COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Cause and Control of Rice Diseases

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:
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OBJECTIVES AND EXPERIMENTS CONDUCTED TO ACCOMPLISH OBJECTIVES:

Continuing objectives of research project RP-2 are to determine the nature and control of rice diseases in California. As such, research on the cause and factors that affect disease severity and loss is needed. By determining the influence of various cultural practices on disease severity we believe rational disease management strategies can be developed. Studies carried out on basic aspects of the pathogens, disease cycles and epidemiology of the diseases caused, complement the overall objective and are necessary in determining the most logical areas to emphasis disease management procedures.

Many aspects of the project require consecutive years of study in the field and are thus continuing.

Specific Objectives For 1986:

(1) Evaluate the role of seedling disease in drill seeded rice as effected by planting depth and seed treatment.

(2) Complete studies on etiology and symptomatology of California rice diseases caused by sclerotial fungi.

(3) Complete studies on effects of cultural practices, i.e. nitrogen fertilization, cultivar selection and seeding rate on severity of Aggregate Sheath Spot and determine optimum management for minimization of both AGS and Stem Rot.

(4) Continue studies on biology, epidemiology, distribution and severity of Kernel Smut of rice.

(5) Continue chemical control tests for Stem Rot, Aggregate Sheath Spot and Kernel Smut.

(6) Complete studies on the effects of water management regimes on disease severity in rice.

Experiments to accomplish the above objectives were carried out in the laboratories and greenhouses of the Department of Plant Pathology, University of California, Davis, at the Rice Research Facility at Davis and in growers fields in Colusa, Sutter, Butte and Yolo counties.

Samples for the continued study of kernel smut distribution and severity were obtained form throughout the California rice growing areas including 14 counties. Butte County Rice Growers, Glenn Growers, Comet, Du Pue Warehouses, Farmers Coop, N. Davis Dryer and RGA all assisted in this effort.

SUMMARY OF 1986 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

Objective 1: Interest in drill seeding rice under reduced tillage schemes requires an evaluation of the role of seedling disease and planting depth in stand establishment. Preliminary studies last year suggested that emergence of different cultivars varies when planted at different depths and that seedling pathogens may effect final stand established. Greenhouse tests this year comparing sterilized and non-sterilized soil suggested that planting depth effected emergence more than seedling disease. To test this possibility under field conditions the following experiment was carried out at the Rice Research facility at Davis. Six basins, each 40 X 150 feet, with individual water systems were established. Seed bed preparation, including fertilization were as practiced for waterseeded rice in each. Ninety lbs of M-101 seed/acre were drilled into 3 of the basins at 1 1/2 depth and three basins at 3 inch depth. All basins were flooded for 24 hours to a depth of 4 inches of water and then drained. A secondary flooding was done after 14 days and again drained. Stand counts in seedlings per foot of drill row were determined after 35 days when a permanent flood was added. Average number of plants established in 1 1/2 inch depth planting was 9.4 plants/foot of drill row and 7.2 in basins planted at the 3 inch depth. Laboratory analysis of plants emerged showed no difference in fungi from either planting depth. Some non emerged plants recovered from the deeper planting depth were infected by Pythium species. Number of tillers per plant did not differ significantly between the planting depths. Average yield was 7352 lbs/acre for rice planted at 1.5 inches and 6775 lbs/acre for that planted at the 3 inch depth. Results indicate that planting depth does affect stand establishment and final yield. Further study of the causes of these results is needed.

Objective 2: Complete studies on the etiology and symptomatology of California rice diseases caused by sclerotial fungi.

Studies to determine effective control measures of diseases require a precise identification of the symptoms and causes of the diseases involved. This year we completed studies on the symptomatology and identification of sclerotial fungi causing diseases of rice in California.

