Influence of Crop Rotation on Inoculum Density of *Rhizoctonia solani* and Sheath Blight Incidence in Rice

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ABSTRACT

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A linear correlation ($P = 0.01$; $r^2 = 0.85$) was observed between the number of sclerotia of *R. solani* recovered from soil and sheath blight incidence at the panicle initiation growth stage of rice. Cropping systems for 34 fields had a significant effect ($P = 0.05$) on the preplant inoculum density of *R. solani* and the percentage of sheath blight incidence. Mean numbers of sclerotia recovered (per kilogram of soil) were 4.02, 1.43, and 0.07 with an average disease incidence of 5.4, 2.7, and 0.4% for rice-soybean-rice, soybean-soybean-rice, and pasture-pasture-rice cropping systems, respectively. Significantly higher ($P = 0.05$) inoculum densities and disease incidence were found in alternate year rotations out of rice than in 2-yr rotations out of rice. Spatial patterns of inoculum and disease were best described as aggregated in seven fields where individual soil core processing allowed for analysis of the population distribution. Inoculum was spatially autocorrelated in these fields, whereas disease was not. In matrix surveys conducted at two sites in 1984, inoculum density ranged from 0 to 44 sclerotia recovered per 440-cm^3 soil core, and disease incidence ranged from 0 to 26 diseased tillers per 50-tiller sample. Inoculum and disease were aggregated in the quadrat sampled sites at large (> 1 m) sample spacings and random at smaller sample spacings. A rapid and reliable method of quantifying sclerotia of *R. solani* from field soil was developed.

Additional key words: aerial blight, cultural control, *Glycine max*, *Oryza sativa*, soybean, spatial pattern.

Sheath blight of rice (*Oryza sativa* L.) and aerial blight of soybean (*Glycine max* (L.) Merrill) are caused by *Rhizoctonia solani* Kühn, teleomorph *Thanatephorus cucumeris* (Frank) Donk (syn. *Pellicularia sasakii* (Shirai) S. Ito, *Corticium sasakii* (Shirai) Matsumoto). The pathogen belongs to anastomosis group 1 (2) and causes an aerial blight of the foliar tissue of many agronomically important crops (1,27,32,36) and weeds (12,34). Recent changes in rice culture, including the adoption of soybean as a rotational crop, have enhanced the severity of sheath blight in southern rice growing areas of the United States since the early 1970s (17,21,22,28).

Sheath blight is initiated when buoyant sclerotia float in the paddy and germinate, and hyphae infect tillers at the water line (15,19,21,29). Sclerotia can survive and remain viable up to 21 mo in dry soil but survive less than 7 mo in saturated soils (30,31). Basidiospores of *T. cucumeris* can also initiate infections in upland rice (12,29) but are considered unimportant in the epidemiology of the disease on short-season cultivars grown under flooded culture (21,27). The teleomorph has been described on sorghum (*Sorghum vulgare* (L.) Moench) (27) and on bermudagrass (*Cynodon dactylon* (L.) Pers.) (10) but has not been characterized on rice in the United States.

Hashiba (14) identified temperature, relative humidity, and the quantity of sclerotia per unit of field area as systems components regulating the horizontal development and subsequent yield loss in rice caused by sheath blight. Temperature, humidity, cultivar susceptibility, and plant growth stage were found to influence vertical disease progress. An understanding of both horizontal and vertical components is necessary to estimate potential yield loss and evaluate control practices in commercial fields where inoculum and disease are not evenly dispersed. Greatest loss in yield is evidenced when initial plant infection occurs during the late vegetative and early reproductive growth stages than when initial infection occurs at a later stage (6,14,16,21).

To facilitate studies on the relationship between preplant inoculum density and the incidence of rice sheath blight at a subsequent critical growth stage, it was necessary to devise a rapid and reliable method to quantitatively recover sclerotia from infested soil. Weinhold (37) described wet-sieving procedures to assay soils for *R. solani*. Elutriation procedures for quantitative assay of soils for viable propagules of *R. solani* have been described by Clark et al (9) and further characterized by Martin et al (24). Sclerotia of *R. solani* that cause sheath blight (sasakii forms) have been quantitatively recovered from soils with wet-sieving (20) and hydrogen peroxide flotation methods (25). The sclerotia of this fungus would appear well suited to extraction from soil by elutriation because they are large (about 1 to 2 mm), discrete, and buoyant.

The objective of our study was to survey commercial rice fields and examine the relationship between preplant inoculum of *R. solani* and subsequent disease incidence at a critical growth stage. The influence of three popular cropping rotations was studied to determine the effect of rotation length and rotational crop type on the development of sheath blight in subsequent rice plantings. Finally, the spatial patterns of inoculum and disease were investigated as initial steps in developing an assay service to aid producers with management decisions. Preliminary reports have been published (3–5).

