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ROLE OF SILICATE IN THE UPTAKE OF NUTRIENTS BY RICE PLANTS IN THE LATERITE SOILS OF KERALA*

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It is an accepted fact that under certain conditions, application of silicates helps in increasing the uptake of nutrients by plants and thereby their yield. In rice these have been reported by Kohayashi *et al* (1956), Datta *et al* (1962), Utagawa and Kashima (1963) and Mitsui *et al* (1961). Silicon has also been associated with the strength of rice stem (Hadeen 1916, Doughlas 1916). There is however, no precise information on the influence of varying the doses of silicates in soil on the availability and translocation of nutrients in rice plants. The present studies were hence undertaken to determine the effect of different doses of silicates on the uptake of nutrients by rice plants and on the strength of the straw, when grown in laterite soil.

Material and Methods

The experiments were conducted in pots using laterite soil (of Vellayani, Kerala) with a pH of 4.5 and containing 1.34 per cent organic carbon, 6.0 C. E. C. (me/100 g), 4.35 percent acid soluble silica and traces of water soluble silica. The paddy strain used was PTB 10. The treatments were :—

1) N_0 S_0 2) N_0 S_1 3) N_0 S_2
4) N_1 S_0 5) N_1 S_1 6) N_1 S_2
7) N_2 S_0 8) N_2 S_1 9) N_2 S_2 where,

N_0, N_1 and N_2 were 27, 54 and 81 kg N per hectare respectively. S_0 was zero SiO_2 and S_1 and S_2 were 89 kg each SiO_2 per hectare applied as Na_2SiO_3 and as $CaMgSiO_3$ respectively. N was applied as ammonium sulphate. P_2O_5 (as super phosphate) and K_2O (as muriate of potash) were applied uniformly in all pots at 27 kg each per hectare as basal dressing.

The results were assessed by chemical analysis of straw in the first month and of the grain and straw in the second and third months after transplanting. N was estimated by Kjeldahl method. Phosphorus, potassium, calcium and magnesium were estimated in known aliquots of the triple acid extract (Jackson 1962). Silicon was determined by using the method given by Piper (1950). The number of silicated cells and the breaking strength of the straw also were determined. To determine the silicated cells, the third leaf from the top of the plant from each treatment was collected and preserved in a mixture of formalin, acetic acid and alcohol (1 : 1 : 10). The

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middle third of the leaf was cut into small bits and heated in a test tube with concentrated nitric acid and a few crystals of potassium chlorate. The leaf bits were then washed in water and stained in safranin. The silicated cells remained bright and were counted under the microscope. Similar counts of silicated cells were made of the stem from the middle of the lower internode.

To ascertain the breaking strength of the straw, the lower internode of the rice plant of 10cm length was set horizontally with a balance pan in the centre. Weights were added on the pan till the straw broke. This weight was taken as the breaking strength of the straw. For each treatment, the breaking strength of four plants was determined and the mean weight calculated.

Results and Discussion

The results are given in Tables 1, 2 and 3 and tbe coefficients of correlations in Table 4. It will be seen that nitrogen contents of the straw had a positive correlation with the silica contents on the 30th and 90th day after transplantation and a negative correlation on the 60th day. It thus appeared that silicon helped the translocation of the assimilated nitrogen from the vegetative part to the panicle at the beginning of the reproductive phase. Sodium silicate with N at the 54kg level was found to enhance the nitrogen contents of the straw to the maximum on the 60th and 90th days, after transplantation. Similar results were reported by Okamota (1959). Uptake of nitrogen in the grain followed the same trend as in the straw. On the 90th day a linear relationship was evident between nitrogen and silicon contents of the grains. Thus it was credent that silicon application improved the quality of paddy grains by the higher nitrogen build up facilitating a corresponding increase in the protein contents.

The phosphorus contents of straw was more in treatments including silicon than in treatments without silicon in all the growth phases under study. Though

Table 1

Nutrient contents of rice straw (moisture free basis) on 30th day after transplantation under different fertilizer treatments.