There are several diseases of rice caused by species of *Rhizoctonia* de Candolle that occur worldwide and are similar in symptomatology. These are: sheath blight caused by *R. solani* Kuhn (Ag-1), aggregate sheath spot caused by *R. oryzae-sativae* (Saw.) Mordue (Gunnell and Webster 1984), bordered sheath spot (or sheath spot) caused by *R. oryzae* Ryker and Gooch (Ryker and Gooch 1938) and a sheath spot disease caused by *R. zeae* Voorhees (Ryker and Gooch 1938). All four *Rhizoctonia* species produce lesions that are circular to elliptical and have gray-green to straw-colored centers and a brown margin. Lesions produced by these species are generally restricted to the leaf sheaths except for those of *R. solani* which also occur on the leaf blades. Lesions on the leaf sheath or blade usually result in death of the leaf. *R. solani* and *R. oryzae-sativae* may also invade and rot the culm of the rice plants. Primary infections of rice tillers are produced by sclerotia of the fungi floating on the paddy water and the first symptoms are not usually observed in the field until the rice plants have reached the maximum tillering stage. *R. solani* is an aggressive pathogen of rice, *R. oryzae-sativae* and *R. oryzae* are weaker pathogens of rice, and *R. zeae* is a minor pathogen of rice. In the United States, *R. solani*, *R. oryzae* and *R. zeae* occur on rice in Louisiana, Texas and Arkansas and *R. oryzae-sativae* and *R. oryzae* occur on rice in California.

Although the above *Rhizoctonia* species produce similar symptoms on rice, the species are easily identified by their sclerotial characteristics on the host and in culture. *R. solani* produces large, globular, dark brown sclerotia, up to 5 mm in diameter. *R. oryzae-sativae* produces smaller, globular, brown sclerotia, up to approximately 1 mm in diameter. *R. oryzae-sativae* also produces sclerotia in the cells of diseased rice sheaths that are cylindrical in shape. *R. oryzae* reported not to produce sclerotia on diseased plants, but we have often found sclerotia of *R. oryzae*, which are cylindrical in shape in infected rice sheaths in California and O'Neill reported finding sclerotia of *R. oryzae* between diseased sheaths in Louisiana. Sclerotia of *R. zeae* are globose, small, .5-1.0 mm in diameter, and reddish brown in color and are generally submerged in culture.

R. solani is multinucleate and the teleomorph of *R. solani* is *Thanatephorus cucumeris* (Frank) Donk (Talbot 1970). *R. oryzae-sativae* is binucleate and we have proposed the name *Ceratobasidium oryzae-sativae* for the teleomorph. *R. oryzae* and *R. zeae* are both multinucleate and have a perfect state that is morphologically similar to *Waitea circinata* Warcup and Talbot. We have proposed that the teleomorphs of *R. oryzae* and *R. zeae* be classified as varieties of *W. circinata*. Little is known about the role of the basidiospores of these species in disease development. In California the perfect states of *R. oryzae-sativae* and *R. oryzae* are only found on rice after it has fully headed and neither fungus fruits profusely in the field. In the southern U.S., *R. solani* can fruit profusely under field conditions and can occur before the heading stage. It is possible that basidiospores of r. solani may play a significant role in dispersal of the pathogen and initiation of secondary infections.

Objective 3: Effect of cultural practices, i.e. nitrogen fertilization, cultivar selection and seeding rate on severity of Aggregate Sheath Spot.

Severity and incidence of AGS has increased in California in recent years. Possibility this has been in response to changes in cultural practices such as use of higher amounts of nitrogenous fertilizers, culture of semidwarf, early maturing cultivars and higher seeding rates. These factors have been reported to enhance sheath blight severity and our past studies have shown that high levels of nitrogen enhance stem rot severity.

We have conducted trials at Davis and in Grower's fields in Butte County over the past four years to determine which factors encourage severity of AGS in attempts to define culture practices that minimize the disease.

