Minnesota Wild Rice Research 1987

Miscellaneous Publication 54-1988
Minnesota Agricultural Experiment Station
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St. Paul, Minnesota

CONTENTS

Most of the research reported here is preliminary; thus, the results should be interpreted with caution and should not be used in publications unless arrangements are made with the authors.

The wild rice team wishes to acknowledge the assistance provided by many people. The cooperation of Dr. Nyvall, Superintendent of the North Central Experiment Station, Grand Rapids, and Dr. Wilcox, Superintendent of the Rosemount Experiment Station, was greatly appreciated. The use of facilities at the Horticultural Research center at Excelsior was appreciated. We are thankful also for the help of Drs. Rabas and Boedicker at the North Central Experiment Station, Grand Rapids. The daily supervision of the research plots and laborers at Grand Rapids by Henry Schumer, Research Plot Coordinator, was very valuable. We are also extremely grateful to the growers and processors for providing seed, land area and facilities for research. Funding from the Minnesota Wild Rice Research and Promotion Council for some of the research was very helpful. We are also indebted to the Council for obtaining the necessary State funds to conduct research on a peat site in Aitkin County. We are especially grateful to Vomela Wild Rice, Inc. for the use of their land for this research and to George Shetka and Franklin Kosbau who helped in the construction of the site. We appreciate the continued support of the Agricultural Experiment Station for wild rice research.

Wild Rice Production Research - 1987

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1987 Wild Rice Growing Season

The 1987 growing season was very warm throughout Minnesota compared to 1986 and the long-term (30 year) average (Table 1). The Aitkin County growing area was the warmest with 809 growing degree days (GDD) more than normal; this compares to 613 GDD more for Grand Rapids and 492 GDD more for Red Lake. At all locations every month was warmer than normal. The warm temperatures during the season resulted in poor grain fill and rapid brown spot development, especially in the Aitkin area, thus reducing yield per acre.

Table 1. Growing degree days[a] comparisons for 1986, 1987 and normal.

	Aitkin			Grand Rapids			Red Lake		
Month	1986	1987	Normal	1986	1987	Normal	1986	1987	Normal
	- - - - - - - - - - - - - - - - GDD - - - - - - - - - - - - - - - -								
April	218	345	114	157	311	107	139	279	105
May	501	632	414	499	520	381	487	536	403
June	720	900	677	680	765	634	696	801	672
July	917	981	871	882	938	817	902	936	855
August	713	812	785	677	751	733	731	759	784
Total	3069	3670	2861	2895	3285	2672	2955	3311	2819

[a] $\frac{\text{Maximum temp.} + \text{Minimum temp.}}{2}$ -40° F; data from Mark Seeley, Soil Science Dept., Univ. of Minn.

Total rainfall was considerably less (6.26 inches) in Aitkin than normal. Most of this resulted from the low amounts in April and June (Table 2). Grand Rapids had slightly more (1.22 inches) than normal but the higher average resulted from the very wet July. April and June were also very dry at Grand Rapids. At Red Lake the average rainfall was also higher (2.24 inches) than normal. May and July were wet while April and June were dry. The dry April and lack of snow during the winter resulted in a shortage of flood water, consequently some fields were not flooded while others were flooded very late.

[1/] Professor, Graduate Research Assistant and Senior Research Plot Technician, respectively.

Table 2. Precipitation comparisons for 1986, 1987 and normal.

Month	Aitkin			Grand Rapids			Red Lake		
	1986	1987	Normal	1986	1987	Normal	1986	1987	Normal
	- - - - - - - - - - - - - - - - Inches - - - - - - - - - - - - - - - -								
April	4.28	0.15	2.27	3.50	0.31	1.99	2.82	0.28	1.59
May	2.67	2.72	3.39	2.49	4.90	3.16	1.11	5.81	2.43
June	5.65	1.00	3.83	6.10	1.16	3.79	3.99	0.39	3.64
July	6.25	4.36	4.79	5.45	8.46	4.12	3.56	6.66	3.81
August	5.40	3.98	4.19	2.34	2.83	3.38	1.50	3.82	3.25
Totals	24.25	12.21	18.47	19.88	17.66	16.44	12.98	16.96	14.72

Total wild rice production from paddies in 1987 was down from the record production of 5,313,000 pounds of processed grain produced in 1986 (Table 3). Some of the decrease resulted from less yield per acre, especially in the Aitkin area due to diseases while the remainder was due to late flooding of fields. Total production since 1968 has steadily increased as more acreage was planted each year and yield per acre increased. Since 1984 approximately 25,000 acres were in production each year with a slight reduction in 1987.

Table 3. Minnesota paddy wild rice production (1000 processed pounds).

Year	Production	Year	Production
1968	36	1978	1761
69	160	79	2155
70	364	80	2320
71	608	81	2274
72	1496	82	2697
73	1200	83	3200
74	1036	84	3639
75	1233	85	5172
76	1809	86	5313
77	1031	87	4500[a]

[a] Estimate from Minnesota Paddy Wild Rice Research and Promotion Council; remaining data also from the Council.

Research

We continued our research on weed control, shading effects on wild rice and effects of drying wild rice seed before storage on seed viability and storability. The above research was conducted on University plot land at Grand Rapids and in growers' fields near Aitkin. A glasshouse was utilized for some of the research in St. Paul. A new study was established on the Aitkin peat site to study the influence of residue removal on nitrogen fertilizer requirement and disease. The warmer temperatures reduced yield due to poor grain fill and rapid disease

development late in the growing season.

Weed Control Research

Screening Herbicides for Wild Rice Tolerance

Three broadleaf herbicides not previously tested for use in wild rice were evaluated. They were acifluorfen (Blazer), 4-(2,4-dichlorophenoxy) butyric acid (Butyrac 200) and bromoxynil (Buctril). Wild rice was planted on April 21 into a rototilled, fumigated (methyl bromide) seedbed which had 40 lb/A nitrogen applied as urea before rototilling. Phosphorus and potassium were at adequate levels. Wild rice was planted into one inch deep trenches spaced one foot apart and covered with soil and flooded to a depth of 6 inches after planting. Plots were 4 x 10 foot in size with the center two rows harvested. The experimental design was a randomized complete block with three replications. The herbicides were applied with a hand CO_2 sprayer at 25 psi at a total volume of 20 gal/A. The first application date was on June 12 when wild rice had 3 to 4 exposed leaves above the water while the second date was June 17 when wild rice was in early tillering. Tables 4 and 5 give the injury ratings, plant height and grain yield of wild rice when treated with herbicides.

Table 4. Influence of several herbicides applied to wild rice when 3 to 4 leaves were exposed above the water 5 to 6 inches (late aerial leaf stage), Grand Rapids-1987.

Treatment	Rate	Injury rating[a]			Plant height	Stem number	Grain yield[b]
		7 days	14 days	Harvest			
	lb/A a.i.	- - -	Number	- - - -	cm	/ft^2	lb/A
Blazer + crop oil	.25 + 1 qt.	1.7	0.0	1.0	198	11.6	915
	.50 + 1 qt.	3.7	1.0	0.3	137	7.7	649
Butyrac 200	.50	0.0	0.0	0.0	210	8.4	730
	.75	1.7	0.0	0.7	205	7.6	638
Basagran + Butyrac 200 + 28% UAN	.50 + .03 + 1 gal	6.3	4.3	0.7	193	9.2	650
Buctril	.25	5.0	2.0	0.0	200	11.6	760
	.50	4.7	1.3	2.0	188	9.2	467
MCPA + 28% UAN	.50 + 1 gal	6.7	7.0	4.7	172	7.9	437
2,4-D + 28% UAN	.50 + 1 gal	9.7	9.7	10.0	0	0	0
MCPA	.25	4.0	3.3	0.7	198	8.6	598
2,4-D	.25	7.0	8.0	8.3	140	4.4	178
Untreated check	0	0.0	0.0	0.0	203	10.6	922
LSD (5%)		2.7	2.4	3.0	67	4.7	461

[a] Days after treatment; 0 = no injury, 10 = complete kill. [b] 40% moisture.

Table 5. Influence of several herbicides applied to wild rice when 1 to 2 tillers had leaves exposed above the water 3 to 4 inches (early tillering), Grand Rapids - 1987.

Treatment	Rate	Injury rating[a] 7 days	Injury rating[a] 14 days	Injury rating[a] Harvest	Plant height	Stem number	Grain yield[b]
	lb/A a.i.	- - -	Number	- - - -	cm	1 ft^2	lb/A
Blazer + crop oil	.25 + 1 qt.	1.0	0.0	0.0	187	7.1	854
	.50 + 1 qt.	1.6	0.0	2.0	168	9.6	878
Butyrac 200	.50	0.0	0.0	0.0	190	8.1	773
	.75	0.0	0.0	0.0	203	8.5	874
Basagran + Butyrac 200 + 28% UAN	.50 + .03 + 1 gal	5.0	4.6	2.0	162	6.3	438
Buctril	.25	2.7	3.3	2.0	156	9.5	779
	.50	4.0	4.0	1.0	175	7.8	618
MCPA + 28% UAN	.50 + 1 gal	6.3	5.3	7.0	133	4.1	221
2,4-D + 28% UAN	.50 + 1 gal	6.6	7.0	9.3	60	1.1	89
MCPA	.25	1.0	0.7	1.0	191	7.7	606
2,4-D	.25	3.7	4.0	5.0	153	5.6	392
Untreated check	0	0.0	0.0	0.0	173	9.0	871
LSD (5%)		1.9	1.7	2.4	38	2.4	285

[a] 0 = no injury, 10 = complete kill. [b] 40% moisture.

Blazer and Butyrac 200 injured wild rice less than the other herbicides at both application dates (Tables 4 and 5). At the early date the yield of wild rice was similar to the untreated check when the low rate of Blazer was applied. The wild rice yields from all the other treatments were lower than the check. At the later treatment date, the Blazer treated plots had similar yields as the check. The yields from the Butyrac 200 treated plots were also similar to the check. Thus, it appears that these two compounds warrant further testing as possible broadleaf herbicides from the standpoint of wild rice tolerance.

The same herbicides were also applied to a uniform stand of giant burreed (Sparganium eurycarpus Engelm.) at Grand Rapids. Giant burreed corms were planted into a small paddy in 1985 and the weed was allowed to spread throughout the paddy for 2 years. The paddy was rotovated and flooded each year. In 1987 the paddy was flooded on April 15. Plot size was 4 x 10 feet and the herbicides were applied with the same CO_2 sprayer as previously described. The herbicides were applied on June 11 when the leaves of giant burreed were 10 to 12 inches above the

water. Table 6 gives the injury ratings of giant burreed one and two weeks after application.

Table 6. Influence of several herbicides applied to giant burreed when leaves were exposed 10 to 12 inches above the water, Grand Rapids - 1987.

Treatment	Rate	Giant burreed injury[a] 7 days	14 days
		- - - Number - - -	
Blazer + crop oil	.25 + 1 qt	7.3	5.3
	.50 + 1 qt	7.3	4.7
Butyrac 200	.50	0.6	0.6
	.75	1.3	1.7
Basagran + Butyrac 200 + 28% UAN	.50 + .03 + 1 gal	5.7	6.3
Buctril	.25	6.7	6.0
	.50	8.3	9.0
MCPA + 28% UAN	.50 + 1 gal	1.7	8.0
2,4-D + 28% UAN	.50 + 1 gal	5.3	8.3
MCPA	.25	3.3	5.7
2,4-D	.25	1.7	6.6
Check	0	0.0	0.0
LSD (5%)		2.6	3.3

[a] 0 = no injury, 10 = complete kill

Blazer, which looked promising based on wild rice tolerance, had good early control 7 days after treatment but regrowth appeared by 14 days resulting in a lower control rating. It may, however, reduce the competition from giant burreed sufficiently to allow wild rice to compete. We plan to test Blazer next year in a mixed population of giant burreed and wild rice. Since 2,4-D and MCPA can presently be used in wild rice, applying either of these chemicals at .5 lb/A + 28% UAN as spot treatments to dense stands of giant burreed would help the spread of this weed in a field. However, any wild rice in with the giant burreed would be severely injured. We plan to repeat these experiments next year.

Giant Burreed Control with Herbicides Applied Through a Pipewick Applicator

Experiments were conducted in 1987 to determine the efficacy of several herbicides and surfactants applied through a pipewick applicator on the

control of giant burreed. In one experiment, a paddy with a heavy giant burreed population at the Grand Rapids Experiment Station was seeded with wild rice and flooded on April 15. Herbicides were applied with a handheld pipewick applicator when giant burreed was 8-10 inches tall (May 29) or 18-20 inches tall (June 11). Giant burreed was at least 8 inches taller than wild rice at each application. Visual injury ratings were taken 2 and 4 weeks after each application. The experiment was conducted as a randomized complete block design with three replications. Table 7 gives the treatments and giant burreed injury ratings 2 and 4 weeks after treatment. No wild rice injury was noted for any treatment.

Table 7. Effects of 2,4-DB, 2,4-D, and MCPA with surfactants applied through a pipewick on vegetative control of giant burreed. Grand Rapids - 1987.

	2 week injury rating[a] Surfactant			4 week injury rating Surfactant		
	None	COC (1%)[b]	UAN (5%)[c]	None	COC (1%)	UAN (5%)
8-10 inch stage						
2,4-DB (66%)	3.3	2.0	3.0	0.7	1.0	0.7
2,4-D (33%)	1.0	7.0	1.3	0.3	2.3	0.3
MCPA (33%)	9.0	9.3	8.3	7.3	7.0	8.0
18-20 inch stage						
2,4-DB (66%)	1.3	1.7	0.7	0.0	0.3	0.0
2,4-D (33%)	5.3	7.7	8.0	5.7	4.3	5.3
MCPA (33%)	5.7	7.0	4.3	4.3	4.0	4.3
LSD (5%)		2.5			1.3	

[a] 0 = no injury, 10 = complete kill. [b] COC = crop oil concentrate.
[c] UAN = 28% urea, ammonium nitrate fertilizer.

2,4-DB (Butyrac 200) provided poor control of giant burreed, regardless of application date or surfactant. 2,4-D applied at the 10-12 inch stage with crop oil concentrate provided good early giant burreed control, but 2,4-D with either no surfactant or 28% UAN provided only poor control. Giant burreed recovered from 2,4-D injury almost completely by 4 weeks after application. 2,4-D gave good early control when applied at the 18-20 inch stage when either crop oil concentrate or 28% UAN was added. Giant burreed recovered to some extent from 2,4-D injury when either surfactant was used, but not when 2,4-D was used alone.

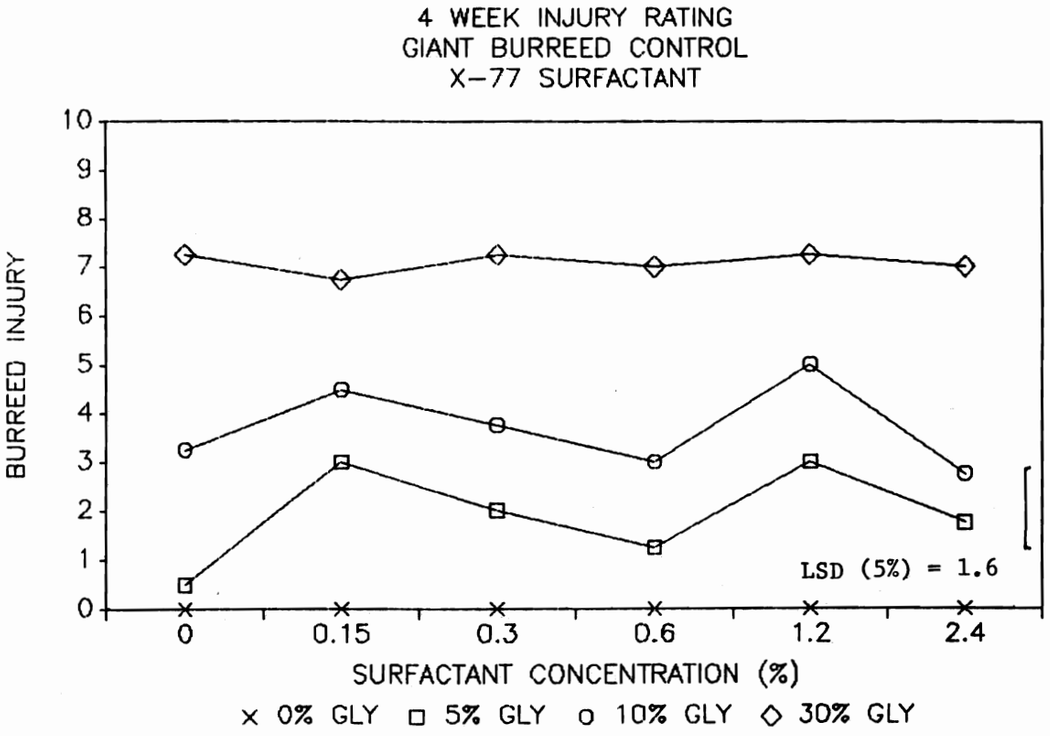
MCPA provided excellent early giant burreed control when applied at the 8-10 inch stage, regardless of surfactant. Control of giant burreed was good to excellent after 4 weeks, as well. When applied at the 18-20 inch stage all MCPA treatments gave approximately 40% control 4 weeks after application.

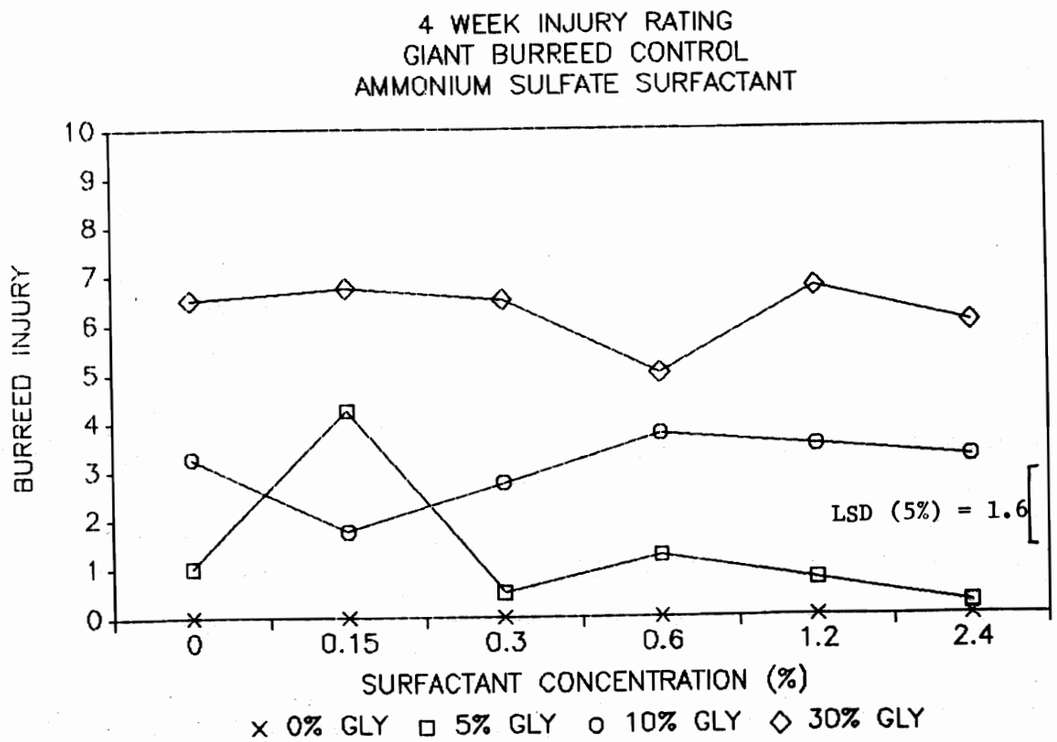
These first year data suggest that MCPA applied at the 8-10 inch stage of giant burreed growth should provide effective long term vegetative control. Surfactants such as crop oil concentrate or 28% UAN may not be necessary. 2,4-D applied at the 18-20 inch stage was more effective than when it was applied earlier, but 2,4-D applied at either stage was not as effective as MCPA applied at the 8-10 inch stage. Further testing will be done to determine if these results are repeatable. It should be noted that this experiment examines only vegetative control. Control of the underground reproductive systems with these treatments have not been determined.

In a second experiment, a fallow paddy near Aitkin, MN was treated with various glyphosate (Rodeo) + surfactant treatments. Herbicides were applied with a handheld pipewick applicator to 4 x 10 foot plots when giant burreed was 18-10 inch tall (June 23). Injury ratings were taken 4 weeks after herbicide application, and plant height was taken before burreed harvest (Sept. 16). Giant burreed vegetation and underground reproductive structures (rhizomes and corms) were harvested from a 2 x 2 foot area in the middle of each plot. Vegetation was dried at 105° F for 10 days and weighed. The underground reproductive structures were washed and weighed, and put into cold storage (34° F) for 3-4 months. Corms and rhizomes were separated and grown in the greenhouse to test for viability. The experiment was conducted as a randomized complete block design with four replications.

Analysis of variance showed a significant interaction between surfactant, surfactant concentration, and Rodeo concentration for injury and reproductive structure weights. Four week injury ratings are shown in Figure 1. Ammonium sulfate (AMS) concentration influenced the effectiveness of the 5% Rodeo concentration. 0.15% AMS increased burreed injury at 5% Rodeo over any other AMS concentration at the 5% Rodeo level. Injury given by that combination was as good as any of the 10% Rodeo solutions. However, 30% Rodeo concentration provided the best control rating, regardless of AMS concentration. X-77 concentration influenced the effectiveness of the 5% and 10% Rodeo concentrations but not the 30% Rodeo solution. 0.15% X-77 increased burreed injury over 0% X-77 with the 5% Rodeo solution. 1.2% X-77 increased burreed injury with the 10% Rodeo solution, but injury with that combination was not significantly different from the 0.15% X-77 with 5% Rodeo solution. As with AMS, X-77 concentration did not influence the 30% Rodeo solution, and injury with the 30% Rodeo solution was higher than with the 5% or 10% solutions.

