HILGARDIA
JOURNAL OF AGRICULTURAL SCIENCE PUBLISHED BY
THE CALIFORNIA AGRICULTURAL EXPERIMENT STATION

Volume 49, Number 3 • February, 1981

Epidemiology of Stem Rot Disease of Rice: Effects of Burning vs. Soil Incorporation of Rice Residue

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Sclerotium oryzae, the cause of stem rot of rice, overwinters as sclerotia either free in the soil or in association with rice residue. When residues were incorporated in soil rather than burned, *S. oryzae* inoculum levels increased, stem rot severity increased, and yields decreased. Inoculum levels remained nearly constant where residues were burned. Under the conditions of this study, the incorporation of residue did not affect rice yield by altering nutrient availability. It was concluded that burning of residue is beneficial in minimizing severity of stem rot disease in areas where it is a problem, and further, that open-field burning is effective in minimizing the buildup of *S. oryzae* where it presently occurs at inconsequential levels.

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Epidemiology of Stem Rot Disease of Rice: Effects of Burning vs. Soil Incorporation of Rice Residue[1]

INTRODUCTION

STEM ROT, a serious disease of rice (*Oryza sativa* L.) (Ou, 1972), occurs in most rice-producing countries of the world (Butler, 1913; Miyake, 1910; Park and Bertus, 1932; Shaw, 1913; Teodora and Bogayong, 1926). The disease is widespread in California, being most prevalent in the northern rice-producing areas of the state (Webster *et al.* 1971). The causal organism, *Magnaporthe salvinii* (Cattaneo) Krause and Webster (1972b), is best known for its sclerotial state, *Sclerotium oryzae* Catt. The conidial state has been referred to as *Nakatea sigmoidea* (Cav.) Hara, *Vakrabeeja sigmoidea* (Cav.) Sub., or *Helminthosporium sigmoidium* Cav.

Investigations have shown that sclerotia of this fungus overwinter either free in the soil or in association with plant residues, the latter case being the most important in survival (Keim and Webster, 1974b, 1975; Bockus, Webster, and Kosuge, 1978; Bockus and Webster, 1979; Bockus, Webster, Wick and Jackson, 1979). In water-sown rice, sclerotia float to the water surface when fields are flooded and provide the primary inoculum that infects young rice plants at the waterline when environmental conditions are favorable. The disease first appears as small, dark lesions on the leaf sheaths at the water level. Disease progression is characterized by the death and sloughing of the infected sheaths followed by penetration of the entire culm. When the culm is infected, both grain quality and panicle size are reduced. When infection occurs very early in the season, tillers are either killed or fail to produce panicles. Additional losses often result from increased lodging of infected plants.

Sclerotia of *S. oryzae* form abundantly in infected tissues near the time of plant maturity and continue to form in crop debris as long as suitable temperature and moisture conditions persist. Disease severity in a current crop is correlated with inoculum level for subsequent crops. The inoculum level in the seedbed is also correlated with disease severity and yield loss in a single season (Krause and Webster, 1973; Webster, 1974; Webster *et al.*, 1976).

Production of rice, straw and grain in California is approximately 6,000 kilograms per hectare (kg/ha) (Williams, Morse, and Ruckman, 1972). Most growers have traditionally burned the rice residue, mainly to eliminate its interfering with the preparation of seedbeds for the next season under the common practice of continuous rice culture. At the onset of experiments reported here, it was not known if burning was also beneficial in minimizing inoculum levels of *S. oryzae,* even though such a practice had been recommended in other rice-producing areas for disease control (Ou, 1972). Open-field burning of rice residue may not be permitted in California in the future since ventilation patterns of the upper Sacramento Valley (where over 85% of California's rice is grown) are unfavorable for dispersal of the smoke created by burning. At the same time, the effects of soil incorporation (a most likely alternative) of large volumes of residue, often in-

[1]Accepted for publication July 17, 1980.

fested with *S. oryzae,* on the incidence and severity of rice stem rot were not known. For these reasons long-term trials comparing the effects of burning versus various methods of total residue incorporation under continuous rice cropping were established. For this report data were collected and compared from measurements of inoculum levels, disease severity, and yield. The additional effects of incorporating large amounts of residue on nutrient availability were also studied.

