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RESEARCH PAPER

Effect of nano silicon on the performance of transplanted rice (*Oryza sativa* L.)

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Abstract: A field experiment was conducted during *summer* season of 2020-21 at Agricultural Research Station, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka to study effect of nano silicon on the performance of transplanted rice. The experiment was laid out in randomized complete block design consisted of nine treatments and replicated thrice. The results revealed that application of silicon in the form of orthosilicic acid 12 per cent effervescent tablets as foliar spray @ 1.0 g lit^{-1} at 25, 40, and 55 days after transplanting resulted in the maximum uptake of silicon and nutrients like N, P and K. Silicon application improved the growth parameters like plant height, number of tillers plant^{-1}, functional leaf area and dry matter production of rice in turn resulted in best partitioning of dry matter into yield components such as a more number of panicles per sqm^{2}, more number of filled spikelets panicles^{-1} and higher test weight which in turn have contributed for higher grain and straw yield, gross returns, net returns and b-c ratio than no silicon control and also other silicon treatments.

Key words: Benefit cost ratio, Days after transplanting, Orthosilicic acid

Introduction

Rice (*Oryza sativa* L.) is the staple food crop for more than half of the world's population and its cultivation secures livelihood for more than two billion people. It is also the staple food crop of India with an area of 46.20 million hectares with productivity of 117.32 million tones and wilt productivity of 2585 kg ha^{-1}. India will need to produce more rice if it has to meet the growing demand which is likely to be 130 m t of milled rice by 2030 with an average productivity of 4.03 t ha^{-1} to maintain the present level of food self-sufficiency (Anon, 2019).

In Karnataka, rice is cultivated in the command areas of Cauvery, Tungabhadra (TBP) and Upper Krishna with total area of 8.74 lakh ha^{-1} with an annual production of 23.59 lakh tones and with a productivity of 2699 kg ha^{-1} (Anon, 2018).

In the intensive irrigated rice system in Tungabhadra command area the most commonly applied fertilizers for rice includes N, P, K, S, Zinc and Iron as essential nutrients. Apart from these nutrients silicon (Si) is considered as a beneficial element for crop growth, especially for crops under Poaceae family.

Potassium silicate is traditionally recommended as a silicon fertilizer for rice. However due scarce availability, require large amounts and due to high cost farmers are not usually practiced. Presently nano silicon products are gaining importance in rice nutrition. Studies on all India coordinated rice improvement programme revealed the beneficial effects Orthosilicic acid effervescent tablets (nano product) on the yield of transplanted rice (Anon, 2016). By using nano-silicon, the spread of silicon into ground is more secure because of their small size. Beside with very small size of the rice plants ability to absorb silicon through the roots and leaves will be greater, so that more silicon is absorbed. Ranjbar and Shams (2009) reported that nano fertilizer is more readily absorbed by the plants and more efficient than conventional silicon fertilizers. Keeping the above facts in view, an investigation was conducted to find out the best silicon fertilizer for transplanted rice.

Material and methods

A field experiment was conducted during summer season of 2020-21 at Agricultural Research Station, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka. The soil of the experimental site was medium black clay in texture classified under the order *Vertisols*. The experiment was laid out in randomized complete block design replicated thrice. The treatments comprised of T_1: soil application of orthosilicic acid 12% effervescent tablets @ 2.5 kg ha^{-1} at 25 days after transplanting (DAT), T_2: soil application of orthosilicic acid 12% effervescent tablets @ 2.5 kg ha^{-1} at 50 DAT, T_3: soil application of orthosilicic acid 12% effervescent tablets @ 2.5 kg ha^{-1} at 25 and 50 DAT, T_4: orthosilicic acid 12% effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 DAT, T_5: orthosilicic acid 12% effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 and 40 DAT, T_6: orthosilicic acid 12% effervescent tablets foliar spray @ 1.0 g l^{-1} at 25, 40 and 55 DAT, T_7: rice husk ash equivalent of silicon 2.5 kg ha^{-1}, T_8: soil application of potassium silicate @ 50 kg ha^{-1} at 25 DAT and T_9: Control (no silicon).

Half dose of nitrogen, entire dose of phosphorous and potassium in the form of urea and diammonium phosphate (DAP) and muriate of potash (MOP) respectively were broad casted on the field. The remaining N was top dressed ¼ each at active tillering and panicle initiation stage. A total of 150:75:75 kg ha^{-1} of N, P_2O_5, K_2O was applied. Orthosilicic acid effervescent tablets as SiO_3 @ 2.5 kg ha^{-1}, potassium silicate as $K_2Si_2O_5$ @ 50 kg ha^{-1}, rice husk ash equivalent @ 2.5 kg ha$^{-1,}$ were applied to

the respective plots as per the treatments at the time of sowing. Foliar application of orthosilicic acid effervescent tablets @ 1.0 g l^{-1} were applied as per the treatments, with a spray volume of 500 l ha^{-1} and sprayed uniformly on surface of the leaves. Observations on growth and yield parameters were recorded and economics was worked out.