MATERIALS AND METHODS

Collection of soil samples from a field survey. Thirty-four rice fields, representing 728 ha, from eight counties in the Texas Upper Gulf Coast were surveyed in 1984 (16 fields) and 1985 (18 fields). Sixteen fields had a cropping history of rice rotated with soybeans in alternate years (R-S-R), 10 fields had cropping histories of 2 yr of soybeans followed by rice (S-S-R), and eight fields had native pasture for 2 yr followed by 1 yr of rice (P-P-R). Native pasture consists primarily of coastal bermudagrass (*C. dactylon*). All fields were sampled 1 to 2 mo before planting rice during the sample year.

Soil samples were collected during February and March each year with a modified sod planter (Young Industries, Mountain View, CA) that removed a 440-cm^3 soil core (7.6 × 7.6 × 7.6 cm). Fields were sampled at 64-m intervals along a W-shaped sampling

pattern, which resulted in collecting one soil core per 0.4 ha. Individual fields had a variable number and length of transects in the sampling pattern to adjust for differences in field size. Soil cores were either placed individually in paper bags (11 fields) or bulked by transect (23 fields) and then air dried on a greenhouse bench for 2 wk before processing. Soils with appreciable clay contents (greater than 40%) were pulverized with a mallet before mixing by hand. Two unbiased subsamples (500 g) were collected from each bulk sample with a riffle-type sample splitter with 2.5-cm spacings (Model H-3987, Humboldt Mfg. Co., Chicago, IL). The remainder of the soil was assayed in 500-g aliquots to determine the total number of sclerotia recovered per transect sample. Soil cores collected individually were processed individually.

Collection of soil samples in a matrix survey. In February 1984, a 9 × 9 matrix of 81 contiguous quadrats (81 m^2 each) was established in each of two fields with a rice-soybean-rice cropping history and known to be infested with *R. solani*. Eighty-one contiguous quadrats of three other matrix sizes (quadrat areas equal to 9 m^2, 1 m^2, and 0.1 m^2) were nested in the central nine quadrats of each test site. All 9 × 9 matrix patterns had the same central sampling point, and each successive matrix contained nine common sample points with the matrix of the next successive size. Common sample points were only sampled once. Individual soil cores were removed from the center of each quadrat, placed in paper bags, and air dried before processing.

Elutrition and enumeration. Samples were crushed manually, weighed, and processed for 4 min using a semiautomatic elutriator (7). Air and water flow rates were adjusted to 50 cm^3/sec and 100 cm^3/sec, respectively. Sclerotia were collected from the effluent on a 0.6-mm-mesh sieve nested under a 1.7-mm-mesh sieve (20). Sclerotia and debris retained on the smaller pore size sieve were rinsed onto paper towels and air dried overnight. Soils with 40% clay content required a 3-hr soaking in water before processing. Recovery efficiencies for elutriation were 92.5% for sandy soils and 70.5% for clay soils (3).