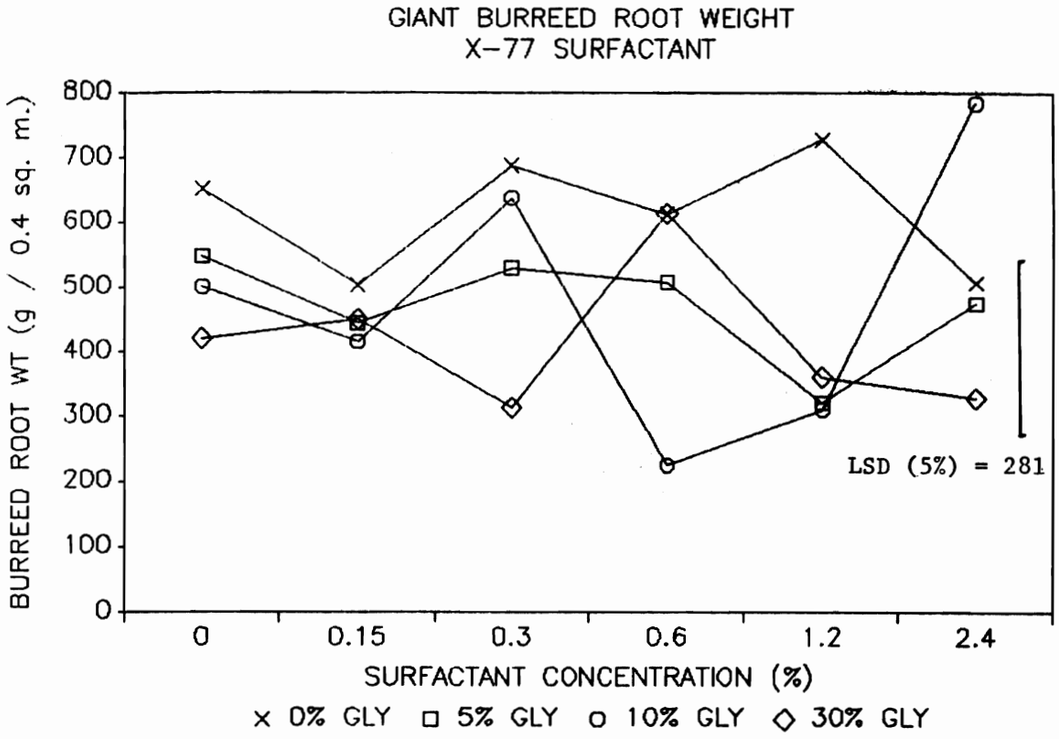
Giant burreed root weights were quite variable, so detection of significant mean differences was difficult. Root weights (underground reproductive structures) are shown in Figure 2. 0.15% AMS with 5% Rodeo solution caused a decrease in root weight from the 5% Rodeo concentration without AMS. This root weight was similar to that of the 30% Rodeo solution, regardless of AMS concentration. All other Rodeo + AMS concentrations gave similar root weights. 0.6% X-77 concentration + 10% Rodeo decreased root weight of giant burreed below all other Rodeo concentrations with 0.6% X-77. Root weight with that combination was similar to that of the 30% Rodeo concentration with most other X-77 concentrations.

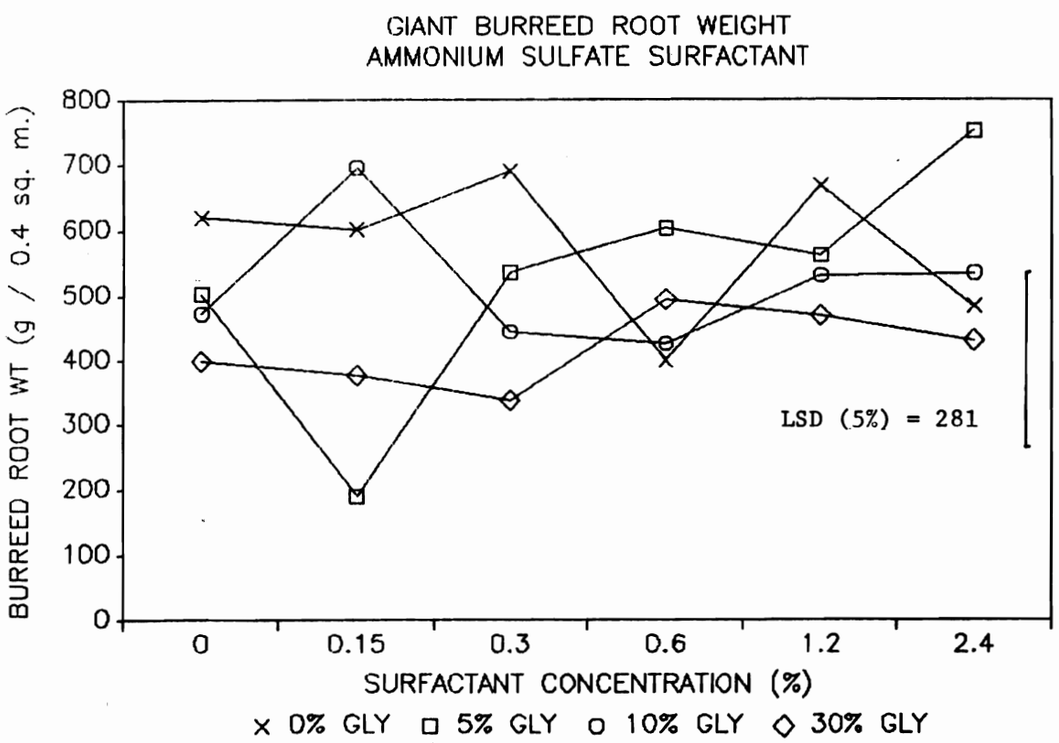




LSD (0.05) = 1.6

Figure 1





LSD (0.05) = 281

Figure 2

These first year data indicate that using Rodeo at 30% gave 65% vegetative control regardless of surfactant or surfactant concentration. However, a more important consideration in giant burreed control is the control of the underground reproductive system. If root weight is a good indication of the control of the underground system, using a low concentration of surfactant (0.15-0.6%) with a low concentration of Rodeo gave control similar to or better than that of a high rate of Rodeo. These results are similar to those found with other perennial weeds, such as Canada thistle (Circium arvense) and field bindweed (Convolvulus arvensis). Rhyzome control was better with a low surfactant concentration and low Rodeo concentration than with high concentrations.

Root viability tests have not been completed at this time. That information should give a better indication of the effectiveness of the various combinations on killing the underground reproductive system. This experiment will be repeated in 1988 to determine if these results are repeatable.

Rate and Method of Nitrogen Fertilizer Application on First Year Peat Fields

A new research site on peat soil near Aitkin was established on the Vomela Farm in the fall of 1986. This was made possible by additional funding from the legislature for wild rice research thanks to the efforts of the Minnesota Paddy Wild Rice Research and Promotion Council and the generosity of Vomela Farms for use and maintenance of the site. Bob Racek of Pro Farm supervised the application of fertilizer and fungicide to the plots. This research is being conducted in conjunction with the Plant Pathology and Soil Science projects.

Five 2-acre and one 1.3-acre paddies were constructed so each could be flooded and drained separately. The six paddies will be used for a three year study to investigate the influence of removing the residue on nitrogen fertilizer requirements and on disease incidence. All paddies were fertilized in the spring with a broadcast application of 40 lb/A P and 60 lb/A of K fertilizer. This fertilizer was incorporated with a rotovator. The five larger paddies were divided into four 42 x 500 ft strips while the smaller one was divided into four 42 x 300 ft strips. The four nitrogen treatments in each paddy were granular urea applied at 30 and 60 lb N/A incorporated with a rotovator and liquid urea injected at 30 and 60 lb N/A. After nitrogen fertilization the paddies were seeded with the K2 variety at 40 lb/A. The seed was incorporated with a harrow. The paddies were flooded on May 16 to a depth of 10 inches. The fungicide, Tilt, was applied by airplance at 4 oz/A on August 7 when the plants flowered. The north half of all paddies was treated with Tilt. Brown spot was already evident when Tilt was applied. Our expectation was that on first year paddies a fungicide would not be necessary. However, because of the very warm temperatures brown spot developed even in these first year paddies. A 16 x 200 ft strip from each treatment was harvested by combine.

The fungicide, Tilt, reduced the average leaf infection from 69 to 48% and the average yield was 303 lb/A for the treated plots and 278 for the untreated (Tables 8 and 9). Lodging at harvest was slightly more overall for the untreated plots compared to the treated plots. Generally, the yields were very low due to diseases before Tilt was applied and the warm temperatures causing poor seed set and/or grain fill. The treatments which gave the highest and the lowest yields were the only treatments that were significantly different than each other. The highest yield was obtained when 30 lb N/A were applied as granular urea and the plants treated with Tilt. The lowest yield was obtained when 60 lb N/A were injected and no Tilt was applied.

From this year's data, because of the low yields, it is difficult to make any sound recommendations as to the rate and method of nitrogen application that growers should follow. It was clear, however, during the growing season that generally more lodging occurred in the 60 lb N/A rate than in the 30 lb N/A rate. Also, because of the late application of Tilt its full benefit may not have been realized in these plots. It was very evident, however, that even with the late application, disease infection was reduced in the Tilt treated half of the paddies.

In the fall of 1987 the residue was removed from every other paddy and the same rate and method of nitrogen application treatments were made in the four strips in each paddy. The influence of residue removal on diseases and nitrogen response of wild rice will be measured for the next 3 years.

Table 8 gives wild rice response to fertility and fungicide application.

Table 8. Wild rice response to rate and application method of nitrogen and to fungicide application at Aitkin - 1987.

Treatment			Brown spot infection on upper 3 leaves			Lodging at harvest	Recovery	Grain yield[a]
Nitrogen rate	Application method	Foliar fungicide	Flag	One below	Two below			
Lb/A			- - - - % - - - -			%	%	Lb/A
30	Injected	Yes	33	40	65	0	35	296ab
60			37	41	73	17	34	311ab
30	Incorporated		29	38	63	0	36	325a
60			33	46	75	4	34	280ab
30	Injected	No	50	57	85	11	34	284ab
60			50	80	95	8	33	265b
30	Incorporated		47	65	90	4	34	276ab
60			55	65	90	11	34	289ab
		LSD (5%)	10	16	15	--	NS	51

[a] 40% moisture; means followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 9. Grain yield of wild rice in response to rate and application method of nitrogen and to fungicide application at Aitkin-1987.

Nitrogen fertilizer	Method of Application: Injected, Tilt	Injected, No Till	Incorporated, Tilt	Incorporated, No Till	Average
lb/A	- - - - - - Yield, lb/A - - - - - -				
30	296	284	325	276	295
60	311	265	280	289	286
Average	304	274	302	282	290
Average	289		292		

Growth and Development

Influence of Shading Wild Rice During Grain Fill

A field experiment in 4 x 4 ft boxes was conducted at St. Paul to investigate the influence of reducing natural light by 51% using black plastic screening. The boxes were filled with 4 inches of greenhouse soil mix of soil, sand, peat, and manure (4:3:3:3 v/v/v/v) and fertilized with 30 lb N/A. An excess of wild rice seed was planted on June 3 in 1-ft rows and the boxes flooded to a depth of 4 inches. The boxes were thinned to 4 plants/ft^2 and at flowering (July 26) black plastic screening was placed over the boxes. Some were removed after 2 and 4 weeks and at harvest (6 weeks). The center two rows were harvested for grain yield and plant measurements. Grain was hand stripped 3 times beginning on August 18 and ending on August 24. The experimental design was a randomized complete block with four replications. Table 10 gives plant height, plant number, dry weight per plant, stems per plant and seed dry weight per plot as influenced by length of light reduction.

Plant development was not influenced by the different light reduction treatments, however, grain fill was reduced even by 2 weeks of light reduction after flowering. Longer periods of reduced light reduced yields more but to a lesser degree. It appears that yields could be reduced by long periods of reduced sunlight which could be the case during long periods of cloudy weather.

Table 10. Effects on wild rice of reducing light during grain fill, St. Paul - 1987.

Weeks of light reduction after flowering	Plant height	Plant number	Dry wt /plant	Stems /plant	Seed yield
	cm		gm		lb/A[b]
0	134	26	10.6	4.0	2025
2	132	25	8.7	3.8	1400
4	138	23	10.1	4.1	1210
6[a]	140	26	9.0	3.7	1198
LSD (5%)	NS	NS	NS	NS	300

[a] Harvested on this date. [b] 40% moisture.

Seed Storage and Handling

Effect of Combining or Hand Harvesting on Seed Viability

In the fall of 1986, seed samples were hand harvested from 12 fields of K2, 3 fields of M3, 3 fields of Netum and 5 fields of Voyager. In addition, seed samples from the grower's combine in the same field were collected. All of the samples were immediately placed into plastic bags and taken to St. Paul where they were stored in water in a cooler at 38° F. Seed germination in the spring of 1987 was determined on the hand and machine harvested samples. Germination was determined by placing 100 seeds into a beaker (250 ml) of water kept at 70-74° F. The beakers were kept on a laboratory bench and the water changed every two days. Germinated seeds were counted and removed after 1, 2 and 3 weeks. Seeds were counted as germinated when the coleoptile had grown longer than the length of the seed. Table 11 shows the germination comparisons.

Table 11. Germination comparison of hand and combine harvested wild rice seed.

Harvest method	Variety				
	K2	M3	Voyager	Netum	Ave.
	- - - - - - % germination - - - - - -				
Hand	56.8	52.2	54.1	72.2	58.8
Combine	36.0	49.6	31.5	65.3	45.6
LSD (5%)	8.3	20.0	15.8	17.8	

The hand harvested seed generally had higher germination the following spring, however only the K2 variety was significantly different. In 1986 the Voyager variety seed had a much lower germination than K2 (1986 Research Report) but in 1987 this was not true. In 1986 the average germination for the hand harvested seed was significantly lower than the combine harvested seed. Based on the 2-year study it appears that seed needs to be carefully combined so as to avoid as much injury as possible.

Fall Seed Handling and Storage

The 1986 experiment was continued for a second year to determine if allowing wild rice seed to remain out of water either spread out or in bags on a table before storage for a period of time would decrease viability of the seed the following spring. Immediately after harvest (fall 1986), seed of the variety K2 was spread out on a laboratory bench and three random samples (300 ml volume) taken 18 times during a 10 day period. The laboratory temperature was 70-76° F and the humidity was 40%. The samples were divided into two equal portions. Percent grain moisture for one portion was obtained by drying at 150° F for 7 days and the other portion was immediately put into water at each sampling. The seed in water was stored in a cooler at 38° F and germination checked the following spring. Germination was determined by placing the seed into a beaker (250 ml) of water kept at 70-76° F. The beakers were kept on the laboratory bench and the water changed every two days. Germinated seeds were counted and removed after 1, 2 and 3 weeks. Seeds were counted as germinated when the coleoptile had grown longer than the length of the seed. Two seed lots were evaluated; one that was cleaned for seed purposes by a commercial seed cleaning firm and one directly from the combine. Figure 3 shows the loss in grain moisture over the drying period for the 2 years combined and Figure 4 the germination in spring for the 2 years.

The percent moisture declined about 3.8% per day from 37 down to 10.5% up to the 7 day drying period but remained at 10.5% for the next 3 days. This was true for the cleaned and uncleaned seed lots. Germination, although somewhat erratic, increased initially from 40% to 70% after 2 days of drying. Then it decreased steadily to 0 after 10 days of drying (Figure 4). Based on 2 years results, loss of germination does occur if the seed is allowed to dry below 26% in the fall before storage in water. However, germination initially increased and some germination still occurs even if the seed is dried to 10% moisture.

Some of the same seed was also allowed to remain in plastic mesh bags (15 lbs each) in each of the 2 years on the laboratory bench and seed samples were removed for a period of 28 days. Percent grain moisture was determined at each sampling period and some seed at each sampling date was stored in water until the following spring when germination was determined. Seed was taken from the center of the bag at each removal date. Grain moisture and germination were determined as previously described. The experiment was conducted on two seed lots, one that was cleaned for seed and the other directly from the combine. Figure 5 gives the loss in seed moisture during the sampling period.

The loss in seed moisture was not as rapid as the seed spread out on

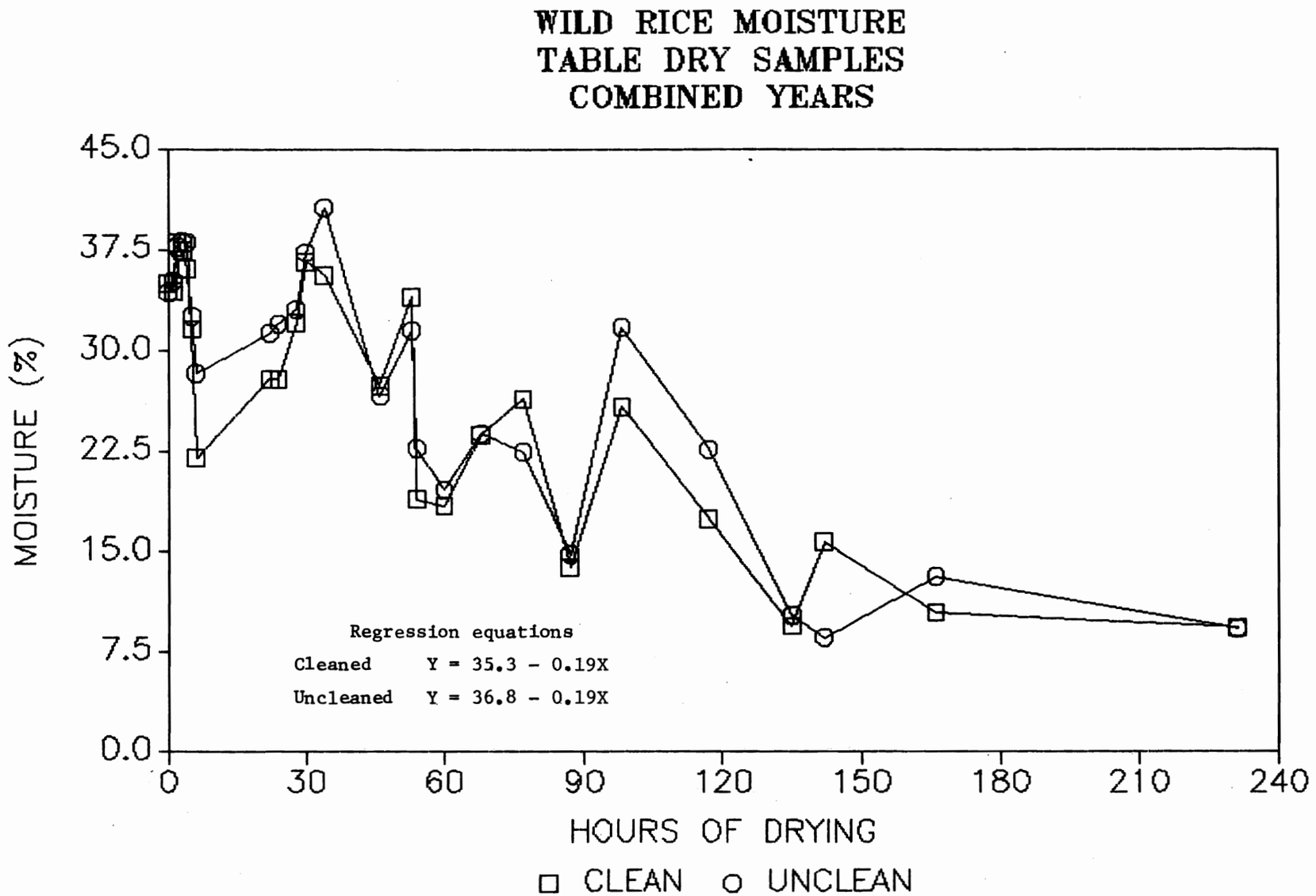

WILD RICE MOISTURE
TABLE DRY SAMPLES
COMBINED YEARS
45.0
37.5
30.0
22.5
15.0
7.5
0.0
MOISTURE (%)
0
30
60
90
120
150
180
210
240
HOURS OF DRYING
Regression equations
Cleaned Y = 35.3 - 0.19X
Uncleaned Y = 36.8 - 0.19X
CLEAN
UNCLEAN

Figure 3

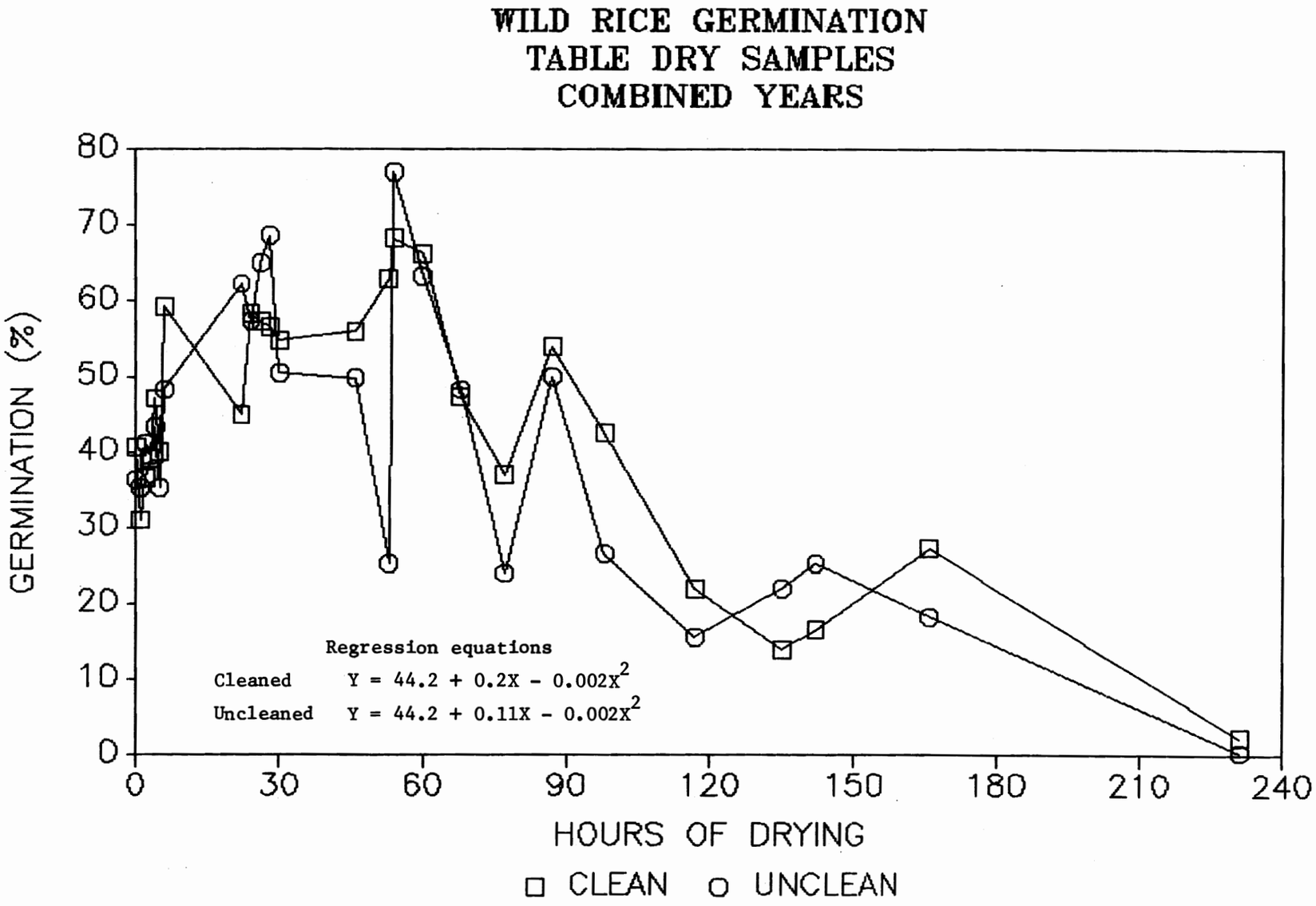

WILD RICE GERMINATION
TABLE DRY SAMPLES
COMBINED YEARS
GERMINATION (%)
80
70
60
50
40
30
20
10
0
0
30
60
90
120
150
180
210
240
HOURS OF DRYING
Regression equations
Cleaned Y = 44.2 + 0.2X - 0.002X2
Uncleaned Y = 44.2 + 0.11X - 0.002X2
□ CLEAN ○ UNCLEAN

