Effect of Calcium Silicate on Blast and Brown Spot Intensities and Yields of Rice

L. E. DATNOFF, Assistant Professor of Plant Pathology; R. N. RAID, Assistant Professor of Plant Pathology; G. H. SNYDER, Professor of Soils; and D. B. JONES, Associate Professor of Agronomy, Institute of Food and Agricultural Sciences, University of Florida, Everglades Research and Education Center, P.O. Box 8003, Belle Glade 33430

ABSTRACT

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Rice production in the subtropical climate of Florida is on Histosols, which are high in organic matter content and low in plant-available silicon (Si). Broadcast rates of calcium silicate slag were 0, 5, 10, and 15 Mg/ha in 1987 and 1988. In 1987, applications of calcium silicate slag reduced blast by 30.5% and brown spot by 15.0% over the control. In 1988, blast and brown spot were reduced by 17.4 and 32.4%, respectively, over the control. Linear and quadratic equations significantly ($P \leq 0.05$) described the slag-disease and slag-yield relationships. In rice straw samples, only Si, not Ca, significantly increased ($P \leq 0.05$) with increasing slag rates over the control. It appears that reduction in disease intensities can be accounted for only by Si in this study.

Florida rice (*Oryza sativa* L.) production in the Everglades Agricultural Area (EAA), located south of Lake Okeechobee, began during the 1950s (1). Numerous investigations during the industry's infancy identified some of the major diseases limiting rice production, such as blast caused by *Pyricularia oryzae* Cavara and brown spot caused by *Bipolaris oryzae* (Breda de Haan) Shoemaker (= *Helminthosporium oryzae* Breda de Haan) (8). In 1957, hoja blanca, a serious viral disease, was first reported in Florida (9,10). A self-imposed quarantine forced the destruction of commercial and experimental rice fields to prevent the potential spread of this disease to other rice-growing states. This act, plus other problems associated with rice production, brought this burgeoning industry to a halt.

The rice industry made a resurgence in the 1980s. The area planted increased from less than 810 ha in 1978 to 5,844 ha in 1988 (2). Rice is usually grown in rotation with sugarcane and vegetables on muck soils (Histosols) with organic matter contents in excess of 80% (1,22). Rice traditionally is not grown on soils with high organic matter around the world, in part because of problems related to plant nutrition (7,21,22). For example, rice production in the EAA has suffered from iron deficiency, panicle sterility, lodging, and severe epidemics of blast and brown spot (7,8,21). These conditions probably have contributed to lower yields in the past.

It is known that the silicon (Si) concentration of plants varies by soil (13). Soils such as highly weathered tropical uplands, Ultisols, are low in plant-available Si because of leaching losses (26). Latosols and strongly acid alluvial soils are responsive to silicate slag applications (15), however, some soils are not responsive to silicate fertilization. Rodriguez and Ponce (19) applied Si in several forms for controlling rice blast, but no response to Si fertilization was observed. This failure was believed to be attributable to the use of low rates of Si fertilizers or soils that were not deficient in plant-available Si. Thus, it is important to be able to determine soil responsiveness to Si fertilization.

Silicon concentrations are lower in organic soils than in most mineral soils (5,7,22). Recent research in the EAA demonstrated that rice yields could increase in excess of 30% on Histosols amended with calcium silicate slag (22). A positive linear relationship was observed between straw Si content and grain yields. Moreover, Si has been reported to benefit rice by increasing its resistance to insect and disease problems (5,17).

Although blast and brown spot severities were reduced by the addition of Si on mineral soils (17,23), little information is available for these diseases on Histosol-grown rice. In addition, fungicides that are currently used for managing these aforementioned diseases are being scrutinized by environmental groups and government agencies as potential carcinogens. These social concerns have already caused the removal of certain fungicides from the market. Consequently, other alternatives, such as Si fertilization, are needed for plant disease management. The objective of this study was to measure the effects of Si on blast incidence, brown spot severity, and subsequent rice yields. Portions of this study were published previously as reports (3,4,18).

