Influence of Silicon Fertilizer Grades on Blast and Brown Spot Development and on Rice Yields

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ABSTRACT

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Calcium silicate slag, applied as a source of plant-available silicon on silicon-deficient soils, reduces plant disease and increases yields of rice. The purpose of this experiment was to evaluate performance of three forms of slag and three rates of application on disease and yield. Calcium silicate slag was applied at 0, 2.5, and 5.0 Mg/ha as a fine-grade material (100% < 0.15 mm), a standard-grade material (90% < 2.36 mm), or as pellets (100% > 1 mm and < 3.35 mm) made from the fine-grade material. Brown spot (caused by *Bipolaris oryzae*) severities decreased over the controls by 48–80%, 33–60%, and 2–23% for the fine, standard, and pelletized forms, respectively, in 1990 and 1991. Blast (caused by *Pyricularia grisea*) severities also decreased by 50%, 23%, and 4% for the fine, standard, and pelletized forms, in comparison with the control in 1991. Plant tissue silicon content and grain yields increased with increasing slag rates. Silicon content in plant tissue increased 131–246%, 208–122%, and 108–192% with the fine, standard, and pelletized forms, and yields increased 20–26%, 18%, and 4–11% for both years. The fine grade of silicon fertilizer was best for increasing silicon content and grain yields and for reducing the severity of brown spot and blast. These results are encouraging, since lower slag rates of finer grades may be used to reduce production costs while enhancing integrated management of several important rice diseases.

Additional keywords: nutrition, *Oryza sativa, Pyricularia oryzae*

Rice (*Oryza sativa* L.) is grown in Florida in the Everglades Agricultural Area, south of Lake Okeechobee, on muck soils (Histosols) with organic matter contents in excess of 80%. Silicon (Si) concentrations are lower in organic soils than in most mineral soils (7). This deficiency can be corrected by amending soils low in plant-available Si with calcium silicate slag. Slag, containing approximately 22% Si, is a by-product of elemental phosphorus production in an electric furnace (12).

Recent research in the Everglades Agricultural Area demonstrated that amending these Si-deficient organic soils with calcium silicate slag reduced blast, caused by *Pyricularia grisea* (Cooke) Sacc. (syn. *P. oryzae* Cavara) (10), 73–86% and reduced brown spot, caused by *Bipolaris oryzae* (Breda de Haan) Shoemaker, 58–75% (3). Subsequently, yields increased 56–88%. Further research also demonstrated the potential of integrating fungicides with calcium silicate slag applications for disease management (5). Since application of this material may be quite cumbersome and expensive, a study was conducted to determine the efficacy of application rates and forms of calcium silicate slag on disease development and yield. A preliminary report was published (4).

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MATERIALS AND METHODS

Two experiments were conducted, the first in 1990 and the second in 1991. In 1990, calcium silicate slag was applied at 0, 2.5, and 5.0 Mg/ha as a fine-grade material (100% < 0.15 mm), a standard-grade material (90% < 2.36 mm), or as pellets (100% > 1 mm and < 3.35 mm) made from the fine-grade material. In 1991, the same grades were applied, but only at the 5.0 Mg/ha rate. Pellets in both experiments were bound using a lignosulfate binder (M. Elizer, *personal communication*). The materials contain-

Table 1. Analysis of variance of silicon content in rice straw, brown spot severity, and grain yields of rice cultivar Lemont in 1990

		Mean square		
Source	**df**	**Silicon in rice straw**	**Brown spot severity**	**Rice grain yields**
Replication	3	0.1312	1,447,262.70**[a]	362.64*
Form	2	0.9936**	988,885.86**	1,074.32**
Rate	1	1.2742**	1,233,812.44**	776.34**
Form × rate	2	0.0980	130,931.35	91.72
Error	15	1.1775	1,263,692.39	519.32

[a]* and ** = Significant at the 0.05 and 0.01 levels of probability.