MATERIALS AND METHODS

Two sites were studied—site 1 in Butte County and site 2 in Yolo County. At site 1 (Lindberg Ranch), rice had been grown continuously for several years on Stockton clay adobe soil, and stem rot was considered to be occurring at a level where yield losses were resulting. A 6.5-hectare trial was established to compare the effects of residue incorporation by various methods at different times with the effects of open-field burning over 5 years of continuous rice-cropping.

The following residue management and tillage treatments, selected on the basis of current grower practices, were compared:

(i) straw and stubble were burned and stubble disk-plowed to a depth of approximately 15 to 20 cm in the fall as soon after harvest of the previous crop as possible;

(ii) crop residue was not burned, but residue and soil were stubble disk-plowed to a depth of approximately 15 to 20 cm following harvest in the fall;

(iii) residue was not burned but allowed to overwinter and then residue and soil were stubble disk-plowed in the spring to a depth of 15 to 20 cm as soon as weather and soil moisture conditions would allow;

(iv) residue was not burned, residue and soil were moldboard-plowed to a depth of 25 to 30 cm following harvest in the fall;

(v) residue was not burned but allowed to overwinter, and then residue and soil were moldboard-plowed in the spring to a depth of 25 to 30 cm; and

(vi) residue was not burned, and residue and soil were tilled in the fall after harvest with a Howard rotovator, which simultaneously chopped the straw and blended it uniformly in the top 15 cm of soil.

It proved necessary to chop straw in windrows left by the harvester to sizes usually less than 10 cm in length before the initial tillage operations in treatments ii to vi to facilitate operation of equipment. The stubble-disk plow tilled the soil with a slicing action and distributed the residue vertically through the soil. The moldboard plow inverted 25 to 30 cm-deep strips of soil and residue. The effectiveness of inversion depended on soil moisture conditions and was more complete in the spring than in the fall operations. Treatments were replicated four times; each plot was 14.5 by 155 meters, separated by soil levees and provided with an individual water system that precluded the exchange of soil and water between plots. After the initial residue management and tillage practices described above, all remaining operations were those of normal production of a rice crop in California (Lindt, 1966). Typical tillage operations required in the spring to prepare the soil for water-seeding and other cultural and pest control measures employed to produce the rice crop in the experimental area are depicted in figure 1. The