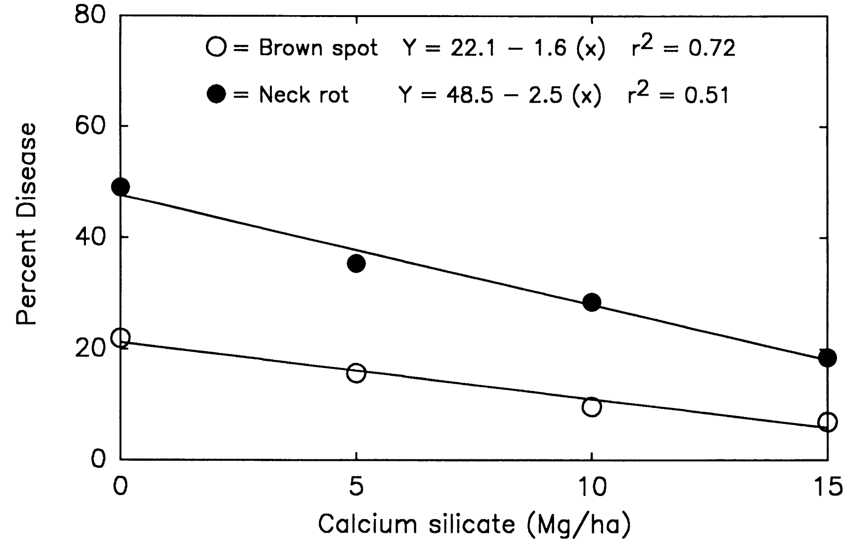

Fig. 1. Relationship of brown spot severity and neck rot incidence to rates of calcium silicate slag in 1987.

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MATERIALS AND METHODS

Broadcast rates of calcium silicate slag were 0, 5, 10, and 15 Mg/ha in 1987 and 1988. Calcium silicate slag, hereafter referred to as slag, was preplant incorporated before seeding on individual plots (8.0 × 1.2 m) with five replications in a randomized complete block design. The same rates were applied to unamended plots in 1988 and, in addition, 5 Mg/ha of slag was applied to each of the residual plots receiving slag treatments in 1987. The slag used in this study is a by-product of elemental P production by an electric furnace (22). The chemical analysis of the slag as previously described (22) in decagrams (dag) per kilogram are Si, 22.0; Ca, 33.0; P, 0.5; K, 0.1; Mg, 0.3; and Fe, 0.5. In milligrams per kilogram, the concentrations of Mn, Zn, and Cu were 190, 12, and 15, respectively.

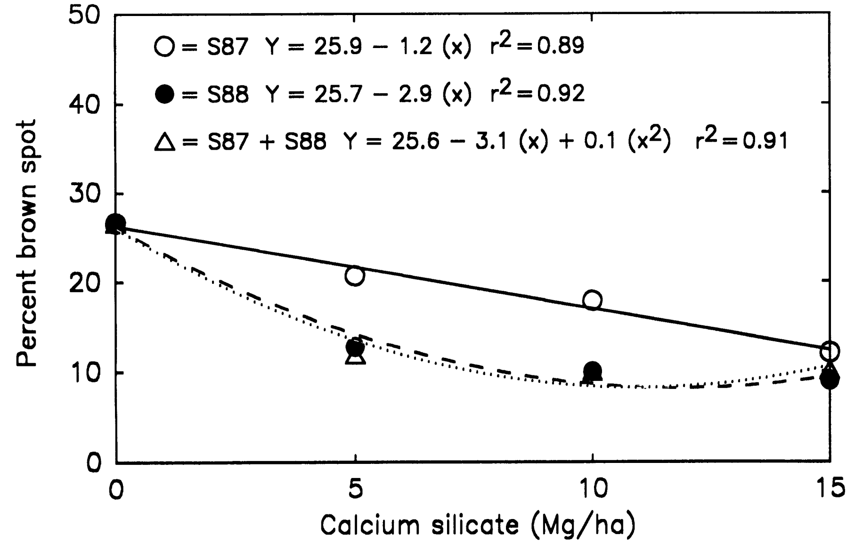

Fig. 2. Relationship of brown spot severity to rates of calcium silicate slag in 1988. S87 or S88 = slag applied at given treatment rates only in 1987 or 1988; S87 + S88 = 5 Mg/ha of slag applied in 1988 to each of the residual plots receiving the 1987 slag treatments.