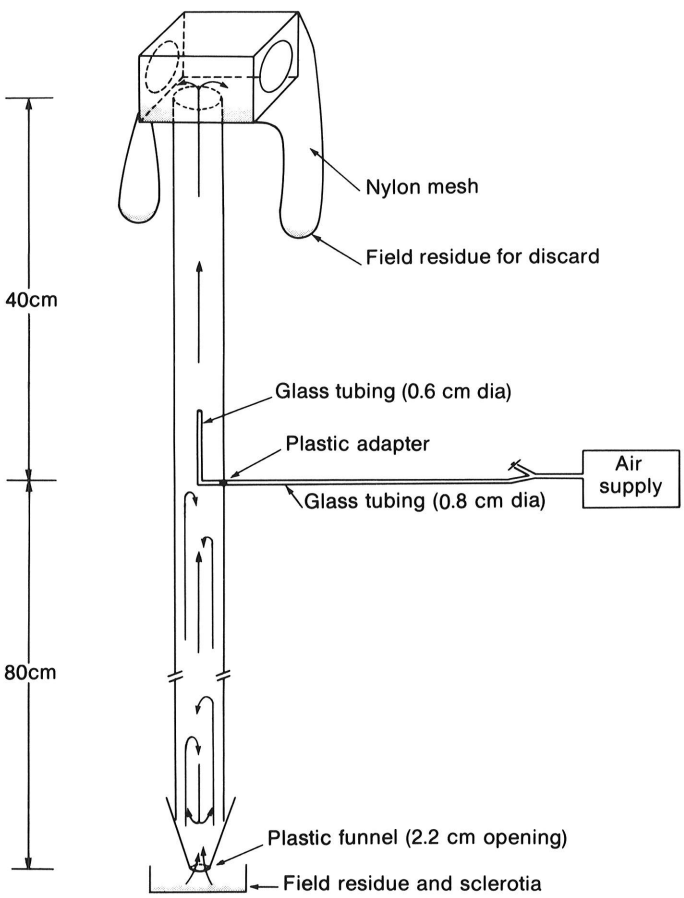

Fig. 1. Schematic of mass density separator used to separate sclerotia of *Rhizoctonia solani* from debris. Airflow draws sample into lower chamber. Lightweight material is drawn into upper trap. Sclerotia and other dense debris fall back into collecting dish when airflow is switched off.

A mass density separator (Fig. 1) was employed to reduce the time for enumeration of extracted sclerotia by eliminating about 75% of the lighter weight debris in extracted samples (3). Sclerotia and field residue were pulled into a 5.5-cm-diameter- × 120-cm Plexiglas tube by the negative pressure created with an introduced airflow of 400 cm/sec and circulated for 15–30 sec to allow the sclerotia to separate out. Lighter material was collected in an upper trap by increasing the airflow to 800 cm/sec. Large sclerotia and denser field debris either fell directly into a dish placed under the funnel at the base of the apparatus or reflux in the circulating air in the lower portion of the separator until the infow source is switched off. Residue in the upper trap was repeatedly examined during the separation of the samples involved in this study and loss of sclerotia was negligible (< 0.01%).

Sclerotia were separated from other sample residues by using 10× magnification and identified based on size, color, texture, and shape. Viability was estimated by placing sclerotia onto water agar (WA) and incubating them 48 hr at 28 C. Hyphal morphology and growth rate were used as additional characters in identification. Initially, isolates were transferred from WA to potato-dextrose agar (PDA) and incubated 1 to 2 wk until confidence in identification was assured. Pathogenicity of 129 arbitrarily selected isolates was confirmed on 14-day-old rice (cultivar Lemont) and 21-day-old soybean (cultivar Ransom) seedlings as described previously (3).

Disease survey. Follow-up surveys to quantify the incidence and spatial pattern of sheath blight in surveyed fields were conducted between May and June at the panicle initiation growth stage of the rice (35). All fields were planted to the semidwarf cultivar Lemont and were surveyed along parallel transects 64 m apart and sampled at 64-m intervals along the transects. Two samples of 25 tillers, about 1 m apart, were examined at each sampling site and the number of tillers exhibiting typical symptoms of sheath blight (21) recorded. Presence of *R. solani* rather than *R. oryzae* Ryker & Gooch (33) was confirmed by isolation on WA and PDA for arbitrarily selected symptomatic tillers.

Disease incidence in the two matrix surveyed sites was determined 28 May 1984 by counting the number of rice tillers exhibiting sheath blight symptoms from one sample of 50 tillers from each of the 81 contiguous quadrats of the largest matrix (81-cm^2 quadrat size). Field markers allowed the disease sample to be collected in nearly the same location as the preplant soil sample.

Data analysis. Statistical analysis was performed using the General Linear Models procedure of the Statistical Analysis System (11). Analysis of variance for numbers of sclerotia recovered, viability of sclerotia, and disease incidence was performed. In these analyses, the effects of cropping system and time (year) were determined. An arc-sine transformation was used on these percentage data to stabilize variances. The relationship between inoculum density and disease incidence was examined using linear regression. Paired "t" analysis was used to compare data collected as subsamples of soil from fields that were transect sampled with the number of sclerotia from the total transect sample.

Frequency classes for sclerotia per 440 cm of soil and the number of diseased tillers per 50 sampled were analyzed for goodness-of-fit to eight discrete frequency distributions by using a FORTRAN program (13). Frequency classes were whole units and program truncated. The null hypothesis (i.e., that the observed frequency count data do not differ from the expectations) is rejected in this program when the probability of a greater chi-square is less than 0.05. Indices of dispersion including the variance to mean ratio, Lloyd's index of patchiness, and Morisita's index were calculated from the data (8,26). Significance testing was by chi-square analysis. Spatial patterns of inoculum and disease were analyzed by computation of a coefficient of spatial autocorrelation (Moran's I statistic). These calculations were performed on an Apple IIe microcomputer using a BASIC program provided by Nicot et al (26).