Preliminary trials to assess the affect of nitrogen fertilization, cultivar and seeding rate were established at the Davis Rice Research facility where we inoculated twelve cultivars with R. oryzae-sativae at two pre-plant N rates of 168 and 216 Kg/ha (ammonium sulfate). Results showed no difference in disease severity between the N rates and early vs late maturing cultivars. Semidwarf cultivars had consistently more disease than older tall cultivars. Cultivars most susceptible to AGS were least susceptible to Stem Rot. In a second trial (six cultivars at three N rates; 112, 168, 224 kg/ha) differences in AGS severity were seen only between semidwarf and tall cultivars, not between N rate or maturity of cultivars.

A trial to determine effect of seeding rates of 134, 168 and 202 kg seed/ha and two N levels of 134 and 268 kg/ha (as urea) on six semidwarf early maturing cultivars was conducted in Butte County. The field had a history of AGS. Again, we found that disease severity differed among cultivars, but that AGS was not significantly affected by the seeding rate or N level. Disease was greatest overall, however, at the 134 kg/ha seeding rate.

The above results suggested that additional trials to establish cultural practices to obtain optimum yield and minimum disease were needed. Consequently, we established trials to examine a greater range of N rates and an additional trial to assess the effect of seeding rate (stand density) on disease severity.

Nitrogen Level x Cultivar: This trial was conducted in Butte Co. in a field with a high level of AGS the previous year. The experimental design was a randomized complete block, split plot. Main plots were N at 5 rates of 0, 56, 112, 168, and 224 kg/ha. Early maturing cultivars

M-201, L-202, M-9, Cal Pearl, California Belle, S-201, (semi-dwarfs) and Earlirose and S-6 (Tall) were the sub-plots. Nitrogen was applied preplant as aqueous ammonia. Tissue samples for N content, (60 days) disease severity and yield were determined. A similar trial was conducted the following year.

Results of trials over the past two years to determine effects of N fertilization x cultivar on severity of AGS were similar. Namely, N content of rice leaves increased with increased levels of applied N for all cultivars tested. Analysis showed the nitrogen x cultivar interaction was not significant ($P > 0.05$). Response of % foliar N to applied N was characterized by both a significant linear and quadratic component ($P < 0.01$). Effect of cultivar on % foliar N was also significant ($P < 0.01$). The overall N content of M-201 was 3% and was significantly greater than that of the other cultivars which ranged from 2.7-2.8%. The overall % foliar N of the other cultivars did not differ significantly.

Both the rate of applied N and the cultivars contributed significantly to variation in disease severity. However, 85% of the treatment sum of squares was attributable to disease differences among cultivars whereas only 8% was due to differences in disease among the various nitrogen levels. Severity of AGS showed a significant linear and quadratic response to increased N rates. In general, disease severity was greatest at 0 or no N, decreased for 0-168 kg N and increased at 224 kg N. Regression equations for disease severity curves of Cal Pearl and Cal Belle were not significant while they were significant for the remaining six cultivars. Four R squared values indicated the majority of variation in disease severity was not accounted for by response to N.

The cultivars tested differed significantly in susceptibility to AGS. The semi-dwarfs except S-201 had greater disease severity than the tall cultivars. Susceptibility of the semidwarfs to AGS also varied with M-201 and L-202 being the most susceptible.

Mean Disease Severity Index to AGS of 8 Cultivars

M-201	L-202	M-9	Cal Pearl	Cal Belle	S-201	Earlirose	S-6
24.9 a[y]	22.6 b	17.5 c	15.2 d	12.9 e	9.3 f	9.0 f	4.5 g
(1.4)[z]	(1.0)	(1.0)	(.94)	(.83)	(.66)	(.86)	(.76)

[x]** = Significant at $P < 0.01$.

[y]Cultivar means followed by a common letter are not significantly different (LSD = 2.03 P = 0.05).

[z]Standard error of the mean.

The response of yield to applied N was comprised of a significant linear and quadratic component. Individual cultivars yielded more at intermediate levels of N (112 and 168 kg) except L-202 yielded most at 224 kg N.

Seeding Rate x Cultivar: Four cultivars, M-201, L-202, Cal Pearl and Cal Belle were seeded at 100, 134 and 168 kg/ha. N was applied at 112 kg/ha as ammonia preplant. Seed was hand planted after flooding. Tissue samples for N were taken (60 days), disease severity and yield determined.