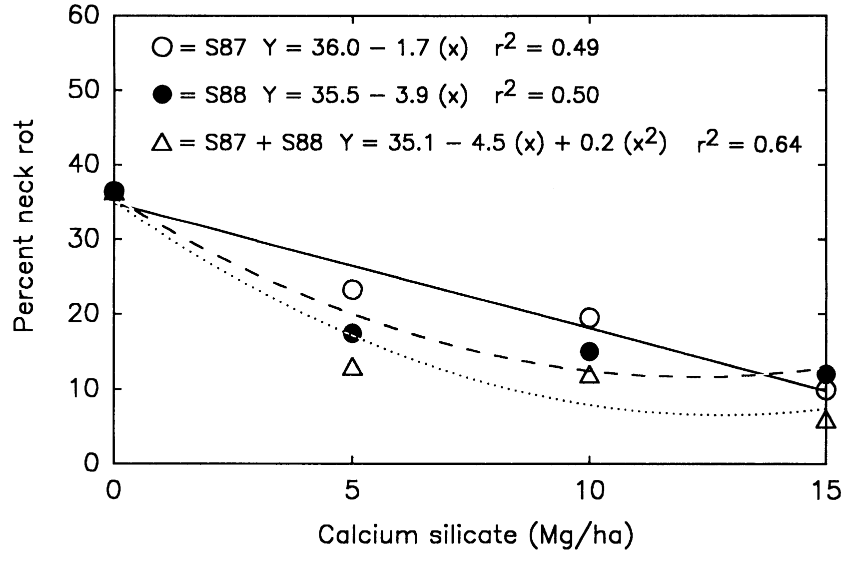

Fig. 3. Relationship of neck rot incidence to rates of calcium silicate slag in 1988. S87 or S88 = slag applied at given treatment rates only in 1987 or 1988; S87 + S88 = 5 Mg/ha of slag applied in 1988 to each of the residual plots receiving each of the 1987 slag treatments.

Table 1. Influence of calcium silicate slag on rice plant tissue Ca and Si content (dag/kg)

Slag rate (Mg/ha)	1987		1988					
			S87[a]		S88[a]		S87 + S88[a]	
	Ca	Si	Ca	Si	Ca	Si	Ca	Si
0	0.54	1.55	0.53	1.76	0.53	1.76	0.53	1.76
5	0.47	4.04	0.57	2.88	0.54	4.94	0.56	5.14
10	0.47	5.60	0.57	4.30	0.57	6.14	0.51	5.90
15	0.38	5.98	0.55	4.44	0.53	6.22	0.53	5.12
FLSD[b] ($P \leq 0.05$)	NS	0.97	NS	0.59	NS	0.59	NS	0.59

[a] S87 or S88 = slag applied at given treatment rates only in 1987 or 1988; S87 + S88 = 5 Mg/ha of slag applied in 1988 to each of the residual plots receiving each of the 1987 treatments.

[b] FLSD = Fisher's Least Significant Difference; NS = nonsignificant.

Experiments in both years were conducted on a Terra Ceia muck (Euic, hyperthermic Typic Medisaprist) with a pH of 6.0. The cultivar Lemont was seeded at a depth of 3 cm with a 20-cm row spacing on 24 and 25 April in 1987 and 1988, respectively. The seeding rate was approximately 100 kg/ha. Propanil (1.7 kg a.i./ha) was applied as a postemergence herbicide, and methyl parathion (1.1 kg a.i./ha) was applied for insect control as needed. Fungicides were not applied in either year.

Rice was harvested on 17 and 26 August in 1987 and 1988, respectively. Grain yields (unhulled rice) were adjusted to 12% moisture. Disease ratings were recorded between dough and mature grain, GS8 to GS9 (11). Severity of brown spot was determined with a modified illustrated assessment key ranging from 0 to 40% (12). Ten flag leaves per experimental unit were scored. Incidence of blast (neck rot) was based on examining 100 heads of rice per experimental unit and calculating the percentage of heads exhibiting symptoms. Si and Ca in plant tissue was determined as described previously (22) from about 300 g of bulked plant tissue that included leaves and stems randomly gathered from each experimental unit at harvest. All treatments in each year were analyzed as a factorial experiment arranged in a randomized complete block design. Data were subjected to ANOVA and linear and polynomial regression procedures (20).

RESULTS AND DISCUSSION

Both brown spot severity and neck rot incidence were significantly ($P \leq 0.05$) influenced by slag applications during 1987 and 1988. Both diseases decreased with increasing slag rates. In 1987 (Fig. 1), linear regression models described the disease-slag relationships, whereas in 1988 (Figs. 2 and 3), linear and quadratic were used. In 1987, brown spot severity and neck rot incidence at the highest slag rate decreased 15.0 and 30.5% over the control, respectively (Fig. 1). In 1988, brown spot severity at the highest slag rate decreased 14.5, 17.6, and 16.5% over the control for residual 1987 slag effects on the 1988 rice crop, 1988 slag applications, and residual 1987 slag rates each receiving 5 Mg/ha of slag in 1988, respectively (Fig. 2). In addition, neck rot incidence at the highest slag rate decreased 29.1, 27.0, and 32.4% over the control for residual 1987 slag effects on the 1988 crop, 1988 slag applications, and residual 1987 slag rates each receiving 5 Mg/ha of slag in 1988, respectively (Fig. 3). Although the application of slag in 1988 suppressed disease more than the 1987 residual applications on the 1988 rice crop, the residual applications were very effective.