RESULTS

A highly significant ($P < 0.001$) linear relationship ($y = 0.48 + 1.26\,x$; $r^2 = 0.85$) was observed between the inoculum density (ID) expressed as sclerotia recovered per kilogram of air-dried soil and disease incidence (DI) at the panicle initiation growth stage of rice (Fig. 2). There was no improvement in the linear correlation when adjustments were made in the ID to compensate for viability or recovery efficiency of sclerotia. The ID and DI had a combined average for the 2 yr of 2.33 and 3.42, respectively. Analysis of the sclerotia recovered per kilogram of soil according to the cropping system showed 4.02 for R-S-R, 1.43 for S-S-R, and 0.07 for P-P-R (Table 1). Inoculum density for the R-S-R cropping system was significantly different from P-P-R ($P = 0.05$). No difference was detected between sampling years with means of 2.50 and 2.17 sclerotia per kilogram of soil for 1984 and 1985, respectively. A nonsignificant trend of higher viability in sclerotia of *R. solani* was noted for the R-S-R cropping system compared with the other two cropping systems (Table 1). The viability of sclerotia was significantly higher ($P < 0.001$) in 1984 (72.0%) than in 1985 (20.0%). Average DI was 5.4 for R-S-R, 2.7 for S-S-R, and 0.4 for P-P-R and the average DI for R-S-R was significantly greater ($P = 0.05$) than P-P-R. There was no significant difference in DI between years (3.3 vs. 3.6%). Significantly higher ($P = 0.05$) ID and DI were found in alternate-year rotations with rice (R-S-R) versus rotations where land was out of rice for two full years (S-S-R and P-P-R). Similarly, more sclerotia and disease were observed in soybean-rice rotations (R-S-R and S-S-R) compared with pasture-rice (P-P-R) rotations (Table 1).

In an effort to minimize labor input, subsampling procedures were evaluated for estimating sclerotia populations and disease incidence. Twenty-three of 34 fields were sampled using a bulking procedure. Paired "t" analysis of the ID as estimated by the subsampling means compared with the ID obtained when all soil collected from a field was averaged showed the $P > |T|$ to decrease with increasing inoculum levels. There was insufficient evidence at ($P = 0.05$) to reject the null hypothesis that the mean number of sclerotia per kilogram of soil (subsamples) equals mean number of

TABLE 1. Effect of cropping systems on number and viability of recovered sclerotia of *Rhizocotonia solani* and incidence of sheath blight from fields surveyed in 1984 and 1985

Main effect	Fields[a] (no.)	Sclerotia recovered per kg soil (no.)	Viability (%)[b]	Disease incidence (%)[c]
Cropping system[d]				
R-S-R	16	4.02 a[e]	48.6 a	5.4 a
S-R-R	10	1.43 ab	26.3 a	2.7 ab
P-P-R	8	0.07 b	25.0 a	0.4 b
Year				
1984	16	2.50	72.0	3.3
1985	18	2.17	20.0	3.6
	P > F	0.951	0.001	0.748
Rotation crop				
Soybean	26	3.02	39.9	4.4
Pasture	8	0.07	25.0	0.4
	P > F	0.045	0.907	0.009
Cropping duration				
1 yr out of rice	16	4.02	48.6	5.4
2 yr out of rice	18	0.83	26.1	1.7
	P > F	0.003	0.221	0.010

[a] Fields were sampled by collecting a 440-cm^3 soil core per 0.4 ha along a W-shaped sampling pattern. Soil was air-dried in the greenhouse for 2 wk before processing.
[b] Determined after 48 hr on water agar at 28 C.
[c] Based on diseased tillers per 50 tillers sampled per 0.4 ha at the panicle initiation growth stage of rice cultivar Lemont.
[d] Soybeans (S) rotated with rice (R) in alternate years (R-S-R), or 2 yr in three (S-S-R), or pasture (P) rotated with rice 2 yr in three (P-P-R). Soil samples were collected just before the final rice (R) crop and disease was assessed in that season.
[e] Means within columns with a common letter are not significantly different ($P = 0.05$) by Duncan's multiple range test.