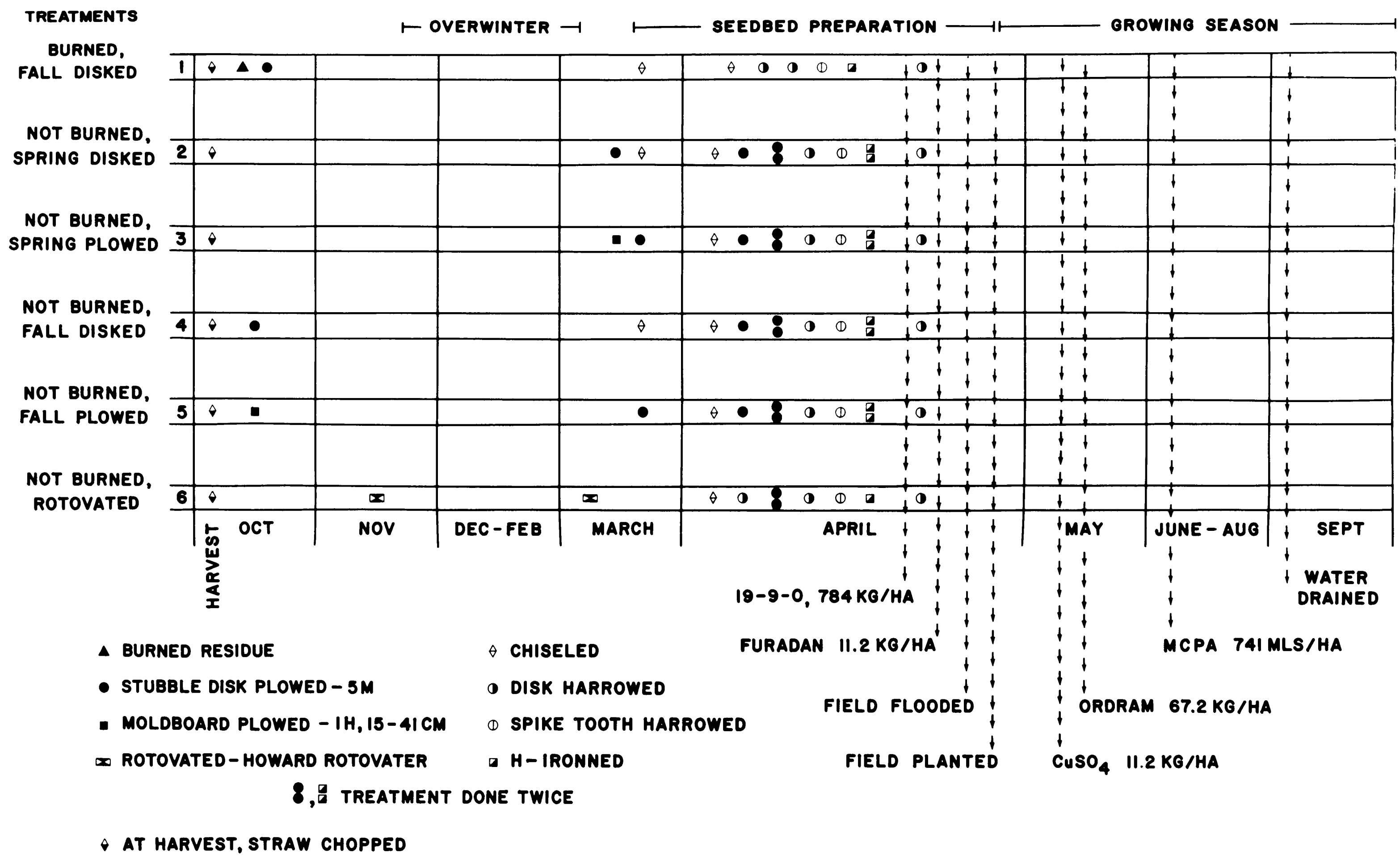

Fig. 1. Treatments, cultural practices, and schedule of events for 1 year (of a 4-year trial) to compare methods of rice residue management.

rice cultivar 'Calrose' was grown all five seasons during the experimental period. These described procedures were followed for four consecutive cropping seasons at this site. After harvest of the fourth consecutive crop, the entire experimental area was burned in the fall to allow a determination of the effects of burning residue after four years of consecutive incorporation by the various methods described.

At site 2, Yolo County, California (Geer Ranch) rice had been grown continuously for several years on Sacramento clay soil, and stem rot disease was not a problem. A 3-hectare experimental trial was established and six different residue management practices were compared with four nitrogen fertilizer levels superimposed on the tillage treatments. Whole plots were treated as follows:

(i) straw and stubble were burned and stubble-disk plowed in the fall to a depth of 15 to 20 cm;

(ii) straw and stubble were not burned, windrows of straw were chopped, and residue and soil were stubble-disk-plowed together 15 to 20 cm deep;

(iii) residue was not burned, and residue and soil were tilled in the fall with a Howard rotovator;

(iv) residue was not burned; windrows of straw were chopped, and residue and soil were moldboard-plowed in the fall 25 to 30 cm deep;

(v) residue was not burned, windrows were chopped, and residue and stubble brought into soil contact by a light disk treatment in the fall; and

(vi) residue was not burned, windrows were chopped—followed by overwintering and stubble-disk-plowed in spring.