Slag contains a number of plant nutrients, of which Si at 22.0 dag/kg and Ca at 33.0 dag/kg are the two most abundant elements. However, only Si in the rice straw samples significantly increased ($P \leq 0.05$) with increasing slag rates over the control in both years (Table 1). Snyder et al (22) also observed that Si was the only element significantly increasing in plant tissue of rice grown on Histosols amended with slag over a 3-yr period. Ca either decreased or remained the same in 1987 and 1988, respectively (Table 1). The decrease in Ca with increasing rates of slag in 1987 might have occurred as a result of dilution by the taller growing rice plant. Furthermore, no differences in disease intensities have been observed between a check treatment and a treatment of lime applied preplant at a rate equal to a Ca rate associated with slag applications of 10 Mg/ha (L. E. Datnoff, *unpublished*). Thus, in this study, it appears that reduction in disease intensities can be accounted for only by Si.

Other investigators have demonstrated that blast, brown spot, and other diseases can be reduced by amending the soil deficient in nutrient elements such as Si (6,14,16,24,25). N, P, K, Ca, and Mg have also been identified as playing a role in disease reduction (5,6,17,23). The mechanism of disease reduction is believed to be conferred by the Si association with cell wall constituents, making them less accessible to the enzymatic degradation by these fungi (17). However, in the case of blast, some cultivars with low Si are resistant, whereas those with high Si are susceptible (17). This variation in cultivar susceptibility with either high or low Si content may reflect variability within the pathogen.

Rice yields increased significantly ($P \leq 0.05$) with increasing slag rates. Quadratic models significantly ($P \leq 0.05$) described the rice yield-slag relationship in 1987, the 1988 residual 1987 slag rates each receiving 5 Mg/ha of slag, or 1988 slag applications (Figs. 4 and 5). However, the residual 1987 Si effects on the 1988 crop yield was best described linearly. The greatest yield increases in 1988 occurred with slag applications

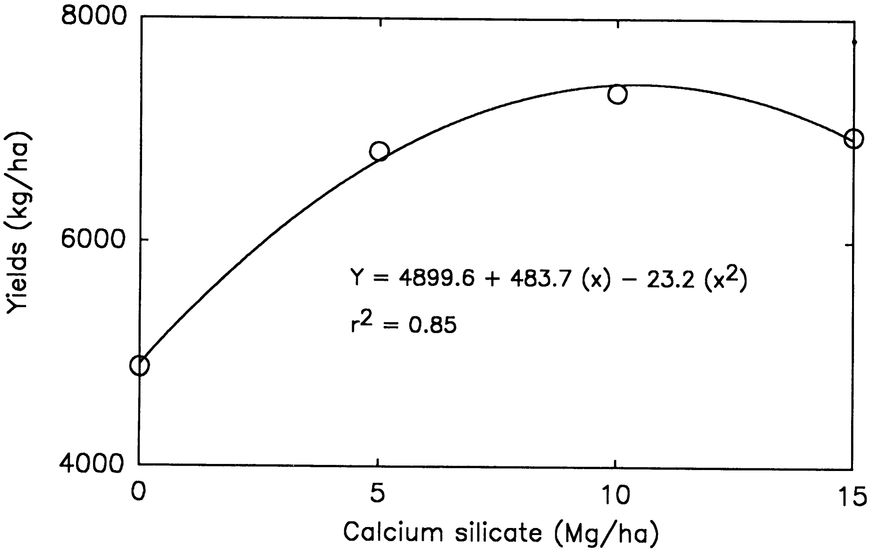

Fig. 4. Relationship of rice yield to rates of calcium silicate slag in 1987.