Analysis of results from the seeding rate x cultivar trial showed that seeding rate x cultivar interactions were not significant. The effect of seeding rate (stand density) on AGS disease severity was not significant but the cultivar effect was. M-201 had significantly more disease than the other cultivars. Foliar N did not differ significantly among the cultivars or among the three seeding rates. Further, yields of the four cultivars were not significantly affected by the three seeding rates.

Conclusions on effect of culture practices on AGS Severity: The collective results of the above studies indicate that the increase in Aggregate Sheath Spot severity in California has been due primarily to the greater susceptibility of the semidwarf cultivars and has been largely unaffected by the use of greater amounts of nitrogenous fertilizers or higher seeding rates. Tall statured cultivars are less susceptible to AGS but this does not appear to be due to height alone since height of individual cultivars increased with applied N, but disease severity was largely unaffected. Also, the semidwarf S-201 did not differ significantly in disease severity from tall cultivars.

That level of N did not greatly influence AGS severity and that increased N suppressed AGS at some levels, differs from the known effect of N levels on severity of stem rot and sheath blight or rice. It is common for both stem rot and AGS to occur in the same field and even on the same plant. Thus as far as rice disease management in California is concerned, intermediate levels of N maximize rice yields, limit the severity of stem rot and tend to decrease severity of Aggregate Sheath spot.

Objective 4: Continue studies on biology, epidemiology, distribution and severity of Kernel Smut of rice.

Kernel smut of rice caused by *Neovossia horrida* (Tak.) Padwick and Khan (*Tilletia barclayana*) is wide spread in most rice growing areas of the world including Africa, North America, South America, Central America, Fiji and Asia. The disease was first reported in the United States in South Carolina in 1899, Arkansas in 1926, Texas in 1937 and Louisiana in 1953. In 1984 it was reported to be widespread in California by Matsumoto and coworkers. Using a seed wash-centrifugation technique, 382 seed samples gathered from storage facilities in eight counties were studied. Chlamdospores of *T. barclayana* were identified from 16% of the samples tested from the 1983 crop.

Attempts to formulate control measures must be based on an increased knowledge of the epidemiology and nature of the disease cycle of kernel smut. For example, if the centrifuge-wash technique rated samples positive for smut that were in fact contaminated in the harvest, drying and storage process, then use of non-contaminated seed or disinfested seed might help limit further spread of the pathogen. Such misclassification could also confuse attempts to determine prevalence of the disease as related to cultivars and cultivar characteristics.

In an attempt to eliminate the possibility of samples becoming infested from other sources, we conducted an extensive survey for kernel smut as follows: Aggregate lot samples (1 per field) were collected at various dryers throughout California and observed directly for the presence of smutted or partially smutted kernels. We recognize that this sampling method may result in an underestimate of actual smut incidence but positive samples represent true occurrence of smut in the field from which it was drawn. This approach also allows for observation of a larger sample than would direct observation in fields.

Results obtained for the 1984 crop showed that kernel smut occurred in 17.6 of over 1100 fields surveyed. Highest incidence of kernel smut was observed in major Northern California rice producing counties: i.e. 22.2% in Butte, 20.9% in Glenn and 12.8% in Colusa and 4% in Sutter.

Classification of kernel smut incidence in relationship to cultivar, grain type and maturity was as follows: Incidence of kernel smut on short grain cultivars was 13.6%, medium 14.5 and long grain 57.3. This result is consistent with previous reports that high incidence of kernel smut on long grain cultivars may be due to the fact that florets open wider and that anthesis duration is longer in long grain cultivars. Incidence of kernel smut was highest on very early maturing cultivars, 28.1%, compared to 22.0% on Intermediate, 15.7% on early with no smut observed on samples from late maturing cultivars in the 1984 samples. These results are in contrast with reports from Southern states where incidence is reported to be highest on late maturing cultivars suggesting that environmental conditions have a larger affect on kernel smut incidence than does maturity type. This conclusion is further supported by results of controlled inoculation tests in the greenhouse that did not reveal differences in kernel smut infection between cultivars of varying maturity times.