Treatments	Chemical contents in mg/pot					
	N			Ca	Mg	Si02
$N_0 S_0$	80	6.8	14.8	22	19	128
$N_0 S_1$	67	5.4	12.2	11	13	106
$N_0 S_2$	79	9.5	21.1	16	22	131
$N_1 S_0$	56	4.2	11.2	7	9	79
$N_1 S_1$	68	4.5	8.7	10	12	84
$N_1 S_2$	60	6.5	11.6	13	14	91
$N_2 S_0$	64	6.2	8.7	9	10	115
$N_2 S_1$	65	4.7	12.8	14	10	117
$N_2 S_2$	69	9.2	9.5	15	15	88

sodium silicate appeared to be superior in the initial stages calcium magnesium silicate proved to be better at the later stages. Phosphorus and silicon contents of the grain were positively correlated on the 90th day of the crop. The higher grain production with calcium magnesium silicate treatments and higher rates of phosphorus can be attributed to the beneficial soil conditions favouring greater phosphorus uptake created by calcium and magnesium.

Table 2

Nutrient contents of rice straw and grains (moisture free basis) on 60th day after transplantation under different fertilizer treatments.

Treatments	Chemical contents in mg/pot											
	Straw						Grain					
	N	P	K	Ca	Mg	SiO2	N	P	K	Ca	Mg	SiO2
$N_0 S_0$	126	38	138	64	74	1120	124	24	261	77	109	1375
$N_0 S_1$	134	44	161	83	98	1162	141	36	640	106	141	2404
$N_0 S_2$	156	50	158	95	104	1016	177	37	629	101	138	2278
$N_1 S_0$	159	40	132	65	82	1009	205	34	420	104	117	2286
$N_1 S_1$	235	60	221	99	113	1475	257	44	511	109	137	2703
$N_1 S_2$	187	60	191	74	111	869	252	56	539	127	151	2818
$N_2 S_0$	182	52	101	67	77	859	157	47	396	109	127	1361
$N_2 S_1$	191	53	119	79	86	1060	160	52	349	108	100	2958
$N_2 S_2$	166	59	103	86	124	1090	199	56	407	124	156	1721

Table 3

Nutrient contents of rice straw and grains (moisture free basis) on 90th day after transplantation under different fertilizer treatments.

Treatments	Chemical contents in mg/pot											
	Straw						Grain					
	N	P	K	Ca	Mg	SiO2	N	P	K	Ca	Mg	SiO2
$N_0 S_0$	78	12	32	19	27	434	124	43	66	30	39	952
$N_0 S_1$	123	16	47	2,2	38	971	173	57	96	37	44	2194
$N_0 S_2$	127	18	51	28	41	945	178	6!	101	49	61	1939
$N_1 S_0$	118	14	41	30	28	512	181	46	79	36	45	1776
$N_1 S_1$	164	24	64	27	34	128	217	77	115	44	52	1330
$N_1 S_2$	134	17	51	29	35	795	266	78	125	66	67	1722
N, S-	158	23	52	29	32	502	165	45	78	23	38	1088
N_2 S,	198	35	81	33	47	1113	270	82	148	43	53	2615
$N_2 S_2$	152	27	69	44	48	592	243	84	126	51	72	1697

Table 4

Correlation coefficients between silicon and nutrient contents in rice.

Relationship	Correlation coefficient
Straw	
Silica uptake vs nitrogen 30th day	+ 0.929 ***
Silica uptake vs nitrogen 60th day	_ 0.714 *
Silica uptake vs nitrogen 90th day	+ 0.723 *
Silica uptake vs calcium 60th day	+ 0.746 *
Grain	
Silica uptake vs magnesium 60th day	+ 0.728 *
Silica uptake vs nitrogen 90th day	+ 0.918 **
Silica uptake vs phosphorus 90th day	+ 0.757 **

* Significant at 5% level. *** Significant at 0,1% level.
** Significant at 1% level.

