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Determination and Effects of N and Si Fertilization Levels on Grain Quality and Pests of Rice after Winter Green-house Water-melon Cropping

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ABSTRACT : In Korea, rice cultivars have been changing to "quality" rice rather than high yielding cultivars. However, more than 10% of paddy field has been changed to greenhouse in winter season for cropping of water-melon, oriental-melon, straw berry and et cetra. This experiment has been made to identify the usefulness of critical N and Si fertilization(SF) level to obtain high grain quality rice with reduced insect pest damage by N and SF combination. Before the experiment, watermelon-rice cropping system was maintained for three seasons by farmer from 1998 to 2001. The experiment of N and Si (silicate) fertilization levels was evaluated with Hwayoung-byeo (*Oryza sativa* L., medium-maturing variety) in 2002 and 2003 in Uiryeong, Korea. Nitrogen fertilization (NF) levels were three and five in 2002 and 2003, respectively, and three SF levels were compared for getting the valuable N/SF level in both years. TOYO-value was positively affected by Si application in N100% plot but it was negatively related with NF level. Normal grain percentage was positively related with TOYO-value and it was highest in 0N plot and Si plots in N100%. Other appearance qualities like powdered, damaged, and cracked grain, were decreased with increasing N fertilization level. SF improved appearance quality in N100% plots but no effects in other treatments. Leaf sheath related diseases were significantly decreased by SF but it was negatively related with NF. In conclusion, SF could be improve grain quality at the same yield levels of conventional fertilization and it also could be reduce the diseases damages of rice plant in all N treatments. NF treatment reduced grain quality and improved grain yield at N50% level, however NF above N50% could not get any kind of benefits. So, compared with conventional fertilizer, reduced NF level is recommended for high grain quality with reduced insect pest damage.

Keywords: grain quality, N fertilization (NF), rice (*Oryza sativa* L.), silicate fertilization (SF)

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Nowadays in Korea, cropping acreage of rice cultivars has been changing to "quality" rice rather than high yielding cultivars. The nutrient demands of the main "quality" rice is generally described as most N, less P and relative more K and especially for silicate. Rice, unlike most other cereals, is consumed as a whole grain after steaming. Therefore physical properties such as size, shape, uniformity, and general appearance are of utmost importance. Furthermore, because most rice is milled, the important physical properties are determined primarily by the milled endosperm. Significant differences in rice quality also occur as a result of the environmental conditions and cultural practices during growth. These factors may under some circumstances have a greater impact on quality than inherited traits. Physically moving the rice with machines can damage the kernels and decreases head yields. Or as frequently occurs, prolonged periods of storage or unfavorable conditions can result in objectionable flavors or odors. Rice quality, therefore, can be divided into five broad descriptive categories. These interrelated categories are: 1) milling quality; 2) cooking and eating quality; 3) processing quality; 4) nutritive quality; and 5) purity and cleanliness standards. Each category is described by a specific set of criteria that collectively determine the suitability of rice for a specific market. The accumulation of silicon in leaf surface is resulted in the hardness of fungal penetration into leaf inside and encouraged the physical resistance against rice blast (Hayasaka *et al.*, 2002). The silica contents in rice plant with basal application were increased most highly compared with the split applications during the all growing stage, but they were all the same between the basal and split application at the harvest (Lee and Shin, 1974). The percents of diseased panicles were decreased to 20% with wollastonite and to 10% with high concentrated fused silicate material (Lee and Shin, 1974). The optimum levels of N-fertilizer for maximum yield were 16.5 kg/10a for improved plot and 15.9 kg/10a for controlled plot (Lee *et al.*, 1987). The uptakes of SiO_2 and K_2O, and the uptake ratios of SiO_2/N and K_2O/N by rice plant at improved plot were considerably higher than those at controlled plot. The critical uptake by rice plant which showed maximum yield was 13.5 kg for N and 112 kg for SiO_2, respectively. And the critical contents of organic matter and available silica of soil for maximum using efficiency were 3.0% and 200 ppm, respectively.

