^{-1} by Calcium Silicate	339.33	342.67	341.00	19.57	19.77	19.67
T5 : RDF + 50 Kg Si ha^{-1} by Fly ash	300.22	303.56	301.89	16.17	16.33	16.25
T6 : RDF + 100 Kg Si ha^{-1} by Fly ash	318.33	321.67	320.00	16.83	17.17	17.00
T7 : RDF +150 Kg Si ha^{-1} by Fly ash	330.89	334.22	332.56	18.10	18.33	18.22
T8 : RDF + 50 Kg Si ha^{-1} by paddy straw	307.78	312.78	310.28	16.33	16.83	16.58
T9 : RDF + 100 Kg Si ha^{-1} by Paddy straw	321.89	323.56	322.73	17.10	17.67	17.38
T10 : RDF + 150 Kg Si ha^{-1} by Paddy straw	333.11	334.44	333.78	18.63	18.83	18.73
S Em (±)	3.59	3.24	3.42	0.77	0.74	0.76
CD (*p=0.05*)	10.67	9.62	10.15	2.30	2.20	2.25

RDF = Recommended Dose of Fertilizers, Si = Silicon, CD = Critical Difference, SEm± = Standard error of mean

Table 2: Effect of Silicon Sources and levels on panicle weight (g) and filled grain panicle^{-1}

Treatments	Panicle weight (g)			Filled grain panicle^{-1}		
	2017-18	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**
T1 : Control (RDF)	1.58	1.60	1.59	110.67	111.67	111.17
T2 : RDF + 50 Kg Si ha^{-1} by Calcium Silicate	1.65	1.70	1.68	116.67	117.00	116.83
T3 : RDF + 100 Kg Si ha^{-1} by Calcium Silicate	1.74	1.77	1.76	118.67	119.00	118.83
T4 : RDF +150 Kg Si ha^{-1} by Calcium Silicate	1.85	1.88	1.86	121.33	122.00	121.67
T5 : RDF + 50 Kg Si ha^{-1} by Fly ash	1.60	1.63	1.62	114.67	114.67	114.67
T6 : RDF + 100 Kg Si ha^{-1} by Fly ash	1.67	1.72	1.69	117.33	117.67	117.50
T7 : RDF +150 Kg Si ha^{-1} by Fly ash	1.77	1.78	1.78	119.33	119.67	119.50
T8 : RDF + 50 Kg Si ha^{-1} by paddy straw	1.62	1.67	1.64	115.67	116.33	116.00
T9 : RDF + 100 Kg Si ha^{-1} by Paddy straw	1.69	1.73	1.71	118.00	118.33	118.17
T10 : RDF + 150 Kg Si ha^{-1} by Paddy straw	1.80	1.82	1.81	119.67	120.67	120.17
S Em (±)	0.05	0.06	0.06	1.05	1.54	1.30
CD (*p=0.05*)	0.15	0.19	0.17	3.13	4.59	3.86

RDF = Recommended Dose of Fertilizers, Si = Silicon, CD = Critical Difference, SEm± = Standard error of mean

Table 3: Effect of silicon sources and levels on grain yield (q ha^{-1}) and straw yield (q ha^{-1})

Treatments	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
T1 : Control (RDF)	31.52	32.2	31.86	47.58	48.62	48.10
T2 : RDF + 50 Kg Si ha^{-1} by Calcium Silicate	34.9	35.3	35.10	51.92	52.53	52.22
T3 : RDF + 100 Kg Si ha^{-1} by Calcium Silicate	38.33	38.91	38.62	55.41	56.26	55.83
T4 : RDF +150 Kg Si ha^{-1} by Calcium Silicate	44.97	45.8	45.39	62.75	63.94	63.35
T5 : RDF + 50 Kg Si ha^{-1} by Fly ash	32.83	33.26	33.05	49.07	49.73	49.40
T6 : RDF + 100 Kg Si ha^{-1} by Fly ash	35.6	36.03	35.82	52.74	53.39	53.07
T7 : RDF +150 Kg Si ha^{-1} by Fly ash	39.57	40.57	40.07	55.85	57.28	56.56
T8 : RDF + 50 Kg Si ha^{-1} by paddy straw	33.87	34.27	34.07	50.31	51.07	50.69
T9 : RDF + 100 Kg Si ha^{-1} by Paddy straw	36.89	37.45	37.17	53.38	54.23	53.81
T10 : RDF + 150 Kg Si ha^{-1} by Paddy straw	42.42	43.08	42.75	59.38	60.32	59.85
S Em (±)	2.13	2.11	2.12	3.11	3.08	3.10
CD (*p=0.05*)	6.32	6.25	6.29	9.24	9.15	9.20

RDF = Recommended Dose of Fertilizers, Si = Silicon, CD = Critical Difference, SEm± = Standard error of mean

Table 4: Effect of silicon sources and levels on harvest index (%) and test weight (g)

Treatments	Harvest index (%)			Test weight (g)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
T1 : Control	39.84	39.17	39.51	20.50	20.73	20.62
T2 : RDF + 50 Kg Si ha^{-1} by Calcium Silicate	40.20	40.19	40.20	21.13	21.23	21.18
T3 : RDF + 100 Kg Si ha^{-1} by Calcium Silicate	40.89	40.88	40.89	21.57	21.67	21.62
T4 : RDF +150 Kg Si ha^{-1} by Calcium Silicate	41.74	41.74	41.74	23.13	23.23	23.18
T5 : RDF + 50 Kg Si ha^{-1} by Fly ash	40.09	40.08	40.08	20.83	20.93	20.88
T6 : RDF + 100 Kg Si ha^{-1} by Fly ash	40.30	40.29	40.29	21.23	21.33	21.28
T7 : RDF +150 Kg Si ha^{-1} by Fly ash	41.47	41.46	41.46	21.87	21.97	21.92
T8 : RDF + 50 Kg Si ha^{-1} by paddy straw	40.24	40.16	40.20	21.07	21.17	21.12
T9 : RDF + 100 Kg Si ha^{-1} by Paddy straw	40.86	40.85	40.86	21.33	21.43	21.38
T10 : RDF + 150 Kg Si ha^{-1} by Paddy straw	41.67	41.67	41.67	22.30	22.40	22.35
S Em (±)	0.19	0.21	0.20	0.51	0.46	0.48
CD (*p=0.05*)	0.57	0.63	0.60	1.50	1.36	1.43

RDF = Recommended Dose of Fertilizers, Si = Silicon, CD = Critical Difference, SEm± = Standard error of mean

CONCLUSION

On the basis of above study, we can conclude that the different sources and increasing levels of silicon significantly affect the yield attributes and yield of rice. Results indicated that yield attributes and yield of rice significantly increased with the application of different silicon sources at different levels compared to control. Calcium silicate @ 150 kg Si ha^{-1} found superior in all the treatments. All the sources of silicon were found at par at lower level.

CONFLICT OF INTEREST

All the authors hereby declare that there is no conflict of interest regarding the publication of this article.

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