After the basic treatments, finished seedbeds for sowing were prepared using cultural practices similar to those shown in figure 1 for site 1. Whole plots were 13.7 by 91.5 meters replicated four times with each plot separated by soil levees to preclude the exchange of soil and water between treatments. Subplots (13.7 × 15.2 m) of four nitrogen levels (0, 44.8, 89.6, and 134.4 kg/ha) were superimposed onto each whole plot. Subplots recurred in the same site for each of the four consecutive years the experiment was continued. Pre-flood application of granular ammonium sulfate (21% nitrogen) at desired rates were harrowed into the soil surface of all treatments.

Determination of soil inoculum levels

Sclerotia of *S. oryzae* that survived various culture practices and existed in the surface of the seedbed before flooding constituted the inoculum that caused stem rot disease in the current rice crop (Krause and Webster, 1973; Webster *et al.*, 1976). Inoculum level was expressed as viable sclerotia per gram soil. Methods for soil sampling and inoculum level determination, described in detail by Krause and Webster (1972) were applied as follows:

Collection of soil samples.—All soil samples analyzed for the study were collected from the top 10 cm of finished seedbeds just before flooding. Each plot at site 1 was subdivided into six equal subplot areas approximately 14.5 by 25 meters. Eight to 10, 200 to 250-gram soil samples were collected at random from each subplot to comprise one sample per subplot—and six bulk samples per plot. One such bulk sample was collected from each of the four subplots where different N levels at site 2, were tested. The bulk samples were then run through a soil grinder to reduce clod size and to insure, as much as possible, an even mixing of the sample.

Determination of viable sclerotia per gram soil.—The method used to determine inoculum levels was based on the fact that *S. oryzae* sclerotia are hydrophobic, buoyant and of fairly uniform size ($\bar{x}$ dia 270 μ). In addition, upon germination on water agar, the sclerotia produce charactistic conidiophores and conidia of the conidial state, *Nakatea sigmoidea.* Three 50-gram samples were taken at random from each of the bulk samples from the subplot (at each site) and placed in 400 ml beakers and covered with water. After soaking overnight, the samples were blended for 10 to 15 seconds in a Waring blender with approximately 250 ml of water. Each sample was then washed through a 20-mesh (Tyler and Standard Scale) screen. The material collected on a 100-mesh screen was then washed into a 400-ml beaker with a wash bottle and water added to make approximately 300 ml. After 10-15 minutes, sclerotia from the sample floated to the surface, and the heavier soil particles settled. Sclerotia were then vacuumed from the surface of the water into a vacuum flask and filtered onto a 15-cm #1 Whatman filter paper disc in a Buchner funnel. The filters bearing the sclerotia were air-dried and the sclerotia brushed into petri dishes for counting with a dissecting microscope.

Viability was tested by placing 50 sclerotia from each sample on water agar plates containing streptomycin sulfate and penicillin G, each at 3000 ppm, and incubating the plates plus sclerotia at room temperature (24 ± 2 °C) under white fluroscent light for 12 days. Only sclerotia that produced conidiophores and conidia of *Nakatea sigmoidea* were recorded as viable.

Seed beds of all subplots at each study site were sampled and viable sclerotia per gram of soil recorded for each year of the study. Values obtained for year 1 at each site were considered the "base" for future comparisons. Values obtained for succeeding years indicated the effects various residue management treatments had on inoculum level of *S. oryzae* under continuous rice cropping.

Determination of stem rot disease severity

Collection of plant samples.—Samples of tillers were collected at random from areas corresponding to those from which soil samples were collected in each plot and subplot. At least 300 individual tillers per sample were rated for disease severity.