Over 1300 samples were collected from the 1985 rice crop and examined this year. Overall, incidence was 5.1% as compared to 17.6% for the 1984 crop. Again, highest incidence was observed in samples from Northern counties. Results of the sample as to cultivar were:

Incidence of Kernel Smut in Samples from the 1985 California Rice Crop Identified to Cultivar

Cultivar	No. Samples	% with Smut
S-201	209	13.4
Cal Pearl	9	0
M-101	38	0
M-201	562	.71
M-401	14	0
M-9	19	0
L-202	77	22.1
Others	372	3.4

The marked differences in incidence between successive years suggests the need for additional information on effect of environmental conditions on kernel smut incidence during specific developmental stages of the rice crop.

Above results apply only to incidence of kernel smut and do not indicate relative susceptibilities under field conditions. To gain some insight into this aspect we selected samples rated smut positive and quantified the amount of smut in subsamples of 250 grams. The average number of smutted grains in L-202 was 34.6 as compared to 14.4 in S-201. This supports other findings that the long grain cultivars are more severely affected by kernel smut than the short grain cultivars.

Studies conducted in the laboratory were directed toward determining factors that affect germination, survival and function of chlamydospores, sporidia and secondary sporidia. The purpose being to attempt to identify a phase in the kernel smut disease cycle amenable to control attempts.

Germination of Chlamydospores: Laboratory tests under controlled conditions showed that the chlamydospores; (a) remain viable for at least two years, (b) can germinate after being submerged in water for up to 5 months, (c) germinate readily on the surface of wetted soil or floating on water, (d) low concentrations of NaOCl stimulate % germination.

Factors Affecting Germination and Growth of Sporidia: Since infection of florets is by germination and growth of secondary sporidia produced after germination of chlamydospores, we studied the factors affecting their germination and growth. We found that secondary sporidia germinate over a temperature range of 5-42°C with an optimum of 26-33°C. Secondary sporidia germinated and grew over a pH range of 3-11 with a maximum between 5-9. Secondary sporidia germinated and grew well in darkness or under flourescent light but were inhibited by direct sun light. Secondary sporidia will germinate under conditions of limited oxygen. Sporidia were not produced in the absence of oxygen. Germination of secondary sporidia declines rapidly in dry (low RH) conditions as temperature increases. Optimum temperature for growth of secondary sporidia lies between 26-30°C.

As a result of these and other studies we have projected the disease cycle of kernel smut as follows: Smutted grains or chlamydospores overwinter in the field. Chlamydospores released from smut balls or soil may float to the surface of paddy water within 4-20 days (6-8% germination) and produce hyphae from which 2° sporidia are produced. Secondary sporidia may be produced for an extended time period (limits not yet known). These are ejected into the air and serve as inoculum for infecting florets. The precise time and point of infection is not known. All of our studies on inoculation in the greenhouse show that % infection of grains is significantly higher when inoculated in the boot stage as compared to inoculation after panicles emerge. Whether sporidia survive on the surface of the vegetative growth or grow into or between leaves surrounding the emerging panicles is not known. Highest percent infection results when sporidia are applied to the plants 7 days before panicles protrude. Very low % infections occur when sporidia showers are provided after panicles emerge. This may be the actual time of infection in the field since only low % infections have been observed in nature. If this is so, it corresponds with data on the low survival of sporidia in dry temperatures that usually occur at this stage of development in the field. If our projections are correct, the data thus far also accounts at least in part for the sporadic occurrence and variation in incidence for the survey data. The results are also consistent with reports that kernel smut is much more severe in rice growing regions where relative humidity is significantly higher during the rice season than that in California. Our future studies will be concentrated on attempts to determine if control, aimed at the vulnerable points in the disease cycle can be effected.

Objective 5: Continue attempts to develop chemical control for rice diseases.