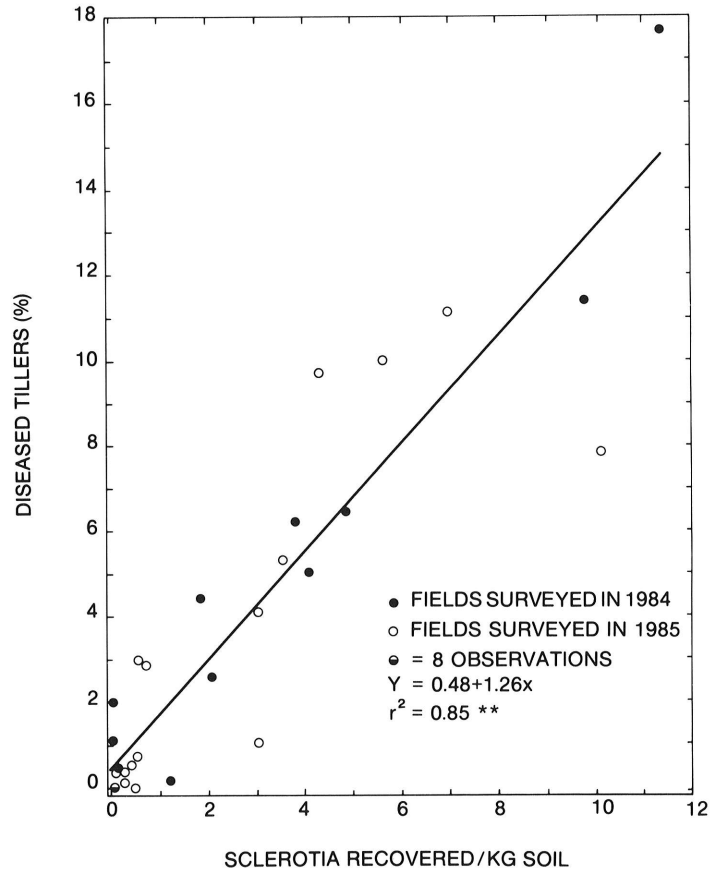

Fig. 2. Relationship between percent diseased tillers and sclerotia of *Rhizoctonia solani* recovered per kilogram of soil for 34 rice fields. Asterisks denote significance at $P < 0.001$.

TABLE 2. General population statistics, frequency distribution parameters, and spatial autocorrelation index for inoculum density and disease incidence of sheath blight caused by *Rhizoctonia solani* for seven commercial rice fields

Field no.	Sclerotia recovered/440 cm^3 soil							Diseased tillers/50 sampled					
	n	$\bar{x}$	Range	$s^2\bar{x}$[a]	k	Model with best fit[b]	Moran's I	$\bar{x}$	Range	$s^2\bar{x}$	k	Model with best fit	Moran's I
1	40	1.1	0–06	1.9	1.21	NB (0.902)	0.060	1.3	0–05	1.6	1.67	NB (0.640)	−0.122
2	40	2.3	0–23	7.3	0.71	NB (0.124)	0.208	2.5	0–14	6.1	0.47	NB (0.257)	0.117
3	40	5.0	0–17	5.0	1.20	NB (0.577)	0.274*[c]	5.7	0–31	8.5	0.69	NB (0.075)	0.111
4	40	6.0	0–35	9.2	0.88	NB (0.378)	0.181	8.9	0–38	14.4	0.41	NB (0.090)	0.115
5	66	2.4	0–22	5.8	0.48	NB (0.456)	0.168	3.1	0–27	6.4	0.56	NB (0.647)	−0.085
6	40	2.5	0–13	4.1	0.74	NB (0.721)	0.257*	3.3	0–29	13.4	0.12	NB (0.663)	−0.033
7	58	0.8	0–12	4.2	0.40	NB (0.672)	0.078	2.2	0–21	8.0	0.25	NB (0.618)	0.373*

[a] Variance-to-mean ratio calculated from actual data.
[b] NB represents the negative binomial distribution, and value in parentheses represents fit of the frequency count data to the model $P > X^2$.
[c] Asterisks indicate $P(|Z| \geq z)$.

sclerotia per kilogram of soil (total). Although the mean numbers of sclerotia per kilogram of soil recovered in this study were reported based on all soil cores collected from a field, these data indicated that two homogenous subsamples of soil collected at 64-m intervals along transects would adequately estimate inoculum densities. Unpaired "t" analysis comparing the disease incidence around the outer perimeter of commercial fields with estimates obtained by sampling the entire field along a transect pattern indicated that estimates of sheath blight using only the sample sites around the perimeter of a field (one sample per 64 m collected 32 m inward from the field edge) could estimate the DI for the entire fields surveyed along a transect pattern in 32 of 34 cases (94%) at $P = 0.05$.

The horizontal spatial pattern of sclerotia was examined in seven of 11 individually sampled commercial fields (ID was zero in four fields). Data were best described by the negative binomial probability distribution with low values (0.04–1.21) for the k parameter and variance-to-mean ratios significantly greater than unity (Table 2). The range of sclerotia recovered per 440 cm^3 of soil was 0–35. The mean ID per field varied from 0.8 to 6.0. The index of spatial autocorrelation (Moran's I) was positive in all cases and the null hypothesis (no spatial autocorrelation) could be rejected ($P = 0.5$) in two of seven cases using a two-sided ($P|Z| \leq z$) test (Table 2) and in five of seven cases using a one-sided ($P Z \leq z$) test. Spatial autocorrelation of inoculum at this sample spacing was not observed in two fields (1 and 7). These fields also had the lowest mean levels of inoculum (1.1 and 0.8 sclerotia recovered per 440 cm^3 of soil, respectively).