Nitrogen mineralization due to application of silica materials was rapidly occurred in Suweon sand soil than in Honam clay soil. Also wollastonite application more stimulated the nitrogen mineralization than calcium silicate (Lee *et al.*, 1975). Nitrogen should be applied with organic matter to improve the supply of nitrogen nutrient to plant when silica materials were applied (Lee *et al.*, 1975). Rice grown on the organic soils of the Everglades is routinely fertilized with silicon (Si). Nitrogen concentration increased with Si and maturity was earlier in the Si fertilized rice (Deren, 1997). Rice quality is influences by characteristics under genetic control, environmental conditions, and processing techniques. In the latter case, characteristics are principally a function of handling, storage, and distribution. N increase grain yield of rice, however it negatively related with grain quality (Kim *et al.*, 1992). Si was very useful for improving tolerances to fungal diseases and insect pests (Chung *et al.*, 1980; Djamin and Pathak, 1967; Volk *et al.*, 1958; Yoshida, 1965). Low protein, high Mg/K rate and high grain quality could be possible by SF (Nam *et al.*, 1995; Jung *et al.*, 1997; Kang *et al.*, 1997). Additionally, Si could reduce heavy metal content in hulled rice by reducing availability in soil (Jung *et al.*, 1997).

Sheath blight is considered a major constraint to rice production where rice is grown under intense production systems in both temperate and tropical production areas (Cu *et al.*, 1996). Sheath blight is perhaps the most important disease of rice in the world. Initial symptoms usually develop as lesions on sheaths of lower leaves near the water surface when plants are in the late tillering or early internode elongation stage of growth (approximately 10-15 days after flooding). Infection spreads rapidly in humid high temperature by means of runner hyphae to upper plant parts, including leaf blades, causing extensive, tan, irregularly shaped lesions with brown borders (Groth and Nowick, 1992). Disease development progresses very rapidly in the early heading and grain filling growth stages during periods of frequent rainfall and overcast skies. In recent years, the wide acceptance of susceptible varieties, because of their high yielding potential, has contributed greatly to the rapid increase in sheath blight. Yield loss can occur at any stage but it is higher when infection occurs at panicle initiation, booting, and flowering (Sharma *et al.*, 1990, Cu *et al.*, 1996). Sheath blight infection from panicle initiation to flowering resulted in yield loss by reducing the mean grain weight and the number of filled grains (Cu *et al.*, 1996). Sheath blight also interferes with grain filling and can reduce rough rice yield by 39%, but that loss can increase to 50% in terms of kg/ha (Marchetti 1983).

The rice leaf-folder which is widely distributed in rice cultivating areas in South and Southeast Asia is presumed to be migrated from Southeastern part of China to Korea during rainy season annually. In Korea, the rice leaf-folder passes 2 or 3 generations annually, and its peak occurrence appear at both late July to early August and early to middle of September (Lee, 1992). Although the migrating times and population of the rice leaf-folder are depend upon the environmental conditions such as the seasonal rainfall distribution patterns, times and period, etc. its population and occurrence, generally, are more and faster at Southern costal area than inner area in Korea (Lee, 1992). Its larva rolls the leaf by tying silk to the margins and feeds within the rolled leaf, removing the green layer (Kraker *et al.*, 2000). Thereby damage usually occurs during the reproductive stage of the rice plant growth, and results in low ripening rate due to loss of effective leaf area for photosynthesis (Watanabe 1999). However, it is generally accepted that populations are often highest in field that have received high rates of nitrogen fertilizer and late transplanting field (Kushwaha, 1980; Ma and Lee, 1996).

The purpose of this experiment was to find out the best fertilization combination of N and Si in view of improved grain quality of medium-maturing variety rice and relationships among characteristics of them and reduced sheath blight disease of rice after winter green-house water-melon cropping.

MATERIALS AND METHODS

Site details

The field experiments were conducted during 2002 and 2003 at Uiryeong (35°25'N, 128°22'E) in southern part of Korea. The soil was a sandy loam (68.0% sand, 27.5 % silt and 4.5 % clay) with a pH of 5.9 (1:5, soil : water); mean available P_2O_5, 350 mg kg^{-1}; exchangeable potassium, 1.14 $cmol^+ kg^{-1}$; exchangeable Calcium, 2.6 $cmol^+ kg^{-1}$; exchangeable magnesium, 1.1 $cmol^+ kg^{-1}$; available SiO_2, 75 mg kg^{-1}; and 2.3 g · kg^{-1} organic matter. Chemical analyses of soil were followed by NAIST (2000).