Figure 4

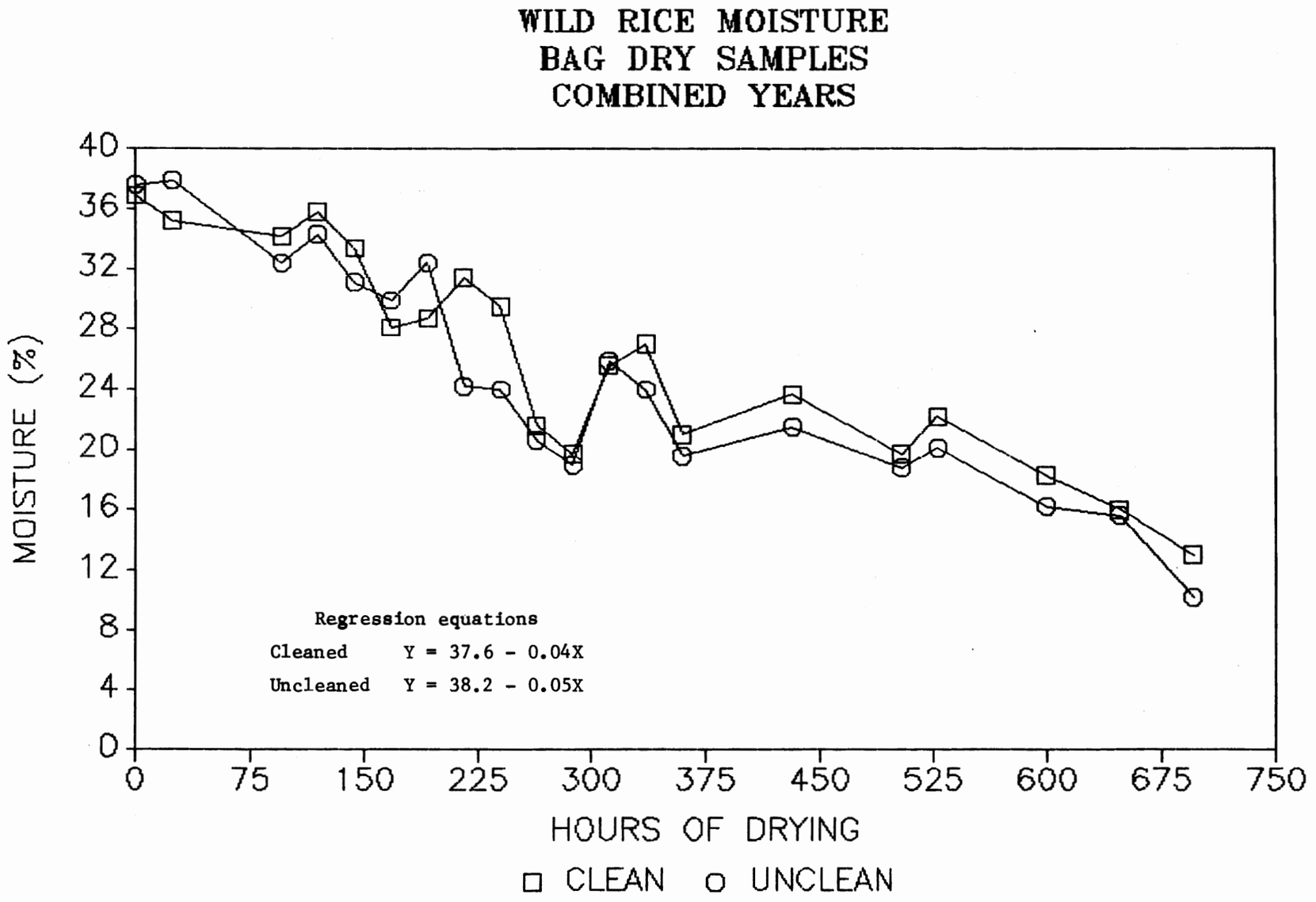

WILD RICE MOISTURE
BAG DRY SAMPLES
COMBINED YEARS
MOISTURE (%)
40
36
32
28
24
20
16
12
8
4
0
0
75
150
225
300
375
450
525
600
675
750
HOURS OF DRYING
Regression equations
Cleaned Y = 37.6 - 0.04X
Uncleaned Y = 38.2 - 0.05X
CLEAN
UNCLEAN

Figure 5

the bench (Figure 3). This was expected since the seed was confined in a mesh bag. The final moisture decreased to about the same compared for the seed on the bench. However, mold was evident on the hulls during the later sampling periods. Also the seed was heated to 110° F in the bags during the first few days. Germination percentages are given in Figure 6. There was actually an increase in germination for the cleaned seed during the first 13 days and then it decreased again but only to 45%. The average germination percent for the 2 years for the unclean seed was variable and did not show a trend.

Based on the 2 years of results seed can be allowed to dry down to about 26% moisture before loss of germination occurs. Leaving seed in plastic mesh bags prevents rapid moisture loss but molds quickly develop. It is desirable to put bagged seed into water within a day or two to prevent aerobic mold development.

Seed Viability After Exposure to Liquid Nitrogen

In 1987 an experiment was initiated to investigate if seed could remain viable if exposed to liquid nitrogen. This experiment is being done in cooperation with Dr. Phillip Stanwood of the National Seed Storage Laboratory, Fort Collins, Colorado.

Seed was allowed to dry down in the laboratory as previously described for a period of 12 days. Each day about 100 grams of seed were collected and sealed in a bottle. Three random samples were taken each day. The seed was sent to Dr. Stanwood for determination of whole seed moisture and freezable water. Some of the seed was also subjected to liquid nitrogen temperatures (-196° C) for approximately 24 hours. Viability of the seed was tested by the tetrazolium test.

Figure 7 shows the seed moisture decline over the 12 day sampling period. Moisture decreased from 35 to 13%. Figures 8, 9 and 10 show the detection of freezable water in the seed. The amount of freezable water (DTA) declines as moisture declines and by day 7 no freezable water was detected. Since no freezable water can be detected at this seed moisture (21%) it should be possible to store seed at this moisture level at liquid nitrogen temperatures. Table 12 shows the tetrazolium viability tests for seed subjected to liquid nitrogen temperatures.

Much of the nontreated seed tested positive even at 13% moisture (Table 11). However, the liquid nitrogen treated seed did not test positive except at 15 and 13% moisture. A germination test by scarification was also done on the same seed samples. The aleurone layer was carefully scraped off above the embryo and the seed germinated in beakers as described previously. Table 13 shows the germination of the liquid nitrogen exposed and unexposed seed. Germination by scarification was much lower than indicated by the tetrazolium test. Even the untreated seed had poor germination. No germination was obtained at any of the seed moistures. Some of the same seed samples were stored in water (38° F) and will be checked for germination after 3 months in cold storage.

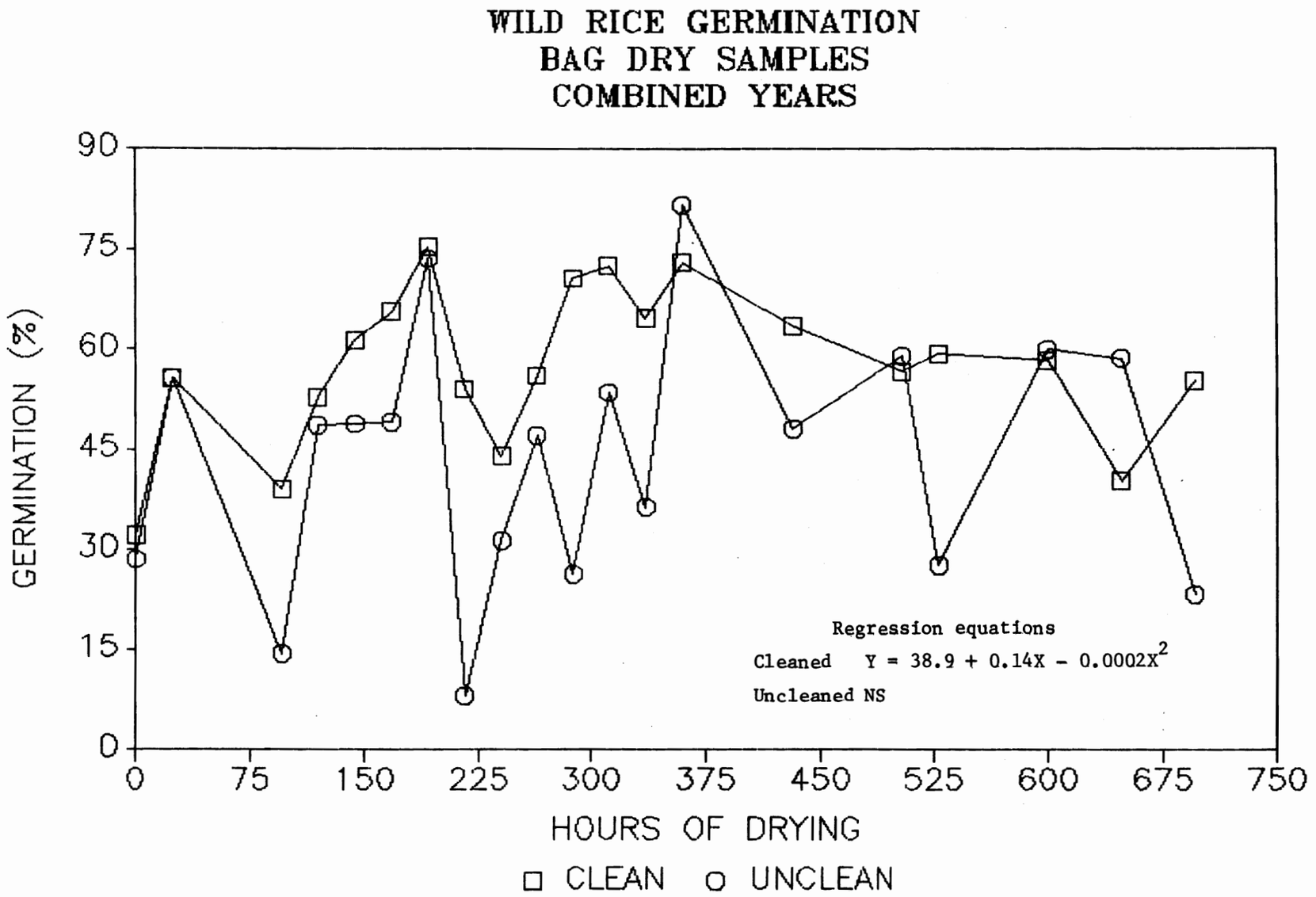

WILD RICE GERMINATION
BAG DRY SAMPLES
COMBINED YEARS
GERMINATION (%)
90
75
60
45
30
15
0
0
75
150
225
300
375
450
525
600
675
750
HOURS OF DRYING
Regression equations
Cleaned Y = 38.9 + 0.14X - 0.0002X2
Uncleaned NS
CLEAN
UNCLEAN

Figure 6

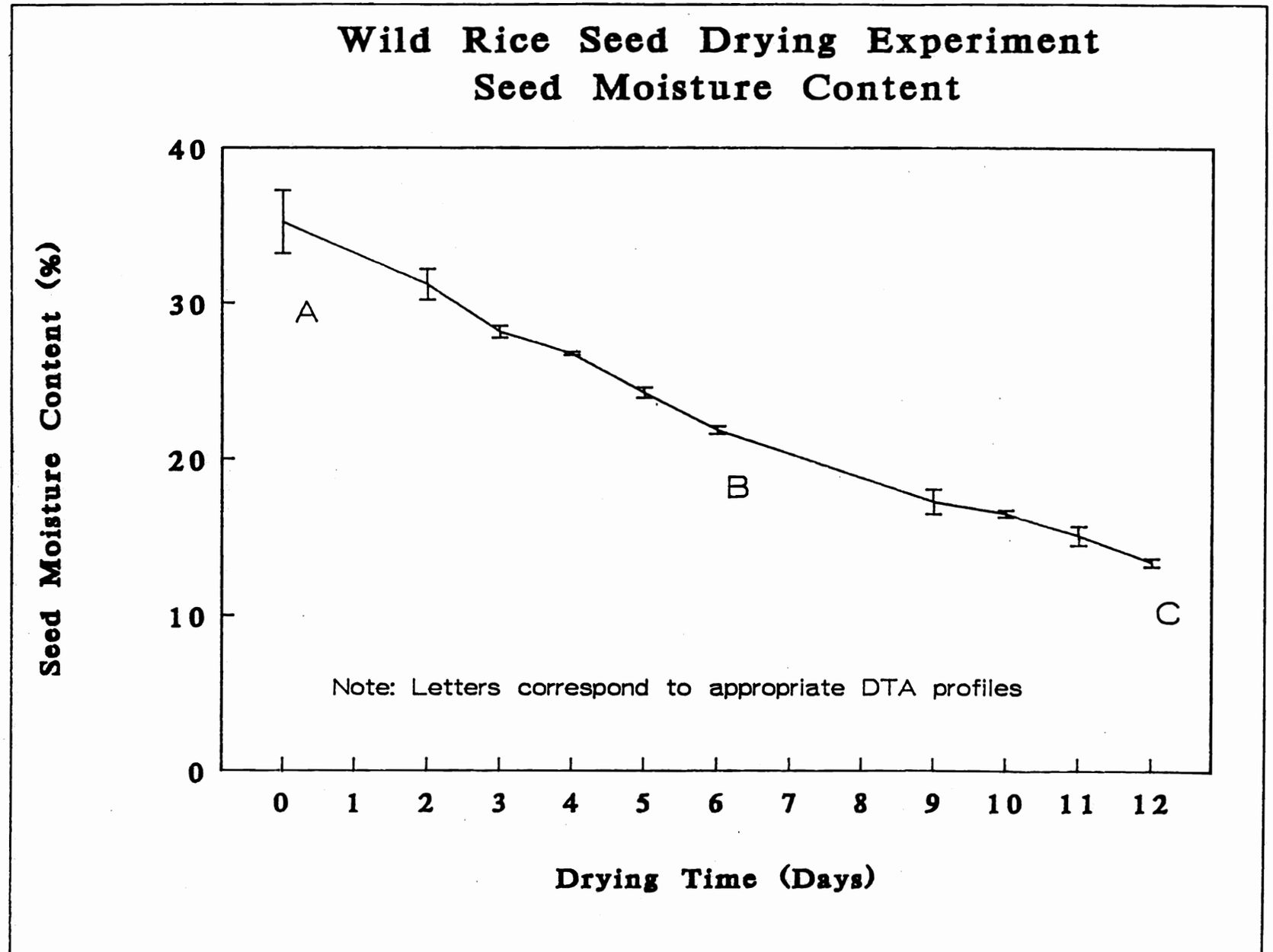

Wild Rice Seed Drying Experiment
Seed Moisture Content
Seed Moisture Content (%)
40
30
20
10
0
A
B
C
Note: Letters correspond to appropriate DTA profiles
0 1 2 3 4 5 6 7 8 9 10 11 12
Drying Time (Days)

Figure 7

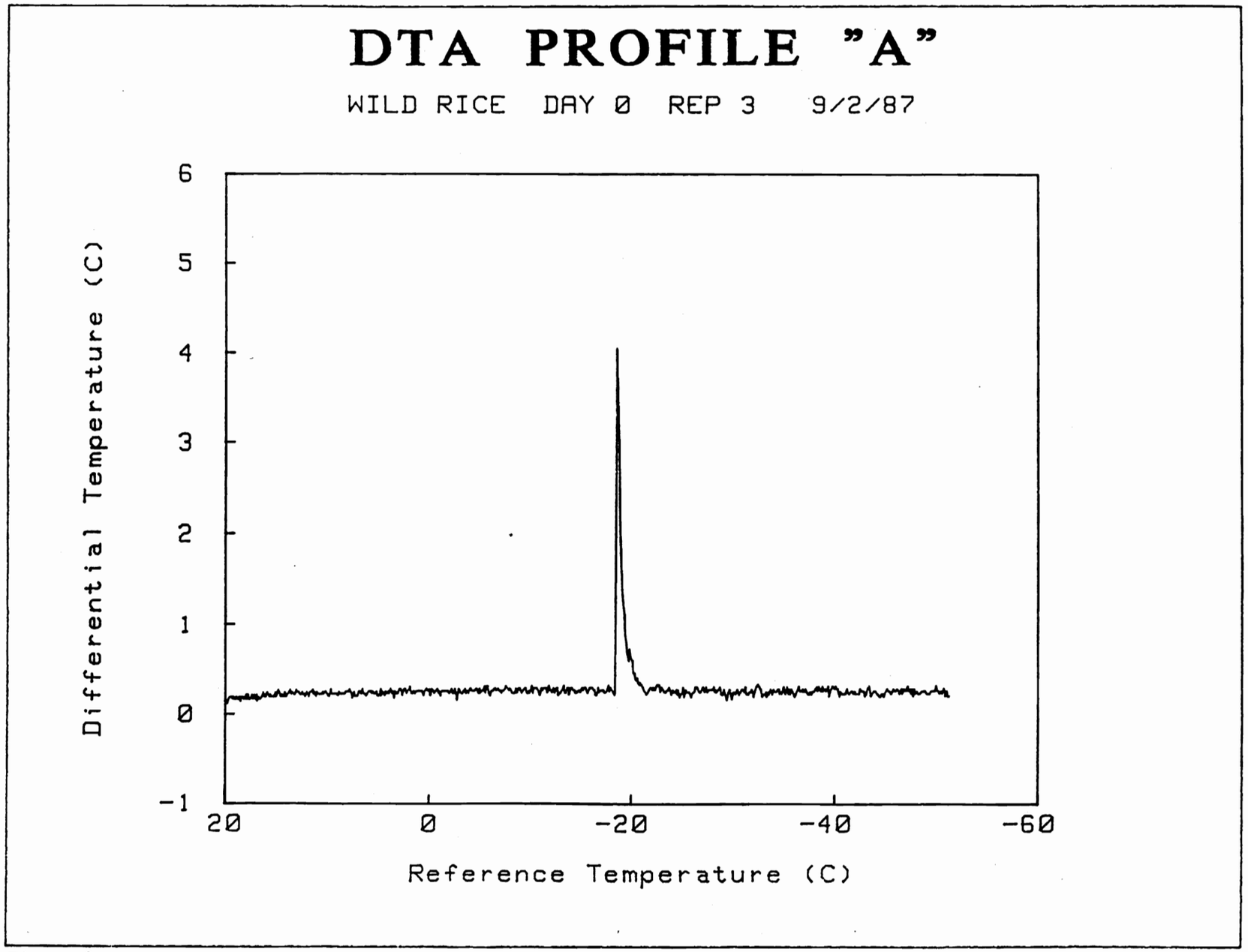

DTA PROFILE "A"
WILD RICE DAY 0 REP 3 9/2/87
Differential Temperature (C)
6
5
4
3
2
1
0
-1
20
0
-20
-40
-60
Reference Temperature (C)

Figure 8

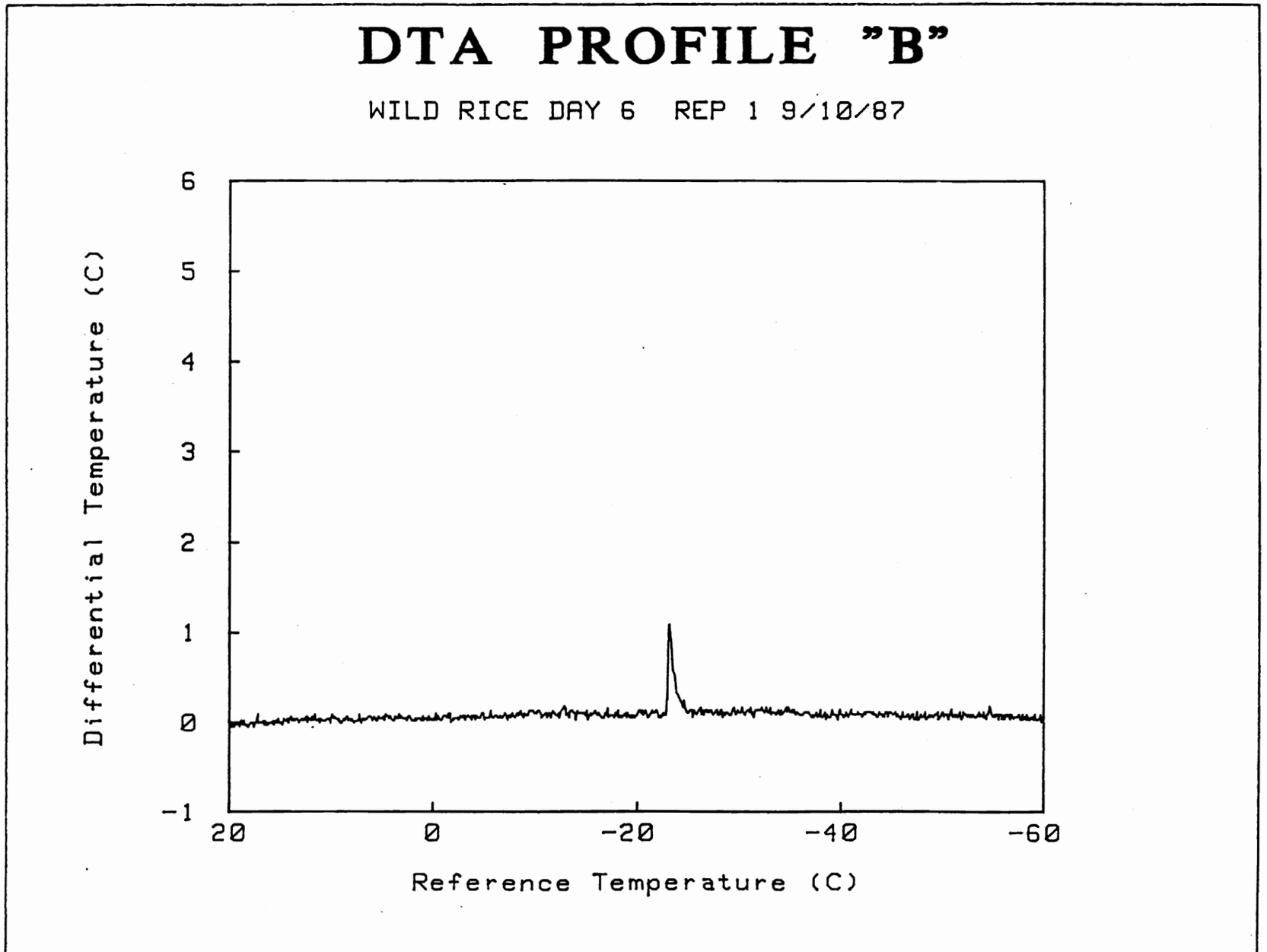

DTA PROFILE "B"
WILD RICE DAY 6 REP 1 9/10/87
Differential Temperature (C)
6
5
4
3
2
1
0
-1
20
0
-20
-40
-60
Reference Temperature (C)

