PROJECT NO. RP-2

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 1991 - December 31, 1991

PROJECT TITLE: Cause and Control of Rice Diseases

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:

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LEVEL OF 1990 FUNDING: $ 44,501

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

Our overall research objective is to understand the biology of California rice diseases well enough to develop effective cultural and biological control methods.

Since the major disease problem in California continues to be stem rot, we have focused our research on it the past three years. This report summarizes the information we have obtained during this past year with respect to straw decomposition, destruction of the overwintering sclerotia of the stem rot fungus, and potential for in-season biocontrol of the disease. Where appropriate, we have included previously reported information to provide a more complete understanding of our results.

Specific Objectives for 1991 were:

(1) to continue evaluation of different rice residue management systems with regard to effect on residue decomposition and viability of stubble-borne sclerotia.

(2) to continue isolation and identification of indigenous fungi from field collected rice stubble and stubble-borne sclerotia of S. oryzae.

(3) to continue to screen isolated fungi in the lab for ability to decompose rice stubble and destroy sclerotia of S. oryzae.

(4) to continue screening the best decomposer and hyperparasite candidates from lab assays in the field.

(5) to continue isolation and testing of in-season biocontrol agents of stem rot.

(6) to establish a field trial where promising fungi for biocontrol of stem rot are added and monitored for effect on stem rot severity over at least three continuous years of residue incorporation.

Field research in 1991 was conducted in cooperating grower's fields in Butte county and the Rice Experiment Station (Objective 6). Laboratory and greenhouse studies were conducted at University of California, Davis facilities.

SUMMARY OF 1991 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

(Objective 1): Mesh bags containing weighed amounts of rice stubble were placed in different residue management systems in early December and collected after 100 days to determine weight loss (Table 1). The degree of weight loss appeared limited during this time period regardless of system. This is probably a reflection of the composition of rice residue as well as the poor conditions for decomposition during the winter months. Non-burned systems had a higher level of decomposition than burned systems but the effect was not altogether consistent. The major effect on weight loss was placement of the straw in relation to the soil, i.e., buried straw decomposed to a much greater extent than straw placed on the soil surface. These results illustrate the importance of degree of soil contact for effective decomposition.

Stubble containing sclerotia of known viability was also placed in the different systems for the same period to determine effect on survival (Table 2). Flooded systems and standing stubble (no treatment) were the least effective in reducing sclerotial viability. Ironically, buried placement was less effective than surface placement in reducing viability.

The viability of sclerotia collected from native stubble of the different systems in March is listed in Table 3. Burned systems had the least viable sclerotia while untreated (standing) stubble and flooded systems had the most viable.

(Objective 2)- Isolation and identification of indigenous fungi from decomposing stubble and overwintering stubble-borne sclerotia of S. oryzae continued for the third season. Species that were isolated consistently are listed in Table 4.

Fungi isolated from surface disinfested S. oryzae sclerotia from rice stubble are listed in Table 5. This group has several hyperparasitic species. An unidentified pycnidial hyperparasite designated Fungus C continued to be the most frequently isolated from sclerotia from all systems.

(Objective 3)- Fungi isolated from rice stubble were again tested in the lab for ability to decompose sterile rice stubble and filter paper under cool temperature conditions. Results of several assays are listed in Table 6. A binucleate Rhizoctonia sp. and two species of Gelasinospora continued to exhibit the strongest

decomposer abilities.

We continued to assay fungi for ability to parasitize S. oryzae sclerotia under laboratory conditions (Table 7). Various isolates of Fungus C were consistently the most effective at reducing viability of S. oryzae sclerotia.

Since Fungus C is an effective hyperparasite of S. oryzae sclerotia under laboratory conditions and appears to assume that role in nature based on our frequency data, we tested this fungus on other fungal hosts. Results of this host range experimentation is shown in Table 8. Fungus C strongly parasitizes several fungi - especially those with rich storage cells - and moderately parasitizes Rhizoctonia spp. and Sclerotium hydrophilum. When tested on sclerotia of other fungi, it strongly attacked only Rhizoctonia solani AG1-1B (Table 9).

(Objective 4)- A field test employing the same BN Rhizoctonia sp. as the previous year was conducted. In addition, Fungus C was utilized in this test because of its ability to parasitize sclerotia. Since this test partially repeats last season's experiment, results of both years are shown in Tables 10 and 11. Although weight loss was increased somewhat by the BN Rhizoctonia last year, there was no significant effect this year. We believe the severe environmental conditions encountered in 1991, beginning with the unusual December freeze followed by drought conditions until later in the spring were at least partially responsible for the lower activity of this fungus. Colonization of inoculated stubble by the fungus is shown in Tables 12 and 13. The fungus appeared slower and less aggressive to colonize inoculated stubble compared to last year.

Fungus C did not appear to greatly influence the viability of sclerotia in the inoculated stubble under field conditions (Tables 14 and 15). However, variability in sclerotial viability in this experiment was high and significant effects may have been missed. Additional research on method of application for this fungus should be conducted.

(Objective 5)- Antagonists of S. oryzae continued to be assessed in the laboratory and greenhouse for in-season biocontrol potential. Several fungi were identified as hyperparasites of S. oryzae in culture (Table 16) including Sclerotium hydrophilum and Rhizoctonia oryzae-sativae. These two fungi are considered minor pathogens of rice with the latter causing aggregate sheath spot. These two fungi appeared to be the most effective of the organisms tested in the greenhouse at reducing severity of stem rot when co-inoculated with S. oryzae (Table 17).

Sclerotium hydrophilum appeared especially effective in the greenhouse and has been tested repeatedly. Results of these experiments are shown in Table 18. Although occasionally inconsistent, it appears that S. hydrophilum can effectively reduce stem rot severity on rice. Because this fungus has been listed as a minor pathogen, we tested it for pathogenicity on rice in the

greenhouse. It produced neither discernible symptoms nor yield reduction and seemed to survive as an epiphyte of the rice sheath.