Experimental design and treatments

The experiments were conducted by a randomized block design with three replications in 2002 and 2003. The treatments were three levels of N (N0%, N50%, N100%: 0, 57, 114 kg ha^{-1}) and three levels of SiO_2 (Si100%, Si150%, Si200% of recommendation: 75, 130 and 180 mg kg^{-1} with

Si fertilizer 0, 520, 790 kg ha^{-1}, respectively). The fertilization amount was followed by RDA (Rural Development Administration of Korea) model:

N-fertilization amount (kg ha^{-1}) = 127.4 - 15.2 [OM] + 0.28 [SiO_2].

Where, OM: organic matter (%) content in top soil

SiO_2: available silicate content (mg kg^{-1})

Si application (kg ha^{-1}) = ((Target uptake - Natural supply) – (Si concentration in soil (mg kg^{-1})) × 3.8

Applied silicate fertilizer, calcium silicate: pH 9.7-10.7, contained 25% of SiO_2, 40% of Al_2O_2, 40% of CaO and 2% of MgO.

The experimental design in 2003 was same with 2002, and N25% and N75% treatments were added to determine critical N level.

Each subplot size was 30 m^2 (5 m × 6 m) and the main plot treatments were three levels of N and SF(Si fertilization) rate and followed by the recommendation for rice cultivation in RDA of Korea. Phosphate (P: calcium super phosphate) and potassium (K: potassium chloride) fertilizers were applied at 30 and 21 kg ha^{-1} as basal application, respectively. For the top-dressing, N was applied at 17 and 34 kg ha^{-1} in N50% and N100% plots, respectively, and K was applied with 7 kg ha^{-1} at panicle initiation stage (25 days before heading) by urea and potassium chloride.

Cultural practice, fertilization methods and rice cultivation

Watermelon was cultivated in plastic film house during the seasons of winter (November-February) and spring (March- Mid. of June), and plastic film was eliminated during rice cultivation. Compost contained 3.5-4.0% of N and other nutrients were applied 30-40 t ha^{-1} for watermelon cultivation. Watermelon-transplanted rice rotation cropping system has been maintained on the site for 3 and 4 years in 2002 and 2003, respectively.

Field was tilled at dry condition after harvesting watermelon and each plot was separated by levee. Fertilizer was applied on the soil surface followed by rotary tilled by 15-cm soil depth for well mixing applied fertilizer. After mixing dry soil, water was irrigated at 5cm level. Rice cultivar, Hwayeongbyeo (*Oryza sativa* L., Midium-maturing cultivar) was grown for thirty days in the seedbed and it was planted using trans-planter by 30 × 15cm distance and 5-6 seedlings per hill at 2-3cm soil depth.

Herbicide (Nonanme: soil-applied herbicide) was sprayed after seven days of rice transplanting to control the growth of initial growing weeds. Conventional cultivation instructions were followed for all other treatments.

Post-harvest handling of rice grain

Rice with straw was harvested in 2 × 2 m for determination of grain yield and analysis of grain quality then put in nylon bag for drying in plastic film house. Harvested rice within nylon-bag was dried in the sunlight and the temperature ranged from 15°C at night to 28°C at day time, which were mostly depends on outside weather condition. One month after harvesting, rice grain was harvested by thresher at 150-200 rpm then ripened grain only used for measuring grain weight and moisture content then sampled 1000 g/ sample for grain quality and others were used for the determination of grain yield.

Harvested grain was put in zip-lock bag for maintain same moisture content and brown rice was collected after milling within 1 week after threshing. Appearance quality of brown rice was measured by Shizuokseiki (RS-2000X, Japan) within 2 weeks after threshing.

Parameters measured

The appearance quality of brown rice was classified as normal grain, powder, unripened, damaged, and cracked grain.

TOYO-tester (MA90B, Toyo, Japan) was used for measuring of TOYO-value (cooked rice quality).

Calculation of sheath blight and rice leaf damage by leaf-folder

Severity was determined in 20 hills/subplot and expressed as percent infected rice tillers which was calculated by the formula: infected rice tiller (%) by sheath blight = (total infected tillers/total tillers of 20 hills) × 100. On the other hand, rice leaf damage fed by leaf-folder was calculated by the formula: rice leaf damage (%) = total number of damaged leaf/(upper 3 leaves/hill × 20 hills) × 100.

