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EFFECT OF SILICON AND BORON ON NUTRIENT STATUS AND YIELD OF RICE IN LATERITE SOILS

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ABSTRACT

A greenhouse experiment was conducted at College of Agriculture, Padannakkad, Kasaragod, Kerala, India during 2013 to study the effect of silicon and boron on nutrient status and yield of rice. Experiment was laid out in completely randomised design replicated thrice with nine treatments using Aishwarya as the test variety. The results revealed that the soil and foliar application silicon and boron had a synergistic effect on the availability of nutrients in the soil. Foliar application of 0.5 % silicon as potassium silicate and 0.5 % as boron as borax was more effective in improving the uptake of silicon and boron by the crop compared to soil application of silicon and boron. Application of three sprays of silicon and boron proved significantly superior with respect to yield and yield attributes of rice. The tune of increase in grain and straw yield with 3 sprays of 0.5 % potassium silicate + 0.5% borax was 34.34 and 44.64 g pot^{-1}, respectively.

Key words: Silicon, boron, rice, nutrient uptake, yield

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple crops in many countries. Rice yields are decelerating / stagnating / declining in post green revolution era mainly due to imbalance in fertilizer use, soil degradation, lack of suitable rice genotypes for low moisture adaptability and disease resistance (Prakash, 2010). Crop production in laterite soils has been found to be low due to several constraints. However, there is considerable scope for improving the productivity of soils through proper land management. Silicon (Si) is the second most abundant element in soil. Si is assimilated by plant roots as monosilicic acid (H_4SiO_4) (Epstein, 1999). Rice is a high silicon accumulating plant. Silicon is a beneficial element for plant growth and is agronomically essential for improving and sustaining rice productivity. Besides rice yield increase, Si has many fold advantages of increasing nutrient availability (N, P, K, Ca, Mg and Zn) and minimizing biotic and abiotic stress in plants. Hence the application of Si to soil or plant is practically useful in laterite derived paddy soils. Ahmad *et al.* (2013) reported that application of Si fertilizers enhanced the growth parameters, increased yield, yield attributes and quality of rice crop. The boron requirement is much higher for reproductive growth than for vegetative growth in most plant species. Boron uptake correlated well with the concentration of H_3BO_3 in soil solution. Boron is immobile in plant, deficiency symptoms of B in rice begin with a whitish discoloration and twisting of new leaves (Barman *et al.* (2014) observed that application of boron significantly increased N, P, K, Ca, Mg, S and Zn content in soil due to application of boron. The application of boron through different sources either through soil or foliar spray was found to be beneficial in stimulating plant growth and in increasing yield of rice (Rao *et al.*, 2013). With this background, the present study on the silicon and boron nutrition of rice to increase the nutrient status and rice yield in laterite derived paddy was carried out.

MATERIALS AND METHODS

A greenhouse experiment was conducted at College of Agriculture, Padannakkad. The experiment was laid out in complete randomized design replicated thrice with test crop of rice variety Aishwarya. There were 9 treatments *viz.* T_1- control- T_2- Calcium silicate @ 4 g kg^{-1} soil, T_3- 3 sprays of 0.5% potassium silicate, T_4- borax @ 0.5 g kg^{-1} soil, T_5 - 3 sprays of 0.5% borax, T_6- calcium silicate @ 4 g kg^{-1} soil + borax @ 0.5 g kg^{-1} soil, T_7- calcium silicate @ 4 g kg^{-1} soil + 3 sprays of 0.5% borax, T_8- 3 sprays of 0.5 % potassium silicate + 0.5% borax and T_9- 3 sprays of 0.5% potassium silicate + borax @ 0.5g kg^{-1} soil.Laterite derived paddy soil (10 kg) was filled in each pot for conducting pot culture experiment. The experimental soil was sandy clay belonging to the taxonomical order Inceptisol having pH 4.7, EC 0.16 dSm^{-1}, CEC 7.5 c mol (p^{+}) kg^{-1}, organic carbon 3.6 g kg^{-1}, available nitrogen 201 kg ha^{-1} available P_2O_5 15 kg ha^{-1}, available K_2O 152 kg ha^{-1}, available Ca 1114 mg kg^{-1}, available Mg 45 mg kg^{-1}, available B 0.17 mg kg^{-1} and available Si 24 mg kg^{-1}. Nitrogen, P and K fertilizers were applied as per recommendations. Collected soil samples were analyzed, for available N, P (Bray and Kurtz 1945) and K using standard methods (Jackson, 1973).