(Objective 6)- A continuous year trial was established at the Rice Experiment Station near Biggs in 1991 with separate water systems for each plot. Three promising biocontrol fungi - Fungus C3, Sclerotium hydrophilum, and Rhizoctonia oryzae-sativae - were added to appropriate replicated plots. Beginning stem rot levels and disease severity were determined for each plot. This year is considered the starting point or base line for measurements in successive years. Observations on disease severity, yield, establishment and prevalence of the disease management fungi will be continued for at least 3 years to determine their true potential to control stem rot under field conditions.

PUBLICATIONS OR REPORTS:

Webster, R.K. Report to the California Rice Research Board. Project RP-2. Cause and Control of Rice Diseases, pp. 76-92. In: Annual Report of Comprehensive Rice Research. 1990. University of California and U.S. Dept. of Agriculture.

Cartwright, R.D., Wick, C.M., and Webster, R.K. 1991. Indigenous hyperparasitic fungi as potential biocontrol agents of stem rot disease of rice. 1991 Rice Field Day, Rice Experiment Station, Biggs, Ca., pg. 12.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Several rice residue management systems were again surveyed for their effect on straw decomposition and survival of stubble-borne sclerotia of the stem rot pathogen, Sclerotium oryzae. Our results indicate that decomposition during the winter months is rather limited. Non-burned systems appear to decompose straw to a greater extent than burned systems but differences between systems was small. Of much greater importance, regardless of system, was degree of soil contact with the residue. In general, buried straw decomposed to a much greater extent than that placed on the surface.

Viability of stubble-borne S. oryzae was generally greater in buried stubble than in stubble placed on the soil surface. It also appeared highest in non-treated (standing) stubble and flooded systems. Viability of sclerotia from field collected stubble from the various systems was lowest in burned systems and highest in standing, non-burned stubble.

A wide array of saprophytic fungi was again isolated from decomposing stubble. An unidentified binucleate Rhizoctonia sp. continued to be the most consistent decomposer in lab assays, however, was ineffective this year in increasing decomposition of inoculated rice stubble in a field experiment. Since this fungus worked to some extent last year in the field, we believe extreme environmental conditions in 1991 were responsible for the failure. Additional research is needed on this organism.

A limited number of fungi were again isolated from sclerotia of S. oryzae, several of which were hyperparasites. An unidentified pycnidial fungus continued to be the most aggressive parasite of S. oryzae in the lab and was placed in the field experiment mentioned previously. Although no significant effect on sclerotial viability in the field trial was noted, it appears that additional research on this fungus is also warranted. This fungus parasitized several other fungi in the lab, including Rhizoctonia solani.

Of the many organisms tested in the lab and greenhouse as potential in-season biocontrol agents for stem rot, only Sclerotium hydrophilum and Rhizoctonia oryzae-sativae appear to have much promise. Although these fungi are minor parasites or pathogens of rice and may outcompete S. oryzae for the rice stem, it was noted that they were hyperparasitic on S. oryzae in the lab.

Table 1. Percent loss in dry weight of bagged rice stubble placed in various rice residue management systems.

1989-1990 RESIDUE MANAGEMENT SYSTEM	SITE	Percent Loss Dry Weight COMBINED	BURIED[a]	SURFACE[a]
Burned	3	25.08 a	28.02 ab	22.15 a
Nonburned-Organic, Standing Stubble	18	21.23 ab	26.91 abc	15.54 bc
Nonburned, Standing Stubble	19	21.22 ab	29.16 ab	13.27 bc
Nonburned, Standing Stubble	17	20.70 ab	24.64 abc	16.76 ab
Burned	16	20.59 ab	30.03 ab	11.15 bc
Nonburned, Flooded, Rolled	13	20.51 ab	28.72 ab	12.31 bc
Nonburned-Organic, Rolled, Chiseled	15	20.17 ab	32.62 a	10.83 bc
Nonburned, Rolled, Chiseled	14	20.06 ab	25.18 abc	14.94 bc
Nonburned, Rolled, Chiseled	4	19.44 b	23.87 bc	15.02 bc
Burned	12	19.12 b	29.32 ab	8.92 c
Nonburned, Standing Stubble	11	18.79 b	22.40 bc	15.18 bc
Burned	10	16.48 b	19.75 c	13.21 bc

1990-1991 RESIDUE MANAGEMENT SYSTEM	SITE	Percent Loss Dry Weight COMBINED	BURIED[a]	SURFACE[a]
Nonburned, Flooded, Rolled	7	26.06 a	28.54 a	23.58 a
Nonburned, Rolled, Chiseled	4	23.47 ab	23.29 ab*	23.66 a*
Nonburned, Fall Disked	8	22.73 ab	27.77 a	17.69 ab
Nonburned, Rolled	6	22.42 ab	22.80 ab*	22.03 a*
Nonburned, Flooded, Rolled	5	22.30 ab	24.21 ab	20.78 a
Nonburned, Disked, Flooded	2	19.02 bc	20.84 ab	17.20 ab
Nonburned, Standing Stubble	1	18.50 bc	23.50 ab	13.50 bc
Burned	3	15.04 c	18.40 b	11.69 bc
Burned, Flooded	9	7.31 d	6.01 c*	8.61 c*

Column means within year followed by the same letter are not significantly different according to Tukey's HSD test (P=.05).

[a] Placement means within systems were significantly different according to Tukey's HSD test (P=.05) except where indicated by *.

Table 2. Viability of stubble-borne sclerotia of S. oryzae from bagged rice stubble placed in various residue management systems (1990-1991).