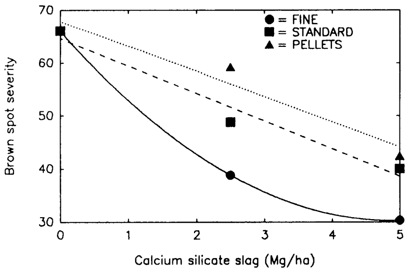

Fig. 1. Relationship between brown spot severity and rates of calcium silicate slag in 1990. Fine, $Y = 66.1 - 14.7x + 1.5x^2$; standard, $Y = 64.7 - 5.2x$; and pellets, $Y = 67.8 - 4.8x$. The percent mean leaf area affected for each numerical rating for each replication was used for calculating regression equations ($n = 5$).

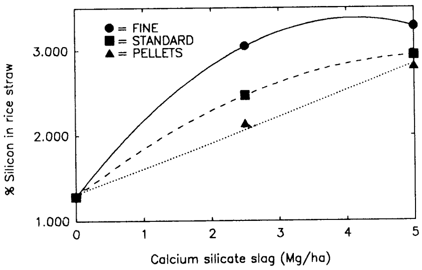

Fig. 2. Relationship between percent silicon in rice straw and rates of calcium silicate slag in 1990. Fine, $Y = 1.3 + 1.0x - 0.1x^2$; standard, $Y = 1.3 + 0.6x - 0.06x^2$; and pellets, $Y = 1.3 + 0.3x$ ($n = 5$).

Table 2. Influence of calcium silicate slag grades on brown spot and blast severities on rice cultivar Lemont in 1990 and 1991

	Percent brown spot[b]		Percent blast[b]
Grade[a]	**1990**	**1991**	**1991**
Fine	34.5	5.2	20.8
Standard	44.4	10.5	31.8
Pellet	50.8	24.6	39.9
Control	66.1	26.2	41.4
FLSD[c] ($P = 0.05$)	7.1	11.6	36.4

[a]Calcium silicate slag was applied as a fine-grade material (100% < 0.15 mm), a standard grade (90% < 2.36 mm), or as pellets (100% > 1 mm and < 3.35 mm).
[b]Brown spot severity was determined using a standardized rating scale of 0 to 9, where 0 = no disease and 9 ≥ 76% of affected leaf area, and blast severity was determined using a similar rating scale of 0 to 9, where 0 = no disease and 9 ≥ 51% of panicle area infected. The percent mean affected area of leaf or panicle for each numerical rating was used for estimating differences between treatments ($n = 5$).
[c]Fisher's least significant difference value.

ing Si were incorporated before planting on individual plots (8.0 × 1.2 m) with five replications. The experiments were conducted on a Terra Ceia muck soil (Euic, hyperthermic Typic Medisaprist) with a pH of 6, as determined by the Everglades Research and Education Center soil testing laboratory. The cultivar Lemont was drill-seeded at a depth of 3 cm with 20-cm row spacing on 25 April 1990 and 5 May 1991. The seeding rate was approximately 100 kg/ha.

Disease ratings were recorded at dough and mature grain stages of plant growth, GS8 and GS9 (9). Brown spot severity was determined using a standardized rating scale of 0 to 9, where 0 is no disease and 9 is 76% or more of leaf area affected (9). Ten flag leaves per experimental unit were scored. Blast severity was determined using a similar rating scale of 0 to 9, where 0 is no disease and 9 is 51% or more of the panicle area infected (9). Five random areas per experimental unit were scored. The percent mean affected area of leaf or panicle for each numerical rating was used for estimating differences between treatments. Rice was machine-harvested on 8 August 1990 and 16 August 1991. Grain yields (unhulled rice) were adjusted to 12% moisture. Si in plant tissue was determined using the method of Elliott and Snyder (8) from about 300 g of bulked plant tissue that included leaves and stems randomly gathered from each experimental unit at harvest. All treatments were analyzed as a factorial experiment arranged in a randomized complete block design. Data were subjected to ANOVA and linear and polynomial regression procedures (11). Means were tested for significant differences ($P = 0.05$) using Fisher's least significant difference.