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Calcium and Mg contents were determined by EDTA titration method.. DTPA – Cu and Zn were determind by AAS (Lindsay and Norvell, 1978). Plant samples were analyzed for N by Kjeldahl method. Phosphorus was analyzed in di acid digest by vanado molybdate yellow colour method, K by flame photometer, and Ca, Mg, (Issac and Kerber, 1971) Cu and Zn on atomic absorptions spectrophotometer. Boron was analysed by azomethine - H colorimetric method and Si by blue silicomolybdous acid method. Biometric observations *viz.,* plant height, number of productive tillers plant^{-1}, thousand grain weights, grain and straw yield were recorded at maturity. The results obtained were statistically analyzed using statistical analysis software (SAS).

RESULTS AND DISCUSSION

There was no significant difference between the treatments with respect to available N, Mg, S, Zn and Cu content in soil. Available P content (33.84 kg ha^{-1}) in soil was significantly higher with application of calcium silicate @ 4 g kg^{-1} soil + borax @ 0.5 g kg^{-1} soil (Table 1). This might be due to the fact that the anion monosilicic acid [Si(OH)3]$^{-}$ can replace the phosphate anion [HPO4]$^{2-}$ from aluminum and iron phosphates there by increasing the solubility of phosphorus (Subramanian and Gopalswamy, 1990). The available potassium content in soil was maximum (270.1 kg ha^{-1}) with 0.5% potassium silicate + 0.5% borax (T_8). This may be due to the production of hydrogen ions during reduction of Fe and Al toxicity which would have helped in the release of K from the exchange sites or from the fixed pool to the soil solution. The highest available Ca content (1516 mg kg^{-1}) in soil was obtained from the application of 4 g calcium silicate kg^{-1} soil + 0.5 g borax kg^{-1} soil (Table 1).

Table 1: Effect of silicon and boron on status of nutrients in post harvest soil

Treatment	kg ha^{-1}			mg kg^{-1}			
	N	P	K	Ca	Mg	Zn	Cu
T_1	230.7	19.38	202.8	1230	49.58	3.91	3.60
T_2	241.0	31.60	223.0	1481	51.91	4.14	3.81
T_3	232.6	28.17	254.1	1315	51.98	4.08	3.83
T_4	236.0	25.61	215.0	1285	50.17	4.01	3.70
T_5	235.3	24.92	217.4	1291	50.25	4.00	3.68
T_6	240.4	33.84	220.4	1516	53.41	4.09	3.79
T_7	239.3	29.09	231.7	1489	52.58	4.04	3.76
T_8	241.7	31.84	270.1	1347	52.52	4.18	3.79
T_9	238.3	28.00	266.0	1313	51.41	4.12	3.75
CD (P=0.05)	NS	7.29	24.7	76	NS	NS	NS

The silicon availability showed a concomittant increase with application of silicon as soil and foliar spray (Table 2). The silicon availability increased from maximum tillering stage to flowering stage and then decreased at harvest. This decrease may be due to dilution effect. At flowering stage significantly higher available silicon was observed in the treatment receiving calcium silicate @ 4 g kg^{-1} soil (44.5 mg kg^{-1}) while at the harvesting stage calcium silicate @ 4 g kg^{-1} soil + borax @ 0.5 g kg^{-1} soil (T_6) was superior (38.50 mg kg^{-1}). The silicon applied as soil application of calcium silicate would have prevailed in soil as monosilicic acid (H_4SiO_4) and enhanced soil silicon availability (Singh *et al.* 2006).

