Silica as a Nutrient to the Rice Plant

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Requirement of silice by rice plant

Silica (SiO_2) is a major constituent of the soil (over 50% of soil) and is present in almost all plant species. However, silica contents of many crop plants are generally low (under 1-2% of dry matter) with the exception of some limited species. This is partly attributable to the low solubility of silica in the soil, but mainly due to the physiological property of the crop plants. Because many crop plants with low silica content do not uptake silica so much even in the presence of a large amount of soluble silica.

One of the plants noted for a remarkably high silica content is the rice plant; the silica content in the stem and leaves ranges from 10

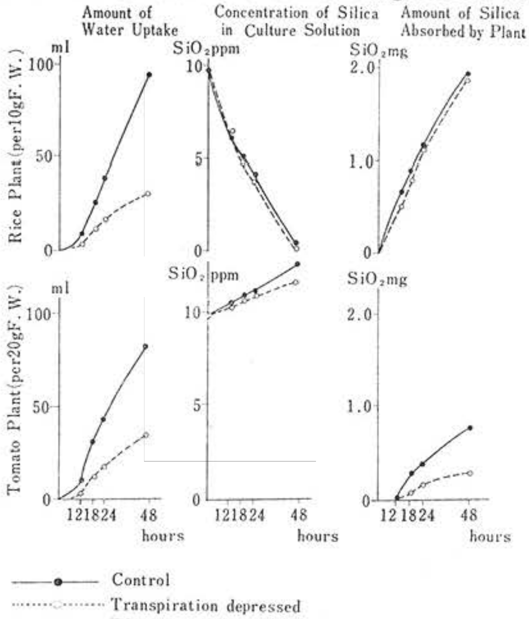

Fig. 1 Effect of transpiration on silica uptake by lowland rice and tomato (E. Takahashi 1962)

the rice plant itself has a particular ability to take up silica very actively.

Table 1 shows the results of a water culture, in which six different plant species were cultured with or without silica supply.[2] Given an equal supply of silica (100ppm in nutrient solution), the rice plant took up silica far more intensively than another species.

Table 1. Effect of silica on the growth of some crop plants (E. Takahashi 1961)

Plant species	SiO_2 % in the top		Dry weight of whole plant (gm per pot)	
	Treatments		Treatments	
	−Si	+Si*	−Si	+Si*
	%	%	gm	gm
Chinese Cabbage	0.01	0.30	4.5	4.4
Green Onion	0.01	0.35	4.9	5.1
Radish	0.01	0.86	3.1	2.9
Tomato	0.01	1.02	11.2	11.1
Barley	0.01	2.09	22.4	26.8
Lowland Rice	0.03	10.41	27.6	38.3

* Concentration of soluble silica in culture solution is 100ppm.

to 20%. For one thing, the paddy field is more rich in available silica than upland. For another,

The mode of silica uptake by rice plant is an active uptake linked with aerobic respiration, and as shown in figure 1, it suffers little from transpiration.[3] But in the case of crop plants with low silica content such as the tomato plant, the silica uptake is a passive one accompanied with water uptake and it suffers intensively from transpiration.

The remarkable silica uptake power of rice plant is located in the root. When the root is excised, the silica uptake power of the top is slackened to low level as is seen in the case of crop plants with a low silica content.

When the rice plant is water-cultured without

Table 2. Effect of variable levels of silica on the growth of lowland rice (E. Takahashi 1961)

SiO_2 concentration in culture solution ppm	SiO_2 % in whole plant %	Dry weight of whole plant per pot gm	Weight of mature grains per pot gm	Number of panicles per pot	Number of spikelets per panicle	Percentage of fully ripened grains %
0	0.03	22.4	2.9	11	50.7	26.9
5	0.62	24.8	3.7	12	48.5	31.1
20	2.00	27.6	6.3	12	52.3	45.6
60	5.19	29.7	8.6	13	51.4	61.7
100	8.01	32.3	11.2	13	53.5	78.0

Table 3. Effect of the period of silica supply on the grain yield of lowland rice (E. Takahashi 1961)

Period of silica supply*		SiO_2 % in whole plant %	Dry weight of whole plant per pot gm	Weight of mature grains per pot gm	Number of panicles per pot	Number of spikelets per panicle	Percentage of fully ripened grains %
Vegetative growth stage	Reproductive growth stage						
−Si	−Si	0.03	27.1	4.7	9.5	49	50
+Si	−Si	2.23	30.8	6.6	10.3	47	67
−Si	+Si	6.42	35.2	10.3	10.0	65	78
+Si	+Si	8.30	38.3	10.8	11.0	63	77

* Concentration of soluble silica in culture solution is 100ppm.

any silica supply, the growth decreases and the grain yield is poor even in the case of free from any disease and lodging. And when silica is applied to the rice plant the growth and grain yield increases according as the amount of supplied silica increases (Table 2).[4]

However, as shown in Table 1, the crop plants having a low degree of silica uptake power such as Chinese cabbage, green onion, radish and tomato plant, do not show any appreciable difference in their growth and yield, whether they are supplied with silica or not.

From these facts showed above, it may be assumed that the rice plant requires silica and its requirement is derived from the physiological peculiarity of the rice plant.

Role of silica in rice plant.

