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EFFECT OF AVAILABLE SILICON IN PADDY SOIL ON THE GROWTH OF RICE PLANTS[1,2]

HSO-FRENG YUAN and YANN-SHEE CHANG

Institute of Botany, Academia Sinica
Taipei, Taiwan, Republic of China

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Abstract

Oxidizing power of rice roots, available silicon level in paddy soil and silica content in leaves and sheaths of rice plants were determined throughout the growth period of rice plants in both the first and second crop seasons. The leaf angle of flag leaves was also measured during the ripening stage. Finally, the grain yield and yield components were analyzed. The oxidizing power of rice roots decreased faster in the second crop season than the first crop in the later growth stage, but there was insignificant difference as applied by different nitrogen fertilizers. The oxidizing power of the rice roots was stronger in the treatment of calcium silicate applied into pots than that without silicate application in the later growth stage. In the early growth stage, the available silicon in paddy soil was much higher during the second crop season than the first crop; but in the later growth stage, the available silicon content in paddy soil was lower during the second crop season than the first crop. In the later growth stage, the silica content in leaves and sheaths of the first crop was slightly higher than those in the second crop; but there was almost no difference between the two crops after the application of silicate into the pot. At the heading stage, the young panicles accumulated more silica in the first crop than in the second crop. At the ripening stage, the silica content was much higher in flag leaves of the first crop than that of the second crop. The application of silicate into the pot decreased the leaf angle of flag leaves. When calcium silicate was applied into the pot with ammonium sulfate, the grain yield increased markedly in the second crop.

Introduction

Whether or not silicon is essential to higher plants has long been the subject of conflicting views (Lewin and Reimann, 1969) and silicon has often been described as a beneficial element. Since Japanese scientists found that the application of silicate slag to degraded paddy soil effectively increased grain yield, and many outstanding studies demonstrated that silicon was responsible for improving growth of rice plants (Okamoto, 1959; Mitsui and

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Takatoch, 1963; Yoshida *et al.*, 1959; Okuda and Takahashi, 1965). The low silica content in river or in drainage water suggests that most of the silica or silicate in soil are relatively insoluble and are not available to crops. However, the rice plants can absorb silicon in very large amounts. Lian (1976) indicated that the optimum silica content of rice straw at the harvesting stage should be around 13%; in fact, the average silica content of rice straw is around 11% in Japan, around 9% in Taiwan and around 8% in Korea. In general, yield response to silicate application are inversely proportional to the level of silica content of rice straw or the level of available silicon in paddy soil. The total amount of silicon yearly removed from paddy soil in Taiwan is far greater than that in Japan or Korea, because one more rice crop is planted in Taiwan. And the proportion of silica content in the irrigation water is very low due to the multiple use of the irrigation water through rotational irrigating practices. Consequently, the greastest part of the silicon taken up by rice plants and originated from the soil and the silica cotnent in rice straw is greatly influenced by the silicon supplying ability of the soil. Therefore, it becomes important to evaluate the presence of available silicon in paddy soil during rice growth. Furthermore, the silicon was able to decrease transpiration of rice plants (Yoshida *et al.*, 1959), to increase oxidizing power of rice roots, and to reduce the toxicity of some heavy metals in soil (Okuda and Takahashi, 1965) resulting in the promotion of root activities during rice growth. This paper was therefore to investigate the dynamics of available silicon in paddy soil and the silica content in leaves and sheaths as well as the oxidizing power of rice roots during rice growth, and particularly in the difference between the first and second crop of rice plants.

Materials and Methods

The studies including both field and pot experiments were conducted at the Institute of Botany, Academia Sinica, Taipei, Taiwan. Calcium silicate was placed into the pot to increase the silicon supplying ability of paddy soil to see the effect of silicate on the growth of rice plants.