The horizontal spatial pattern of diseased rice tillers in seven commercial fields was determined to be aggregated because the data were best described by the negative binomial distribution with low values (0.12–1.67) for the k parameter and variance-to-mean ratios significantly greater than 1.0. The incidence of diseased tillers ranged from 0 to 38 per 50 sampled. The mean diseased tillers per field ranged from 1.3 to 8.9 (2.6–17.8%). Disease incidence was not found to be spatially autocorrelated in six of the seven fields studied ($P = 0.05$). An I statistic that rejected the null hypothesis of no spatial autocorrelation was observed only in Field 7 (Table 2).

Inoculum density at the two matrix surveyed sites varied from a mean of 1.5 sclerotia recovered from the 297 soil cores at site A to 12.6 sclerotia at site B (Table 3). The range of sclerotia recovered per sample was 0–25 and 3–44 for each site, respectively. Inoculum was judged to be random in the 0.1-m^2 quadrat size matrix at both sites and aggregated in all matrices with larger quadrat sizes. The fit of discrete frequency distributions identified the Poisson distribution as best describing the data within the 0.1-m quadrat matrices at both sites. The variance-to-mean ratios were not significantly greater than unity ($P = 0.05$). Morisita's index and Lloyd's index of patchiness also suggested a random pattern of sclerotia at this sample spacing.

The negative binomial distribution described the pattern of sclerotia in matrices with quadrat sample spacings of 1, 9, and 81 m^2. Estimates of the k parameter ranged from 0.8 to 15.2 and generally decreased with increased sample spacing. Variance-to-mean ratios were significantly greater than 1.0 ($P = 0.05$). Morista's index and Lloyd's index suggested an aggregated pattern of sclerotia for larger matrix sizes at site A but a random pattern at site B (Table 3).

Moran's index identified spatial autocorrelation in the 1-m^2 quadrat size matrix at site A and the 81-m^2 quadrat size matrix at site B. In all other sample spacings, the null hypothesis (no spatial autocorrelation) could not be rejected at $P = 0.05$. The BASIC program of Nicot et al (26) allows for the computation of the I statistic given various weights. The I can be computed for the nearest neighbors (radius equals 1), next nearest neighbors (radius of computation evaluates autocorrelation between any point and its neighbor at a distance of two quadrats away). The I statistic for the matrix samples sites that showed significant autocorrelation was computed for radii of 1, 2, and 3. The hypothesis of no spatial autocorrelation could be rejected for the 1-m^2 quadrat size at site A when the radius = 1 quadrat but not for radius = 2 or 3 (Fig. 3A). This would suggest a small area of spatial autocorrelation where one or more quadrats are related to their nearest neighbors at a radius of 1 m away but not 2 or 3 m. The hypothesis of no spatial autocorrelation could be rejected for the 81-m^2 quadrat size at site B for radius = 1 or 2 but not for radius 3. This would indicate large areas of spatial autocorrelation (up to 18 m away in all directions) as can be seen in Figure 3B.

The incidence of diseased tillers (DI) in the 81-m^2 quadrat-size matrices ranged from 0 to 20 per 50 sampled at site A and 0 to 26 at site B. The mean of diseased tillers over the 81 sampling sites was 4.3 (8.6%) and 2.5 (5.0%) for the two sites, respectively. All indices of dispersion suggested an aggregated pattern of disease (Table 3). Moran's I statistic was 0.039 for site A and 0.048 for site B suggesting no spatial autocorrelation.

DISCUSSION

Numerous cultural, biological, and chemical methods for controlling rice sheath blight have been proposed (12,16,19,21,29). This study evaluates the impact of crop rotations to minimize the disease. Each of three cropping systems had a significant effect on the preplant inoculum density (sclerotia of *R. solani*) and subsequent sheath blight incidence. More sclerotia and disease were found in fields cropped to soybeans than in fields where rice was rotated with pasture. While rice producers have shifted to row

TABLE 3. General population statistics, frequency distribution parameters, and spatial indices for sclerotia of *Rhizoctonia solani* recovered/440 cm^3 soil (ID) and sheath blight disease incidence (DI) at two intensively (grid) surveyed sites