RESULTS AND DISCUSSION

Grain quality of rice

Nowadays, TOYO-value does not acceptable for the evaluation of grain quality of rice because of the variable cultivars and physicochemical characteristics, however, there is no valuable methods for evaluation eating quality scientifically. So, in this experiment, we adapted TOYO-tester for evaluating eating quality of rice.

In 2002, eating quality (TOYO-value) was highest in N0% plots and it was same as the result of Lee and Oh (1991) and they mentioned that reduced NF (Nitrogen fertil-

Table 1. TOYO-value and appearance quality of brown rice as affected by N and SF level in watermelon-rice cropping systems in 2002.

N (%)	Si (%)	TOYO-value	Normal (%)	Powder (%)	Unripened (%)	Damaged (%)	Cracking (%)
	100	70.3b[†]	65.9b	7.7cd	13.2a	13.0ab	0.6e
0	150	73.5a	69.3a	5.5e	11.8b	11.8bc	0.7e
	200	72.7a	63.2bc	7.5cd	11.6b	11.6bc	1.4d
Mean		72.2a	66.1	6.9	12.2	12.1	0.9
	100	67.3c	62.9bc	7.0d	12.6ab	12.6ab	2.0cd
50	150	61.3d	57.2cd	11.0a	13.7a	13.7a	1.4d
	200	62.1d	60.1c	8.5c	11.4b	11.4bc	2.4c
Mean		63.6	60.1	8.8	12.6	12.6	1.9
	100	60.3e	44.8f	10.4b	12.2b	12.2b	5.1a
100	150	64.4cd	58.8cd	11.1a	8.5c	7.5d	3.2b
	200	57.2f	51.7e	8.2c	12.9ab	12.9ab	3.5b
Mean		60.6	51.8	9.9	11.2	10.9	3.9

[†]Means with the same letter in a column are not significantly different at the 5% level by DMRT.

Table 2. TOYO-value and appearance quality of rice as affected by N and SF level in watermelon-rice cropping systems in 2003.

N (%)	Si (%)	TOYO Value	Normal (%)	Powder (%)	Unripened (%)	Damaged (%)	Cracking (%)
	100	73.3a[†]	44.5bc	3.7de	30.3d	16.6bc	4.9gh
0	150	69.8b	45.0bc	11.4a	23.7f	16.8bc	3.1h
	200	71.4ab	51.2a	6.6b	21.1g	18.3a	2.8i
Mean		71.4	46.9	7.2	25.0	17.2	3.6
	100	71.8ab	43.1c	4.2d	29.5d	15.6cd	7.6ef
25	150	70.3b	46.1b	7.0b	28.0e	14.6d	4.3h
	200	73.7a	42.9c	11.1a	26.5ef	14.2d	5.3g
Mean		71.9	44.0	7.4	28.0	14.8	5.7
	100	65.5d	34.5e	6.2b	36.0b	14.7d	8.6e
50	150	74.2a	43.5c	11.5a	24.3f	15.3cd	5.4g
	200	69.4b	38.7d	5.7bc	30.4d	17.0bc	8.2e
Mean		69.7	38.9	7.8	30.2	15.7	7.4
	100	67.3c	31.0f	4.8d	39.3a	12.3e	12.6c
75	150	68.9bc	35.3e	3.5de	37.1ab	13.5de	10.6d
	200	70.2b	38.7d	2.6f	35.6bc	16.0cd	7.1f
Mean		68.8	35.0	3.6	37.3	13.9	10.1
	100	69.5b	32.2g	5.7cd	34.0c	14.0de	14.1b
100	150	67.6c	26.4h	6.0bc	37.8ab	18.6a	11.2cd
	200	64.4d	26.8h	6.7bc	34.8c	15.7cd	16.0a
Mean		67.2	28.5	6.1	35.5	16.1	13.8

[†]Means with the same letter in a column are not significantly different at the 5% level by DMRT.

ization) increased grain quality (Table 1). In common, eating quality of rice grain negatively correlated with the grain protein content (Kim *et al.*, 1992). So, high NF might be results low eating quality. Silica application with 150% increased TOYO-value in N100% plot, however, it was not significant in N50% with both SF levels and N100% with Si200% plots. For the appearance quality, normal grain percentage was positively related with TOYO-value in both years (Table 4) and it was highest in N0% plot and N100% combined with SF. Other appearance qualities, powder, unrip-

Table 3. Correlation coefficient of rice between yield components and characteristics of grain quality (n=28).