Figure 9

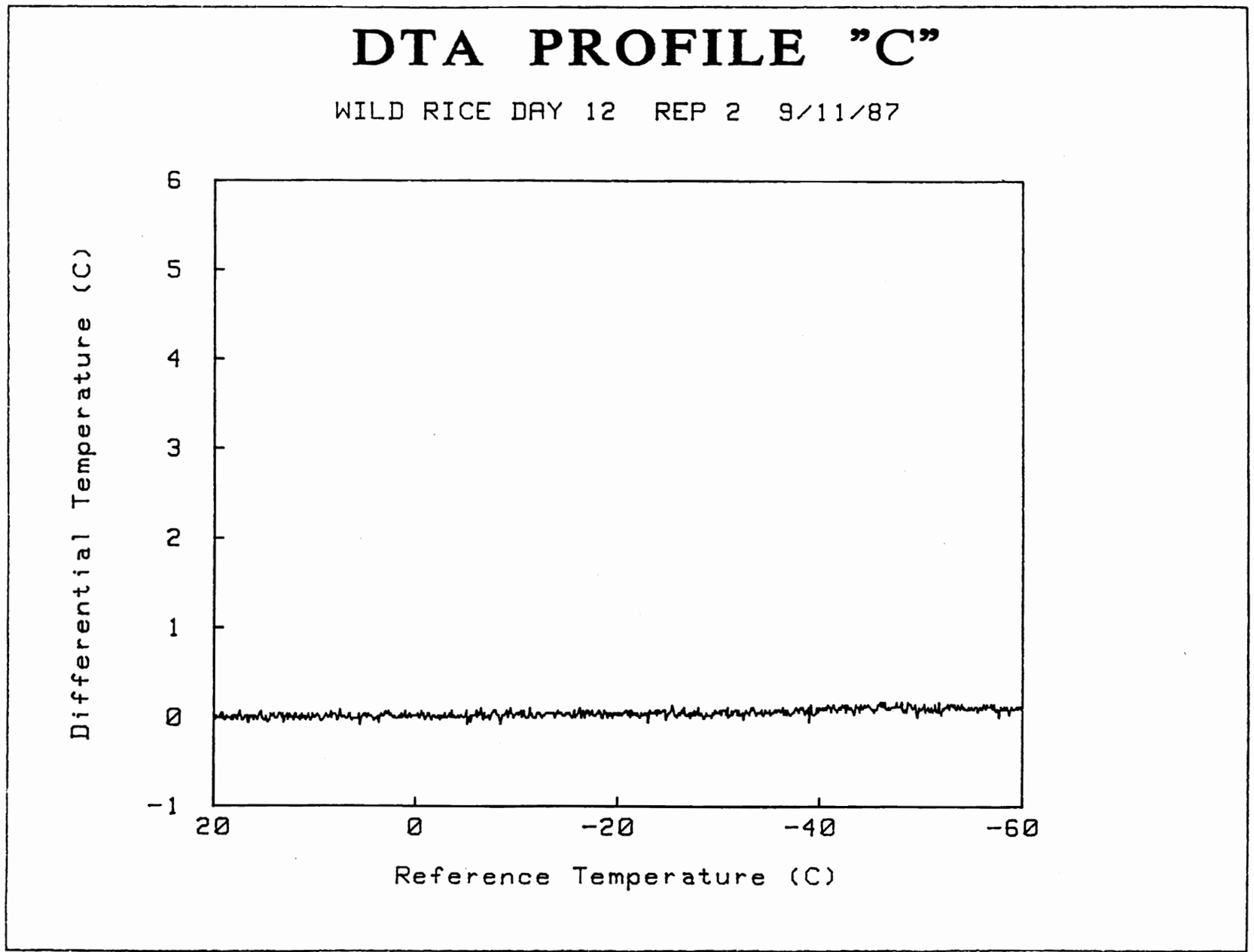

DTA PROFILE "C"
WILD RICE DAY 12 REP 2 9/11/87
Differential Temperature (C)
6
5
4
3
2
1
0
-1
20
0
-20
-40
-60
Reference Temperature (C)

Figure 10

Table 12. Wild rice seed air dried. Exposed to liquid nitrogen and evaluated for vital staining using the TZ test.

Air drying time	Seed moisture	Positive TZ Stained (25 seeds)[a]	
		Control	LN2 exposed
Days	%		
0	35.2	23.0a	0.7e
2	31.2	23.0a	0.7e
3	28.1	21.7abc	2.0e
4	26.7	20.7abcd	6.0e
5	24.2	22.3ab	1.0e
6	21.8	20.3abcd	0.0e
9	17.3	14.7d	2.0e
10	16.5	18.3abcd	6.0e
11	15.1	15.7cd	15.0d
12	13.4	18.3abcd	16.7bcd

[a] Means followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 13. Wild rice seed air dried. Exposed to liquid nitrogen and evaluated for germination by scarification.[a]

Air drying time	Seed moisture	Germination (25 seeds)	
		Control	LN2 exposed
Days	%	------- numbers	--------
0	35.2	16	0
2	31.2	12	0
3	28.1	9	0
4	26.7	6	0
5	24.2	5	0
6	21.8	0	0
9	17.3	0	0
10	16.5	3	0
11	15.1	1	0
12	13.4	3	0

[a] Evaluated on 10/16.

It appears that even though no freezable water was observed at the low moisture levels subjecting the seed to liquid nitrogen, temperature is lethal. Since part of the seed subjected to liquid nitrogen temperature was placed in water after treatment, germination will again be determined after the seed has been in cold (+2° C) for three months.

Acknowledgement

We wish to thank Henry Schumer, plot coordinator at Grand Rapids, for his continued support. The help of Drs. Nyvall, Boedicker and Rabas at Grand Rapids was much appreciated. Numerous growers allowed us to sample fields and their cooperation is greatly appreciated. The help of George Shetka and Bob Racek at the Aitkin location is deeply appreciated.

SILICON AND NITROGEN NUTRITION OF WILD RICE

Paul Bloom and Mike Meyer[1]
Soil Science Department

During the past year we have studied several fertility factors concerning wild rice. Our efforts have concentrated on silicon (Si) and nitrogen (N) nutrition of wild rice but we have also looked at sulfur (S), to some extent, and the routine analysis of other elements. In this report we will present the following:

A. Plant uptake of silicon and nitrogen in a 1986 nitrogen rate study at Aitkin (Hedstrom).

B. Plant response to a high silica slag in 1987 at Aitkin (Shetka).

C. Nitrogen mineralization and silicon availability in 51 wild rice paddy soils.

D. A brief discussion of plant response to a paper mill fly ash.

E. Tentative results of a greenhouse silicon and nitrogen study.

A. Plant Uptake of Silicon and Nitrogen, 1986:

Randomized field plots 40 by 200 feet were treated with 0.0, 30, 75, and 150 lbs urea-N/acre and replicated eight times. Urea was broadcast and rotovated to six inches. Care was taken to rotovate with slow forward motion to incorporate the urea throughout the soil plow layer. Deep placement of urea would have been preferred but was not possible due to very wet conditions in the Fall of 1985. Hand harvested wild rice was sampled from each plot by combining three separate one square yard samples. Plants were cut one inch above the soil to obtain the above ground plant biomass produced per unit area.

The processed yield increased from 264 lbs/acre in the control to 366 lbs/acre with the high nitrogen treatment, an increase of 36% (Fig. 1). The harvest index (HI) was approximately 7% in all treatments. Harvest index is the mass of the processed wild rice yield divided by the total dry biomass of plant production per acre. The harvest index for wheat or corn is usually 45 to 50%.

The increased yield was due to increased mass per panicle rather than an increase in panicle number (Fig. 2). The seed

1. Associate Professor and Graduate Research Assistant

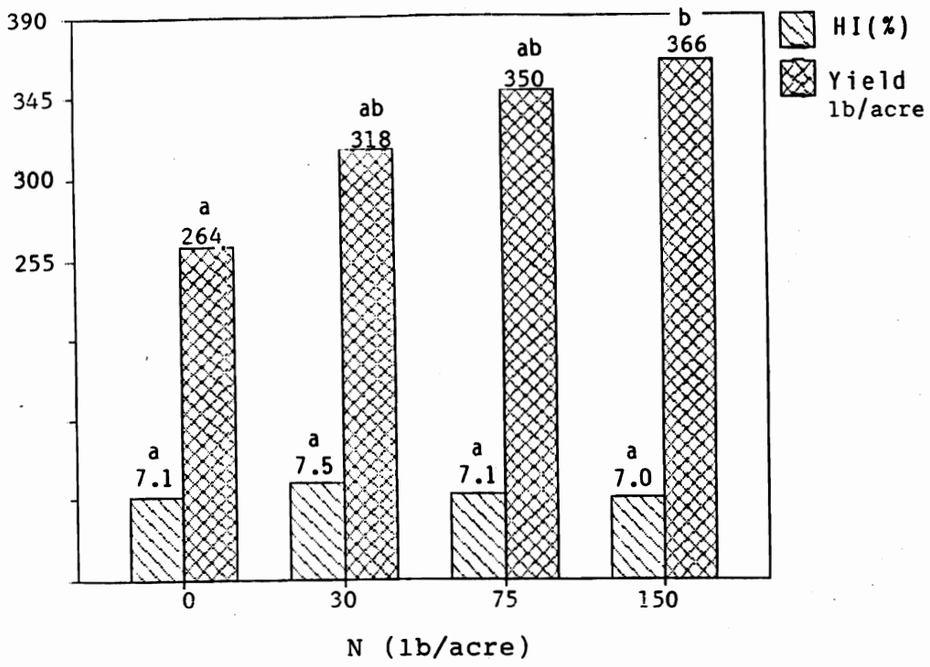


Fig. 1. Processed yield and harvest index (HI).

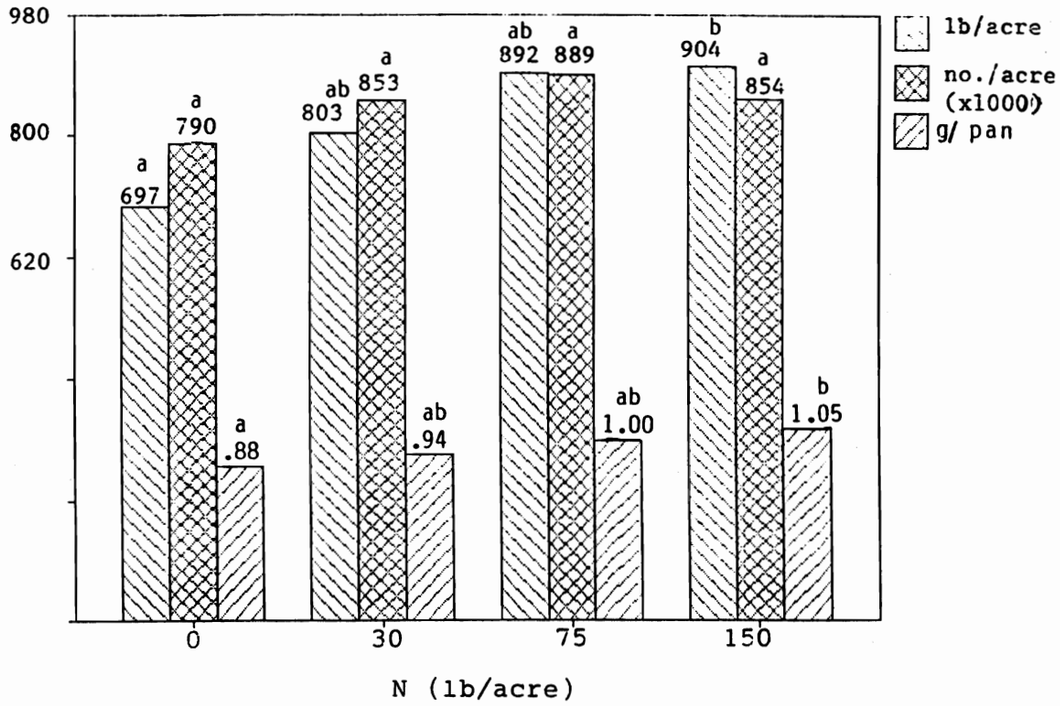


Fig. 2. Panicles: lb/acre, number/acre, and grams/panicle.

weight, as determined from the 100 seed weight, did not change with N treatment (data not shown) indicating that seed size did not change with increased nitrogen.

The N and Si content in the straw was affected by the increased application of nitrogen fertilizer (Fig. 3). Silicon in the straw decreased from 1.8% to 1.3% when N application increased from zero to 150 lbs/acre. Nitrogen in the straw increased from 0.95% to 1.2% with increased application of urea.

Using the total plant biomass per acre and the concentration of a nutrient in the tissue we can calculate the "uptake" of a plant nutrient from the soil. The nitrogen uptake in the control was only about 33 lbs/acre but it increased to about 58 lbs/acre with the 150 lb. N treatment (Fig. 4). There was no change, however, in the Si uptake from the soil with increased N application. The silicon uptake remained at approximately 62 to 67 lbs/acre across all N treatments (Fig. 4.). With increased plant biomass from the addition of more N the Si was "diluted" by increased biomass.

At the high N rate (150 lb/acre) there was some lodging. Furthermore, the increase in yield was not economical when compared to the 75 lb/acre treatment.

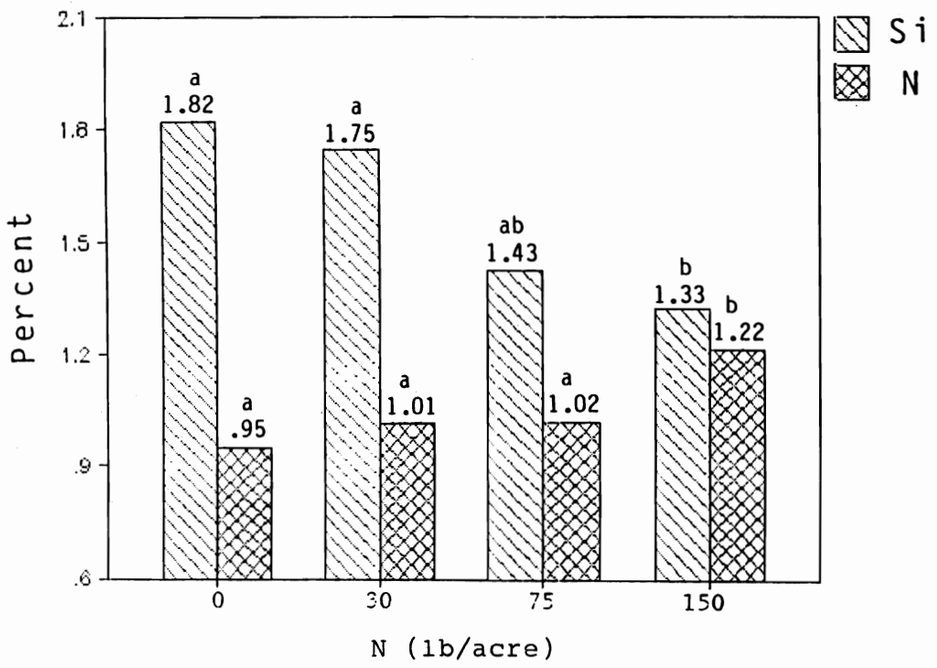


Fig. 3. Straw N% and Si% vs N rate.

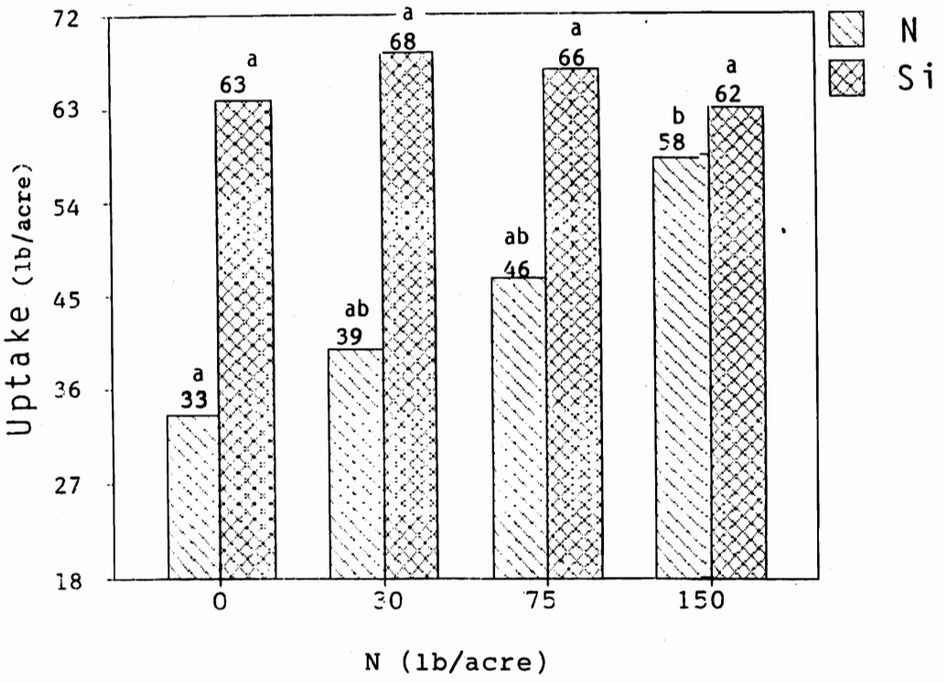


Fig. 4. N and Si plant uptake.

B. Plant Response to High Silica Slag, 1987:

Coinvestigators: Jim Percich and Richard Zeyen
Department of Plant Physiology

Partial funding supplied by the Minnesota Wild Rice Council
and Progress Fertilizer, Inc.

In the Spring of 1987 twenty-two tons of slag (calcium silicate) was donated to the University of Minnesota, Soil Science Department, by Progress Fertilizer of Florida for wild rice research.

Joe Shetka provided a one acre site on organic soil. The soil was approximately 25% ash with a pH of 6.5. Slag and agricultural lime (calcium carbonate) treatments were broadcast and rotovated at zero, one, three, and six tons per acre and replicated four times in a complete randomized block design with each plot 20 by 30 feet. The paddy was treated with 60 lbs/acre of N. Hand harvested plant biomass and processed yield were determined in 4 by 4 ft subplots.

Yield increased from 326 lbs/acre in the control to 485 lbs/acre with the the high slag treatment, an increase of 49%. (Fig. 5). There was no increase in yield with any of the lime treatments. The incidence of brown spot was decreased by about 50% with the high slag treatment (see the Plant Pathology report). Harvest index remained the same across all slag treatments at approximately 8% (Fig. 5). The yield increase is due to an increase in the number of panicles per acre (Fig. 6).

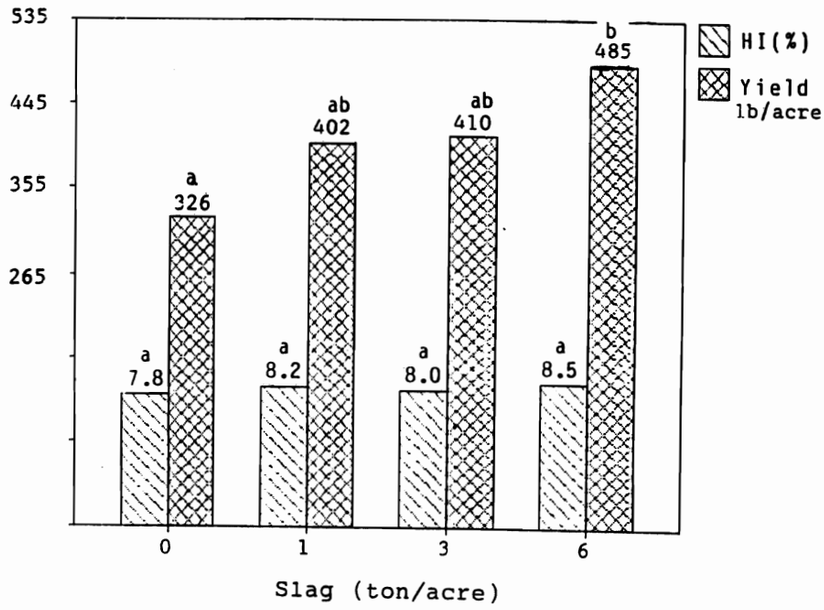


Fig. 5. Processed yield and harvest index (HI).

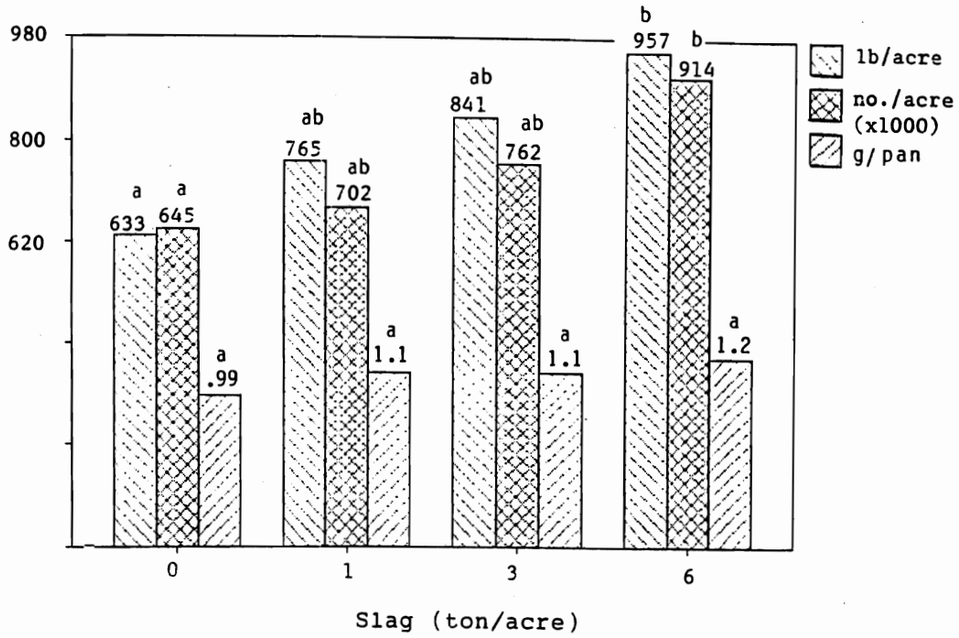


Fig. 6. Panicles: lb/acre, number/acre, and grams/panicle.

There was a very significant increase in Si in the straw with increased slag application (Fig. 7). In the control Si was 1.7% and in the six ton slag treatment 3.9%. The data suggest that the plant has the potential for a much greater Si content. The Si in a straw sample from a mineral paddy soil near Aitkin (Ward) was approximately 7.0% Si.

The uptake of silicon from the soil, which increased from 59 lbs/acre in the control to 182 lbs/acre in the high slag treatment, was only about 7% of the Si applied (Fig. 8).