Table 2: Effect of treatments on silicon and boron content in soil at different stages of rice

Treatment	Silicon (mg kg^{-1})			Boron (mg kg^{-1})		
	Maximum tillering stage	Flowering stage	Harvesting stage	Maximum tillering stage	Flowering stage	Harvesting stage
T_1	25.0	25.2	23.9	0.22	0.23	0.20
T_2	26.0	44.5	37.6	0.23	0.28	0.25
T_3	27.5	35.2	32.8	0.23	0.27	0.26
T_4	26.0	27.0	25.6	0.23	0.55	0.32
T_5	26.4	27.8	26.1	0.23	0.34	0.30
T_6	27.5	43.7	38.5	0.26	0.58	0.32
T_7	26.2	43.0	36.2	0.24	0.35	0.28
T_8	26.0	32.0	27.8	0.23	0.28	0.26
T_9	25.9	33.3	29.9	0.23	0.46	0.21
CD (P=0.05)	NS	5.0	5.8	NS	0.04	0.07

The available boron content of soil increased from maximum tillering stage to flowering stage. Application of calcium silicate @ 4 g kg^{-1} soil + borax @ 0.5 g kg^{-1} soil gave the highest value of 0.58 mg kg^{-1} which was on par with borax @ 0.5 g kg^{-1} soil (0.55 mg kg^{-1}). The boron applied to soil would have dissociated to soluble boric acid form which would have increased the boron availability in soil and reached just sufficiency level in the treatment as compared to the critical limit of 0.5 mg kg^{-1} fixed for soils. While for the other treatments though it was increased to a statistically significant level, the actual concentration was below the sufficiency level only. Therefore after meeting the requirement of the crop, the added boron might have helped to increase the boron status of the soil from the deficiency to sufficiency level. Highest available boron content at harvesting stage was obtained in calcium silicate @ 4 g kg^{-1} soil + borax @ 0.5 g kg^{-1} soil (0.32 mg kg^{-1}).

Table 3: Effect of silicon and boron on total nutrient uptake by rice crop (g pot^{-1})

Treatment	**N**	**P**	**K**	**Ca**	**Mg**	**Zn**	**Cu**	**Si**	**B**
T_1	0.62	0.066	1.47	8.48	1.79	0.19	0.12	1.65	0.012
T_2	1.61	0.156	3.53	13.53	2.98	0.38	0.55	5.51	0.027
T_3	1.49	0.143	3.47	13.38	2.80	0.32	0.49	4.93	0.025
T_4	1.34	0.128	2.97	12.92	2.71	0.30	0.22	2.68	0.036
T_5	1.36	0.136	3.12	13.74	2.78	0.31	0.25	2.72	0.034
T_6	1.95	0.194	4.35	15.78	3.53	0.39	0.64	5.07	0.043
T_7	1.71	0.168	3.63	14.41	3.18	0.38	0.53	4.45	0.040
T_8	2.32	0.229	4.90	19.11	3.95	0.48	0.78	7.26	0.047
T_9	1.55	0.152	3.65	14.20	2.85	0.38	0.51	5.09	0.035
CD (P=0.05)	0.22	0.013	0.07	0.59	NS	NS	0.06	0.62	0.009

The total uptake of N was maximum with 3 sprays of 0.5 % potassium silicate + 0.5% borax (2.32 g pot^{-1}) which might be due to naturally enhancement in absorption of N by plant ultimately leading to higher N uptake (Table 3). The available P in the soil was also high in the treatments due to the fact that the anion monosilicic acid $[Si(OH)_3]^-$ can replace the phosphate anion $[HPO_4]^{2-}$ from aluminum and iron phosphates thereby increasing the solubility of phosphorus. This would have resulted in better absorption of P by plant which has reflected in better content and uptake of P in 3 sprays of 0.5 % potassium silicate + 0.5% borax with 0.229 g pot^{-1} (Table 3). Application of 3 sprays of 0.5 % potassium silicate + 0.5% borax contributed to greater K and Ca absorption by plant which has reflected in higher content and total uptake of K (4.90 g pot^{-1}) and Ca (19.11 g pot^{-1}). Considering that the available Mg, Zn and Cu content of the soil was not influenced by the treatments, it should be persumed that the greater dry matter produced would have improved the absorption of nutrients including Mg, Zn and Cu from the soil which would have translated into increased content and uptake of Mg, Zn and Cu (Table 3). Hence it can be persumed that the foliar application of potassium silicate and borax (0.5 % spray 3 rounds) would have resulted in better absorption and translocation of silicon compared to soil application of calcium silicate which would has reflected in the significantly higher content and uptake of Si (7.26 kg ha^{-1}) in plant. Application of 3 sprays of 0.5 % potassium silicate + 0.5% borax was superior in terms of B uptake