Attempts to determine optimum rates, time of application and efficacy of fungicide sprays for control of the rice diseases, Stem Rot and Aggregate Sheath Spot were continued this year. Two trials were established in Butte County. The rates, time of application, chemicals tested, disease ratings and yield were as follows:

1986 Fungicide Trials for Control of Aggregate Sheath Spot

	Time and Rate		oz/acre	Trial 1		Trial 2	
Treatment	Internode Elongation	Early Boot	80% Headed	AGS Disease Severity	Yield/lbs/ 175 ft^2	AGS Disease Severity	Yield/lbs/ 175 ft^2
Tilt 3.6 E	6	6	-	259	38.7	165	40.0
Tilt 3.6 E	8	8	-	212	37.5	119	39.1
Tilt 3.6 E	10	-	-	249	37.4	226	39.0
SDS 45037	20	20	-	185	35.5	116	38.4
SDS 45037	30	30	-	199	38.1	114	39.0
SDS 45037	-	30	30	213	37.1	164	41.3
Benlate	16	16	-	136	36.4	32	40.9
Control				282	36.7	220	36.9

20 gals/Acre at 30 psi; Disease Severity = height of lesions on tillers in mm; yield = lbs/plot at 14% moisture.

Disease severity of Aggregate Sheath Spot was reduced in some treatments over the control. This did not result in significant increases in yield. Stem Rot and Kernel smut levels were very low at both sites and treatment affects considered negligible. Results this year showed significant reductions in AGS severity by an application of Benlate. In previous studies Benlate has not been effective for control of stem rot.

We had planned to carry out large scale air applied trials this year. These were not done because of the lack of an experimental use permit and denial of permission by state agencies.

Objective 6: Studies to determine effects of water management regimes on disease severity in rice were completed in Sutter County this year. This cooperative project was coordinated by Jack Williams. Results of two years at the Sutter site and comparisons with the water management trial conducted in Colusa County are still being analyzed. Overall it does not appear that control of rice diseases in California will be significantly affected by various water management regimes tested.

PUBLICATIONS OR REPORTS:

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Williams, J., A. Grigaric, S. Scardaci, C. Wick, J. Hill, and R. K. Webster. 1986. Field evaluation of the effects of coated rice seed on pest damage and crop growth. p. 57. Proceedings. of the 21st Rice Technical Working Group. Agricultural Information Department, Texas A&M University, College Station, Texas.

CONCISE GENERAL SUMMARY OF CURRENT YEAR RESULTS:

Studies to determine effect of planting depth on drill seeded rice showed that a planting depth of 3 vs 1 1/2 inches resulted in fewer plants established and lower final yield for the 1 1/2 in deep planting. Amounts of seedling disease did not differ between the two treatments. The ability and vigor of rice seedlings to emerge and establish plants from planting depths deeper than 1 1/2 inches needs further study.

Our ability to formulate control practices for various rice diseases depends on precise identification of the pathogens. We have completed study on the taxonomy of sclerotial fungi that cause disease in California rice. Pathogens that cause diseases in California in order of importance are; Sclerotium oryzae, Rhizoctonia oryzae-sativae, R. oryzae and R. zeae. Each responds differently to different fungicides, thus complicating attempts at fungicidal control.

The increased severity of Aggregate Sheath Spot in recent years has been due primarily to greater susceptibility of semi-dwarf cultivars. It is less affected by N level fertilization than is Stem Rot. It is common for both Stem Rot and AGS to occur in the same field. Thus as far as the relationship of N to rice disease management is concerned, intermediate levels of N maximize yields, limit the severity of stem rot and tend to decrease severity of AGS.

Kernel smut severity varies from year to year most likely due to environmental conditions required for sporidial production, survival and infection. The disease is most prevalent and severe on long grain rice.

Experiments to evaluate time, rate and efficacy of fungicides showed that AGS can be minimized by applications of Benlate but not Tilt which was less effective in 1986 than in previous tests. Effective disease control with fungicides is complicated due to differences in efficacy of fungicides to the various rice pathogens in California.