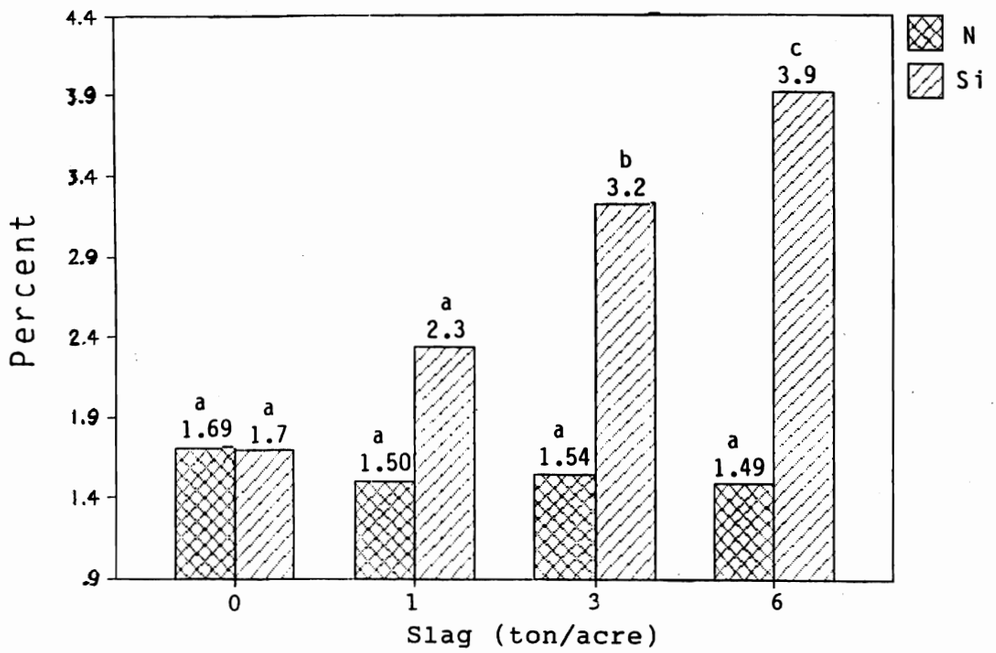


Fig. 7. Straw N% and Si% vs Slag rate.

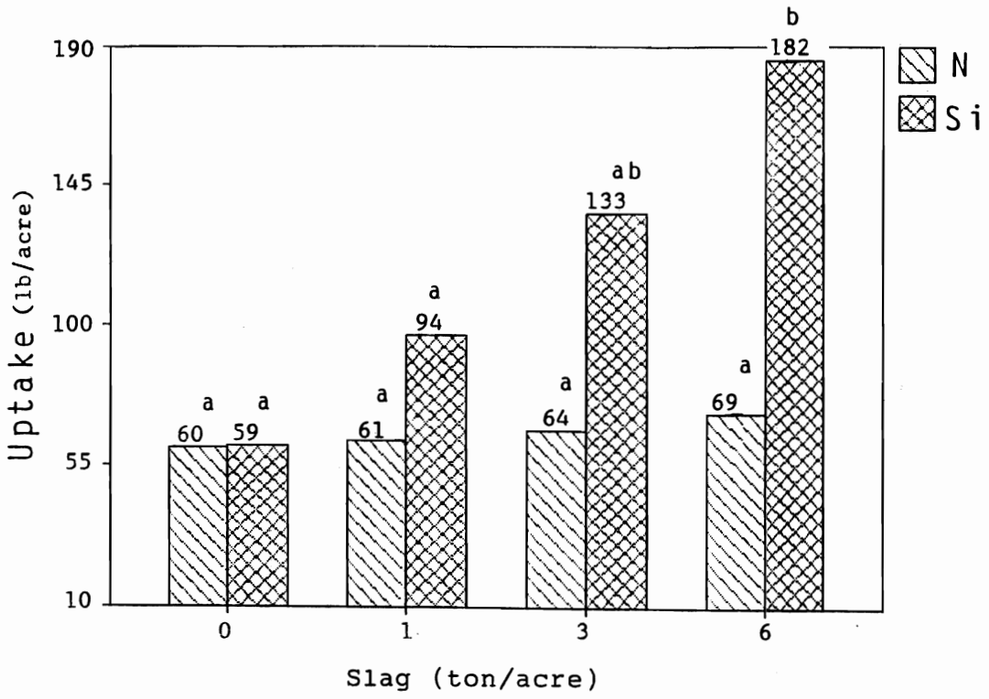


Fig. 8. N and Si plant uptake.

C. Nitrogen Mineralization and Silicon Availability Study:

Paddy soil samples were collected from 51 sites at the following growers: T. Godward (G), Kosbau Bros. (K), J. Shetka (J), University of MN experimental paddy (U), D. Brink (B), P. Olson (O), R. Skoe (S), P. Imle (I), and A. Hedstrom (H). The soils were characterized for pH, the ash content (485 degrees centigrade), bulk density (g/cm3), and organic nitrogen content.

Ash contents ranged from 4.4% to 96% and pH ranged from 4.5 to 7.9. When the soil ash content is greater than 30% soil pH is generally greater than 6.5 (Fig. 9).

Bulk density of flooded soils was determined by flooding a soil sample for two days and determining the grams of soil (dry weight basis) in a cubic centimeter. The results (Fig. 10) indicate a strong relationship between ash content and bulk density. Soils with a low bulk density have high organic content and low ash.

The content of organic nitrogen per unit weight of soil is

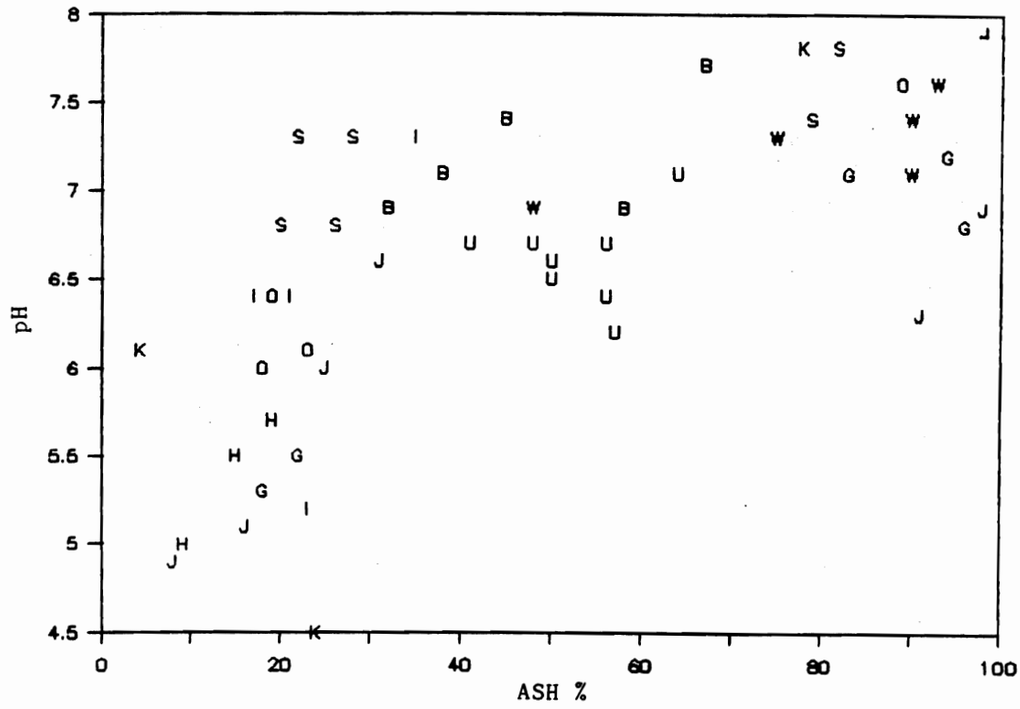


Fig. 9. Soil pH vs ash content.

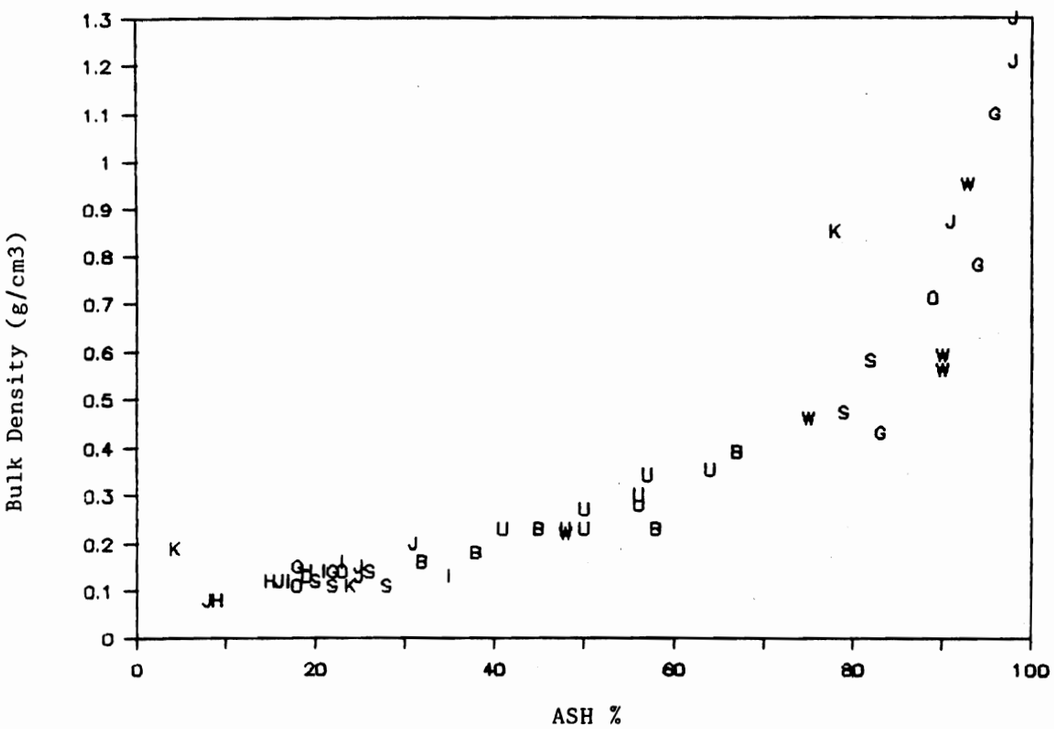


Fig. 10. Soil bulk density vs ash

much greater in the low ash, high organic matter peats (Fig. 11). If however, nitrogen contents in Figure 11 are multiplied by bulk density to give a volumetric organic N content (ug/cm3) the N content of the low ash soils is not greater than that of the high ash soils (Fig. 12). Since the plow layer of a soil represents a fixed volume of soil regardless of bulk density, the volumetric N content is proportional to the N content in the plow layer.

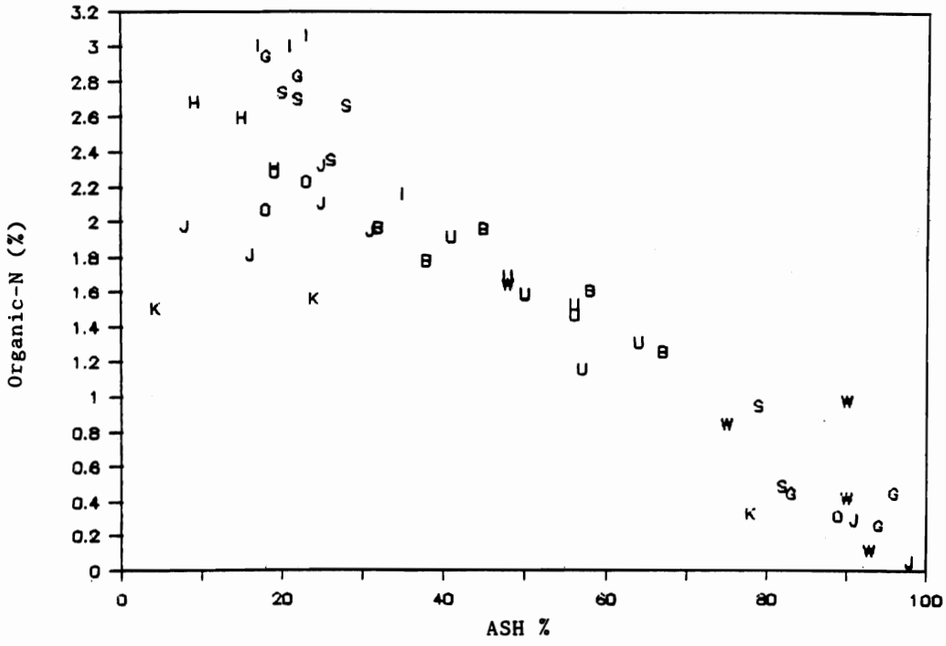


Fig. 11. Organic nitrogen vs ash.

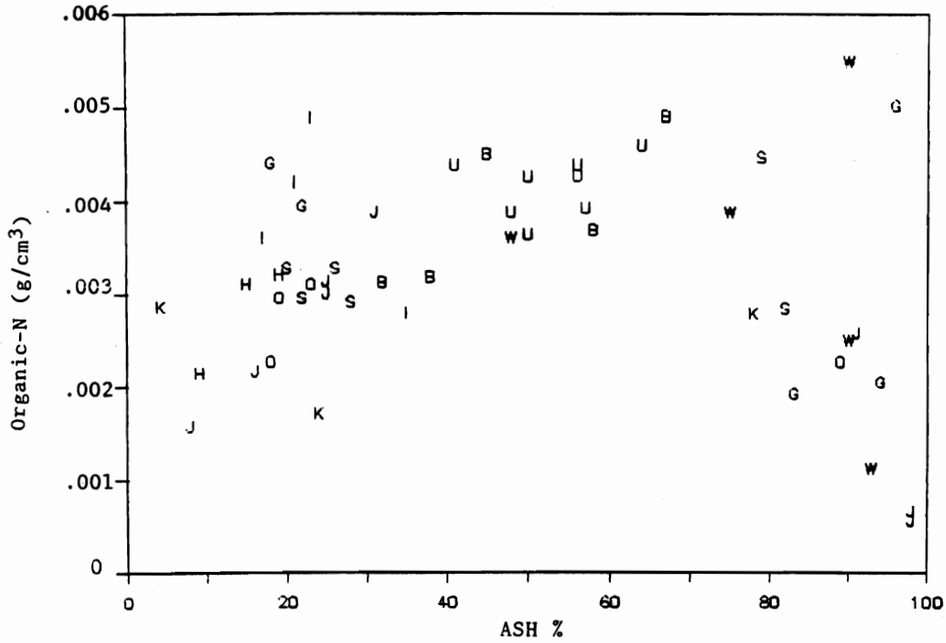


Fig. 12. Volumetric organic-N content vs ash.

The next part of our experiment was to assess the potential of soils to mineralize nitrogen. Each soil was flooded and incubated anaerobically (without air) for seven days at 40°C. The soils were then analyzed for the amount of available inorganic nitrogen produced. The mineralized nitrogen in micrograms (ug) per gram of soil is plotted against the soil ash content (Fig. 13). The low ash peats tend to produce more available nitrogen than the high ash soils. However, when these results were corrected for bulk density to determine the quantity of N mineralized by a volume of soil we found that soils with 10% to 80% ash had no difference amoung soils (Fig. 14). When the ash content is greater than 80% there is less available mineralized nitrogen in a plow layer.

Some of the soils mineralized high amounts of nitrogen (B and O samples). These soils had been recently tilled at the time of sampling and contained large amounts of poorly decomposed straw.

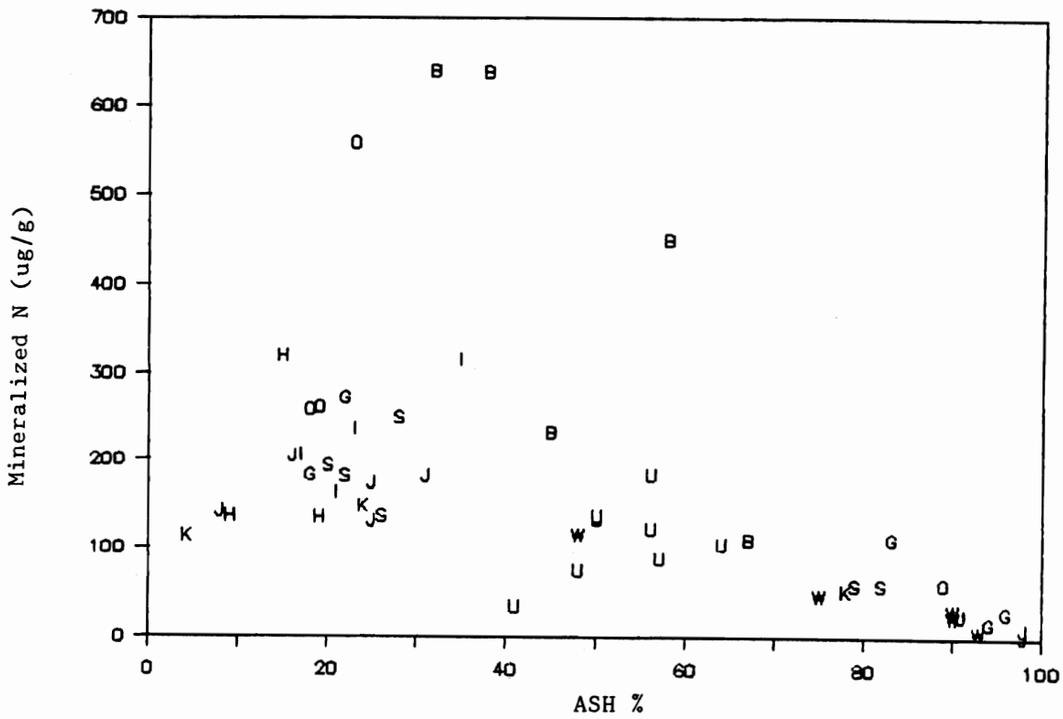


Fig. 13. Mineralized N vs ash.

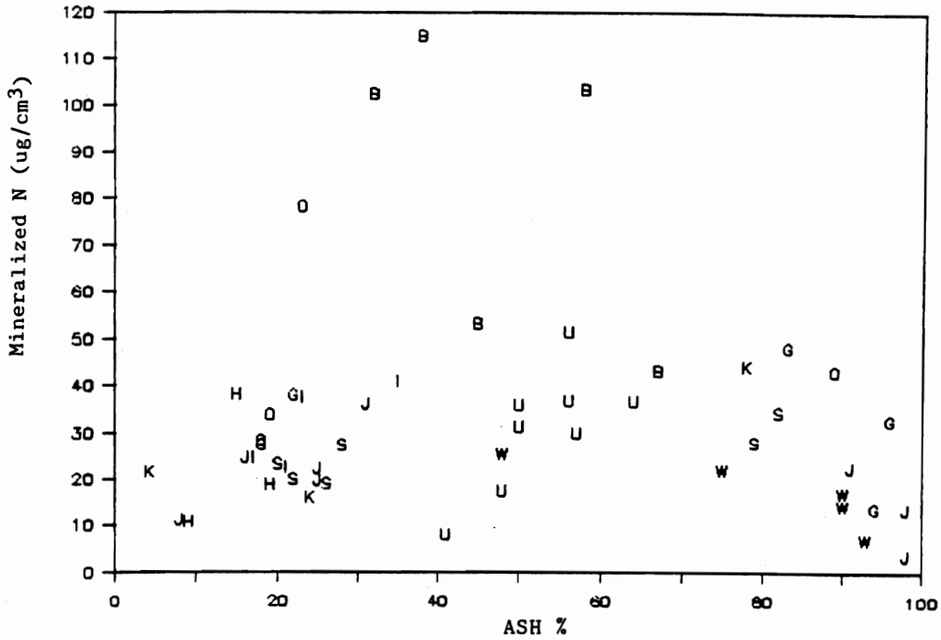


Fig. 14. Volumetric mineralized N content vs ash.

Mineralized nitrogen was also plotted against soil organic N (Fig. 15). As organic N increases mineralized N also increased. But, when we correct for bulk density almost all soils produce a similar amount of available N in a given volume of soil (Fig. 16).

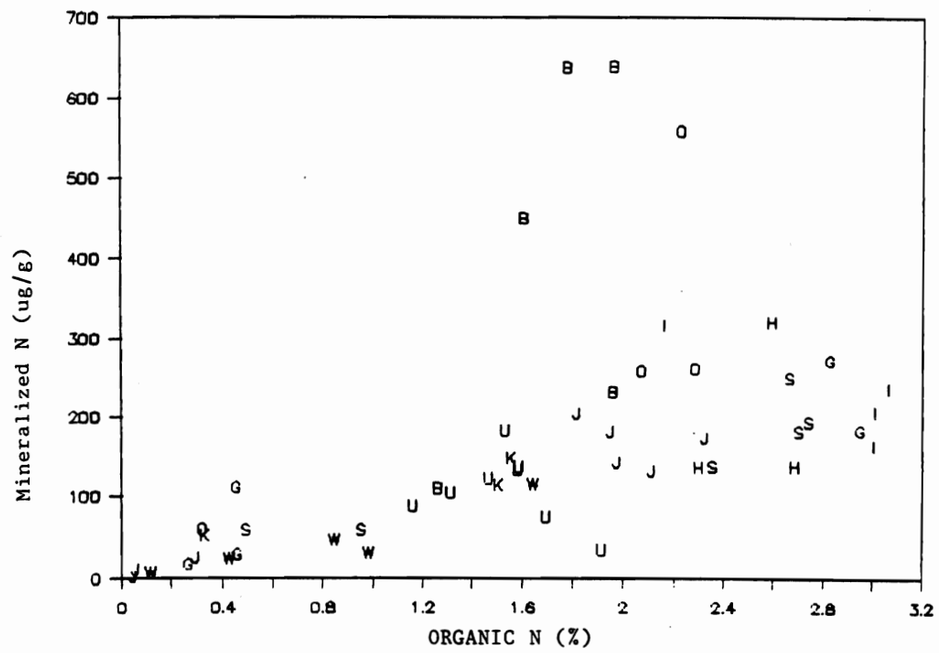


Fig. 15. Mineralized N vs soil organic-N.

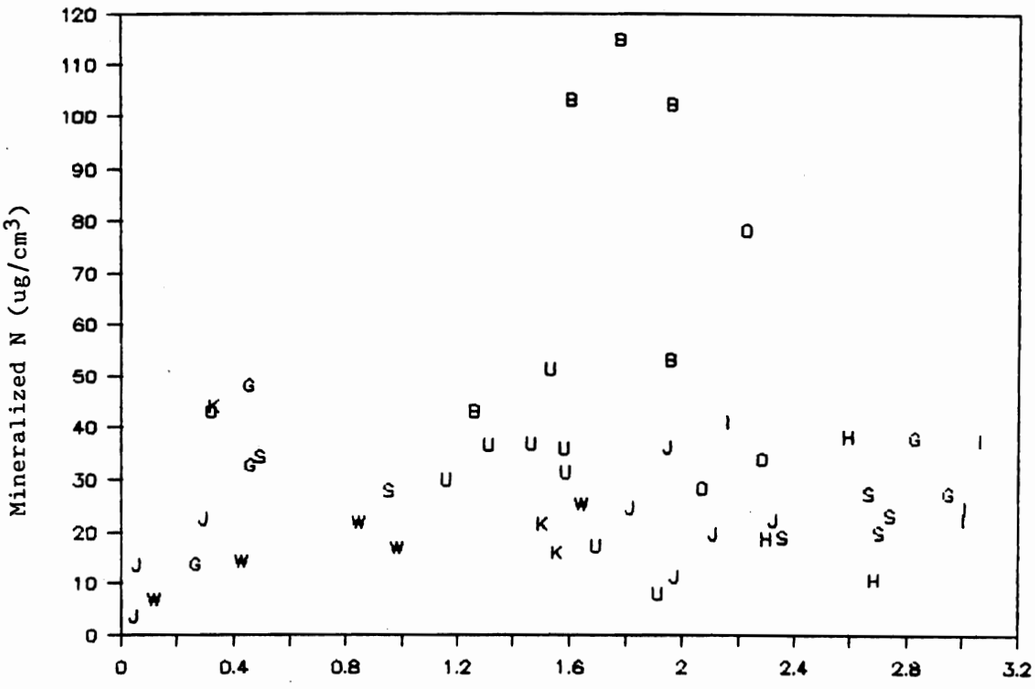


Fig. 16. Volumetric mineralized N content vs organic-N.