Table 4: Effect of silicon and boron on yield and yield attributes of rice

Treatment	**Plant height (cm)**	**Productive tillers plant^{-1}**	**Thousand grain weight (g)**	**Grain yield (g pot^{-1})**	**Straw yield (g pot^{-1})**
T_1	91.6	14.66	23.00	33.96	44.15
T_2	110.0	18.33	25.53	53.30	69.29
T_3	107.3	17.00	25.70	49.63	64.52
T_4	115.0	16.33	25.80	48.63	63.22
T_5	105.0	19.00	25.10	50.96	66.25
T_6	120.0	21.33	26.03	62.30	80.99
T_7	101.6	19.33	24.80	56.30	73.19
T_8	131.6	23.33	27.16	68.30	88.79
T_9	106.6	17.00	24.86	49.46	64.30
CD (P=0.05)	18.6	4.53	1.01	0.88	1.15

(0.047 g pot^{-1}). This is because the available boron content of soil also was increased from sub optimal level to the sufficiency level for the addition of borax as soil and foliar spray (Table 3). Application of 3 sprays of 0.5 % potassium silicate + 0.5% borax recorded maximum plant height (131.6 cm), number of productive tillers plant^{-1} (23.33), thousand grain weight (27.16 g), grain yield (68.30 g pot^{-1}) an straw yield (88.79 g pot^{-1}). The tune of increase in grain yield in the superior treatment (3 sprays of 0.5 % potassium silicate + 0.5% borax) was 34.34 g pot^{-1} compared to control. This can be attributed to the significant increase in available nutrients and positive influence on the availability and uptake of macro and micronutrients.

It may be concluded that three sprays each of 0.5 % potassium silicate + 0.5% borax at 15 days interval significantly improved the uptake of nutrients and yield of rice.

REFERENCES

Ahmad, A., Afzal, M., Ahmad, A.U.H. and Tahir, M. (2013) Effect of foliar application of silicon on yield and quality of rice (*Oryza sativa* L.). *Ceecetari Agronomice* **10**(3): 21-28.

Barman, M., Shukla, L.M., Datta, S.P. and Rattan, R.K. (2014) Effect of applied lime and boron on the availability of nutrients in an acid soil. *Journal of Plant Nutrition* **37**: 357-373.

Bray, R.A. and Kurtz, L. T. (1945) Determination of total, organic and available forms of phosphorus in soils. *Soil Science* 59: 39-45.

Epstein, E. (1999) Silicon. *Annual Review of Plant Physiology and Plant Molecular Biology* **50**: 641-644.

Issac, R.A. and Kerber, J.D. (1971) Atomic absorption and flame photometry techniques and uses in soil, plant and water analysis. *In:* Walsh, L.M. (ed.), *Instrumental methods for analysis of soil and plant tissue*. *Soil Science Society America, Madison, USA,* pp. 17-37.

Jackson, M.L. (1973) *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Lindsay, W. L. and Norvell, W. A. (1978) Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of Americ Journal* **42**: 421-448.

Prakash, N.B. (2010) Different sources of silicon for rice farming in Karnataka. Paper presented in Indo-US workshop on silicon in agriculture, held at University of Agricultural Sciences, Bangalore, India, 25-27th February 2010, 14p.

Rao, P.R., Subrhamanyam, D., Sailaja, B., Singh, R.P., Ravichandran, V., Rao, G.V.S., Swain, P., Sharma, S.G., Saha, S., Nadaradjan, S., Reddy, P.J.R., Shukla, A., Dey, P.C., Patel, D.P., Ravichandran, S. and Voleti, S.R. (2013) Influence of boron on spikelet fertility under varied soil conditions in rice genotypes. *Journal of Plant Nutrition* **36**: 390-400.

Singh, K., Singh, R., Singh, J.P., Singh, Y. and Singh, K.K. (2006) Effect of level and time of silicon application on growth, yield and its uptake by rice. *Indian Journal of Agricultural Sciences* **76**(7): 410-413.

Subramanian, S. and Gopalaswamy, A. (1990) Effect of moisture, organic matter, phosphate materials on availability and uptake of silicon and phosphorus in acid soils. *Oryza* **27**: 267-273.