1990-1991	Percent Germination		
RESIDUE MANAGEMENT SYSTEM	COMBINED	BURIED	SURFACE
Burned (3)	54.90 a	58.24 a	51.56 a
Burned, Flooded (9)	61.11 ab	67.96 abc	54.26 a
Nonburn, Fall Disked (8)	63.10 abc	65.16 ab	61.04 ab
Nonburn, Rolled, Chiseled (4)	63.30 abc	75.03 abcd	51.56 a
Nonburn, Rolled (6)	69.06 bc	76.81 abcd	61.31 ab
Nonburn, Standing Stubble (1)	74.81 bcd	82.49 bcd	67.13 ab
Nonburn, Flooded, Rolled (5)	75.83 cd	71.68 abc	79.14 bc
Nonburn, Flooded, Rolled (7)	85.12 d	93.43 d	76.82 bc
Nonburn, Disked, Flooded (2)	88.14 d	86.02 cd	90.25 c

Column means followed by the same letter are not significantly different according to Tukey's HSD test (P=.05).

Table 3. Viability of stubble-borne S. oryzae sclerotia collected from different residue management systems.

1989-1990 RESIDUE MANAGEMENT SYSTEM	SITE	% GERMINATION
Burned	3	5.32 a
Burned	10	11.14 a
Burned	12	25.50 b
Nonburned, Rolled, Chiseled	4	72.23 c
Nonburned, Fall Disked	20	72.26 c
Nonburned-Organic, Rolled, Chiseled	15	78.04 cd
Nonburned, Standing Stubble	11	81.88 cde
Nonburned, Rolled, Chiseled	14	84.04 de
Nonburned, Flooded, Rolled	13	87.04 de
Nonburned, Standing Stubble	17	89.20 e
Nonburned-Organic, Standing Stubble	18	90.43 e

1990-1991 RESIDUE MANAGEMENT SYSTEM	SITE	% GERMINATION
Burned	3	29.26 a
Nonburned, Rolled, Chiseled	4	70.79 b
Nonburned, Rolled	21	80.62 bc
Nonburned, Flooded, Rolled	7	82.56 bc
Nonburned, Fall Disked	8	82.91 bc
Nonburned, Disked, Flooded	2	84.12 bc
Nonburned, Standing Stubble	1	87.69 c

Means followed by the same letter are not significantly different according to Tukey's HSD test (P=.05).

Table 4. Predominant fungi isolated from rice stubble over 3 seasons (1988-1991).

FUNGUS	CODE NO.	YRS[b]
Absidia glauca Hagem	50	2,3
Acremonium terricola (Miller & al.) W. Gams	45	1,2,3
Acremonium strictum W. Gams	4	1,2,3
Alternaria alternata (Fr.) Keissler	8	1,2,3
Aspergillus terreus Thom	19	1
Botrytis cinerea Pers. ex Nocca & Balb.?	64	2,3
Candida sp.	9	1,2,3
Ceratocystis sp.?	25	2,3
Cladosporium cladosporioides (Fres.) de Vries	1	1,2,3
Cladosporium herbarum (Pers.) Link ex Gray	1a	1,2,3
Coprinus sp.	59	2,3
Doratomyces microsporus (Sacc.) Morton & G. Sm.	99	2,3
Epicoccum purpurascens Ehrenb. ex Schlecht.	6	1,2,3
Fusarium moniliforme Sheld.	16	1,2,3
Fusarium complex	71	1,2,3
a) Fusarium reticulatum ?		
b) Fusarium avenaceum (Corda ex Fr.) Sacc.		
c) Fusarium graminearum Schwabe		
d) Fusarium culmorum (W.G. Smith) Sacc.		
Gelasinospora seminuda Cailleux	31	1,2,3
Gelasinospora retispora Cain	31b	1,2,3
Gonatobotrys sp.	47	1,2,3
Harzia verrucosa (Togn.) Hol.-Jech.	46	2,3
Humicola grisea Traaen var. grisea	13	2,3
Microdochium bolleyi (Sprague) de Hoog & Hermanides-Nijhof	56	1,2,3
Monacrosporium sp.	48	1,2,3
Mortierella elongata Linnemann	75	2,3
Mucor hiemalis Wehmer	14	1,2,3
Mucor mucedo Mich. ex St.-Am.?	54	1,2,3
Neurospora sp. (No perithecia observed)	53	2,3
Nigrospora oryzae (Berk. & Br.) Petch[a]		1,2,3
Papulaspora irregularis Hotson	73	2,3

Table 4. (Continued).

Penicillium sp.	55	1,2,3
Penicillium sp.	10	1,2,3
Phoma medicaginis Malbr. & Roum. var. pinodella (L.K. Jones) Boerema	26	2,3
Phoma sp. (Probably anamorph of Leptosphaeria)	51	2,3
Ramichloridium schulzeri (Sacc.) de Hoog	49	2,3
Rhizoctonia sp. (Unknown Binucleate species)	18	1,2,3
Rhizoctonia oryzae-sativae (Sawada) Mordue[a]		1,2,3
Rhizoctonia oryzae Ryker & Gooch[a]		1,2,3
Rhizopus circinans van Tieghem	57	2,3
Sclerotium hydrophilum Sacc.	11	1,2,3
Sclerotium oryzae (Catt.)[a]		1,2,3
Sistotrema brinkmannii (Bres.) John Erikss.	98	1,2,3
Slime molds	90	1,2,3
Sporobolomyces sp.	3	1,2,3
Thamnidium elegans Link ex Gray	97	2,3
Trichoderma harzianum Rifai	17	1,2,3
Ulocladium atrum Preuss	58	1,2,3
Unidentified Gray Yeast	2	1,2,3
Unidentified sclerotial fungus	74	2
Unknown Sterile Fungus	66	2,3
Waitea circinata Warcup & Talbot	27	1,2,3

[a] denotes isolation only at room temperature. All other fungi were isolated at 10 C.

[b] denotes year(s) isolated : 1 = 1988-1989, 2 = 1989-1990, 3 = 1990-1991.