Site	Area (m^2)							Model with best fit[b]	Morisita's index	Lloyd's index of patchiness	Moran's I
	Matrix	Quadrat	n	$\bar{x}$	Range	$S^2/\bar{x}$[a]	k				
A—Total (ID)			297	1.5	0–25	3.4	1.1	NB (0.179)[c]	2.598	2.632	...
A	9	0.1	81	1.0	0–05	1.1	8.3	PB (0.599)	1.135	1.135	0.082
A	81	1.0	81	2.3	0–25	4.7	1.1	NB (0.429)	2.573	2.578	0.152
A	729	9.0	81	1.5	0–12	2.8	1.4	NB (0.138)	2.148	2.153	−0.031
A	6,561	81.0	81	1.2	0–09	2.8	0.8	NB (0.434)	2.487	2.491	0.055
DI-A	6,561	81.0	81	4.3	0–20	5.3	0.9	NB (0.876)	2.003	2.013	0.039
B—Total (ID)			297	12.6	3–44	3.0	7.6	NB (0.288)	1.155	1.156	...
B	9	0.1	81	11.9	3–20	1.0	571.3	PB (0.752)	1.002	1.003	0.036
B	81	1.0	81	12.2	2–28	1.9	14.1	NB (0.171)	1.074	1.075	0.046
B	729	9.0	81	9.7	3–21	1.7	15.2	NB (0.346)	1.069	1.069	0.089
B	6,561	81.0	81	16.4	4–44	4.3	5.3	NB (0.392)	1.205	1.199	0.296*[d]
DI-B	6,561	81.0	81	2.5	0–26	6.6	0.5	NB (0.550)	3.252	3.269	0.048

[a] Variance to mean ratio.
[b] Negative binomial (NB), Poisson binomial (PB).
[c] The fit of the model $P > X^2$.
[d] Asterisks indicate $P(z < |Z| > z)$.