Cultivation of rice plants

The rice variety of Taichung 65 was used in this experiment. The rice seedlings at four leaves stage were transplanted to paddy field or pots. About 5 to 7 seedlings for one hill were transplanted to paddy field, while three seedling were transplanted in each pot. The second crop began in the middle of August and harvested in the middle of December in 1976, while the first crop began in the middle of March and harvested in the middle of July in

1977. A split-plot design was adopted in this experiment and each treatment was replicated four times in randomization. The planting density in the field was 20×17 cm (29 hills/m^2). The fertilizers with a basal dressing of N, P, K (130: 65: 65, kg/ha) was supplied on the soil surface within 4 cm. The management of rice plants and the times, quantities and forms of fertilizer treatment for top dressing are summerized in Table 1.

For the pot experiment, each pot contained about 12 kg soil which was obtained from the same field. The management of rice plants grew in pots was the same as in the field except without the drying treatment at the middle growth stage. Furthermore, two grams of calcium silicate was supplied into each pot at the same time when the top dressing of fertilizing was applied into the pot every time accroding to the scheme of growth control as Table 1.

Sampling and treatment of samples

The oxidizing power of rice roots, the available silicon in paddy soil, and the silica content in leaves and sheaths were analyzed in four replications at every two- or three-week intervals throughout the growth period of rice plants. The sampling method was that the whole hill of rice plants with the soil within a radius about 10 cm and deepth in 20 cm was scooped out, and three hills were taken for one sample. The paddy soil was collected at 5 to 10 cm soil layer below the soil surface, placed in a plastic bag and stored in a cold room of 5°C for determination of available silicon content. The roots was washed with tap water to remove the soil and cleaned with distilled water, then the oxidizing power of roots was determined at once. The leaves and sheaths were washed with distilled water, and dried at 80°C for determination of silica content.

Determination of oxidizing power of rice roots

The oxidizing power of rice roots in this study was determined by using α-naphthylamine (α-NA) oxidation power of rice roots according to the method described by Chen and Houng (1976). The fresh rice roots were rinsed with runing tap water followed with distilled water and blotted with tissue paper. Two grams of intact roots were transferred into a 125-ml Erlenmeyer flask, followed with 50 ml of potassium-sodium phosphate buffer (0.05 M, pH 7.0) in which contained 20 ppm of α-NA. Then the mixture was incubated in a a water bath at 30°C and shaken for 10 minutes to exclude the contamination of oxidizing power of ferric salts adhering on the sulface of roots. Then, the concentration of α-NA in the reaction mixture was determined as the zero time and the next four hours later. This reaction procedure had been carried out in triplicate for each sample.

It was found that α-NA oxidation by rice roots follows the first order

Table 1. *Scheme for growth control of rice plants*[1]

Basal dressing of fertilizing (kg/ha)	Treatment	Crop season	Early growth stage (leaf-age index before 69): Irrigation	Early: Top dressing of fertilizing (kg/ha), NH_4^+-N, Rooting stage	Early: NH_4^+-N, Tillering stage	Early: NO_3^--N, Supplied at every 10-day interval			Middle growth stage (leaf-age index between 69-92): Drying treatment	Later growth stage (leaf-age index after 92): Irrigation	Later: Top dressing of fertilizing (kg/ha), NH_4^+-N, Meiosis[2] stage	Later: NH_4^+-N, Ripening stage	Later: NO_3^--N, Meiosis[2] stage	Later: NO_3^--N, Ripening stage
NH_4^+-N (40 kg)	1	I	Deep water 5-7 cm	25	20	—	—	—	To stop water supply until the surface of paddy soil cracked to 1-2 cm width.	3 days shallow water 2 days drainage	20	25	—	—
P_2O_5 (65 kg)		II	Shallow water 1-3 cm						Saturated with water ⇅ Decreased water level 5-10 cm.	3 days deep water 2 days drainage				
K_2O (43 kg)	2	I	Deep water 5-7 cm	—	—	15	15	15	Same as above I	5 days shallow water 2 days drainage	—	—	20	25
		II	Shallow water 1-3 cm						Same as above II	5 days deep water 2 days drainage				

(1) Abbreviations: NH_4^+-N, ammonium sulfate; NO_3^--N, calcium nitrate.