Results and discussion

Effect of nano-silicon fertilizers on the growth and yield of transplanted rice

A significant difference in rice growth and yield was observed due to application of silicon treatments. Application of orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g lit^{-1} at 25, 40 and 55 DAT was found significantly superior by recording significantly higher grain yield (5798 kg ha^{-1}) than all the other treatments. While the no silicon (control) treatment recorded significantly lower grain yield (5023 kg ha^{-1}). This finding corroborates with the results of Ahmed *et al*. (2011) in wheat and Prakash (2010) in rice. The next best treatments in the order in terms of grain yield were soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 and 50 DAT(5509 kg ha^{-1}), orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0g lit^{-1} at 25 and 40 DAT (5498 kg $ha^{-1}$and soil application of potassium silicate @ 50 kg ha^{-1} (5421 kg ha^{-1}). Application of orthosilicic acid 12 per cent effervescent tablets as foliar spray @ 1.0 g lit^{-1} at 25, 40 and 55 DAT recorded 13.36 per cent higher grain yield than no silicon control indicating the role of silicon as beneficial element in increasing the rice grain yield (Table.1). Similar results are observed by Lavinsky *et al*. (2016) and Sarma *et al.* (2017) in rice.

Application of orthosilicic acid 12 per cent effervescent tablets as foliar spray @ 1.0 g lit^{-1} at 25, 40 and 55 DAT recorded significantly higher straw yield than all the other treatments (6534 kg ha^{-1}) except soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 and 50 DAT (6407 kg ha^{-1}), where in it remained on par. The no silicon control recorded significantly lower straw yield (6003 kg ha^{-1}). Similar results are observed by Ma *et al.* (2009) in rice.

Silicon application influenced the grain yield of rice by improving the yield components such as number of panicles per m^2, panicle length, number of filled spikelets $panicle^{-1}$ and test weight. Among all treatments orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25, 40, and 55 DAT recorded significantly higher panicles m^{-2}. A greater number of filled spikelets per panicle, test weight and panicle length thus contributed to higher grain yield. This indicated the beneficiary influence of silicon on yield components and improving the grain yield of rice. Similar results are observed by Singh *et al.* (2007) and Dastan *et al.* (2012) in rice.

Silicon application increased the grain yield of rice by increasing the dry matter production at all growth stages of rice. Application of orthosilicic acid 12 per cent effervescent tablets foliar spray @1.0 g lit^{-1} ha^{-1} at 25, 40, and 55 DAT resulted in significantly higher total plant dry matter production at 30, 60 and 90 DAT respectively (14.13, 30.18 and 43.36 g $hill^{-1}$) (Table.2). Similar results are observed by Ma (2009) and Liang *et al.* (2013) in rice.

The plant height (cm) at 30, 60, 90 DAT and at harvest were highest with application of orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25, 40, and 55 DAT respectively (37.80, 48.60, 69.70 and 79.20 cm) than other treatments and control. Similar results are observed by Yogendra *et al.* (2014) and Sarma *et al.* (2017) in rice.

Among all the treatments, application of orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25,

Table 1. Yield attributing characters, grain yield, straw yield and harvest index of transplanted rice as influenced by silicon nutrition

Treatments	No. of paniclesm^{-2}	Panicle weight (g)	No.of filled spikelets $panicle^{-1}$	No.of unfilled spikelets $Panicle^{-1}$	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1	334.5	3.36	127.5	18.8	13.6	5175	6123	0.45
T_2	343.4	3.53	132.6	16.9	13.7	5300	6221	0.46
T_3	372.2	3.61	137.3	14.4	13.8	5509	6407	0.46
T_4	336.1	3.32	126.3	15.7	13.5	5270	6132	0.46
T_5	368.2	3.65	135.8	14.1	13.6	5498	6274	0.46
T_6	385.6	3.93	145.8	11.7	13.9	5798	6534	0.47
T_7	341.1	3.33	126.4	18.2	13.4	5063	6102	0.45
T_8	356.1	3.56	134.2	14.6	13.7	5421	6271	0.46
T_9	320.3	3.30	125.4	19.7	13.0	5023	6003	0.45
S.Em±	4.78	0.09	1.89	0.23	0.30	75	87	0.01
C.D. (P=0.05)	13.77	0.26	5.46	0.67	0.88	217	251	0.03

T_1 : Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 DAT
T_2 : Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 50 DAT
T_3 : Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 and 50 DAT
T_4 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 DAT
T_5 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 and 40 DAT
T_6 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25, 40 and 55 DAT
T_7 : Rice husk ash equivalent of silicon 2.5 kg ha^{-1}
T_8 : Potassium silicate @ 50 kg ha^{-1} at 25 DAT
T_9 : Control (No Silicon)