The soil pH does not have much effect on nitrogen supplying power of the soil. There was a poor relationship between mineralizable nitrogen and pH.

Our next experiment was to look at the ability of each soil to supply silicon (Si). In this procedure soils were extracted with distilled water for three days and then the solutions were analyzed for Si. The first step was to calculate and plot the amount of soluble Si in micrograms per gram (ug/g) of soil (Fig. 17). We were surprised to find that the low ash peats produced more Si per gram than the high ash peats. But, correcting for bulk density shows that the high ash soils produce the greatest amount of Si per unit volume of soil for mineral soils (greater than 80% ash). However, the amount of Si produced in the peats does not appear to be ash dependent.

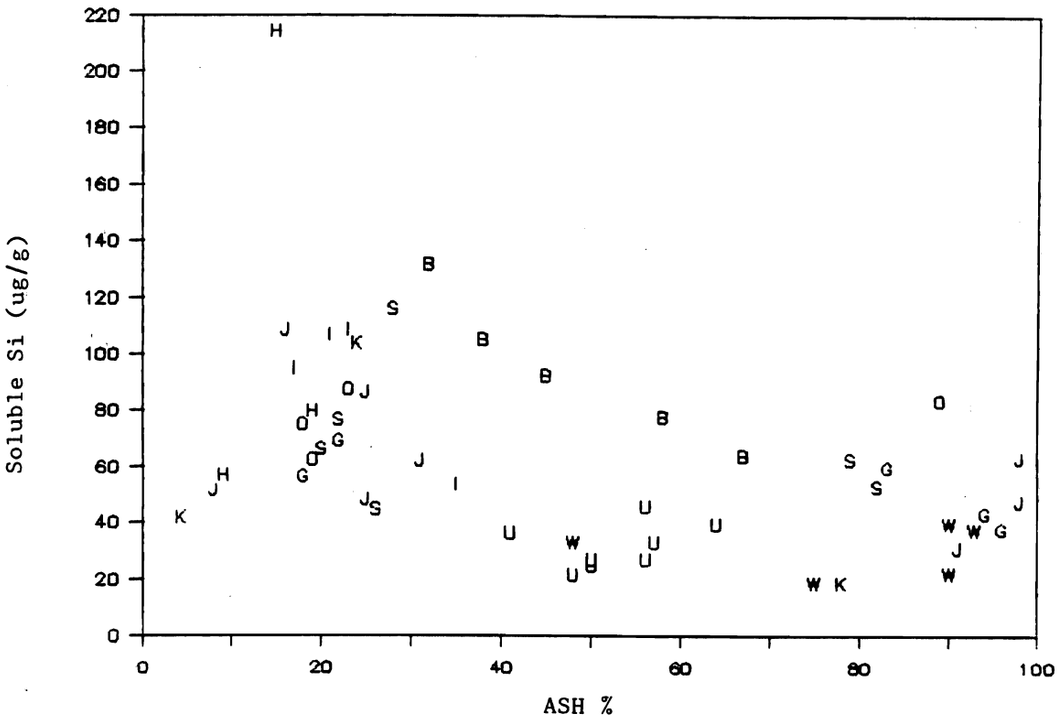


Fig. 17. Soluble Si vs ash.

D. Paper mill fly ash and wild rice.

Very preliminary yield results suggest that the addition of a coal/wood fly ash to peats that have low fertility can increase yield. The tissue analysis, however, show that the yield increase is not due to an increase in Si. With increasing yield tissue Si concentrations decreased because of the dilution of the limited available Si (unpublished data). The only element that was determined to increase with fly ash was sulfur but the evidence is hardly conclusive, especially since the measured sulfur in the straw was well within the published adequate range for white rice.

E. Greenhouse silicon and nitrogen study:

A greenhouse study was conducted to determine if silicon addition to a low ash peat could reduce transpiration and decrease leaf angle. The results indicate that silicon may reduce transpiration and decrease leaf angle. Plants with low Si content tended to have weaker stems and more delicate leaves. However, the results are not conclusive and need further investigation.

Acknowledgement

We would like to thank Ron Nelson for arranging funding with the Wild Rice Research Council for part of research. We thank Joe Shetka for the use of a tractor, rotovator, and field hands. We would also like to thank Henry Shomer for soil sampling.

Wild Rice Breeding

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Meter planting density experiment

Six planting densities, .5, 1.0, 1.5, 2.0, 4.0 and 8.0 plants per square foot were evaluated at Aitkin using the variety Meter. Our objective was to investigate the response of Meter to increasing plant density. Four-row plots, ten feet long in rows spaced 15 inches apart were established in low and high seeding rates. At approximately first aerial leaf growth stage, the low rate plantings were thinned to .5, 1.0, or 1.5 plants per square foot, and the high planting rate plots were thinned to the 2.0, 4.0 or 8.0 plants per square foot densities. The seeding rates were established prior to planting such that the experiment was arranged as a randomized complete block design with eight replicates. Stand counts were made at late first aerial to tillering stage to determine the actual stand densities. The high rate plots did not have sufficient plants to permit thinning to 8 plants per square foot. Final densities are given in Table 1. Periodic observations of the plots indicated good uniformity and few weed problems. A severe thunderstorm July 28 caused complete lodging in the area of the Meter plots, but Meter was largely unaffected. A general incidence of disease (leaf blight) was noted on July 25. The disease spread throughout much of replicates 1 through 4, but did not significantly affect reps 5 through 8--some 30 feet removed. The disease effect was of considerable interest in that the density of plants in the plots had no obvious effect on the spread of the disease or its final effect. Notes on plant height were taken prior to harvest, as were notes on disease rating. At harvest, stems from the center two rows of each plot were hand harvested, counted, and subsequently threshed with a Vogel plot thresher. Green weight of grain was recorded, grain samples were dried at Grand Rapids and reweighed to permit calculation of % dry weight at harvest.

Replicates 1 through 4 were harvested August 14 because of concern for the disease incidence. Replicates 5 through 8 were harvested Aug. 17. Since the border rows appeared to be retaining seed near the end of August, we harvested them at time of plot clean-up on other experiments in the area (September 3). Results are presented from the center rows averaged over all replicates in Table 1 and by the harvest dates for dry weight and percent dry weight in Table 2.

No response of plant height to increased planting density was found, but maturity as measured by % dry weight, stem number and grain weight showed significant increases (Table 1). Stem number increased significantly as did yield; stems per plant appear to reflect the wild

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rice plants' ability to adjust for low stand density by tillering. The yield increases, while significant, must be regarded with caution. The August 17 harvest (Table 2) and the late harvest indicate to us that at least two plants per square foot would be desirable. Because of the disease problems in wild rice, we believe stand densities should be kept low if yield is not significantly reduced.

Table 1. Agronomic data from the variety Meter evaluated [1/] at six planting densities at Aitkin, MN (planted May 29, 1987).

Planting density	Stand density	Plant height	% Dry weight	Stem number	Stems per plant	Grain[2/] weight
-----plants/ft^2-----		inches	%			--lb/A--
.5	.7	57.5	62.2	134	9.3	378
1.0	1.2	59.1	62.3	155	6.5	443
1.5	1.8	58.3	64.3	152	4.2	485
2.0	2.5	59.1	65.0	195	3.9	572
4.0	4.6	59.8	65.1	224	2.4	634
8.0	6.5	59.4	65.1	255	2.0	727
LSD (5%)	--	NS	.4	10	--	106

[1/] 4-row plots in 15-inch rows ten feet long; 8 replicates.
[2/] Grain weight dried to approximately 7% moisture, hulls included.

We were impressed by the yield of the late harvest--just slightly less than the yield at August 17. However, these data reflect largely the wild rice variety's capacity to continue to set seed, probably through continued development of tillering. The mean difference between the first harvest and second harvest was not large. Nevertheless, the loss to disease would have been significant on replicates 1 to 4 had we delayed harvest. By September 3, there were few stems remaining that had green tissue and/or any seed. The remaining replicates still appeared promising and indeed did yield well. The message to us is clear and of course will not surprise Minnesota wild rice growers; if leaf blight becomes a problem, harvest cannot be delayed.

Table 2. Grain dry weight and % dry weight of Meter density experiment at three harvest dates.

Planting density	Harvest date: August 14 % Dry weight	August 14 Grain[2] weight	August 17 % Dry weight	August 17 Grain[2] weight	September 3[1] % Dry weight	September 3[1] Grain[2] weight
		--lb/A--		--lb/A--		--lb/A--
.5	61.1	315	63.4	441	67.3	469
1.0	59.6	387	65.0	498	67.9	531
1.5	62.1	526	66.6	445	68.9	421
2.0	63.6	529	66.5	616	70.1	609
4.0	63.7	646	66.5	621	70.0	578
8.0	63.5	752	66.7	701	69.5	620
Mean	62.3	526	65.8	554	69.0	538

[1] Late harvest was taken from border rows of plots harvested on August 17 (reps 5 to 8). Reps 1 to 4 were harvested on August 14.
[2] Grain dry weight including hulls.

A word of caution about these data is in order. We had a very late planting due to concern about lack of water for flooding. The hot humid weather which subsequently followed no doubt had a favorable affect on the development of leaf blight and the yields were probably adversely affected by the hot weather as well as by the disease. Further, we believe the effect of stand density cannot be adequately evaluated in small plots separated by 3-foot wide alleys. As long as leaf blight must be controlled by aerial applications of a fungicide, we recommend that growers of Meter try to achieve stands of two to three plants per square foot (assuming that a greater number of plants may result in greater density of the plant canopy).

Evaluation of seed size selection

Dr. G.G. Wandrey completed a Ph.D. thesis which evaluated gain from selection for seed size in half-sib families from K2 (see 1987 progress report in Minnesota Wild Rice Research, pp. 27-55). Results from evaluation of bulked long selections and bulked short selections looked very promising at Grand Rapids, but results from Rosemount tests were disappointing for selection for short seed length. We repeated evaluation of the program in 1987 but changed some of the procedures.

Fourteen half-sib families selected for long seed length and fourteen families selected for short seed length were identified for testing at two locations--Excelsior and Aitkin, MN. Seventeen check populations were included at Aitkin and fourteen were used at Excelsior. The entries were planted (April 28 at Excelsior and May 29 at Aitkin) in two row plots (rows 15 inches apart) ten feet in length in a randomized complete block design replicated three times. We had to use a very low seeding rate in order to plant six replicates; only 12 families were used in each selection group in the Aitkin evaluation because of inadequate seed for four of the families.

Data were recorded for green weight, dry weight and weight per 100 seeds after the hulls were removed. Because we experienced severe seed breakage in hulling of dry seed samples, our procedure for handling samples prior to hulling had to be modified (as reported by Wandrey in our report last year). Samples of green seed were stored in a freezer until we were ready to process them. Three days before hulling, the samples were dried in a hot-air dryer. When samples were removed from the dryers, dry weight was obtained, hulls removed with a mechanical huller, and the weight of 100 unbroken seeds was obtained for each plot. The data presented in Tables 3 and 4 are from weight of 100 seeds in grams. Results from these tests were disappointing because of stand establishment problems. An extremely variable number of plants per plot eliminated useful analyses of the dry weight yields. However, we computed correlation coefficients between yield and weight per 100 seeds to determine if the plots with low yield had larger seed weights than those plots with high yields. The correlations between dry weight yield per plot and weight per 100 seeds were low and nonsignificant. Thus, we concluded that the large variation in dry weight yields did not have an influence on the seed weights we obtained.

The results from the experiments are presented in Table 3 by selection group and evaluation site. Statistical evaluation showed a large significant difference in weight per 100 seeds between the two test sites. The combination of late planting date (May 29, 1987) and hot humid weather no doubt resulted in the poor seed weights at Aitkin.

The effect of selection for long versus short seed was not significant at either site. The correlations between seed weight of families evaluated at Excelsior and seed weight obtained at Aitkin were very low and negligible except perhaps for the K2 derived checks. The results reported herein are not encouraging. Note that we did not measure seed length of the selected families--only seed weight. However, Wandrey in his Ph.D. thesis found the relationship between seed length and seed weight to be large enough to permit us to use selection for seed weight to change seed length. The results we obtained this year are useful but only in the sense that more questions have been identified for research. We must learn more about the effect of environment on seed size (and seed weight) expression. We also must learn more about evaluation techniques. Possibly 100 seeds are not adequate for detecting differences in seed size among wild rice varieties.

Table 3. Effects of seed size selection (based on seed length) evaluated as weight per 100 seeds.

Population or Group	Site				Correlation between site results
	Excelsior		Aitkin		
	$\bar{x}$	σ^2_E [1/]	$\bar{x}$	σ^2_E	
	gm	gm^2	gm	gm^2	
Long selections	2.75	.0713	2.21	.0810	r = .12
Short selections	2.56	.0316	2.13	.0925	r = -.31
Checks	2.57	.0400	2.24	.0285	r = -.12
Site means	2.62	.0476	2.20	.0634	
K2 derived checks	2.53	--	2.20	--	r = -.50

[1/] σ^2_E is an estimate of error variance associated with the entries in each group and site, and indicates the experiments were relatively consistent in quality.

The seed sizes obtained on the check entries are presented in Table 4 by their variety source. Generally the sources are different growers but the K2 sources also involve some bulk populations of random half-sib families used in the selection experiment. Differences among varieties were not significant at either site. The 1987 experiments indicated to us that better techniques for evaluating seed size must be pursued. Further, sampling experiments from grower paddies may be needed to assess some of the environmental influences affecting seed size.

1987 Wild rice variety trials

The results of 1987 variety trials are presented in Tables 5, 6, and 7. We planted the entries at Excelsior (April 28) and Aitkin (May 29) in 4-row plots ten feet in length with rows spaced 15 inches apart, in randomized complete block designs replicated six times. We used multiple entries of several of the varieties. Our purpose with multiple entries was to look for differences in performance due to seed source of the variety. In 1987, K2 and M3 were included as a hand harvested sample (H) and a combine sample (C) from the same field; these were collected by Dr. Oelke as a means of studying combine injury in seed rice. Meter, Voyager, and K2 [no source given in Table 6] were included as additional entries at Aitkin. They came from the larger samples of

seed we obtained from growers to plant experiments for the Cultural practices, Soils, and Plant Pathology projects. The Voyager entries marked (M) and (R) were collected at Clearwater wild rice; the M sample came from bulked seed of mass selected plants which appeared to be holding their seed well (non-shattering) and the R sample resulted from bulking an equivalent number of plants chosen at random.

Table 4. Seed size (weight per 100 seed) of check populations evaluated at Excelsior and Aitkin, MN in 1987.

Entry	n[1/]	Excelsior	Aitkin
		---- gm ----	
K2	8	2.52	2.19
Voyager	4	2.61	2.19
Netum	2	2.68	2.24
Meter	3	2.57	2.42
Site means[2/]		2.57	2.24

[1/] n represents the number of sources of each entry.
[2/] Site means for 100-seed weight are significantly different ($\alpha = .05$).

The Excelsior experiment had relatively low stand density (Table 5), the number of plants per plot in the table translate to .75 to 1.0 plants per square foot. Lodging at harvest was severe for most entries. The % dry weight values indicate relatively uniform maturity at harvest although the K2 (H) entry (760 lb/A at 63.8% dry weight) probably would have equaled the Nor Cal yield had the K2 entry been harvested at an equivalent dry weight percentage. Differences among entries were significant for yield, % dry weight and plant height.

Results from Aitkin are presented in Table 6. Differences among entries were significant for yield, plants per plot and % dry weight. At Aitkin, Meter appeared to be only slightly shorter than Voyager (63 inches versus 67). When Meter was released, it was considerably shorter.

The comparisons permitted by special sampling, (entries from hand harvested seed versus entries from combine harvested seed) indicated a large stand difference for 'combine versus hand harvested' for M3 at Aitkin and Excelsior and for K2 at Aitkin.

Table 5. Results of 1987 wild rice variety trial at Excelsior, MN.

Entry[1]	Yield[2] (lb/A)	Plants/plot	% Dry weight	Height (in.)
Nor Cal	794	20	65.4	88
Voyager (M)	723	24	66.8	73
Voyager (R)	639	19	64.6	76
Erickson K2	495	25	64.1	73
Skoe K2	503	19	63.0	75
Kosbau K2 (C)	580	23	65.1	74
Kosbau K2 (H)	760	27	63.8	72
Sabo K2	484	20	63.7	75
Imle K2	572	28	65.2	74
M3 (H)	733	30	63.9	77
M3 (C)	643	19	63.3	80
LSD[3] (.05)	207		2.8	8

[1] Test harvested Aug. 12 except for Nor Cal which was harvested Aug. 26.
[2] Dry weight.
[3] Three replicates in an RCB design.

The effect of mass selection for seed retention in Voyager (albeit on a very small scale) appeared to follow consistent trends in both yield and height. The mass selected seed resulted in slightly higher yields and shorter plants compared to the randomly chosen plants. At Excelsior, the mass selected population appeared to mature earlier (66.8% dry weight) compared to the random source (64.6%). These results are encouraging since we expect to devote a major effort to mass selection for seed retention in the coming years.

Grower source of K2 seed appeared to affect yield of the variety again in 1987. (We found a major effect of varietal source on productivity in 1986.) While yield differences were not statistically significant, the relative rankings are interesting:

Source	Aitkin Yield	Aitkin Rank	Excelsior Yield	Excelsior Rank
Skoe K2	624	1	503	3
Imle K2	584	2	572	2
Kosbau K2 (C)	560	3	580	1
Erickson K2	516	4	495	4
Sabo K2	407	5	484	5

While we cannot establish a direct cause of these differences, we suspect that stage of maturity at harvest has a major effect on genetic composition of the crop which grows from the seed.

Table 6. Results of 1987 wild rice variety trial at Aitkin, MN.

Entry[1/]	Yield[2/] (lb/A)	Plants/plot	% Dry weight	Height (in.)
Nor Cal	458	27	68.5	77
Voyager (M)	628	41	63.9	67
Voyager (R)	600	47	63.3	75
Voyager	709	42	66.5	67
Erickson K2	516	32	63.0	73
Skoe K2	624	48	62.1	73
Kosbau K2 (C)	560	30	62.7	72
Kosbau K2 (H)	561	65	65.5	72
Sabo K2	407	36	60.3	72
Imle K2	584	37	62.9	75
K2	505	13	62.4	74
M3 (H)	561	66	63.2	73
M3 (C)	472	37	62.2	74
Meter	528	48	66.0	63
LSD[3/] (.05)	144		2.2	

[1/] Nor Cal was harvested Sept. 8, Meter on Aug. 17. All other entries were harvested on Aug. 24.
[2/] Dry weight.
[3/] Three replicates in an RCB design.

Table 7. Means for yield (dry wt) and plant height of varieties averaged over sources from Aitkin and Excelsior, MN.

Variety	Yield (lb/A)		Plant height (in.)	
	Aitkin	Excelsior	Aitkin	Excelsior
Nor Cal	458	794†	77	88
Voyager	645*	681*	70	74
K2	537	566	73	74
M3	517	688†	73	79
Meter	528	--	63	--

*Voyager yield significantly different from K2 yield.
†Large increase in yields of Nor Cal and M3 are a function of a much longer growing period at Excelsior compared to Aitkin in 1987. Later varieties tend to respond much better than medium maturity or early varieties.

The varietal means are presented by location in Table 7 for yield and plant height. The variety Nor Cal--provided two years ago by Dr. Ken Foster--is not a useful variety for Minnesota. We did manage to get yield data this year, but Nor Cal was harvested almost 2 weeks after the other entries and is too tall and rank for production purposes. Voyager was significantly higher yielding than K2 when all sources were considered. Meter yielded well at Aitkin and may be a useful variety if growers can protect it from bird damage. Our yield data is obtained from protected plots.

Pollination biology research (Master of Science research by N.J. Page)

Greenhouse culture has become very important in plant breeding. Greenhouses are used to increase the number of generations grown per year and to facilitate research and crossing by providing a more controlled environment than can be managed in field environments. Increasing the number of generations grown in a year may speed development and release of new varieties. Accumulation of genetic information about a species depends on the ability of researchers to hybridize and self pollinate plants and is facilitated by a consistently high seed set from those pollinations.

Attaining consistently good seed set from hand pollination is dependent on placing viable pollen on receptive stigmas in an environment conducive to fertilization. For most crops, the duration of pollen viability, duration of stigma receptivity, optimum time for pollination, and environmental factors that promote good seed set are well defined. Because of this, researchers can be confident that a reasonable amount of seed will be obtained from a cross.

This is not the case in wild rice. When pollination procedures described by Dr. W. Anson Elliott (Wild Rice, pp. 721-731 in Hybridization of Crop Plants, W.R. Fehr and H.H. Hadley, Eds., ASA Publisher, 1980) were used, recurring problems with low seed set hindered genetic studies. During the last two years, research has been conducted to examine some factors which may affect seed set from controlled pollinations of wild rice in the greenhouse. Specifically, time of pollination, duration of stigma receptivity, and duration of pollen viability, have been investigated, each in an independent set of experiments in greenhouse environments.

Experiments to determine optimum time for pollination were initiated in November of 1986 and repeated in April of 1987. In the study, emasculated plants were pollinated at one hour intervals from 6 a.m. until 3 p.m. There were four replicates in each experiment. In order to have an adequate pollen supply, pollinations for each replicate were made on separate days. Results of the two experiments are shown in Figure 1. Seed set was higher in the April study than in the November trial, but overall percent seed set was still low. The combination of November and April results gives no indication that there is an optimum time of day to make pollinations which will maximize seed set.

Results from experiments on the duration of stigma receptivity are shown in Figure 2. Florets on a panicle that had stigmas of the same age (had emerged from florets over 24-hour period) were identified each day for 10 days to establish a series of plants which had stigma ages from zero to nine days old. When the age range was established all panicles were pollinated at one time. Although seed set was low, stigmas remained receptive for five days after emergence from the floret (Figure 2). After five days stigma receptivity to pollen dropped rapidly. Since most stigmas on a panicle emerge within a 5-day period, multiple pollinations of a panicle should not be necessary to achieve good seed set if adequate pollen is applied as soon as all of the female florets have emerged from the boot.

The last study considered length of pollen viability. Very little pollen is shed from the anthers until the plants are disturbed. Under greenhouse conditions, plants have to be manually agitated to make the anthers dehisce their pollen. General practice has been to collect pollen from a male plant which has been undisturbed for up to 24 hours. However, if pollen is short lived, collecting it from anthers that have been extruded from the florets for up to 2 or 3 days may result in a large portion of collected pollen being nonviable.