(2) The soil was applied with 22 kg K_2O during the meiosis stage.

reaction kinetics (Chen and Houng, 1976); therefore, the rate of α-NA oxidation at any time t by an unit weight of rice roots can be given by the following equation:

$$-\frac{dA}{dt} = KRA \qquad (1)$$

Where A is the molar concentration of α-NA, K is the proportionality constant of reaction rate, R is the dry weight of rice roots. Because of the reaction proceeded in a short time, the dry weight of rice roots could be regarded as as a constant. Consequently, the KR value could also be regarded as a constant K′. And the integrated form of equation (1) is given by:

$$\ln A = \ln A_0 - K't \qquad (2)$$

in which A_0 is the concentration of α-NA at zero time and A is the concentration at time t. When the equation (2) is changed to the common logarithm, it becomes:

$$\log \frac{A_0}{A} = \frac{K't}{2.303} \qquad (3)$$

When A equals $\frac{1}{2} A_0$ in equation (3), the half-time period of α-NA oxidation is given as:

$$t_{1/2} = \frac{0.693}{K'} \qquad (4)$$

Determination of available silicon in paddy soil

Sodium acetate buffer (0.05 M, pH 5.5) was used to extract the available silicon in paddy soil. The ratio of soil to buffer was 1:5 (w/v) and the procedure was as follows: two parts of paddy soil were weighed in equal amount (100 gm). One part using for its dry weight determination was dried in an oven, and another part was homogenized with 400 ml of sodium acetate buffer for 10 minutes in a Waring blandor, then the homogenate was made up to 500 ml by adding the acetate buffer. After standing for two hours at room temperature, the homogenate was clarified by centrifugation and the silica content in the supernatant was determined according to the method of Yuan and Chang (1977).

Determination of silica content in leaf and sheath

The dried leaves and sheaths were pulverized to powder (about 40 mesh) with a mill. The silica content was determined according to the method of Yuan and Chang (1977). The silica content in young panicles at the heading stage and in flag leaves at the ripening stage were also determined.

Harvest and analysis of grain yield

At the ripening stage, the erectness of flag leaves were measured. When grains ripened, the rice plants were harvested to analyze the number of panicle, the grain yield and other yield components. After drying for three days at 80°C, the spikelet number and grain number per hill or per pot were counted, and the grain yield was determined.

Results

The oxidizing power of rice roots

The oxidizing power of the intact root of rice plants both planted in paddy field and pots were determined throughout the growth period of rice plants. The results are shown in Table 2. The oxidizing power was presented by the half-time period of α-NA oxidation, $t_{1/2}$. When the oxidizing power of rice roots was expressed by the half-time period of α-NA oxidation, it was found that the shorter the half-time period, the stronger the oxidizing power of the roots. Table 2 illustrated that the oxidizing power of rice roots in the second crop season decreased faster than in the first crop season in the later growth stage; but there was no significant difference caused by the different forms of nitrogen fertilizers. In the pot experiment,

Table 2. *Changes of oxidizing power of rice roots under different fertilizer treatment during rice growth*

Crop season	Days after transplanting		Half-time period of α-NA oxidation, $t_{1/2}$ in hour					
			Field		Pot			
	Field	Pot	NH_4^+-N	NO_3^--N	NH_4^+-N		NO_3^--N	
					−Si(1)	+Si(2)	−Si	+Si
I	25	31	2.12	2.38	4.93	3.57	5.48	4.20
	39	45	3.51	2.80	5.52	4.63	4.77	4.84
	54	59	6.63	5.64	6.55	6.13	4.76	5.18
	68	73	5.49	5.38	8.15	5.92	8.27	6.69
	82	87	6.00	7.81	10.72	8.69	9.44	7.44
	96	103	14.06	11.40	10.19	8.65	14.31	7.35
II	16	16	2.32	3.60	8.17	6.69	7.26	5.72
	27	30	2.57	4.46	3.15	3.33	4.83	4.88
	58	58	6.69	5.88	3.90	4.28	5.09	5.21
	68	69	8.08	7.61	7.16	8.56	6.91	7.32
	79	82	9.11	8.18	11.49	9.03	8.75	8.66