RESULTS AND DISCUSSION

The interaction between calcium silicate slag application rate and silicon fertilizer grade was not significant ($P = 0.05$) in 1990 (Table 1); consequently, the main effects are presented for this year. Based on this information, only the highest slag rate was used for the differ-

Table 3. Influence of calcium silicate slag grades on silicon content in straw and grain yields of rice cultivar Lemont in 1990 and 1991

	Silicon[a]		Yield[b] (kg/ha)	
Grade	**1990**	**1991**	**1990**	**1991**
Fine	3.2	5.9	6,451.3	5,417.4
Standard	2.7	5.5	6,354.6	5,088.5
Pellet	2.5	4.9	5,980.6	4,492.5
Control	1.3	4.5	5,379.6	4,309.8
FLSD[c] ($P = 0.05$)	0.3	1.2	402.1	610.5

[a]Silicon content in rice plant tissue (measured in decagrams per kilogram).
[b]Grain yield of rough rice at 12% moisture.
[c]Fisher's least significant difference value.

ent grades in 1991.

Brown spot severities were influenced by the rate of application in 1990 and the form of slag application in 1990 and 1991. Brown spot decreased with increasing slag rates. A quadratic regression model best described the relationship between disease and slag rate (Fig. 1) for the fine form, whereas linear regression was best for the standard and pelletized forms.

In 1990, brown spot severities decreased relative to the controls by 48%, 33%, and 23% for the fine, standard, and pelletized forms, respectively (Table 2). The overall tissue levels of Si were higher in 1991, and these same forms of slag decreased severity 80%, 60%, and 2%, respectively. Blast severities also decreased in relation to the control 50%, 23%, and 4% for the fine, standard and pelletized forms (Table 2). Although blast severities decreased with different slag forms, they were not significantly different from the untreated control. Nevertheless, these results are consistent with earlier observations on the relationship of slag to brown spot and blast development (3).

Tissue Si increased with increasing slag rates (Fig. 2). Quadratic regression models described the relationship between plant tissue silicon content and slag rate for the fine and standard forms, whereas a linear model was best for the pelletized form. Silicon content in rice tissue increased relative to the control by 131%, 208%, and 108% in 1990 for the fine, standard, and pelletized forms, and by 246%, 122%, and 192% in 1991 (Table 3). Only the fine grade of slag significantly increased tissue Si in 1991. However, the overall silicon content was consistently higher in rice straw in 1991. The 1991 field location probably contained a naturally higher residual content of elemental Si in comparison to the 1990 location. In addition, the nutrient status of other elements and localized weather patterns might have contributed to differences in Si accumulation in the plant tissues at the two locations.

Linear models adequately described the relationship between grain yield and

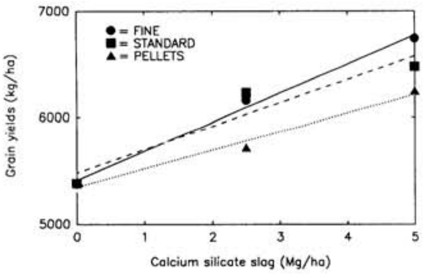

Fig. 3. Relationship between grain yields and rates of calcium silicate slag in 1990. Fine, $Y = 5{,}412.7 + 272.6x$; standard, $Y = 5{,}480.4 + 219.6x$; and pellets, $Y = 5{,}346.8 + 173.4x$ ($n = 5$).

slag rate for the different slag forms in 1990 (Fig. 3). Yields increased 20%, 18% and 4% in 1990 for the fine, standard and pelletized forms, and 26%, 18%, and 11% in 1991 (Table 3).

Evidently, particle size of the silicon fertilizer is important in increasing Si content of leaves and subsequent disease control. Particle size is associated with increased surface area; consequently, the distribution and dissolution of smaller Si particles mixed in the soil is enhanced and the probability of root particle contact is increased. Combining fine particles into pellets probably results in less Si-soil contact, leading to reduced Si availability to the crop, although some particle degradation could occur during soil incorporation. These conclusions are in agreement with other research that demonstrates reductions in soilborne and foliar diseases associated with the rate and particle size of the fertilizer (1,2,6). These results indicated that lower slag rates of finer grades may be used to reduce production costs while enhancing integrated management of several important diseases of rice in Florida.

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