Disease ratings.—Stem rot disease is most evident on plants nearing maturity. At this state, severity ranges from small lesions inflicting little damage through stages of penetration of the culm with severe infections resulting in dead tillers that fail to produce panicles. For the most part, this range of damage is determined by the time the initial infection of a tiller occurs during the growing season. Because of this, the disease-severity rating system used here is more reliable for measuring damage than is percent infection observed at harvest time. The system was applied by dividing healthy and infected tillers into five categories based on the severity of infection: (i) healthy, no symptoms of stem rot; (ii) lightly infected with lesions on the outer leaf sheaths only; (iii) mildly infected with discoloration and infection through the inner leaf sheaths, culm still green without lesions; (iv) infection progressed through the leaf sheaths into the culm; interior of the culm not internally infected; (v) tiller severely infected, infection progressed through and internally infecting the culm with mycelium and sclerotia present in the lumen of the culm; culm may or may not be collapsed.

Each category was weighted and the disease index (DI) for each sample calculated as follows:

$$DI = \frac{1(H^n) + 2(L^n) + 3(M^n) + 4(M^{n+}) + 5(S^n)}{\text{total number of tillers examined}}$$

where H^n = number of healthy tillers, (Class i); L^n = number of lightly infected tillers, (Class ii); M^n = number of mildly infected tillers, (Class iii); M^{n+} = number of moderately infected tillers, (Class iv); and S^n = number of severely infected tillers, (Class v). Therefore, a DI of 1.00 represents all healthy tillers and a DI of 5.00 all severely infected tillers.

Disease index as recorded here is most indicative of actual damage when determined just before draining the fields in preparation for harvest. Consequently, all values for DI were determined at that time for each of the growing seasons covered in this study (Krause and Webster, 1972).

Grain yield determinations

Yields in paddy rice were determined by harvesting with commercial equipment. Moisture determinations were made for grain from each plot and yield weights adjusted to 14 percent moisture for standardization.

Nutritional status.—All plots at site 1 received preplant applications of fertilizers (N, P and K) consistent in rate required for maximum rice growth and yield production in the experimental area (Mikkelsen, Lindt, and Miller, 1967.). Only nitrogen applications varied at site 2 as described. Since it was not known if the various residue management treatments would differentially affect the availability of nutrients and thus nutritional status of plants, leaf samples were collected for each plot for analysis of nitrogen, phosphorus, and potassium by standard methods (Mikkelsen and Hunziker, 1971; Johnson and Ulrich, 1959).

Data analysis.—Analysis of variance and mean separation by Duncan's Multiple Range tests were carried out on all data both within and between years. Statements noting significant differences refer to the 5 percent level except where noted.

RESULTS

Effects of residue management treatments on *S. oryzae* inoculum levels

Mean inoculum levels determined for various treatments at site 1 are shown in table 1. Beginning inoculum levels (year 1) were variable among treatments but not statistically different. This would be expected in a field trial as large as this and was reflected in a statistical difference among replications (year 1).

In subsequent years, no significant increase in inoculum occurred in the burn treatment, whereas significant increases occurred within all incorporation treatments for year 2 and all but one for year 4. All treatments were burned in the fall at site 1 between the fourth and fifth years of the study. This resulted in significant reductions of carryover inoculum in three of the four incorporation treatments and a lesser reduction of inoculum in the other (not-burned, spring-moldboard-plowed).

At site 2 (table 2), inoculum levels were much lower at the beginning of the study (year 1), more uniform throughout the trial area and did not differ significantly between treatments or replications. As at site 1, no significant increase in inoculum occurred in the burned treatment over the next three years, whereas inoculum increased to significant differences in all incorporation treatments by the third year, and was as high or higher than that at the beginning of the study in site 1. At both sites, moldboard plowing was most effective in minimizing inoculum buildup where residue was incorporated.