To measure effect of pollen age on seed set, pollen from anthers that had been extruded for differing lengths of time was used to pollinate emasculated female plants. Male florets that opened in the specified time range were isolated and marked to identify their age when pollinations were made. The pollen was classified into age groups of 0 <, 0-2, 2-4, 4-8, 8-24, and 24-32 hours. The groups represent the amount of time from male floret opening until the anthers were collected to pollinate the females. The 0 < age group consisted of pollen from

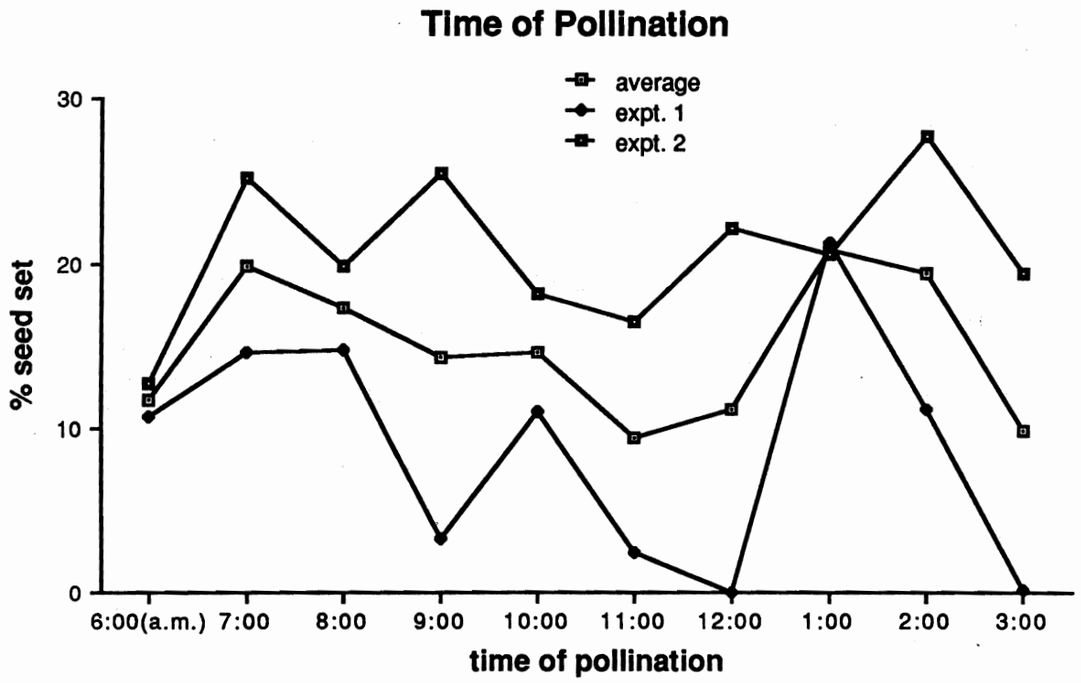

Figure 1. Effect that time of day when pollinations were made had on seed set of emasculated wild rice panicles (4 replicates in each experiment under greenhouse conditions).

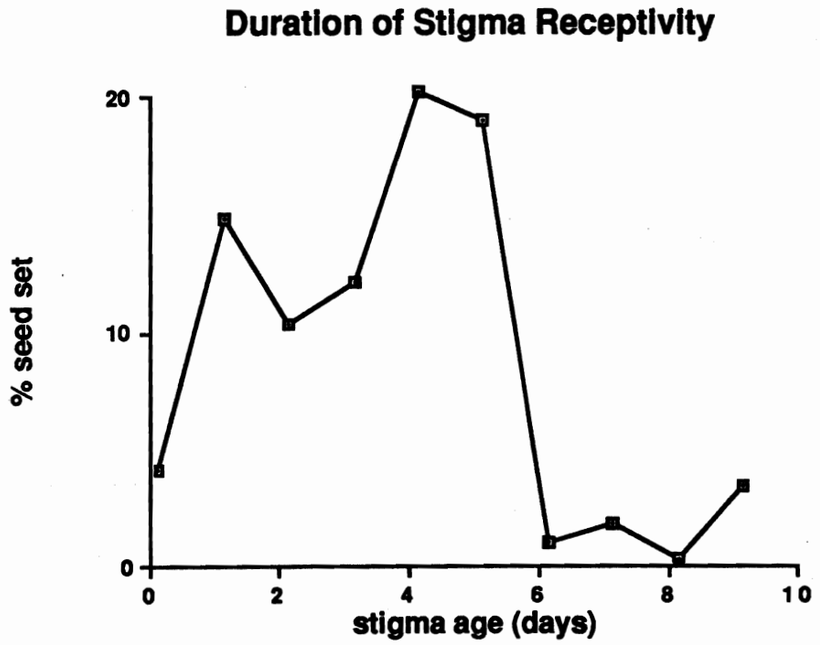

Figure 2. Stigma receptivity to pollen as a function of number of days stigmas were emerged from the floret before pollination (4 replicates in greenhouse).

florets that had not opened to expose their anthers. Once pollen age groups were established, all pollinations were made at one time. Pollen viability was assessed by determining percent seed set.

The experiment was done twice with three replicates in each experiment. The results are shown in Figure 3. In experiment one, only the pollen from the 0-2 hour age group was viable. In experiment two, pollen viability was highest at 0-2 hours old. Viability dropped rapidly when pollen was older than two hours. In experiment two the 8-24 hour age group also had fairly good seed set. Since it is unlikely that viability would increase once it has dropped, there must be another explanation for this result. Probably fresh pollen was mixed in with this age group. When isolating this age group, florets that were not open may have been hidden among those that were open. If the hidden florets opened shortly before pollen was collected, the fresh pollen could have biased the results.

In both experiments, pollen from the 0-2 hour age group gave relatively high seed set, about 50%. The average percent seed set from all other experiments has been about 15%. By using pollen that is no older than two hours, we may be able to triple the amount of seed that is obtained from controlled pollinations in the greenhouse. Additional testing is in progress.

Since the stigma receptivity experiment was done with pollen from male florets which had not been classified for pollen age, it needs to be repeated using pollen less than two hours old. This may give us better results and lead to a more accurate estimate of length of stigma receptivity.

Selection for resistance to shattering

We had selection nurseries for the varieties M3 at Rosemount, Meter at Aitkin, and K2 at Grand Rapids. Since these experiments are only in their initial phases, no results are available except seed numbers from Aitkin.

Meter was planted in 30-inch rows ten feet in length at Aitkin. At first aerial growth stage the plants were thinned to leave about 5 inches between individual plants. At flowering, the main stems of the approximately 3,000 total plants were tagged when the staminate flowers of each plant had emerged from the boot. The tagging was done every three days from July 14 to July 25, at which time most of the plants had flowered. On Aug. 20, the early plants were observed to identify those which appeared to be holding seed on the main stem. Although the main stem was used to make the selection decision, all seed of a selected plant was saved. Since many of the early plants were damaged by leaf blight, we in effect saved all of the seed we could find on those tagged between July 14 and July 18. The plants which flowered between July 19 and July 23 were classed as intermediate in maturity. The strength of seed retention on the main stems of the plants was visually and physically evaluated (by gently stripping the panicle) and we harvested all of the seed from about the best 10% of the plants in the intermediate

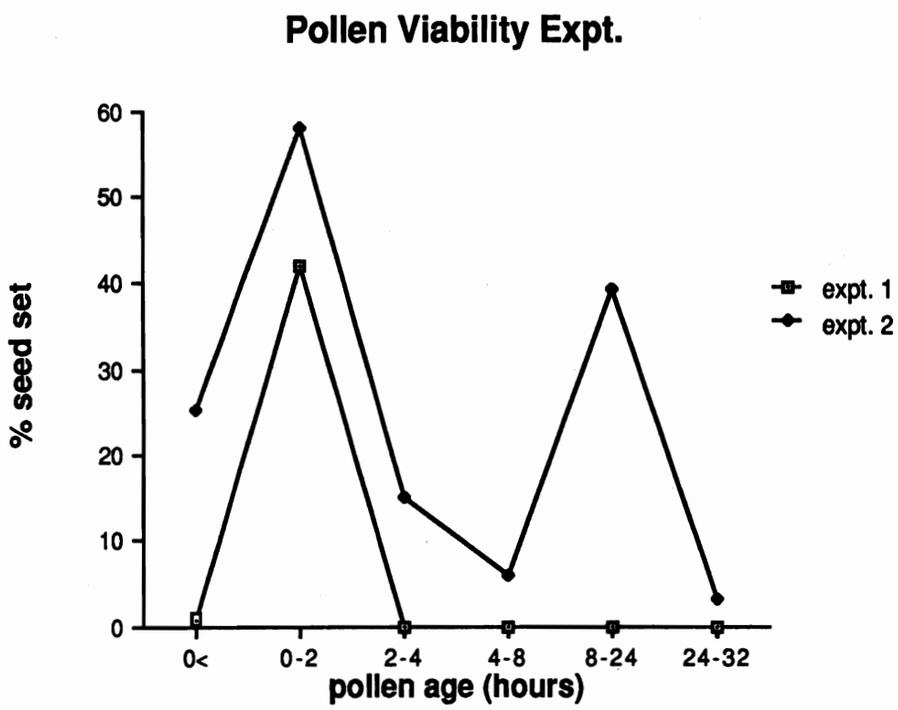

Figure 3. The effect of age of pollen (hours after anthers were extruded) on seed set on emasculated panicles in greenhouse (4 replicates in each experiment).

maturity category. The remaining plants were called late (flowered after July 24) and were treated similarly to the plants in the intermediate category. (To avoid possible environmental effects, the 10% selection was done using 2-row blocks. The tagged plants in the category were counted in the 2-row block, and approximately 10% of the plants were selected.)

The seeds from selected plants in each category were bulked to form three selected populations: early, medium and late shattering resistant populations of Meter. We judged the numbers to be approximately 11,000, 15,000 and 13,000 seeds in each population. The selected populations were fall planted using a low seeding rate at Aitkin in newly constructed paddies. The selection process will be repeated in 1988.

The selection experiments in K2 and M3 involved evaluation of half-sib families. At Grand Rapids, K2 families were planted in 4-foot rows spaced 15 inches apart, with 3-foot alleys. Two hundred half-sib families were replicated and 900 additional families of K2 were planted as unreplicated plots for evaluation. At Rosemount, a total of 600 half-sib families from M3 were planted for evaluation (200 of them replicated) in 5-foot rows.

At flowering, five main stems in each plot were tagged and dated when the staminate flowers had emerged from the boot. The purpose of the tag and the date was to provide a flowering date reference point for evaluating seed retention at harvest.

At harvest stage of maturity, each tagged plant was rated for its seed retention using a 1 (very good) to 5 (shattered) scale. As a check on our ratings, all plants that had been rated 1, 2 or 3, were reclassified at a later date. For each family, plant height was recorded, a sample of seed was collected for seed size measurements, and seed was stored to provide a source of the family for the next generation. Seeds of K2 plants rated "1" or "2" after reclassification were bulked for testing in 1988. A late collection of seed from the paddy was made as plants began to senesce.

The M3 materials used by Tri Hutomo for his Ph.D. research, were also tagged and dated. Plants were rated by subjective classification, visually observing shattering as well as by assessing strength of seed retention by stripping the main stem head with gentle finger pressure. In addition, panicles from M3 plants that had been tagged were harvested approximately 30 days after flowering and stored in a freezer in the laboratory until they could be classified for % seed shattering. The % seed shattering was determined by dividing number of seed obtained at harvest by the number of female florets (or pedicels).

Based on hand stripping classifications, 476 individual plants have been selected for further testing. The % shattering values have not been completed. Some of the selected populations will be tested in 1988. Additional analyses are in progress and will be used to formulate new populations for 1988 testing.

Acknowledgments: We appreciate the cooperative attitude of growers who permitted us to collect seed from their paddies and/or helped us in other ways: Duane Erickson, Ray Skoe and Don Barron, Harold Sabo, Franklin and Harold Kosbau, Art Hedstrom, Tom Godward, Wayne Harrell, Wally Renemo, Paul Imle and John Gunvalson, and, especially, Joe Shetka. We also wish to acknowledge the friendship and gifts of seed from Mr. Eric Koperek, a wild rice researcher who was working in Canada.

WILD RICE DISEASE RESEARCH

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The plant pathology wild rice project concentrated on the following areas of research during 1987:

1. Development of a growth stage system for describing wild rice plant development.

2. Continued evaluation of systemic and protectant fungicides for the control of fungal brown spot (FBS).

3. Investigation of the role(s) that silicon plays in wild rice plant development and fungal brown spot (FBS) disease incidence and severity. This research effort was supported in part by a grant from the Minnesota Paddy Rice Growers Research and Promotion Council.

4. The possible use of tissue culture in a FBS screening program.

I. WILD RICE GROWTH STAGE SCALE

Introduction

During the past 18 years wild rice varietal improvement efforts have been made, resulting in increased "shatter" resistance, higher yields, reduced plant height, and early flowering (10). Despite these efforts and advancements, cultivated wild rice stands seldom exhibit uniform plant development due to asynchronous seed germination (9), genetic heterogeneity (10), water depth (11,13), plant nutrient status (7), and differing physiological maturity of ripening grain (4).

Knowledge of the growth and developmental status of cultivated wild rice is necessary in predicting harvest (8), for safe and efficient fertilization (2), management of weeds and herbicide applications (3,14), and for fungal brown spot (FBS) control using fungicides (5,6). While attempting to develop crop loss data for FBS management we found that previously used field growth stage assessment scales for wild rice were not adequate for this and other needs. Therefore, we developed the wild rice growth stage scale (WRGSS) reported here.

The WRGSS is an expanded and more complete scale when compared to those used previously (2,8). While the WRGSS conforms with the decimal code system for cereal growth stages presented by Zadoks et al. (13), it does not use odd and even decimal codes to indicate synchronous and asynchronous development because in field situations wild rice normally exhibits asynchronous development. Thus, the WRGSS addresses the non-uniform developmental nature of wild rice in a manner that makes it possible to describe the growth stage status of entire fields. The WRGSS has been used in crop-loss and fungicide application studies (5,6) and in assessing plant development due to silicate fertilization (Zeyen, Percich, and Huot; unpublished data).

Materials and Methods

Wild rice seed of cultivar K-2, after 3 months aquatic storage at 2 C, was rinsed twice with tap water, and incubated in the dark at 24 C. After 7 days, 93% of the seed had germinated with the emergence of both coleoptile and primary root. A single germinated seed was planted in each of 200 pots (15 cm diam) containing a greenhouse soil mix consisting of mineral soil, coarse sand, peat, and manure (7:3:2:1 v/v) at a pH of 6.9. A granular fertilizer (10-10-10) was then incorporated at a rate 3.5 g/pot. Twenty pots were placed in each of 22 wooden replicate frames (91.4 x 71.1 x 13 cm) lined with two layers of 4 mil black polypropylene plastic. The frames were filled with tap water to a depth of 13 cm and maintained at this depth by an automated irrigation system. Developing plants were grown in a 24 C greenhouse with supplemental lighting provided by an equal mixture of high output cool white and grow-lux fluouescent lights for 14 hr/day. At boot stage, 70 g of a granular fertilizer (10-10-10) was evenly distributed in each flooded frame. Twenty plants were histologically examined at each of 22 prescribed growth stages and representative descriptive line drawings were made.

Results and Discussion

Wild rice development as described in the WRGSS is composed of both principal and secondary growth stages (GS) (Table 1). The ten principal and secondary growth stages (0 through 9), are broad categories of plant development coded by a single digit: 0) germination, 1) seedling and leaf development, 2) tillering, 3) stem elongation, 4) boot, 5) infloresecence emergence, 6) grain elongation, 7) milk, 8) dough, and 9) grain ripening. The sixty-two secondary growth stages (GS) are specific characteristics of wild rice development which subdivide the principal growth stages and have been given a "decimal code" (Table 1). Since, crop development is often non-uniform, the WRGSS can be used to estimate the proportion of plants possessing different development characters, which are then combined to describe specific growth stages.

Most WRGSS characters used to describe wild rice development may be assessed by observing external plant characteristics. However, the

determination of some characteristics, such as germination, stem, and grain elongation may require removal of the plants from the field for examination.

Germination begins with coleoptile emergence (Figure 1-A), the development of the first and second roots originate in rows about the primary root (Figure 1-B) (8,14). The secondary roots originate in rows about the primary root (Figure 1-C) (9). The number of submerged leaves devloping before the first floating leaf (Figure 1-C), which also will senesce and does not become aerial,is dependent upon water depth (11). The submerged leaves (2nd, 3rd, and 4th) become senescent as aerial leaves develop. Since cultivated wild rice is often observed to be in several different stages of development, percentages of each decimal code combination can be used to portray the crop. As an example, a typical crop on June 7 in Minneosta might be described as being: 30% [GS-10], 40% [GS-11], and 30% [GS-13], indicating that 30% of the plants were still submerged, 40% were in the single floating leaf stage (Figure 1-D), and 30% had one partially aerial leaf, also known as the "bow" stage (Figure 1-E).

The development of secondary tillers in wild rice lags behind main stem development; and because mature grain may not be formed on secondary tillers by harvest, maturation characters are assessed only on the main stem. However, secondary tillers that do produce harvestable grain should be included in the plant development assessment. This is especially important in first year stands having low plant density (2-4 plants/m) and high rates of tillering (6-10/plant) (Figure 1-F & G).

Stem elongation (jointing) determination requires stem dissection of several plants (Figure 1-H). Inflorescence development is completed during this period, and below the young inflorescence is a node where stem elongation will occur (Figure 1-H). The distance separating the most distal and proximal nodes determining the WRGSS character description (Table 1). Examination of the external structures of a small number of plants in conjunction with the internal findings will provide a good estimate of development during GS 30-39 (Table 1).

The principal growth stages of booting [GS-41-47, Figure 2-A] and inflorescence emergence [GS-50-59, Figures 2B & C]. can readily and accurately be determined by visual examination in the field. These growth stages are vital for scheduling fungicide applications for FBS management. Contact fungicides must be applied up to mid-grain elongation to have any effect on disease-related losses (6). Because of the importance of these GS events during and/or after inflorescence emergence, 32 of the 62 GS characters (Table 1) are assigned to these events. Unlike other cereal crops growth stage assessment systems (12,15), anthesis is not a separate category in the WRGSS. Thus, GS anthesis characters have been combined with those of inflorescence because they are often concurrent in wild rice, allowing grain to be a separate category.

Grain elongation is a category not found in most cereal growth

Table 1. Wild rice growth stage scale (WRGSS) development characters.

0) Germination

01 seed dormant
02 endogenous dormancy broken
03 coleoptile emergence
05 primary root emerged
07 secondary root initiated
09 first leaf extended

1) Seedling & leaf development

10 submerged leaves only
11 first floating leaf
12 second floating leaf
13 bow stage (partially aerial)
14 first aerial leaf
15 second aerial leaf emerging
16 third aerial leaf emerging
17 fourth aerial leaf emerging
18 fifth aerial leaf emerging
19 sixth aerial leaf emerging

2) Tillering

21 main stem only
23 main stem and one tiller
25 main stem and two tillers
27 main stem and three tillers
29 stem and four or more tillers

3) Stem elongation

30 nodes not separated
31 node separation initiated
33 ≥2.5 cm of node separation
35 ≥7.6 cm of node separation
37 ≥15.2 cm of node separation
39 flag leaf emergence

4) Boot

41 inflorescence visible - dissected
43 boots visibly swollen
45 boots fully swollen
47 first awns visible

5) Inflorescence emergence

50 first spikelet just visible
51 stigmata exposed
52 1/3 female portion emerged
53 2/3 female portion emerged
54 female portion emerged
55 1/2 male portion emerged
56 male portion emerged
57 anthers nondehiscent
58 anther dehiscence initiated
59 complete anther dehiscence

6) Grain elongation

61 grain elongation initiated
63 1/4 grain elongation
64 1/3 grain elongation
65 1/2 grain elongation
66 2/3 grain elongation
67 3/4 grain elongation
69 grain fully elongated

7) Milk

73 early milk
75 medium milk
77 late milk

8) Dough

83 early dough
85 soft dough
87 hard dough

9) Grain ripening

91 easily dented by thumbnail
93 first seeds turning brown
94 vascular strand expanded
95 slight dent with thumbnail
96 vascular strand brown
97 1/2 panicle's seed darkened
98 vascular strand collapsed
99 panicle dark and hard

stage scales. However, in wild rice it is an important time, occupying the period between fertilization and early milk stage. Grain elongation is easy to assess in the field because dissection is unnecessary (Figure 2-D). Because each individual seed elongates and matures at different rates on a single panicle, an average estimate of this development characteristic is made. A typical population of cultivated wild rice in Minnesota on July 30 may be described using the WRGSS as follows: 50% [GS-25, 45, 47]. 20% [GS-25, 54], and 30% [GS-25, 59]. Therefore, this population would be characterized as having 50% of the plants with fully swollen boots (Figure 2-A) with first awns visible; 20% having 2/3 of the female portion of the flower emerged, but the male parts still within the sheath (Figure 2-B); and finally, 30% with the male portion emerged and releasing pollen (Figure 2-C). All the plants in this particular case have two tillers [GS-25] in addition to the main stem.

The milk stage is characterized by the liquid consistency of the endosperm which gradually increases in solids over time (Table 1). During the milk stage, crushing the caryopsis between the fingers will exude the endosperm. By early dough the endosperm has a pasty consistency but is still not rigid enough to hold a finger nail impression. However, during the soft [GS-85] and hard dough stages [GS-87] the caryopsis gradually firms to retain an impression when pressed. Throughout these periods, the seed coat is still green and the vascular strand expanded (Figure 2-E), similar to pigment strand appearance in hard spring wheat (3).

In summary, due to the inherent flexibility of the WRGSS a high degree of precision can be achieved in assessing this wild rice development. The WRGSS is a valuable tool in the proper scheduling of paddy water drainage, fungicide and herbicide applications, assessing crop loss due to FBS, and the prediction of harvest dates for cultivated wild rice.