In Japan silicate materials such as calcium-silicate slags are being applied widely to the paddy fields with the following beneficial effects on rice yields :

1) When silicate material is applied to the soil of a large phosphorus-fixation capacity, it prevents phosphorus-fixation, releases a Part of fixed phosphorus and thus increases the amount of available phosphrus in the soil.[5]

2) When silica is absorbed by the rice plant in a large amount, silica deposits on the surface of the leaves and stem, and increases the resistance to fungus diseases and lodging.[5]

3) A sufficient supply of silica permits the rice plant to keep the leaves erect and less curved and thus improves the assimilation system.[6]

4) A silica supply for the rice plant increases the leaf area, prevents the decrease of the photosynthetic activity of the lower leaves and thus enhances the photosynthetic capacity as a whole.[5]

5) A silica supply promotes the oxidation power of the rice plant's root and thus alleviates the toxicity of H_2S and the harm that any excessive amount of ferrous iron may do.[7]

Of the five beneficial effects mentioned above, the first effect is that of soil amelioration ; this effect is also expected for those crop plants which do not require silica as a nutrient. Meanwhile, the second and third effects are partially of a "mechanical" nature and the fourth and the fifth effects are "physiological" in character and these effects ($2 \sim 5$) are seemed to be limited to the plants with high silica content.

As a nutrient to the rice plant, silica is particularly effective when it is supplied together with a heavy dose of nitrogen. For one thing, the luxuriance of the plant's foliage and the resultant deterioration of the assimilation system can be held in check and the ratio of photosynthesis to respiration per unit leaf area can be improved. For another thing, the resistance to fungus diseases and lodging can be enhanced at the same time. Thus, the rice plant should be able to enhance "the adaptability to heavy fertilization" in both the narrow and the broad sense of the terms.

It should be noted also that an adequate supply of silica is essential for the rice plant throughout the entire growth period, particularly in and after the stage of panicle primordial formation, as shown in Table 3.[8]

Effect of silicate fertilization to rice plant

In Japan attempts to enhance the fertility of paddy soil with silicate materials were first made in and around 1952. Widely used here as a silicate material are iron slags produced by iron works in large quantities. The demand for silicate materials has since been expanded annually and it is estimated that over one million tons of silicate materials will be used for this purpose in Japan in 1968.

It is assumed that the effect of silicate materials on the rice yield will become visible when the amount of available silica in the soil is smaller than 10.5mg SiO_2/100gsoil in terms of the pH 4 acetate buffer solution extractable, and when the silica content in straw is below 11 per cent.[9]

The Ministry of Agriculture and Forestry's survey conducted on this assumption shows that 880,000 hectares of paddy fields in Japan or nearly as much as 30 per cent of the nation's total rice acreage is deficient in the available silica.

A similar survey is carried out in some Southeast Asian area, for instance, Bukitmerah in Malaysia and Los Banõs in the Philippines to determine the effect of silica supply to the rice plant. As yet, however, they have not reported of any particularly successful case. One reason for this appears to be that both soils and river waters in these areas contain large amounts of available silica. (For instance, paddy fields in and around Los Banõs are reported as containing as much as 42mg SiO_2/100g soil)

According to the reports from elsewhere in Southeast Asia, however, the soil deficient in available silica exists in many different areas. Khorat in Thailand is mentioned as one of such areas in a report by Prof. Kawaguchi and his associates.[10] Thus, in these areas, the effect of silicate fertilization is expected. Moreover, the importance of silicate fertilization to the rice plant is expected to be enhanced with the anticipated increase in the application of nitrogenous fertilizers in Southeast Asia in the future.

References

1) Takahashi E., Okuda A.
The Role of Silicon.
Symposium on the Mineral Nutrition of Rice Plant. (International Rice Research Institute) pp. 123-146. Johns Hopkins Press 1966.

2) ——, ——
Effect of Silicon on the Growth of Barley, Tomato, Radish, Green Onion, Chinese Cabbage, and Their Nutrients Uptake.
J. Sci. Soil and Manure, Japan **32** 623-626, 1961 (in Japanese with English summary).

3) ——, ——
Some Examinations on the Specific Bahavior of Lowland Rice in Silicon Uptake.
ibid **33** 217-221, 1962.

4) ——, ——
Effect of Various Amounts of Silicon Supply on the Growth of the Rice Plant and Its Nutrient Uptake.
ibid **32**: 533-537, 1961.

5) Report of Research and Investigation Supported by the Ministry of Education, Japan. No. 48. 1958.
"Studies on the Promotion of Ultimate Yields of crops by the Application of Silicate Materials". (in Japanese).

6) Iwata I. Baba I.
Effect of Silica Upon the Adaptability of Rice Plant for Heavy Manuring in Relation to Photosynthesis.

Proc. Crop Sci. Soc. Japan **30** : 237-240, 1962
(in Japanese with English summary)

7) Takahashi E., Okuda A.
Effect of Silicon Supply on Iron Uptake by Rice Plant from Ferrous Sulphate Solution and Oxidation Power of the Roots.
J. Sci. Soil and Manure, Japan **33** : 59-64, 1962.

8) ——, ——
Effect of Silicon Supplying Period on the Growth of the Rice Plant and Its Nutrient Uptake.
ibid **32** : 481-488, 1961.

9) Imaizumi K., Yoshida S.
Edaphological Studies on Silicon Supplying Power of Paddy Fields.
Bull. Natl. Inst. Agr. Sci. Japan, Ser. B, **8** : 261-304, 1958.
(in Japanese with English summary).

10) Kawaguchi K.
Fertility of Lowland Rice Soils in Southeast Asian Countries.
The SoutheastAsian Studies 5 : 3-14, 1968.