Effects of residue management treatments on disease severity

Disease severity (DS), determined when fields were drained (approximately 3 weeks prior to harvest), is summarized for each treatment at both sites in tables 3 and 4. Disease severity generally increased with inoculum when less than one viable sclerotium per gram soil occurred; DS was always lowest in burned treatments at both sites and usually highly significantly so. The results from site 2 are of particular interest. There, by the third year of incorporation of residue, the inoculum level had increased at least equal to that at site 1 at the beginning of the study. At this point DS measured in all incorporation treatments was significantly higher than that in the burned treatment. These significant increases occurred within treatments between each year in most cases, particularly at site 2 (LSD .05 = .17).

TABLE 1

INOCULUM LEVELS IN TOP 10 CM OF SOIL OF FINISHED SEEDBEDS FOR FIVE CONTINUOUS CROP YEARS IN TESTS TO COMPARE DIFFERENT METHODS OF RICE RESIDUE MANAGEMENT (SITE 1)

Treatments	Viable sclerotia per gram soil*				
	Year 1	Year 2	Year 3	Year 4	Year 5†
Burned fall stubble-disked	.24a	.28a	.26a	.32a	.26a
Not burned—fall stubble disked	.16a	.52b	.55b	1.15c	.64c
Not burned—fall moldboard plowed	.18a	.46b	.47b	.69b	.37b
Not burned—spring stubble disked	.20a	.56b	.62b	1.08c	.69c
Not burned—spring moldboard plowed	.20a	.42b	.47b	.51b	.46b
Not burned—fall and spring-rotovated	.28a	.48b	.46b	1.01c	‡

* Values are means of four replications with six composite samples per replication (see Methods). LSD between years at 5% = .13.
Values with common letters within years not significant at 1% level. Duncan's Multiple Range test.

† All residue and stubble burned in fall of year 4, followed by tillage as indicated.

‡ Treatment dropped in year 5.

TABLE 2

INOCULUM LEVELS IN TOP 10 CM OF SOIL OF FINISHED SEEDBEDS FOR FOUR CONTINUOUS YEARS IN TESTS TO COMPARE DIFFERENT METHODS OF RICE RESIDUE MANAGEMENT (SITE 2)

	Viable sclerotia per gram soil*			
Treatments	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Burned—fall stubble disked	.05a†	.075a	.06a	.06a
Not burned—fall stubble disked	.07a	.20b	.28b	.29b
Not burned—fall rotovated	.07a	.11a	.26b	.27b
Not burned—fall moldboard plowed	.06a	.18ab	.22b	.26b
Not burned—light fall disk for soil contact†	.06a	.24b	.34b	.53c
Not burned—spring stubble disked	.07a	.15ab	.32b	.47c

* Means of six replications with four composite samples. Combined from 89.6–134.4 kg N/ha subplots. LSD between years at 5% = .17. Values with common letters within years are not significantly different at 1% level.

† Was initiated as a furrowing (fall treatment) for year 1 and changed to fall moldboard plow for year 2, because residue was unmanageable. Thus increase between year 1 and year 2 resulted from residue only partially incorporated in top 1 to 10 cm of soil during overwintering.

TABLE 3

RATINGS OF STEM ROT DISEASE SEVERITY ON RICE GROWN FOLLOWING DIFFERENT METHODS OF RICE RESIDUE MANAGEMENT FOR FIVE CONTINUOUS YEARS (SITE 1)

	Disease severity rating (1 = healthy to 5 = severe)*				
Treatments	**Year 1**	**Year 2**	**Year 3**	**Year 4†**	**Year 5**
Burned—fall stubble-disked	1.72a	1.59a	1.91a	1.77a	1.74a
Not burned—fall stubble disked	1.84a	1.92b	2.27b	2.10bc	2.09b
Not burned—fall moldboard plowed	1.69a	1.90b	2.15ab	2.11bc	1.73a
Not burned—spring stubble disked	1.97ab	2.32cd	2.45bc	2.29c	2.15b
Not burned—spring moldboard plowed	1.99ab	2.21cd	2.18ab	2.02b	2.00b
Not burned—fall and spring-rotovated	1.81a	2.01bc	2.07ab	2.17bc	‡

* Highly significant difference (.01) between treatments and years when combined. LSD within treatment, between years = .15. Values with common letters are not significantly different at 5% level (within years).