(1) −Si: Without calcium silicate supplied.
(2) +Si: Calcium silicate was added into the pot.

in the later growth stage the oxidizing power of rice roots was stronger in the treatment of calcium silicate than that of without calcium silicate.

Change of available silicon in paddy soil

It was thought that the amount of extractable silicate from the paddy soil varied with the pH value of the buffer, the different quantities of soluble silicate was extracted by 0.05 M sodium acetate buffer at different pH values. The results indicated that at pH 4 the amount of soluble silicate was exhibited the highest of 16.6 μg/gm of soil with dry weight basis; at pH 5 that amount was 12.5 μg/gm; and at pH 6 the amount was as low as 4.4 μg/gm.

In this study, the available silicon in paddy soil was extracted with 0.05 M sodium acetate buffer at pH 5.5. The available silicon content in each sample was analyzed in triplicate. The dynamics of available silicon level in paddy soil during the rice growth is shown in Table 3. The results indicated that the available silicn content in paddy soil during the second crop season was much higher than that in the first crop season in the early growth stage; but in the later growth stage, the amount was lower in the second crop season than in the first crop season.

Table 3. *Changes of available silicon in paddy soil during rice growth*

Crop season	Days after transplanting		Content of available silcon, μg/gm dry soil					
			Field		Pot			
					NH_4^+-N		NO_3^--N	
	Field	Pot	NH_4^+-N	NO_3^--N	−Si	+Si	−Si	+Si
I	25	31	12.54	11.64	12.19	10.48	11.37	15.84
	39	45	15.25	14.24	6.26	5.75	5.66	6.57
	54	59	11.00	8.57	4.73	5.23	4.06	6.28
	68	73	11.45	8.92	5.38	5.48	6.17	5.49
	82	87	8.10	9.75	7.19	6.52	6.51	4.34
	96	103	7.05	5.09	6.85	7.86	8.61	7.72
II	16	16	20.04	15.77	19.53	26.82	19.50	16.92
	27	30	16.27	16.65	14.01	16.61	10.53	19.72
	58	58	13.95	14.15	13.15	14.66	13.65	11.15
	68	69	9.75	9.22	9.85	6.50	6.23	6.63
	79	82	4.67	4.19	7.39	5.49	5.50	6.44

Silica content in leaf and sheath

The results of silica content in leaves and sheaths during the rice growth are shown in Table 4. The silica content in young panicles at the heading stage and in flag leaves at the ripening stage were also analyzed, and the results are shown in Table 5 and 6. Table 4 showed that there was almost no difference of silica content in leaves and sheaths between the two crop seasons. When calcium silicate was applied into the pot, the silica content in leaves and sheaths during the first crop season was slightly higher than that without silicate applied. Table 5 illustrated that the young panicles accumulated more silica during the first crop season than the second crop season. Table 6 revealed that the silica content in flag leaves of the first crop was higher than that of the second crop. In the pot experiment, the silica content in young panicles and flag leaves increased markedly due to the application of calcium silicate (Tables 5 and 6).