Table 5. Predominant fungi isolated from surface disinfested sclerotia of *Sclerotium oryzae* collected from rice stubble over 2 seasons (1989-1991).

FUNGUS	CODE NO.	YRS[a]
Acremonium strictum W. Gams	4	2,3
Acremonium sp.	F	2,3
Acremonium terricola (Miller & al.) W. Gams	45	2,3
Alternaria alternata (Fr.) Keissler	8	2,3
Chaetomium sp.	Z	2
Chrysosporium sp.	V	2,3
Cladosporium cladosporioides (Fres.) de Vries	1	2,3
Epicoccum purpurascens Ehrenb. ex Schlecht.	6	2,3
Fusarium moniliforme Sheld.	16	2,3
Humicola grisea Traaen var. *grisea*	13	2,3
Microdochium bolleyi (Sprague) de Hoog & Hermanides-Nijhof	56	2,3
Penicillium sp. complex	J	2,3
Phoma medicaginis Malbr. & Roum. var. *pinodella* (L.K. Jones) Boerema	26	2,3
Phoma leveillei Boerema & Bollen	A	2,3
Trichoderma harzianum Rifai	17	2,3
Unidentified Sterile Fungus	N	2,3
Unidentified Sterile Fungus	E	2,3
Unidentified Pycnidial Fungus	C	2,3
Unidentified Sterile Fungus	O	2,3

All fungi isolated at both room temperature and 10 C.

[a] denotes year(s) isolated : 2 = 1989-1990, 3 = 1990-1991.

Table 6. Loss in dry weight of sterile rice stubble and filter paper inoculated with various fungi under laboratory conditions.

FUNGUS	PERCENT LOSS DRY WEIGHT RS[c] MEAN	RS ASSAY1	RS ASSAY2	FP[d] ASSAY2	CCX[b]
Gelasinospora seminuda (GS)	29.87	29.52	30.21	8.28	201
Gelasinospora retispora	-	29.13	-	-	201
BN Rhizoctonia sp.(BNR)	28.94	25.99	31.89	54.43	202
BNR + C3	28.52	26.00	31.03	27.2	202
BNR + UGY + C2	-	27.09	-	-	202
BNR + UGY	25.87	25.87	-	-	202
BNR+C3+HG+MH+C+GS+TH	-	-	24.84	29.44	-
Waitea circinata	-	22.65	-	-	202
Waitea circinata	21.98	24.63	19.32	-0.52	202
Fusarium graminearum	-	20.60	-	-	101
Microdochium bolleyi	20.38	17.68	23.08	5.98	102
Acremonium terricola	-	19.94	-	-	121
Neurospora sp.	19.67	14.53	24.81	2.35	202
Epicoccum purpurascens	19.01	16.26	21.76	-1.31	101
Phoma medicaginis	18.80	15.79	21.81	-1.04	102
BNR + C2	-	18.64	-	-	202
Ulocladium atrum	17.95	16.88	19.02	-1.04	102
Waitea circinata	-	17.88	-	-	202
Fusarium avenaceum	-	17.52	-	-	102
Humicola grisea (HG)	17.40	11.96	22.83	27.94	120
Acremonium strictum	17.35	16.03	18.66	0.52	111
Alternaria alternata	17.01	14.22	19.80	0.26	202
Pycnidial Fungus (C4)	-	-	16.91	-2.06	-
Trichoderma harzianum (TH)	16.70	11.84	21.55	28.35	112
Fusarium culmorum	-	15.14	-	-	101
Fusarium reticulatum ?	-	14.78	-	-	102
Pycnidial Fungus (C3)	14.72	9.74	19.70	-1.04	101
Trichoderma harzianum (Lab)	-	14.47	-	-	221
Ramichloridium schulzeri	-	-	14.11	16.26	-

Table 6. (Continued).

Cladosporium cladosporioides	13.76	12.04	15.48	-0.52	102
Sistotrema brinkmannii	-	-	13.17	6.43	-
Papulaspora irregularis	-	-	13.09	4.45	-
Coprinus sp.	-	12.57	-	-	210
Phoma leveillei	-	12.41	-	-	102
Penicillium sp.	12.17	5.96	18.38	6.19	100
Pycnidial Fungus (C2)	11.37	11.52	11.22	-1.82	100
Coprinus sp.	-	10.70	-	-	101
Pycnidial Fungus (C1)	10.44	7.97	12.90	-2.82	102
Oxyporus latemarginatus (Lab)	-	-	9.94	5.94	-
Trichoderma viride (Lab)	-	-	8.91	0.27	-
Doratomyces microsporus	-	-	8.85	4.13	-
Botrytis cinerea	8.66	6.56	10.76	3.59	101
Chrysosporium sp.	8.07	7.02	9.11	-0.77	101
Chaetomium sp.	-	5.75	-	-	112
Ceratocystis sp.? (C)	5.62	2.85	8.39	-2.08	100
Aspergillus terreus	4.65	1.32	7.97	-0.79	120
Mucor mucedo	4.40	0.99	7.81	-1.57	020
Mortierella elongata	3.99	2.76	5.21	-2.58	000
Mucor hiemalis (MH)	2.33	0.44	4.22	-0.52	020
Unidentified Gray Yeast (UGY)	2.05	1.42	2.68	-2.09	000
Uninoculated	-0.19	0.10	-0.48	0.12	-
	MSD[a](P=.05) =	8.10	8.90	17.71	

[a] Minimum Significant Difference in percent for each column (Tukey's HSD test).

[b] CCX represents the relative ability of a test fungus to utilize cellulose, chitin, or xylan. CCX means **C**ellulose **C**hitin **X**ylan. Values 0, 1, 2 represent none, low-moderate, and high ability on the respective substrate (e.g. 202 means high activity on cellulose, no activity on chitin, high activity on xylan).