Silicon application stepped up the potassium contents of the straw. Among the carriers sodium silicate was superior to the others. Similar results were observed in the grains also.

A positive correlation existed between silicon and calcium of the straw, and silicon and magnesium of the grain. The increased calcium contents obtained with the calcium magnesium silicate treatment may be attributed to the additional influence of calcium and magnesium besides silicon in enhancing the uptake of calcium.

Table 5

Silica contents, silicated cells and breaking strength of rice straw under different manurial treatments at important growth phases

Treatments	60th day	90th day			
	Silica contents of straw (mg %)	Silica contents of straw (mg %)	No. of silicated cell_Leaf	Straw	Breaking strength of straw (gm)
$N_0 S_0$	7.2	7,2	40.0	25.5	51.00
$N_- S_1$	8.2	9,5	40,7	49.3	84.00
$N_0 S_2$	7.3	9,7	39.7	40.7	82.00
$N_1 S_0$	6.4	9.2	32,3	30 0	71.00
$N_- S_1$	7.6	10.7	40.7	40.3	86.00
$N_1 S_2$	6 4	10.7	40 0	480	87.3
$N_2 S_0$	5.8	8.2	39.3	327	680
$N_2 S_1$	7.5	11.8	45.0	42,7	101.0
$N_2 S_2$	7.2	6.5	44.8	420	108.0

Treatments including silicon produced straw with higher magnesium contents. Among the carriers calcium magnesium silicate was better than the others especially at the higher doses of nitrogen. It appeared that at the higher levels of nitrogen which improved the vegetative growth, magnesium uptake was enhanced assisted by silicon. The influence of silicon in promoting magnesium uptake by grain was evidenced by the significant positive correlation (Table 4).

The contents of silicon itself in the straw increased by silicate applications and sodium silicate was the best form; sodium silicate being easily soluble appeared to facilitate greater absorption and translccation into the shoot system.

Table 5 shows that the silicon content and the number of silicated cells of the straw increased with application of silicates. Sodium silicate was the better carrier in increasing the number of silicated cells in the leaf.

Table 6

Correlations between silica contents and breaking strength of rice stems on 90th day after transplantation

Relationship	Correlation coefficient
Silica contents vs breaking strength	0.875*
Number of silicated cells vs breaking strength	0.861*

Table 7

Analysis of variance for the breaking strength of straw in relation to different treatments

Source	F
Sodium silicate x Ca Mg silicate	5.904*
Sodium silicate x No silicate	6.523*
Ca Mg silicate x No silicate	7.698*
Sodium silicate & Ca Mg silicate x No silicate	9.463**
54 kg nitrogen x 81 kg nitrogen	1.059
54 kg nitrogen x 27 kg nitrogen	12.732**
81 kg nitrogen x 27 kg nitrogen	3.499
54 kg nitrogen & 81 kg nitrogen x 27 kg nitrogen	2.499

* Significant at 5% level
** Significant at 1% level

Table 6 shows that the breaking strength of straw at maturity was positively correlated with Us silicon contents and the number of siiicated cells of the stem. Table 7 giving the analysis of variance of factors governing the breaking strength of straw reveals that the treatments including silicon imparted more strength to the stem to resist breaking than the nonsilicon treatments.

Summary

The influence of silicon in the uptake of nutrients by rice plants from a laterite soil at the tillering, flowering and maturing stages was studied by estimating the nutrient contents in the plants at those stages. Silicon promoted the uptake of nitrogen by straw and grain and calcium magnesium silicate was the best form. Phosphorus uptake in both grain and straw increased with silicon application. Application of sodium silicate enhanced the uptake of potassium by straw and grain, Calcium and magnesium uptakes by straw and grain increased by the application of silicon. Uptake of silicon increased with the application of silicates particularly when applied in the more soluble form of sodium silicate.

The number of silicated cells in the straw and leaves increased with silicon application. Increase in the number of silicated cells and silicon contents in the stalk resulted in the production of stronger straw even at higher levels of nitrogen.

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