Table 4. *Changes of silica content in leaf and sheath during rice growth*

Crop season	Days after transplanting		Silica content, % on dry matter basis					
			Field		Pot			
	Field	Pot	NH_4^+-N	NO_3^--N	NH_4^+-N		NO_3^--N	
					−Si	+Si	−Si	+Si
I	25	31	3.11	2.62	5.87	5.99	5.98	5.82
	39	54	3.25	3.64	6.19	6.53	6.28	6.25
	54	59	4.65	4.81	5.62	5.58	5.73	6.27
	68	73	4.41	4.89	5.51	6.07	5.71	5.85
	82	87	4.70	5.56	5.54	5.89	6.73	4.70
	96	103	6.52	6.56	6.42	6.49	7.25	8.33
II	16	16	3.06	3.24	6.19	6.66	6.01	6.44
	27	30	3.32	4.03	6.32	7.09	6.37	6.85
	58	58	4.50	4.81	5.51	5.19	5.12	6.49
	68	69	5.32	5.67	5.35	5.57	4.93	6.13
	79	82	5.89	6.34	5.64	6.57	5.93	7.47

Table 5. *Silica content in young panicles of rice plants at the heading stage*

Status of panicle	Crop season	Silica content, % on dry matter basis					
		Field		Pot			
		NH_4^+-N	NO_3^--N	NH_4^+-N		NO_3^--N	
				−Si	+Si	−Si	+Si
Before heading	I	2.99	2.56	2.48	2.18	2.79	2.66
	II	2.41	2.47	1.20	1.64	1.35	1.77
After heading	I	4.08	4.27	3.01	3.92	4.26	5.37
	II	3.54	4.24	3.46	4.22	3.90	4.21

Table 6. *Silica content in flag leaves of rice plants at the ripening stage*

Grop season	Silica content, % on dry matter basis					
	Field		Pot			
	NH_4^+-N	NO_3^--N	NH_4^+-N		NO_3^--N	
			−Si	+Si	−Si	+Si
I	7.68	8.16	7.74	10.17	8.57	8.92
II	6.08	6.30	7.09	7.26	7.43	8.98

Analysis of grain yield and yield components

In order to investigate the effect of silicon on leaf erectness, the leaf angle between the surface of flag leaf and the main stem of rice plants that were planted in pots was measured during the ripening stage. The results are shown in Table 7. It indicated that the application of silicate into the pot decreased the leaf angle of flag leaf at the ripening stage.

Table 7. *Effect of silicon on leaf erectness of flag leaves of rice plants at the ripening stage*

Crop season	Leaf angle(1), degree			
	NH_4^+-N		NO_3^--N	
	−Si	+Si	−Si	+Si
I	25.23	18.12	24.83	20.60
II	28.95	22.65	27.25	19.30

(1) The data represent an average of forty flag leaves, and obtained by measuring the degree of leaf angle between the surface of flag leaf and the main stem of rice plants.

After rice was harvested, the yield components, namely test weight, ripening rate, grain number per panicle and grain yield were obtained. The results are given in Table 8 and 9. The results showed that there was no significant difference on grain yield as affected by the different forms of nitrogen fertilizers. The grain yield of the second crop was much lower than that of the first crop. When calcium silicate was applied with ammonium sulfate as a nitrogen fertilizer into the pot, the grain yield increased markedly in the second crop.

Discussion

The beneficial effect of silicon on rice yield has been widely comfirmed, especially on the degraded paddy soil and the regions where the soil is deficient in available silicon or the low amount of the silicon content in

Table 8. *The yield components of rice plants in the field as affected by different forms of nitrogen fertilizer treatment*

Yield component	Crop season	Treatment of fretilizer	
		NH_4^+-N	NO_3^--N
Panicle number per hill	I II	12.80 13.90	9.90 12.90
Spikelet number per hill	I II	899.00 902.90	634.35 803.30
Grain number per hill	I II	766.40 700.50	579.80 665.80
Grain yield (gm/m²)	I II	402.00 300.00	415.00 310.00
Test weight (gm/1000-seed)	I II	26.82 19.56	27.89 21.30
Grain number per panicle	I II	59.77 50.58	58.49 52.33
Ripening rate (%)	I II	85.25 77.58	91.40 82.88

Table 9. *The yield crmponents of rice plants in the pot as affected by calcium silicate and different forms of nitrogen fertilizer treatment*