† All residue and stubble burned in fall of 4th year, followed by tillage as indicated.

‡ Treatment dropped in year 5.

TABLE 4
RATINGS OF STEM ROT DISEASE SEVERITY ON RICE GROWN FOLLOWING DIFFERENT METHODS OF RICE RESIDUE MANAGEMENT FOR 4 CONTINUOUS YEARS (SITE 2)

	Disease severity rating (1 = healthy to 5 = severe)			
Treatments	Year 1*	Year 2	Year 3	Year 4
Burned—fall stubble disked	1.58a	1.63a	1.52a	1.64a
Not burned—fall stubble disked	1.66a	1.87a	2.11b	2.34bc
Not burned—fall rotovated	1.59a	1.87ab	2.37b	2.25bc
Not burned—fall moldboard plowed	1.75a	1.83ab	2.06b	2.14b
Not burned—light fall disk for soil contact	1.57a	1.97ab	2.33b	2.56c
Not burned—spring stubble disked	1.65a	2.00ab	2.23b	2.29bc

* Highly significant difference (.01) between treatments and years when combined. LSD within treatments between years at 5% = .17. Values with common letters are not significantly different at 5% level (within years).

Effects of residue management treatments on yield

Yield, expressed as kg/ha at 14 percent moisture, is summarized for each experimental site in tables 5 and 6. In all cases, after establishment of treatments at site 1, highest yield was obtained when residue was burned, with related lower inoculum levels and subsequent lower disease severity. Yields from year to year were not compared, because cultural and weather conditions, regardless of disease, can cause variation.

Leaf tissue analyses to determine adequacy of nitrogen (N), phosphorus (P), and potassium (K) for maximum yield response were carried out for all treatments as prescribed by Mikkelsen and Hunziker (1971). Results showed sufficient levels of these nutrients above minimum adequate levels for optimum yield (Mikkelsen and Hunziker, 1971; Keim and Webster, 1974). Thus, yield differences were not due to possible nutrient-availability differences among treatments.

At site 2, different N fertilization levels were superimposed as subplots on the residue management whole plots. Yield response between the 89.6 and 134.4 kg/ha N subplots was not significant. Consequently, combined mean values of these are summarized for comparison with DS and inoculum level data. Tissue analyses revealed differences in total N content between the subtreatments, but both contained high enough levels of N to allow maximum yield as determined for the varieties grown. At site 2, yield did not differ significantly between burned vs. incorporation treatments until after the third year when all incorporation treatments yielded significantly less rice than the residue burned treatment. This corresponded with the significant increases in inoculum level and disease severity at that site.

TABLE 5

YIELD OF CALROSE RICE GROWN FOLLOWING DIFFERENT METHODS OF RICE RESIDUE MANAGEMENT FOR 5 CONTINUOUS YEARS (SITE 1)

	Yield at 14% moisture*				
Treatments	**Year 1**	**Year 2**	**Year 3**	**Year 4†**	**Year 5**
	kilograms per hectare				
Burned—fall stubble-disked	66.1a	61.2a	70.2a	71.1a	55.6a
Not burned—fall stubble disked	66.1a	56.3b	66.8ab	63.7b	54.0a
Not burned—fall moldboard plowed	64.4a	56.6b	66.1ab	65.1b	54.5a
Not burned—spring stubble disked	63.9a	56.9b	66.4ab	63.3b	55.7a
Not burned—spring moldboard plowed	68.9a	55.5b	68.2a	65.8b	52.8a
Not burned—fall and spring-rotovated	66.1a	54.6b	66.8a	65.7b	‡

* Values represent means of four replications. Those with common letters do not differ significantly at 5% (within years).
† All residue and stubble burned in fall of year 4, and followed by tillage as indicated.
‡ Treatment dropped in year 5.