[c] RS = Sterile Rice Stubble; RS MEAN is the mean of both assays.

[d] FP = Sterile Whatman No. 1 Filter Paper.

Table 7. Germination and colonization of S. oryzae sclerotia inoculated with various fungi under laboratory conditions.

FUNGUS[a]	ASSAY 1		ASSAY 2		ASSAY 3	
	%GERM[b]	%COLON[c]	%GERM	%COLON	%GERM	%COLON
Pycnidial Fungus C6	-	-	0.85	100.00	-	-
Pycnidial Fungus C4	-	-	12.30	89.73	0.00	94.82
Pycnidial Fungus C3	17.93	92.97	0.26	100.00	0.28	94.75
Pycnidial Fungus C2	18.30	77.59	1.63	100.00	2.52	97.16
Pycnidial Fungus C5	-	-	7.70	93.68	-	-
Pycnidial Fungus C1	23.30	94.96	7.97	92.03	2.67	91.58
Pycnidial Fungus C7	-	-	12.31	89.81	-	-
BNR + UGY + C2	14.34	91.26	-	-	-	-
BNR + C2	19.40	71.85	-	-	-	-
Fusarium graminearum	21.04	59.56	-	-	-	-
Phoma medicaginis	25.20	45.62	-	-	-	-
Fusarium avenaceum	25.38	45.21	-	-	-	-
Trichoderma harzianum (Lab)	30.53	48.17	-	-	-	-
Ulocladium atrum	30.98	52.98	-	-	-	-
Trichoderma viride (Lab)	-	-	25.73	73.79	37.15	48.09
Fusarium reticulatum ?	38.38	53.11	-	-	-	-
BN Rhizoctonia sp. (BNR2)	41.79	34.49	-	-	-	-
Coprinus sp.	19.37	24.59	-	-	70.95	0.55
Chaetomium sp.	14.02	67.59	-	-	82.65	10.97
Mucor hiemalis	50.82	10.98	-	-	-	-
BNR + UGY	51.59	16.29	-	-	-	-
Epicoccum purpurascens	19.42	38.96	79.72	18.00	66.07	26.11
Gelasinospora seminuda	55.76	2.18	-	-	-	-
Phoma leveillei	26.44	54.40	83.37	63.89	67.42	75.68
Acremonium terricola	29.90	25.01	79.92	66.55	68.94	42.99
Trichoderma harzianum (17)	44.44	17.33	72.68	26.76	63.86	22.38
Microdochium bolleyi	26.58	56.46	78.12	50.18	76.71	28.56
Gray Yeast (UGY)	60.93	9.61	-	-	-	-
Waitea circinata (27A)	61.88	0.00	-	-	-	-

Table 7. (Continued).

Chrysosporium sp.	30.27	84.62	77.96	71.57	82.37	68.12
C. cladosporioides	53.16	15.17	74.63	15.73	62.87	27.82
Coprinus sp. (B)	64.72	20.37	-	-	-	-
Penicillium sp.	48.43	12.67	84.16	14.70	-	-
Humicola grisea	23.97	55.98	92.46	5.29	82.72	2.30
Waitea circinata (27B)	69.59	6.94	57.21	56.34	73.01	15.04
Aspergillus terreus	77.80	0.00	60.58	44.79	-	-
Neurospora sp.	46.16	1.93	94.41	0.00	-	-
Botrytis cinerea	71.14	0.00	-	-	-	-
Gelasinospora retispora	72.39	1.59	-	-	-	-
Alternaria alternata	60.49	38.90	83.74	20.82	76.46	23.93
Waitea circinata (27C)	73.75	8.40	-	-	-	-
BN Rhizoctonia sp. (BNR)	50.40	22.94	92.91	1.55	81.30	1.05
Ramichloridium schulzeri	-	-	-	-	76.31	18.94
Harzia verrucosa	-	-	-	-	77.21	5.94
Acremonium strictum	-	-	89.04	39.38	65.96	41.97
Mortierella elongata	70.79	8.67	81.81	2.28	83.33	0.54
Acremonium strictum	-	-	78.80	27.09	-	-
Papulaspora irregularis	-	-	-	-	81.20	4.69
Ceratocystis sp.?	68.80	1.34	93.90	46.69	-	-
Sterile Fungus (O)	-	-	85.55	31.23	77.19	19.53
Mucor mucedo	82.38	0.00	-	-	-	-
Absidia glauca	-	-	-	-	85.30	0.00
Uninoculated	75.47	0.00	96.02	0.00	86.09	0.00
Sclerotium hydrophilum	-	-	92.71	0.00	-	-
MSD[d](P=.05) =	39.19	35.20	24.93	25.06	15.75	22.76

[a] Fungi ranked in descending order based on lowest overall percent germination values.
[b] %GERM= percentage of S. oryzae sclerotia that germinated after 2 month incubation with the test fungus at 10 C and subsequent surface disinfestation with 1% bleach.
[c] %COLON= percentage of S. oryzae sclerotia that the test fungus was recovered from after incubation and surface disinfestation.
[d] MSD= Minimum Significant Difference of Tukey's HSD test for the respective column.

Table 8. Fungal host range of hyperparasitic Pycnidial Fungus C3.