Yield component	Crop season	Treatment of fertilizer			
		NH_4^+-N		NO_3^--N	
		−Si	+Si	−Si	+Si
Panicle number per pot	I II	21.20 17.70	22.20 19.00	17.30 16.00	17.00 14.00
Spikelet number per pot	I II	1536.20 1482.00	1689.00 1622.00	1243.50 1299.00	1276.00 1315.30
Grain number per pot	I II	1366.00 1180.70	1471.00 1287.30	1106.00 1036.30	1120.20 1080.00
Grain yield (gm/pot)	I II	34.43 25.21	36.79 28.60	29.94 22.34	29.72 21.98
Test weight (gm/1000-seed)	I II	25.22 21.39	25.08 22.36	27.09 21.53	26.53 20.32
Grain number per panicle	I II	64.60 66.82	66.70 67.50	64.31 64.99	66.56 77.76
Ripening rate (%)	I II	88.94 79.97	87.71 79.02	89.13 79.81	88.28 82.05

irrigation water. Yoshida *et al.* (1959) mentioned that silicon seems not to be indispansible for the growth of rice plants at least during the vegetative growth stage, but it is necessary for better growth during the reproductive growth stage and better yield. Okuda and Takahashi (1965) clearly indicated that the silicon was particularly important for grain yield; and the more silicon absorbed by rice plants the greater was the oxidizing power of roots.

The oxidizing power of rice roots could be evidently measured by the oxidation of α-NA by the roots (Ota, 1970). In case where the nutrient absorption by the roots was inhibited, the oxidizing power of the roots usually very low. Lai and Hou (1974) concluded that the α-NA oxidation of rice roots is related to the activities of its peroxidase, cytochrome oxidase and glycolate oxidase. This indicated that the α-NA oxidizing ability of the roots seems in correlated intimately with the root activity. Chen and Houng (1976) also indicated that when the oxidizing power of rice roots was low, the response of rice plants to the nitrogen application was in the most case insignificant. It suggested that a high oxidizing power of rice roots can be maintained, resulting in a high yield that could be obtained by increased nitrogen application. Table 2 indicated that the oxidizing power of rice roots in the second crop season decreased faster than that in the first crop season in the later growth stage. Therefore, the efficiency of fertilizing in the later growth stage might be lower for the second crop than that for the first crop. In the pot experiment, the application of silicate to paddy soil could slow down the decrease of oxidizing power of rice roots in the later growth stage. It is beneficial to rice growth regarding to the nutrient absorption by the roots in the later growth stage and especially for the second crop season.

In general, the acetate buffer method has widely been adopted to extract the available silicon in paddy soil, and the results of this study indicated that the quantities of the extractable silicate varied with the pH value of the buffer. Lian (1963) pointed out that the content of soluble silicate in paddy soil is proportional to the pH value of the soil. In this experiment, the pH value of paddy soil is usually about pH 5.5; thus, the 0.05 M sodium acetate buffer at pH 5.5 was adopted for extracting the available silicon in paddy soli. The variation of available silicon in paddy soil during the rice growth (Table 3) suggested that the application of silicate in the later growth stage might be important for rice growth, especially in the second crop season. This is a problem related to the rate of supply and demand of available silicon between the paddy soil and rice plants. Because rice plants absorbed a large amount of available silicon from the soil for its vegetative growth in the early growth stage; thus, the available silicon in the soil was much reduced to meet the requirement of rice plants in the later growth stage. On the other hand, there was no significant increase of available silicon in paddy soil when calcium silicate was supplied into the pot. This might be due to the vigorous absorption of silicon by rice plants, thus, the paddy soil could not accumulate a higher level of available silicon during the rice growth.