Table 2. N, P, K and Si uptake by transplanted rice as influenced by silicon nutrition

Treatments	Nitrogen (kg ha^{-1})	Phosphorous (kg ha^{-1})	Potassium (kg ha^{-1})	Silicon (kg ha^{-1})
T_1	113.4	38.3	100.5	12.89
T_2	117.9	39.1	102.6	14.98
T_3	123.6	40.9	109.3	17.05
T_4	112.6	38.8	101.5	15.95
T_5	118.1	40.8	104.3	13.21
T_6	126.4	42.8	118.0	25.17
T_7	110.4	38.7	100.5	12.82
T_8	118.4	40.7	102.7	13.36
T_9	105.6	38.1	95.8	12.01
S.Em±	1.33	0.28	3.95	2.78
C.D (P=0.05)	3.84	0.82	11.40	8.03

DAT: Days after transplanting

T_1: Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 DAT

T_2: Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 50 DAT

T_3: Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 and 50 DAT

T_4 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 DAT

T_5 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 and 40 DAT

T_6: Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25, 40 and 55 DAT

T_7: Rice husk ash equivalent of silicon 2.5 kg ha^{-1}

T_8: Potassium silicate @ 50 kg ha^{-1} at 25 DAT

T_9: Control (No Silicon)

Table 3. Cost of cultivation, gross returns, net returns and B:C ratio of transplanted rice influenced by silicon nutrition

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1	64125	114798	50673	1.79
T_2	64125	117521	53396	1.83
T_3	69375	122096	52721	1.76
T_4	60175	116802	56627	1.94
T_5	61475	121732	60257	1.98
T_6	62775	128292	65517	2.04
T_7	60875	112425	51550	1.85
T_8	61625	120112	58487	1.95
T_9	58875	111486	52611	1.89
S.Em±	-	1518	1518	0.02
C.D.(P =0.05)	-	4555	4555	0.07

T_1 : Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 DAT

T_2 : Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 50 DAT

T_3 : Soil application of orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 and 50 DAT

T_4 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 DAT

T_5 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25 and 40 DAT

T_6 : Orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g l^{-1} at 25, 40 and 55 DAT

T_7 : Rice husk ash equivalent of silicon 2.5 kg ha^{-1}

T_8 : Potassium silicate @ 50 kg ha^{-1} at 25 DAT

T_9 : Control (No Silicon)

40, and 55 DAT recorded significantly higher number of tillers hill^{-1} at 30, 60, 90 DAT and harvest respectively (12.35,18.21,19.25 and 19.35 no hill^{-1}) than other treatments and control. Similar results are observed by Singh *et al.* (2007) and Muriithi *et al.* (2010) in rice.

Among the treatments, orthosilicic acid 12 per cent effervescent tablets as foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25, 40, and 55 DAT resulted significantly higher leaf area hill^{-1} at 30, 60, 90 DAT and harvest respectively (381.22, 793.24, 882.33 and 598.96 cm hill^{-1}) than other treatments and control. Similar results are observed by Gong *et al.* (2003) in rice and Ahmed *et al.* (2011) in wheat.

Silicon application through orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25, 40 and 55 DAT resulted in significantly higher uptake of N, P, K and Si (126.48, 42.86, 118.03 and 25.17 kg ha^{-1} respectively) than other treatments. compared to no silicon control, indicating positive effect of silicon on the uptake of N, P and K in rice. Similar results are observed by Pati *et al.* (2016), and Akther (2020) in rice.

Among all treatments, orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25, 40, and 55 DAT resulted in significantly the higher gross returns ha^{-1} (128292 ₹ ha^{-1}) net returns ha^{-1} (65517₹ ha^{-1}) with higher BC ratio (2.04) orthosilicic acid 12 per cent effervescent tablets @ 2.5 kg ha^{-1} at 25 and 50 DAT recorded lower B:C ratio (1.76) other treatments and no silicon control (Table.3). Similar results are observed by Jawahar and Vijayapuri (2015) and Jinger *et al.* (2018) in rice.

Conclusion

Application of silicon in the form of orthosilicic acid 12 per cent effervescent tablets as foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25, 40, and 55 DAT resulted in the maximum uptake of nutrients like N, P, K and Si. The highest uptake of these nutrients resulted in improved growth parameters like plant height, number of tillers plant^{-1}, functional leaf area and dry matter production by transplanted rice. The maximum growth parameters in turn resulted in best partitioning of dry matter into yield components such as a greater number of panicles per sqm^2, number of filled spikelets panicles^{-1} and test weight which in turn have contributed for higher grain and straw yield and thus more economical returns. Application of orthosilicic acid 12 per cent effervescent tablets foliar spray @ 1.0 g lit^{-1} ha^{-1} at 25, 40 and 55 DAT resulted in higher gross returns, net returns B:C ratio than other treatments and no silicon control.

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