FUNGUS	SUSCEPTIBILITY RATING	STRUCTURES ATTACKED
Sclerotium oryzae	3	Hyphae, conidia, sclerotia, etc.
Absidia glauca	3	Hyphae, columella, sporangia
Harzia verrucosa	3	Hyphae, conidia, conidiophores
Ascochyta pisi	2	Hyphae
Mucor hiemalis	2	Hyphae, columella, sporangia
Mucor mucedo	2	Hyphae, columella, sporangia
Binucleate Rhizoctonia	1-2	Hyphae
Rhizoctonia oryzae-sativae	1-2	Hyphae, sclerotia?
Rhizoctonia solani AG1-1A	1-2	Hyphae
Rhizoctonia solani AG1-1B	1-2	Hyphae, sclerotia
Rhizoctonia solani AG-4	1-2	Hyphae
Sclerotium hydrophilum	1-2	Hyphae, sclerotia?
Waitea circinata	1-2	Hyphae
Gelasinospora retispora	1	Ascospores
Mortierella elongata	1	Hyphae
Trichoderma harzianum	1	Hyphae
Acremonium sp. (F)	0	None
Acremonium strictum (G)	0	None
Acremonium terricola	0	None
Acremonium strictum (4)	0	None
Alternaria alternata	0	None
Aspergillus terreus	0	None
Ceratocystis sp.	0	None
Chrysosporium sp.	0	None
Cladosporium cladosporioides	0	None
Coprinus sp.	0	None
Epicoccum purpurascens	0	None
Fusarium culmorum	0	None
Fusarium graminearum	0	None
Fusarium reticulatum	0	None
Fusarium avenaceum	0	None
Fusarium moniliforme	0	None

Table 8. (Continued).

Gelasinospora seminuda	0	None
Humicola grisea	0	None
Microdochium bolleyi	0	None
Neurospora sp.	0	None
Papulaspora irregularis	0	None
Penicillium sp.	0	None
Phoma leveillei	0	None
Phoma medicaginus	0	None
Trichoderma viride (Lab)	0	None
Ulocladium atrum	0	None

Rating: 0 = no parasitism observed, 1 = parasitism observed, slow to develop, restricted to small areas of host hyphae, 2 = parasitism of both hyphae and spores observed, moderately slow to develop, 3 = extensive parasitism and destruction of host hyphae and other structures.

Table 9. Colonization and parasitism of sclerotial fungi by Pycnidial Fungus C3.

HOST FUNGUS	UNINOCULATED % GERM[a].	UNINOCULATED % COLON[b].	INOCULATED % GERM.	INOCULATED % COLON.
Botrytis cinerea	100.0	0	100.0	0.0
Rhizoctonia oryzae-sativae	100.0	0	99.4	35.1
Rhizoctonia solani AG1-1A	100.0	0	100.0	1.3
Rhizoctonia solani AG1-1B	100.0	0	100.0	73.8[c]
Sclerotinia minor	100.0	0	100.0	0.0
Sclerotium hydrophilum	99.4	0	100.0	61.9
Sclerotium rolfsii	100.0	0	100.0	0.0
Sclerotium oryzae	83.1	0	13.1	100.0[c]

[a] Germ = percent of sclerotia that germinated after 2 months incubation with C3 at 10 C and subsequently surface disinfested with 1% bleach.

[b] Colon = percent of sclerotia that C3 was reisolated from following incubation and surface disinfestation.

[c] denotes observation of internal colonization of sclerotia by C3.

Table 10. Loss in dry weight of bagged rice stubble inoculated with various fungi, placed in the field, and collected at monthly intervals.

BURIED FUNGUS	Percent Loss Dry Weight JAN	FEB	MAR	APR
BN Rhizoctonia[2]	17.29 a	21.26 a	29.47 a	34.33 a
BN Rhizoctonia[1]	14.01 abc	18.50 abc	27.77 a	28.65 ab
Trichoderma harzianum[2]	14.21 abc	20.48 a	22.09 b	22.89 bc
Alginate Pellet Control	13.19 abc	18.77 abc	21.02 bc	20.87 c
Alternaria alternata[1]	9.45 bc	17.97 abc	19.51 bc	17.85 cd
Combined Fungi[1]	17.80 a	17.36 abc	18.49 bcd	18.48 cd
Uninoculated Control	12.51 abc	19.56 ab	20.04 bc	18.80 cd
Aspergillus terreus[1]	9.68 bc	17.38 abc	19.10 bcd	19.59 cd
Penicillium sp.[1]	15.95 ab	15.22 c	18.14 bcd	17.99 cd
Waitea circinata[1]	15.38 ab	15.51 bc	16.99 cd	16.66 cd
Uninoculated Control, Double-Bagged	7.80 c	14.60 c	14.65 d	13.20 d

SURFACE FUNGUS	Percent Loss Dry Weight JAN	FEB	MAR	APR
BN Rhizoctonia[2]	15.20 a	16.73 a	22.63 a	22.03 a
BN Rhizoctonia[1]	14.84 a	17.03 a	19.52 ab	18.16 b
Trichoderma harzianum[2]	10.22 bc	14.41 abc	13.76 c	17.80 b
Alginate Pellet Control	11.48 abc	15.40 ab	15.06 c	17.87 b
Alternaria alternata[1]	11.34 abc	12.36 abc	17.66 bc	19.25 ab
Combined Fungi[1]	9.13 c	17.05 a	17.19 bc	17.73 b
Uninoculated Control	12.51 abc	11.68 bc	17.75 bc	16.93 bc
Aspergillus terreus[1]	11.39 abc	13.09 abc	17.13 bc	16.08 bc
Penicillium sp.[1]	9.66 bc	10.19 c	15.77 bc	16.88 bc
Waitea circinata[1]	10.34 bc	9.94 c	16.30 bc	17.74 b
Uninoculated Control, Double-Bagged	13.42 ab	14.23 abc	15.36 c	14.20 c

Column means within placement followed by the same letter are not significantly different according to Tukey's HSD test (P=.05).

[1] Inoculum method = infested rice seed.
[2] Inoculum method = calcium alginate pellets.

Table 11. Loss in dry weight of bagged rice stubble inoculated with various fungi, placed in the field, and collected at monthly intervals (1990-1991).