	Year	Yield	Grain weight	Ripened (%)	Spikelet/panicle	Panicles/m^2
Toyo-value	2002	-0.780**	0.255	-0.513	-0.880**	-0.867**
	2003	-0.430	0.383	0.648*	-0.092	-0.333
Normal	2002	-0.564	0.126	-0.303	-0.852**	0.598*
	2003	-0.578	0.571	0.851**	-0.248	0.336
Powder	2002	0.410	0.410	0.535	0.749**	0.566
	2003	-0.308	-0.308	0.235	0.387	-0.537
Unripened	2002	-0.013	0.223	-0.043	-0.223	-0.080
	2003	0.570	-0.723*	-0.727*	0.006	0.683*
Damaged	2002	0.025	0.223	-0.273	-0.253	-0.088
	2003	-0.273	0.401	-0.275	-0.334	-0.154
Cracking	2002	0.523	-0.102	0.259	0.846**	0.869**
	2003	0.585	-0.486	-0.826**	0.331	0.727*

*,**Significant at the 0.05 and 0.01 probability levels, respectively.

Table 4. Correlation coefficient of rice among characteristics of grain quality (n=45).

		Normal	Powder	Unripened	Damaged	Cracking
Toyo-value	2002	0.861**	-0.710*	-0.040	-0.025	-0.770*
	2003	0.785*	0.318	-0.696*	0.111	-0.732*
Normal	2002	-	-0.713*	0.023	0.025	-0.929**
	2003	-	0.321	-0.870**	0.233	-0.940**
Powder	2002	-	-	-0.266	-0.311	0.619
	2003	-	-	-0.870**	0.121	-0.388
Unripened	2002	-	-	-	0.994**	-0.313
	2003	-	-	-	-0.413	0.811**
Damaged	2002	-	-	-	-	-0.304
	2003	-	-	-	-	-0.345

*,**Significant at the 0.05 and 0.01 probability levels, respectively.

ened, damaged, and cracked grain, were decreased with increasing N application level. The SF improved appearance quality in N100% plots but it was not significantly effects on other N treatments.

In 2003, TOYO-value was not significantly affected by NF level which was greatly different to the results in 2002 (Table 2). No NF plot was just 4 points higher TOYO-values than 100%N plot. The SF increased TOYO-value in N25%, N50, and 75% plots and that results are very similar to the previous results (Lee and Oh, 1991; Kim *et al.*, 1992), however it did not effect in N0% and N100% plots. The reasons might be estimate no more improvement in low N level but it was too lower to support in high N level. So, if we increase SF level, TOYO-value might be increased.

In 2003, normal grain percent decreased with increasing NF level and it was especially improved with SF in N50 and N75 in 2003 (Table 3). The percentage of normal rice grain increased by SF in N0, N50, and N75% plots, however, it was decreased in N100% plots. That reason might be related with the unusually low temperature during the vegetative growth stage, which did not increased tillers until panicle initiation stage because of the reduced N uptake, so re-translocation of accumulated leaf blade N might be increased panicle size. Increased panicle size might be reduced ripened grain ratio and the number of normal rice grain.

The percentage of powdered rice was higher in low N fertilized plots and it decreased with increasing SF in N75% plots, however, SF did not increased the percentage of powder rice in other N levels.

The percentage of unripened rice increased by increasing NF level and it was reduced by Si application in all N levels except N100% plots. The percentage of damaged grains was

Table 5. Percent of rice tillers infected by sheath blight and rice plant leaf damage fed by leaf folder at application of N and SF level in watermelon-rice cropping systems in 2002.

N (%)	Si (%)	Infected rice tiller (%) by sheath blight	Rice leaf damage by leaf folder (%)
0	100	2.8e†	57.3e
	150	2.2ef	37.0f
	200	1.6f	22.3g
50	100	4.1c	95.7b
	150	3.5d	90.7c
	200	3.4d	84.0d
100	100	7.4a	100.0a
	150	5.5b	96.3b
	200	14.1c	191.0c

†Means with the same letter in a column are not significantly different at the 5% level by DMRT.

Table 6. Percent of rice tillers infected by sheath blight and rice plant damage fed by leaf folder at application of N and SF level in watermelon-rice cropping systems in 2003.