Lian (1963) also indicated that in Taiwan the silica content of straw at harvesting time varied from 5% to 14% depending upon localities, which reflected the possible difference of silicon supplying ability among the various kinds of soil. Table 4 illustrated the silica content in leaves and sheaths from 2.26% to 8.33% according to the growth stage and fertilizer treatment. Although the silica content in leaves and sheaths was almost no different between two crop seasons during the rice growth, however, the silica content in flag leaves of the first crop was much higher than the second crop (Table 6), and the silica content in young panicles was also higher in the first crop than in the second crop (Table 5). These results indicated that the ability of paddy soil for supplying available silicon during the first crop season was stronger than that during the second crop season in the later growth stage of rice plants. Houston (1971) reported that the silica content in the ash of rice hulls is around 94% to 96%, the accumulation of silica in young panicles was important for hull development of rice grains. In the pot experiment, the application of silicate into the pot increased the silica content in leaves and sheaths, young panicles and flag leaves. This indicated that the application silicate could increase the silicon supplying ability of paddy soil in the later growth stage.

The importance of leaf erectness in the photosynthesis of a crop canopy is well recognized and erect leaves are considered to be desiable in a high yield rice variety. Although leaf erectness is mainly a varietal characteristics, it can be modified by plant nutrition. In general, the application of silicon tends to maintain erect leaves, and the application of nitrogen tends to cause drooping leaves (Yoshida *et al.*, 1969). Table 7 illustrated the decrease of leaf angle of flag leaves at the ripening stage due to the application of silicate into the pot. In the results shown in Table 6, it indicated that the higher the silica content in the flag leaf the less the leaf angle of the leaf.

According to the data in Table 8 and 9, the grain yield of the second crop was 30% lower than that of the first crop. When calcium silicate was applied into the pot, the grain yield increased markedly while ammonium sulfate was used as the nitrogen fertilizer. In the pot experiment, the grain yield increased about 7% for the first crop and 13% for the second crop due to the application of silicate. The increase of grain yield was mainly due to the increase of panicles and spikelets as well as the grains per panicle. But, there was no response to increase grain yield when the application of silicate accompanied with calcium nitrate as the nitrogen fertilizer.

Because the physiological mobility of silicon was very low in rice plants (Yoshida, 1965), the reutilization of silica is unlikely to occure once it has been deposited in rice tissues. This fact indicated that a continued supply of silicon is necessary through the entire growth period of rice plants. From the considerations as discussed above, we can conclude that the application of silicate to paddy soil in the later growth stage the grain yield would be increased especially in the second crop season.

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水田土壤中有效性矽之含量對於水稻生長之影響

袁守方 張燕喜

中央研究院植物研究所

於水稻整個生長過程中，對於水稻根部氧化能力之消長，水田土壤中有效性矽含量之遞降以及葉和葉鞘中矽石(Silica)含量之變遷情形，加以定期測定。同時於抽穗期測定其幼穗中矽石之含量，於成熟期測定其止葉中矽石之含量及止葉之角度。最後將穀粒產量及其產量構成因素加以分析，並於期作間作一比較。於生育後期，二期作水稻根部之氧化能力較一期作遞降得爲快。但不同型態之氮肥對於根氧化能力之衰退沒有影響。於盆栽中添加矽酸鈣後，則於生育後期水稻根部之氧化能力較未添加矽酸鈣者爲强。於生育前期，二期作水田土壤中有效性矽之含量較一期作爲高，但於生育後期，二期作水田土壤中有效性矽之含量返而較一期作爲低。同時於生育後期，一期作之葉和葉鞘中矽石之含量較二期作略高。但於盆栽中添加矽酸鈣後，於期作間，即無顯著差異。於抽穗期，一期作幼穗中矽石之含量較二期作爲高，於成熟期一期作止葉中矽石之含量較二期作高出很多。於盆栽中添加矽酸鈣後則止葉之角度縮小。不同型態之氮肥，對於穀粒之產量並無顯著影響。且二期作之產量遠較一期作爲低。可是於盆栽中，使用硫酸氨爲氮肥時，則由於矽酸鈣之添加而使二期作穀粒之產量有顯著的增加。