TABLE 6

YIELD OF RICE GROWN FOLLOWING DIFFERENT METHODS OF RICE RESIDUE MANAGEMENT FOR FOUR CONTINUOUS YEARS (SITE 2)

	Yield at 14% moisture*			
Treatments	**Year 1**	**Year 2**	**Year 3**	**Year 4**
	kilograms per hectare			
Burned—fall stubble disked	50.0a*	86.7a	60.1a	70.1a
Not burned—fall stubble disked	52.0a	92.4a	53.6ab	59.9b
Not burned—fall rotovated	46.7a	92.9a	55.5ab	62.1b
Not burned—fall moldboard plowed	41.8a	80.2a	58.6ab	63.6b
Not burned—light fall disk for soil contact	49.8a	92.9a	54.0ab	61.1b
Not burned—spring stubble disked	52.1a	90.8a	54.5ab	61.4b
Variety grown	Earlirose	CS-M3	Earlirose	Earlirose

* Values represent means of four replications. Those with common letters did not differ significantly at the 5% level (within years).

DISCUSSION

Data clearly show that in areas where *S. oryzae* occurs, open field burning of rice helps to minimize losses due to stem rot. It should be noted that at site 1, the initial inoculum levels were relatively high as compared to those at site 2. As a result, even in the burned treatment at site 1, there was some loss due to stem rot, but it was significantly less than in all incorporation treatments tested.

Results obtained at site 2 where original inoculum levels were low (.07 v/sc/gm or less) are of particular interest. In this case, even though *S. oryzae* was present, it did not occur at levels high enough to cause significant disease under the standard practice of burning residue before the study, and it remained at that level in the burned treatment throughout the experimental period. However, an increase in inoculum level of *S. oryzae* and subsequent DS was measured in all plots where residue was incorporated. These results indicate that the practice of open field burning has, in fact, minimized losses due to this disease in areas where it is not already established and further suggest that burning should be continued to prevent its buildup. This conclusion is further substantiated when considering the broad distribution of the stem rot organism in California (Webster *et al.*, 1971) and the ease with which it could be introduced into fields via equipment or water.

Whether or not incorporation of large amounts of residue affects the nutritional status of rice plants by altering nutrient availability, thus affecting final grain yields, has been studied by Williams, Morris, and Ruckman, (1972). They found no difference in grain yields between burned and residue-incorporated plots over a range of fertilizer N rates. The experimental design in their study did not provide for separate water systems between plots. Thus, any effect of treatments on the population of *S. oryzae* and possible subsequent differences in stem rot severity would have been masked. Results obtained here regarding effects of N fertilization and burning vs. incorporation of residue were identical to those of Williams, Morris, and Ruckman, (1972) thus supporting our contention that yield differences between treatments compared in this study are in fact the result of the measured differences in stem rot disease severity.

In separate studies (Bockus, Webster, Wick and Jackson, 1979), it was found that cutting rice stubble at ground level (below stem rot infection sites) and removing the straw from the field was nearly as effective in minimizing *S. oryzae* inoculum levels as burning the residue. In addition, sclerotia free from residue are significantly less competitive than those in infested residue when incorporated into the soil (Bockus, Webster, and Kosuge, 1978). Thus, the measured increases in inoculum level in incorporation treatments is, in fact, the result of optimizing the conditions for increase and survival of *S. oryzae*.

ACKNOWLEDGMENT

This study was funded by the California State Rice Research Board. The cooperation of W. Geer, D. Lindberg, and A. Lindberg, Sr., is noted with special thanks.

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