N (%)	Si (%)	Infected rice tiller (%) by sheath blight	Rice leaf damage by leaf- folder (%)
0	100	1.8f†	31.3j
	150	1.6f	26.7k
	200	1.2g	23.0l
25	100	2.9d	55.0g
	150	2.6de	47.7gh
	200	2.2e	37.3i
50	100	3.7c	70.3d
	150	3.3cd	61.7f
	200	3.0d	55.0g
75	100	4.4b	74.0c
	150	4.1bc	70.0d
	200	3.8c	67.3de
100	100	5.7a	87.7a
	150	5.4a	84.0b
	200	4.6b	82.7b

†Means with the same letter in a column are not significantly different at the 5% level by DMRT.

not affected by NF level but it increased with increasing of Si application. The percentage of cracking grains increased with increasing N application level, however, it was decreased by increasing Si application level except in 100%N plots.

In 2002, correlation coefficient of rice between yield components and characteristics of grain quality was negative. And there were negative relationships between TOYO-value and grain yield, spikelets/panicle, and panicle numbers per area (Table 3). In 2003, differently to 2002, TOYO-value was positively related to ripened grain (%) but there was no relation in other characteristics.

In 2002, normal grain was positively correlated with ripened grain (%) and panicle numbers but no relations in other characteristics and it was not at all in 2003. Powder grain (%) was positively related with spikelets /panicle, however no other factors related with it. Unripened grain (%) was negatively correlated with grain weight and ripened grain (%) in 2003 and positively related with panicle numbers in 2003. Damaged grain was not related with any other factors. Cracking grain was positively related with spikelets/panicle in 2002 and panicle numbers in both years, however, it was negatively related with ripened grain (%) in 2003.

Correlation coefficient was greatly related between TOYO-value and normal grain in both years, however, it was negatively related with the percentage of powder grain in 2002, unripened grain in 2003, cracking grain in both years (Table 4). Normal grain was negatively related with the percentage of powder grain in 2002, unripened grain in 2003, and cracking in both years. Powder grain was negatively related with damaged grain only in 2002.

Cracking grain was the most negative factors on TOYO-value and normal grain in both years. So, the cracked(%) rice in fertilized plot ranged from 0.7 to 3.5% in 2002, however it was greatly increased in 2003 and it ranged from 2.8% to 16.0, which are almost 4 times higher than 2002. In no-Si plot, it ranged from 0.6 to 5.1 in 2002 and 4.9-14.1 in 2003. Cracking rice can be increased by drying in high temperature.

Rice sheath blight infection and leaf damage by leaf-folder

In 2002, sheath blight infection percentage of rice plant increased with increasing nitrogen fertilization level, however, it decreased with increasing of silicate fertilization levels (Table 5). The leaf damage by rice leaf-folder feeding also similar inclination like to sheath blight infection and it was 100% in N100%, however it was decreased to 9% by Si application.

In 2003, similar to the results in 2002, sheath blight infection (SBI) and leaf damage by rice leaf-folder (LDRL) were increased with increasing NF level and they were decreased with increasing Si application (Table 6), which results were very similar to those in 2002 and previous result (Lee and Shin, 1974). These results indicate Si might be very useful for decreasing SBI and LDRL simultaneously and the useful level is Si 200% (180 mg/kg) in N 50% of conventional fertilization level.

CONCLUSION

Recommended silicate levels 130 or 180 mg/kg (150 and 200%) for getting high yield and high grain quality in rice cultivation might be effective for rice grain quality and yield, however, it also greatly affected by weather condition and the effect might be reduced in the unusually low temperature like in 2003. Low silicate levels in most of Korean paddy field could be improved by winter cropping of green-house vegetables because of farmers input more amount of macro- and micro-nutrients by compost or inorganic fertilizers before vegetable cropping annually. However, most of nutrients remain in soil or making pollution of ground water or near water stream. So some farmers do not fertilize for rice cropping that decreases soil CEC causing excessive damage to vegetable crops (Park *et al.*, 2004), however, it could not get normal yield and could not get high quality of grain. Silicate fertilization also contributes reducing the damage from the insect-pest diseases and that mechanisms are mostly known as mechanically enriched rice plant (Hayasaka *et al.*, 2002). In conclusion, silicate fertilization on rice could be improve grain quality (eating quality and appearance quality) of rice and could save N fertilization level and additionally silicate fertilization might be reduce insect-pest diseases after winter green-house water-melon cropping with medium-maturing rice cultivar.

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