BURIED FUNGUS	Percent Loss Dry Weight JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	13.75 a	17.00 a	22.75 a	28.50 a
Pycnidial Fungus C3[2] (C3)	15.75 a	18.25 a	22.25 a	29.50 a
BNR + C3[2]	15.50 a	21.25 a	21.75 a	22.25 a
Alginate Pellet Control	16.00 a	20.00 a	20.50 a	28.50 a
Uninoculated Control	15.00 a	19.75 a	23.50 a	30.75 a

SURFACE FUNGUS	Percent Loss Dry Weight JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	11.50 bc	13.25 ab	15.00 ab	12.25 a
Pycnidial Fungus C3[2] (C3)	10.00 c	9.50 b	11.25 b	13.75 a
BNR + C3 [2]	13.75 a	14.50 a	15.00 ab	13.00 a
Alginate Pellet Control	13.75 a	14.50 a	16.25 a	7.50 a
Uninoculated Control	13.25 ab	11.25 ab	13.50 ab	4.50 a

Column means followed by the same letter are not significantly different according to Tukey's HSD test (P=.05).

[2] Inoculum method = calcium alginate pellets.

Table 12. Colonization of bagged rice stubble by inoculated fungi under field conditions (1989-1990).

BURIED FUNGUS	Percent Colonization JAN	FEB	MAR	APR
BN *Rhizoctonia*[2]	100	100	100	83
BN *Rhizoctonia*[1]	92	100	100	67
Trichoderma harzianum[2]	50	58	71	71
Alginate Pellet Control	0	0	0	0
Alternaria alternata[1]	83	67	67	50
Combined Fungi[1]	8	67	58	0
Uninoculated Control	0	0	92[3]	33[3]
Aspergillus terreus[1]	0	0	0	0
Penicillium sp.[1]	8	8	58	67
Waitea circinata[1]	0	42	8	0
Uninoculated Control, Double-Bagged	0	0	0	0

SURFACE FUNGUS	Percent Colonization JAN	FEB	MAR	APR
BN *Rhizoctonia*[2]	50	92	96	100
BN *Rhizoctonia*[1]	50	58	100	100
Trichoderma harzianum[2]	0	8	38	50
Alginate Pellet Control	0	0	0	0
Alternaria alternata[1]	8	8	50	75
Combined Fungi[1]	8	8	92[3]	100[3]
Uninoculated Control	0	0	8[3]	0
Aspergillus terreus[1]	0	0	0	0
Penicillium sp.[1]	17	17	25	0
Waitea circinata[1]	0	0	8	0
Uninoculated Control, Double-Bagged	0	0	0	50[3]

[1] Inoculum method = infested rice seed.
[2] Inoculum method = calcium alginate pellets.
[3] Indicates BN *Rhizoctonia* (contamination due to inadequate plot spacing).

Table 13. Colonization of bagged rice stubble by BN Rhizoctonia under field conditions (1990-1991).

BURIED FUNGUS	Percent Colonization JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	33	91	100	100
Pycnidial Fungus C3[2] (C3)	0	0	0	0
BNR + C3[2]	87	100	97	100
Alginate Pellet Control	0	0	0	0
Uninoculated Control	0	0	0	0

SURFACE FUNGUS	Percent Colonization JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	2	0	66	86
Pycnidial Fungus C3[2] (C3)	0	0	0	0
BNR + C3 [2]	0	0	75	100
Alginate Pellet Control	0	0	0	0
Uninoculated Control	0	0	0	0

[2] Inoculum method = calcium alginate pellets.

Table 14. Viability of S. oryzae sclerotia from inoculated bagged rice stubble placed in the field and collected at monthly intervals (1990-1991).

BURIED	Percent Germination			
FUNGUS	JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	75.16 a	81.92 a	58.23 b	90.91 a
Pycnidial Fungus C3[2] (C3)	55.83 a	84.78 a	60.40 ab	78.13 a
BNR + C3[2]	65.60 a	78.20 a	74.72 ab	79.66 a
Alginate Pellet Control	66.17 a	74.63 a	71.66 ab	84.38 a
Uninoculated Control	69.56 a	71.88 a	82.49 a	85.52 a

SURFACE	Percent Germination			
FUNGUS	JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	86.83 a	75.78 a	73.61 a	63.34 a
Pycnidial Fungus C3[2] (C3)	87.87 a	76.06 a	69.93 a	73.84 a
BNR + C3[2]	83.79 a	72.69 a	68.26 a	61.77 a
Alginate Pellet Control	81.12 a	71.97 a	74.32 a	74.74 a
Uninoculated Control	78.05 a	75.37 a	67.13 a	69.69 a

Column means followed by the same letter are not significantly different according to Tukey's HSD test (P=.05).

[2] Inoculum method = calcium alginate pellets.

Table 15. Colonization of stubble-borne S. oryzae sclerotia by fungus C3 under field conditions (1990-1991).

BURIED	Percent Germination			
FUNGUS	JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	4.7	1.5	8.3	3.9
Pycnidial Fungus C3[2] (C3)	4.1	6.3	19.2	12.2
BNR + C3[2]	6.6	10.6	12.5	15.2
Alginate Pellet Control	2.4	5.8	11.3	8.5
Uninoculated Control	7.7	11.9	8.0	6.1

SURFACE	Percent Germination			
FUNGUS	JAN	FEB	MAR	APR
BN Rhizoctonia[2] (BNR)	3.6	4.1	10.0	14.0
Pycnidial Fungus C3[2] (C3)	3.1	9.2	6.3	7.4
BNR + C3[2]	5.6	14.1	7.5	18.4
Alginate Pellet Control	8.0	7.0	7.5	9.8
Uninoculated Control	2.0	7.4	3.3	8.5

[2] Inoculum method = calcium alginate pellets.

Table 16. Interaction of S. oryzae and various fungi in vitro.