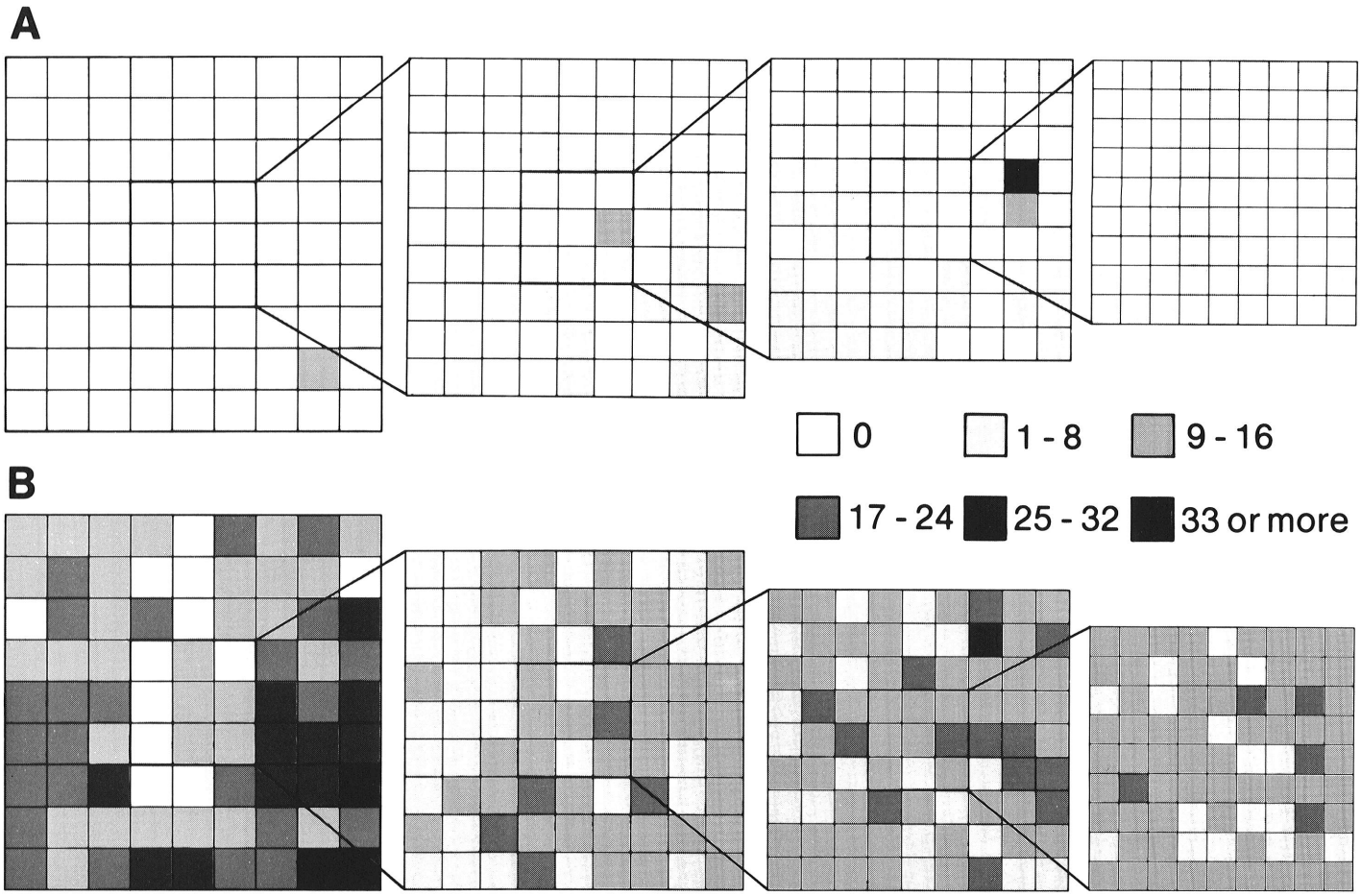

Fig. 3. Spatial patterns of preplant inoculum density (sclerotia of *Rhizoctonia solani*) based on six frequency classes at two sites **(A and B).** Four 9 × 9 matrices were sampled in a nested design at each site. Individual quadrat sizes within respective matrices were 81, 9, 1, and 0.1 m^2, from left to right.

crop production for economic reasons, the adoption of susceptible rotation crops and the shortening of rotation intervals may partially explain the increased losses caused by sheath blight during the last decade (21).

A highly significant linear correlation was demonstrated between preplant inoculum density and disease incidence at a subsequent critical growth stage during 1984 and 1985. The *y*-intercept of this linear relationship (0.48% diseased tillers) was not significantly different from zero and could suggest that without sclerotia there would be little or no disease at the panicle initiation growth stage. However, mycelium in colonized crop debris may still represent a significant source of primary inoculum. Our study only demonstrates a proportionality between sclerotia of *R. solani* and disease incidence at this growth stage and did not examine the potential for additional sources of inoculum. Our results do indicate the value of using preplant populations of sclerotia to predict disease incidence at panicle initiation regardless of other potential sources of inoculum.

In comparison to our method, other techniques to quantify inoculum of *R. solani* such as directly plating extracted field debris on selective media (18) would appear to be more time consuming, expensive, and of limited value for commercial adoption. The diversity of *Rhizoctonia* spp. that naturally occur in rice soils and its associated debris would seem to favor quantification of sclerotia. Colonies with "perpendicular hyphal branching" would have to be transferred for anastomosis determination and/or for the production of characteristic sclerotia (sasakii form) in vitro to differentiate between *R. solani* AG-4, *R. microsclerotia* Matz, *R. oryzae*, *R. oryzae-sativae* (Sawada) Mordue, *R. zeae* Vorhees, and *Sclerotium hydrophilum* Sacc., all of which occur in rice cropping systems (10,29,33).

Spatial pattern analysis has shown *Rhizoctonia* spp. to have negative binomial, Neyman type A, or Poisson patterns (8). Campbell and Noe (8) emphasized that the sampling pattern had a direct effect on the analysis. For the seven fields sampled individually, all were shown to have frequency count data for inoculum density and disease incidence that were best fit with the negative binomial model. Moran's index suggested that the inoculum was spatially autocorrelated for many of the fields, whereas disease incidence was not. Inoculum density at the two matrix surveyed sites was shown to be random (Poisson) for small quadrat size matrices and aggregated (negative binomial) for the larger quadrat sizes despite a nearly 10-fold difference in total sclerotia recovered between the two sites. Moran's index identified spatial autocorrelation in the 3-m^2 matrix at site A and 81-m^2 matrix at site B. This suggests that sclerotia of *R. solani* are distributed in patches of varying size and density. These patches may be the result of sclerotial production in disease foci of previous crops.

All indices of dispersion for the incidence of diseased tillers in the 81-m^2 matrices suggested an aggregated pattern. Moran's I index did not indicate the presence of spatial autocorrelation. Linear, quadratic, and cubic regression models of inoculum density against disease incidence on a sample by sample basis in 81-m^2 matrices were analyzed for both sites and were not significant (P= 0.05) even though the samples were taken in identical locations. This suggests that the buoyant propagules are being redistributed to new areas of field by floodwater. Other practices associated with rice culture including postplant, preflood flushing of fields for stand establishment, and preplant water-leveling may also redistribute buoyant sclerotia.

Considerable progress was made toward the development of an advisory program that could assist growers in making management decisions. Further research is needed in understanding the pathogen and its survival as influenced by various host cropping systems. The limited prospects for useful resistance in long-grain rice cultivars (23) would suggest that genetic control of the disease remains a distant goal. In the interim,

an emphasis must be placed on the development and implementation of integrated cultural and chemical control measures to minimize yield losses in rice due to sheath blight.

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