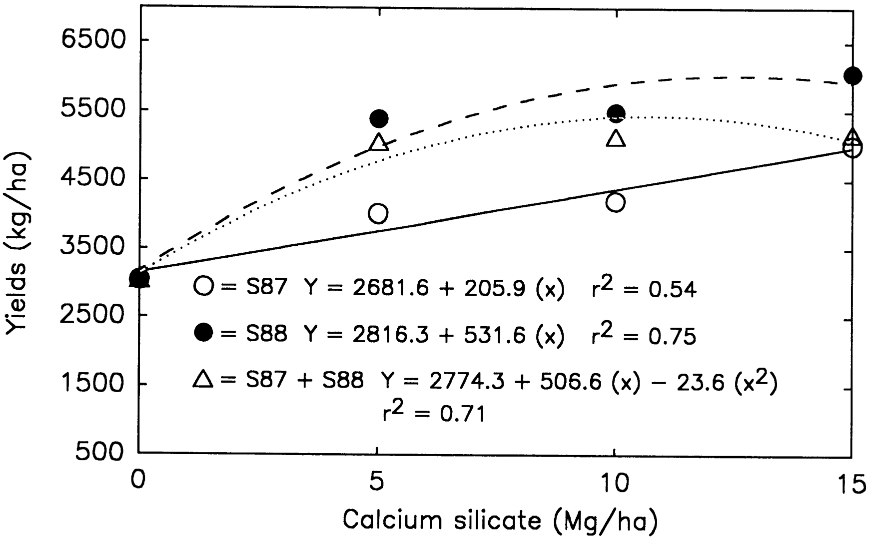

Fig. 5. Relationship of rice yield to rates of calcium silicate slag in 1988. S87 or S88 = slag applied at given treatment rates only in 1987 or 1988; S87 + S88 = 5 Mg/ha of slag applied in 1988 to each of the residual plots receiving each of the 1987 slag treatments.

Table 2. Correlation coefficients of brown spot severity, neck rot incidence, and rice yields with calcium silicate slag

Slag applications[a]	BS[b]	NR[b]	Yield[b]
S87	−0.83***	−0.69***	0.79***
R87 (88)	−0.94***	−0.70***	0.72***
S88	−0.86***	−0.64**	0.78***
R87 (88) + S88	−0.81***	−0.73***	0.69***

[a] Calcium silicate slag applied at 0, 5, 10, and 15 Mg/ha; S87 = slag applied in 1987; R87 (88) = residual slag from 1987 on 1988 crop; S88 = slag applied in 1988; and R87 (88) + S88 = 5 Mg/ha of slag applied in 1988 to 1987 residual slag plots.

[b] BS = Brown spot severity, NR = neck rot incidence, and yield = unhulled rice adjusted to 12% moisture; ** and *** represent significant treatment effects at the 0.001 and 0.0001 levels of probability, respectively.

Table 3. Correlation coefficients of rice yields with brown spot severity and neck rot incidence

Yield[a]	BS[b]	NR[b]
S87	−0.74***	−0.62***
R87 (88)	−0.73***	−0.45*
S88	−0.91***	−0.50*
R87 (88) + S88	−0.90***	−0.64**

[a] Rice yields from all treatments receiving slag at 0, 5, 10, and 15 Mg/ha; S87 = slag applied in 1987; R87 (88) = residual slag from 1987 on 1988 crop; S88 = slag applied in 1988; and R87 (88) + S88 = 5 Mg/ha of slag applied in 1988 to 1987 residual slag plots.

[b] BS = Brown spot severity; NR = neck rot incidence; *, **, and *** represent significant treatment effects at the 0.05, 0.005, and 0.0001 levels of probability, respectively.

made in 1988 and 5 Mg/ha application to plots amended in 1987 (Fig. 4).

Both diseases had highly significant negative correlation coefficients with Si and yield (Tables 2 and 3). In addition, a highly positive correlation existed between Si and yield (Table 2). It is logical that reduced disease severities would be at least partially responsible for increased yield. However, Si in the absence of disease may also increase yield solely as a plant nutrient. Increased yield is probably a function of both reduced disease and more favorable plant nutrition. The relative contributions of these factors need to be identified through experiments including a disease-free control.

In conclusion, the Histosols in the EAA are very low or lacking in Si. By amending these soils with Si, blast and brown spot were reduced by 73–86% and 58–75% in 1987 and 1988, respectively, and rice yields increased 56–88%. Further research needs to be conducted to assess quantitatively the impact of Si on disease development and compare it with the use of fungicides. Because rice response to plant-available Si and disease response to plant Si content can vary among cultivars (17), this line of research also needs to be investigated. This will provide needed information for establishing the best disease management strategies for rice growers in the EAA.

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