FUNGUS	INTERACTION[1]
Pycnidial Fungus C1	4
Pycnidial Fungus C3	4
Pycnidial Fungus C2	4
Pycnidial Fungus C4	4
Pythium oligandrum	4
Pythium periplocum	4
Pythium sp.	4
Trichoderma viride (Lab)	4
Trichoderma harzianum (17)	4
Acremonium strictum (G)	3
Acremonium sp. (F)	3
Chrysosporium sp.	2
Phoma medicaginus	2
Rhizoctonia oryzae-sativae	2
Sclerotium hydrophilum	2
Acremonium terricola	1
Acremonium strictum (4)	1
Alternaria alternata	1
Aspergillus terreus	1
Binucleate Rhizoctonia	1
Cladosporium cladosporioides	1
Coprinus sp.	1
Epicoccum purpurascens	1
Fusarium graminearum	1
Fusarium avenaceum	1
Fusarium reticulatum	1
Fusarium culmorum	1
Fusarium moniliforme	1
Gelasinospora seminuda	1
Humicola grisea	1
Microdochium bolleyi	1
Mortierella elongata	1
Mucor hiemalis	1
Mucor mucedo	1
Neurospora sp.	1
Papulaspora irregularis	1
Penicillium sp.	1
Phoma leveillei	1
Ulocladium atrum	1
Waitea circinata	1
Absidia glauca	0
Ceratocystis sp.	0
Harzia verrucosa	0

[1]Interaction : 0 = no interaction, 1 = antagonism only, 2 = antagonism + limited parasitism, 3 = moderate parasitism ± antagonism, 4 = high parasitism ± antagonism.

Table 17. Greenhouse assays of various fungi and bacteria as potential biocontrol agents of *S. oryzae*.

TRT	DI	% RECOVERY
ASSAY 1		
S. oryzae only (SO) 100 VS/PLT	2.93	
SO + Ca-alginate pellets only	2.28 *	
SO + *Sclerotium hydrophilum* (SH)	1.36 **	100
SO + SH as Ca-alg pellets	1.98 **	77
SO + BN *Rhizoctonia* (18)	2.81	0
SO + *Waitea circinata* (27)	3.28	0
SO + *Trichoderma harzianum* (17)	2.80	84
SO + *Humicola grisea* (13)	3.00	11
SO + Unidentified Yeast (2)	3.02	27
SO + *Sporobolomyces* sp. (3)	3.21	100
SO + *Acremonium strictum* (4)	3.11	100
SO + *Phialophora* sp.	2.97	100
SO + *Epicoccum purpurascens* (6)	2.75	63
SO + *Cladosporium cladosporioides* (1)	2.82	89
SO + *Alternaria alternata* (8)	2.99	42
SO + *Nigrospora oryzae* (7)	3.10	63
SO + *Aspergillus terreus* (19)	3.16	0
SO + *Penicillium* sp. (55)	2.89	15
SO + *Microdochium bolleyi* (56)	2.76	23
SO + *Mucor hiemalis* (14)	2.78	0
SO + *Fusarium moniliforme* (16)	2.94	34
SO + *Gelasinospora seminuda* (31A)	3.02	0
SO + *Trichoderma harzianum* (C)	3.22	88
SO + *Bacillus subtilis* (C)	2.78	0
ASSAY 2		
SO only	3.92	
SO + *Pythium periplocum*	3.50	
SO + *Pythium oligandrum*	3.68	
SO + *Pythium* sp.	3.43	
SO + Combined *Pythium* spp.	3.00	
ASSAY 3		
SO only	3.66	
SO + Ca-alg pellets	3.71	
SO + C3	3.71	
SO + C3 as pellets	2.97 *	
SO + *Rhizoctonia oryzae-sativae* (ROS)	2.18 **	
SO + ROS as pellets	2.77 *	
SO + *Sclerotium hydrophilum* (SH)	1.77 **	
SO + SH as pellets	2.51 *	
SO + SH + ROS	2.33 *	
SO + SH + ROS as pellets	2.25 *	

* and ** (P=.05 and .01, respectively) represent significant differences from SO only control according to Dunnett's T Test.

Table 18. Greenhouse co-inoculation experiments of S. hydrophilum (SH) and S. oryzae (SO).

CULTIVAR =	S201	M202	L202
TRT[a]	MEAN DI	MEAN DI	MEAN DI
EXPERIMENT 1			
1	1.00 a	1.00 a	1.00 a
2	1.00 a	1.00 a	1.00 a
4	3.00 c	3.41 c	4.00 c
5	2.86 b	3.24 c	4.39 c
6	1.39 ab	1.92 b	3.46 bc
8	1.34 ab	1.74 b	2.38 ab
EXPERIMENT 2			
1	1.00 a	1.00 a	1.00 a
2	1.00 a	1.00 a	1.00 a
3	1.00 a	1.00 a	1.00 a
4	3.15 d	2.94 cd	3.52 d
5	2.52 cd	3.48 d	3.40 d
6	1.50 ab	1.98 b	1.72 bc
7	1.98 bc	1.81 ab	1.53 b
8	1.81 bc	2.46 bc	2.16 c
9	1.97 bc	2.49 bc	1.50 b
EXPERIMENT 3			
1	1.00 a	1.00 a	1.00 a
2	1.00 a	1.00 a	1.00 a
3	1.00 a	1.00 a	1.00 a
4	3.19 d	3.50 c	3.46 c
5	2.84 cd	4.16 c	3.66 c
6	2.36 bc	3.02 bc	2.50 abc
7	2.00 b	2.94 bc	1.59 ab
8	2.45 bcd	3.23 bc	2.60 bc
9	2.14 bc	2.12 ab	2.85 bc

[a] Trt : 1 = untreated, 2 = SH 20VS/Plant, 3 = SH 100 VS/Plant, 4 = SO 100 VS/Plant, 5 = SO 100 VS/Plant 2 Wks. Post Inoculation, 6 = 2 + 4, 7 = 3 +4, 8 = 2 + 5, 9 = 3 + 5.

Means followed by the same letter are not significantly different according to Tukey's HSD test (P=.05).