Acknowledgement

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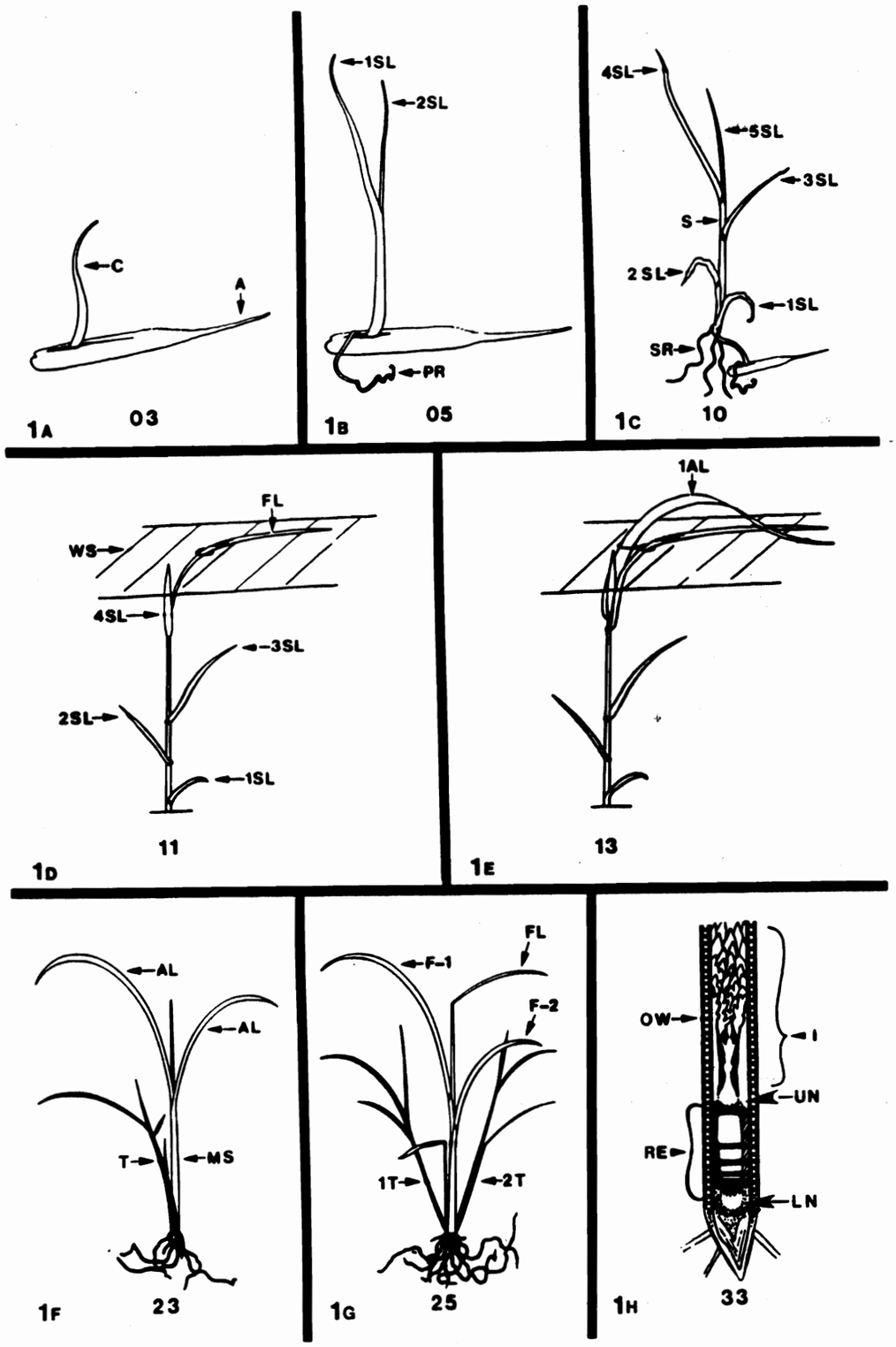
FIGURE CAPTIONS

Fig. 1. Key growth stages, germination through tillering. See Table 1 for complete decimal coded description. A) GS-03 seed germination and coleoptile emergence; C = coleoptile, A = awn. B) GS-05 advanced seed germination with emergence of primary root (PR) and first and second submerged leaves (1SL & 2SL) emerging from the coleoptile (C). C) GS-10 submerged leaf stage of germinating plant with secondary root formation. Number of submerged leaves may vary with water depth; 1SL -5SL = first through fifth submerged leaves with the fifth leaf destined to become the floating leaf when fully expanded, SR = secondary roots, S = shoot. D) GS-11 first floating leaf stage; 1SL-4SL = submerged leaves, FL = floating leaf, WS = water surface. E) GS-13 bow stage defined by the presence of the first aerial leaf whose tip often remains "bowed" and on the water surface (1AL). F) GS-23 main stem and first tiller stage where submerged leaves are senescing (not shown); AL = aerial leaves, MS = main stem, T = first tiller. G) GS-25 main stem with flag leaf evident (FL) and aerial leaves defined as flag minus one (F-1) and flag minus two (F-2); 1T = first tiller, 2T = second tiller. H) GS-33 longitudinal section of basal stem development where the upper most node (UN) is separated by one or more inches of elongation from the lower most node (LN); OW = outer wall of stem, I = immature inflorescence, RE = region of stem elongation.

Fig. 2. Growth stages, boot through grain ripening. See Table 1 for complete decimal coded descriptions. A) GS-45 swollen boot stage; B = boot fully swollen, FL=flag leaf, F-1 and F-2 are aerial leaves defined by positions relative to flag leaf, LC=leaf collar. B) GS-55 through 57 defined as female portion of the inflorescence fully emerged (FI) and the male portion of the inflorescence (MI) one half emerged with anthers nondehiscent; FL=flag leaf. C) GS-58 inflorescence fully emerged and anthers partially dehiscent; FL-flag leaf, FI-female portion of inflorescence, MI=male portion of inflorescence, DA=dehiscent anthers, NA=nondehiscent anthers. D) GS-61 and 65 showing initiation of grain filling and elongation (61) and half full stage (65); A=awn, P&L=palea and lemma, DC=developing caryopsis, PA=panicle attachment area. E) GS-94, 96 and 98 are stages in grain ripening defined by expansion of the vascular strand (V) on a green kernel (94), on a brown kernel (96) and the collapse of the vascular strand on a hardened, mature kernel (98).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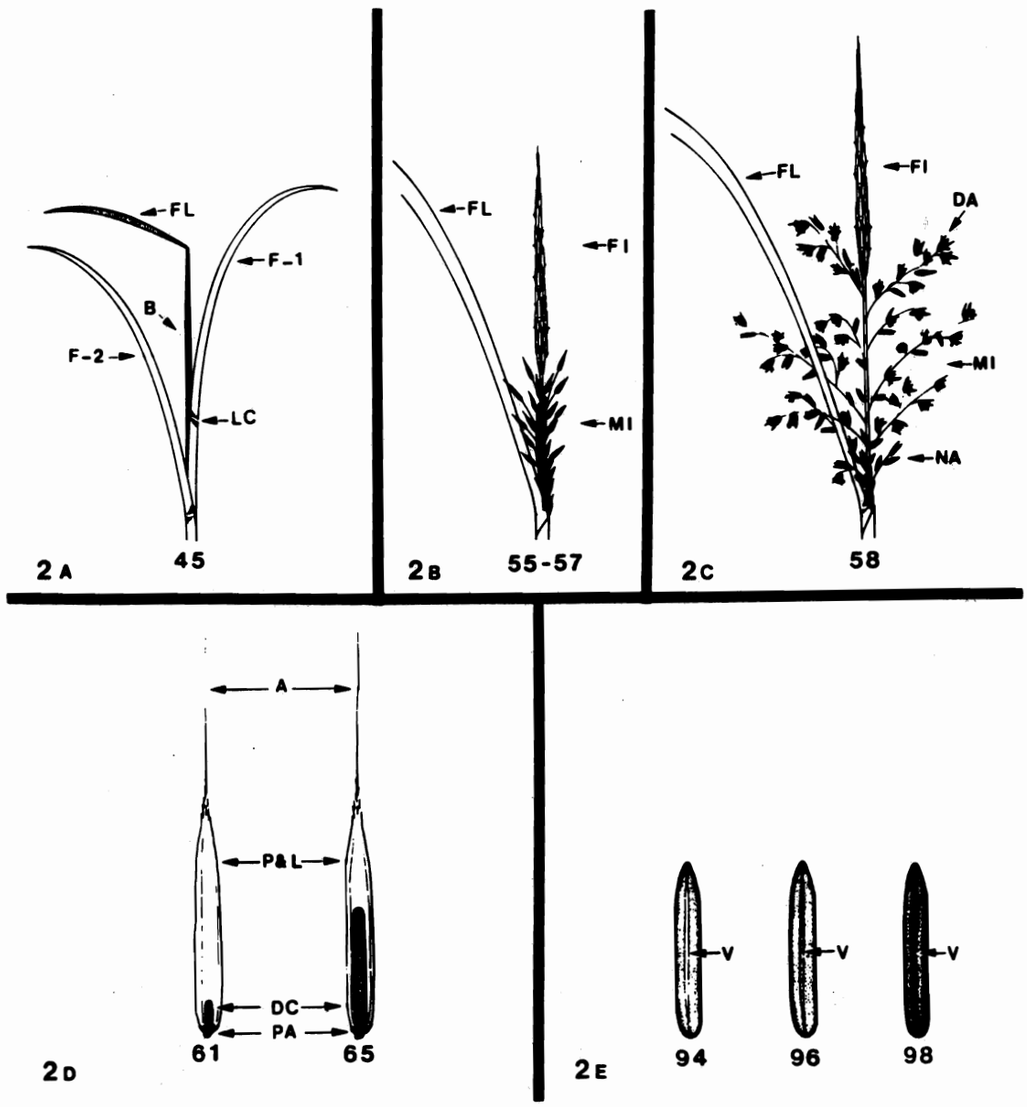
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II. CHEMICAL CONTROL OF FUNGAL BROWN SPOT

Introduction

Propiconazol (Tilt) is a systemic fungicide having both eradicative and protectant properties. It has been proposed that this fungicide be registered for use on wild rice for the management of FBS. Beginning in 1985 Tilt along with several other fungicides have been evaluated at the University of Minnesota's North Central Experiment Station at Grand Rapids, MN under controlled disease conditions.

Methods and Materials

The test paddy was prepared by rototilling and amending the soil with 22.5 kg/ha of nitrogen in the form of urea. Volunteer seed was eliminated by fumigation of the soil with methyl-bromide the previous fall. The experimental design was a completly randomized block consisting of six treatment each replicated four times. Each treatment was planted in a 1.5 x 2.1 m blocks. The wild rice cultivar K-2 was used.

Inoculum increase and storage, plant inoculations, and fungicide applications were performed as previously reported (2). The wild rice plants were inoculated on June 29, 1987 during the boot stage. The fungicide treatments were as follows:

Chemical	Rate a.i./ha (lb a.i./A)	Spray Schedule
Dithane M-45	1.13 kg (1.0 lb)	6/30, 10/7, 7/16, & 7/22
Rovral	1.13 kg (1.0 lb) 0.50 kg (0.5 lb)	6/30, 10/7, 7/17, & 7/22
Tilt	100 g (8.0 oz)	6/30 & 7/10

The control was sprayed with water only. Each plot was 1.5 x 2.1 m, with the inner 1.2 x 1.8 m being harvested. The plants were harvested by hand on August 17, 1987. The plants were counted, threshed, and the seed dried at 90 C. The grain was then dehulled, sized and weighed. Wild rice seeds greater than 1.24 mm in diam were used to determine final yields. Treatment means were compared by Duncan's New Multiple Range Test at the p =0.01 level of significance.

Disease severity ratings were recorded throughout the growing season in treatment plots. If the level of disease was below 1.0%, lessions were individually counted on each of the three upper leaves of the plant (2). As the disease level increased, and the lesions coalesced, the disease severities were assessed by determining the

percent leaf area infected for each of the three uppermost leaves.

Results and Discussion

In 1987 all fungicide treatments resulted in significantly higher yields than the non-treated control (Table 2). Plants treated with either Rovral or Dithane at 1.13 kg a.i./ha had significantly higher yields than the other fungicide treatments. Plants treated with Rovral or Tilt at 0.5 kg a.i. and 100 g a.i., respectively did not differ significantly in yield.

Rovral and Dithane each at 1.13 kg/ha (1 lb a.i./A) and Tilt at the 100 g a.i./ha (8 oz/A)resulted in the highest yields in 1986. However, they were not significantly different from each other (Table 2).

Tilt in 1985 and 1986 resulted in the highest signficant yields when compared to other chemical treatments (2). However, Tilt did not result in the highest yields in 1987. The reason for this is not clear. The 1987 growing season resulted in the highest yields ever at the Grand Rapids test site; even though disease pressure was extremely high between July 29th and Aug. 18th. Also, harvest was 23 days earlier than in 1986, whether or not this influenced plant develpment is unknown. Perhaps the most serious problem was the severe disease pressure that ocurred 19 days after the last applicaton of Tilt on July 10, 1987. The epidemic between July 29th and Aug 18th was of long duration and high intensity. Even the systemic fungicide Tilt could not eradicate the fungus and thus, protect the plant under these severe conditions in 1987.

Even though the harvest date in 1987 was 23 days earlier than in 1986, plant development was extremely slow during the period between July 29th and Aug 14th. for unknown reasons. This period was characterized by severe disease pressure and high humidity (90%) during the day and warm days (32's C) and nights (21's C).

Table 2. The effect of Rovral, Dithane M-45, and Tilt on the yield of wild rice inoculated with Bipolaris oryzae, the causal organism of fungal brown spot in 1987.

Chemical	Rate a. i./ha (a.i./A)	Yield kg/ha [z] (lb/A)
Rovral	1.13 kg (1.0 lb)	851 a (750)
	0.56 kg (0.5 lb)	498 b (439)
Dithane	1.13 kg (1.0 lb)	827 a (729)
Tilt	100 g (8 oz)	486 b (429)
Control		323 c (285)

[z] Means followed by the same letter are not significantly different at the p=0.01 and p=0.01 in 1986 and 1987, respectively according to Duncan's New Multiple Range Test.

In 1987 all fungicide treatments resulted in low disease severities (< 1.0%) on the flag leaf through July 22, 1987 (Table 3). The flag leaves on the control plants had between 1.0 and 2.0% leaf area infected. However, by August 12th, only plants treated with Rovral and Dithane each at the 1.13 kg/ha had 2.0% or less of the flag leaves infected (Table 3).

The Tilt and control plants had 5.0% and 6.0% of their flag leaves infected, respectively by Aug. 12, 1987 (Table 3). When these disease levels are present in plants during the milk stage of plant development, significant reductions in yield can occur (1). The high level of disease in the Tilt treatment ocurred 23 days after the last application of the fungicide during a period of intense disease pressure. Losses in the Tilt treated plants probably would not have ocurred if a single application of Dithane would have been made during this critical period of disease increase. A similiar event occured in the Tilt rate study at the Grand Radids.

Table 3. Fungal brown spot severity ratings on wild rice cultivar k-2 inoculated with Bipolaris oryzae and then treated with various fungicides at Grand Rapids, MN in 1987.

Treatment a. i./ha (lb a. i./A)	Average Percent Leaf Area Infected*			
	7/10/87	7/16/87	7/22/87	8/12/87
Rovral				
1.13 kg (1.0)	0/<1/1	<1/<1/1	<1/1/39	2/13/43
0.56 kg (0.5)	0/1/1	<1/1/1	<1/2/50	2/18/50
Tilt 100 g (8 oz)	0/<1/1	<1/1/9	<1/2/45	5/22/56
Dithane 1.13 kg (1.0 lb)	0/<1/<1	<1/1/10	1/4/44	2/19/49
Control	0/1/<1	<1/1/10	1/10/43	5/45/69

* Percent leaf area infected for the flag/second/third top most leaves.

Tilt Rate Study

Materials and Methods

The experimental paddy was prepared by rototilling and amending the soil with 22.5 kg/ha (20 lb/A) of nitrogen in the form of urea. Volunteer seed was eliminated by fumigation with menthy-bromide the previous fall. The experimental design was a completly randomized block consisting of 6 treatments replicated four times. Each treatment consisted of a 1.5 x 2.1 m (5 x 7 ft) plot.

The inoculum of **Bipolaris oryzae** was prepared approximately one month prior to inoculuation. Galvinized trays (30 x 20 x 10 cm) were filled with a mixture of corn meal plus 300 ml of 1% potato dextrose agar (PDA) and thoroughly mixed. After a 15 min soaking time, 700 ml of rinsed perlite was added and mixed thoroughly. The trays were covered with two layers aluminum foil and autoclaved for one hour. After cooling 2 to 4 hrs, each tray was inoculated with 2 to 3 PDA plates containg 1 to 2 wk old cultures of **B. oryzae** which had been previously diced into 1 cm squares. After 2 wks at 26 C, the inoculum was air dried at 24 C and stored in paper bags at 4 C.

Wild rice plants were inoculated with a conidial suspension consisting of one liter of dried inoculum (screened through a 300

micron screen) and 3 liters of water beginning at the boot stage of development development. Each plot was inoculated using a backpack sprayer (Hudson Stainless Steel Suprema 67367, H. D. Hudson Mfg. Co., Chicago, IL). Immediately following inoculation, the plants were misted every 15 min for 2 min until fungicide was applied. The fungicide was applied (0.33 l per plot) with a hand-held CO_2 pressurized sprayer (20 lb psi). The control was sprayed with water only. The various fungicide rates are as follows:

Rate g. a.i./ha (oz/A)	Plant Growth Stage	Spray Schedule
125 (4)	Boot & Heading	6/30 & 7/10
188 (6)	Boot & Heading	6/30 & 7/10
250 (8)	Boot & Heading	6/30 & 7/10
250 (8)	Boot	6/30
313 (10)	Boot	6/30

The inner 1.2 x 1.8 m (4 x 6 ft) of each plot was harvested by hand on Aug. 17, 1987. The plants were counted, threshed, and grain handled and dried as previoulsy described (2). Disease severity ratings were recorded throughout the growing season.

Table 4. The effects of various rates of Tilt on the yield of wild rice cultivar k-2 infected with Bipolaris oryzae, causal organism of fungal brown spot.

Rate g a.i./ha (oz/A)	Stage of Plant Development	Yield kg/ha (lb/A)*		
		1985	1986	1987
125 (4)	Boot & heading	319 (281) a	420 (370) a	339 (299) a
188 (6)	Boot & heading	315 (278) a	503 (444) b	454(400) b
250 (8)	Boot & heading	508 (448) c	617 (544) d	782 (690) c
250 (8)	Boot	407 (359) b	593 (523) c	491 (433) b
313 (10)	Boot	332 (293) a	444 (392) e	304 (287) a
Control		359 (317) a	299 (264) f	324 (286) a

* Means followed by the same letter are not significantly different at the p = 0.01 level according to Duncan's New Multiple Range Test.

Results and Discussion

In 1987, as in 1985 and 1986, plants treated with 250 g a.i./ha (8 oz/A) at both boot and heading had significantly higher yields than any other treatment (Table 4). In 1987, yields from plants receiving 250 g a.i./ha (8 oz/A) of Tilt at boot only were not significantly different from those receiving 188 g a.i./ha (6 oz/A) at both boot and heading.

Plants treated with either 313 (10) or 125 g a.i./ha (4 oz/A) did not have significantly different yields when compared with the control (Table 4). The 125 g a.i./ha (4 oz/A) did not give sufficient disease control, while the 313 g a.i./ha (10 oz/A) resulted in phytotoxicity. Similar results observed in both 1985 and 1986.

When FBS is present on untreated plants during the milk stage of development, significant yield reductions can result (1). The disease ratings in 1987 were highest for the non-treated controls (Table 5). In the Tilt treated plants, the lowest amount of disease was observed on those receiving 250 g a.i./ha (8 oz/A) at both boot and heading. In general, the lower disease ratings correlated well with increased yields in 1987. The disease severity ratings in 1985 and 1986 also followed the same pattern.

Table 5. Fungal brown spot severity ratings on wild rice cultivar K-2 inoculated with Bipolaris oryzae and then treated with Tilt at rates of Tilt at different stages of plant development at Grand Rapids, MN in 1987.

Rate g a.i./ha (oz/A)	Stage of Plant Development	Disease Severity ratings*				
		6/29	7/10	7/17	7/22	8/12
125 (4)	Boot & heading	0/0/0	0/<1/1	<1/<1/1	1/5/20	2/22/56
188 (6)	Boot & heading	0/0/0	0/<1/1	<1/1/5	1/4/17	2/15/50
225 (8)	Boot & heading	0/0/0	0/<1/1	<1/1/5	1/2/14	3/20/50
225 (8)	Boot	0/0/0	0/<1/1	<1/1/5	<1/3/20	3/20/50
313 (10)	Boot	0/0/0	0/<1/1	<1/1/5	<1/2/18	3/35/72
Control		0/0/0	0/<1/1	<1/12/35	1/12/35	8/50/81

* Percent leaf area infected for the flag/ second/third top most leaves.

Summary

The higest level of significant FBS control on wild rice cultivar K-2 was acheived with one application of Tilt at 225 g a.i./ha (8 oz/A) during boot for the past three years.

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III. SILICON FERTILIZATION OF CULTIVATED WILD RICE: ENHANCED PLANT GROWTH AND DEVELOPMENT, YIELD, NUTRITIONAL STATUS, AND FUNGAL BROWN SPOT RESISTANCE (Supported in part by the Minn. Paddy Wild Rice Research and Promotion Council. Co-investigators Meyer, Percich, & Zeyen).

A. Greenhouse and Laboratory

Introduction

Peat and other organic soils are often unable to supply silicon to some plants whose maximum growth and yield demands this element (1,2,4,5). Plants that require silicon for maximum development are rice, barley, wheat, oats, flax, many small grasses, and others (3). Present difficulties with growing wild rice on peat soils in Minneosta, led to the investigation of silicon's relationship to wild rice. In many parts of the world silicon fertilization is routinely used in growing white rice on organic soils. However, care must be taken when amending organic soils with silicon as to not disrupt the uptake and utilization of other essential elements by the plant.

Rice production on low silicon containing organic (peat-like) soils in Florida are often characterized as having below average yields, excessive sterility, lodging, and severe fungal brown spot, caused by **Bipolaris oryzae**. World-wide, silicon fertilization of rice grown on organic soils has shown the following benefits:

1. Reduced lodging due to increased strength of supportive cells.
2. Increased photosynthetic activity, perhaps, due to more erect leaf growth and utilization of essential nutrients.
3. Reduction in seed shattering.
4. Increased plant tillering, shoot height, number of

spikelets/ear, grain weight, and the percentage of filled spikelets.

5. Increased resistance to certain fungal diseases and insect pests (5,6).

6. Reduction in transpiration (water loss) and accumulation of toxic concentrations of Mn and other heavy metals.

The purpose of this investigation is to determine if any or all of the above benefits for white rice will also apply to cultivated wild rice.

Materials and Methods

Greenhouse study. A peat soil (696 gm) from a wild rice paddy having low ash (6.14%) content was seived through a mesh (0.6 cm) and placed into a 15 cm diam plastic pot. The following six peat soil treatments were utilized:

Treatments

1. Peat, alone
2. Peat + sodium silicate (Na_2 SiO_3 $5H_2O$) 10 g/kg
3. Peat + calcium metasilicate ($CaSiO_3$) 10g/kg peat
4. Peat + fertilizer (10:10:10) 2.8 g/698 g peat
5. Peat + fertilizer + Na_2SiO_3 $5H_2O$
6. Peat + fertilizer + $CaSiO_3$
7. Greenhouse soil mix, consisting of mineral soil, coarse sand, peat, and manure (7:3:2:1 v/v)

The pots were placed into polyethylene-lined flats containing deionized water and maintained at a proper depth by the addition of deionized water. The flats were contained within a clear plastic tent to maintain a dust-free environment for the course of the experiment. Each pot was planted with two seedlings of cultivar K-2 which had been previously germinated in distilled water. The plants were grown under a 14 hr light and a 12 hr dark photoperiod at 24 +2 C. Each treatment consisted of 10 replicate pots in each of two flats.

Four weeks after planting, the stage of plant development using the WRGSS, plant heighth in cm, and total main stem dry wt in grams were determined at harvest from 20 different plants for each treatment. Also, the percent silicon present in the plant tissue for each treatment was determined by the University of Minnesota Soil Testing Laboratory immediately after harvest from 20 different plants. The silicon analysis of the main stem was determined from a 15.2

section above the water surface. The bulk tissue analysis consisted of the main stem tissue minus the flag leaf and the 15.2 cm section.

Results and Discussion

The growth and development of wild rice cultivar K-2 in a fertilized Minnestoa peat soil (A.Hedstrom) amended with silicon resulted in increased plant height, total main stem dry wt, and enhanced development (Table 6). Plants grown in peat soil containing Na_2SiO_3 $5H_2O$ were 20 % taller, main stems 43 % heavier, and had 1/2 of the male inflorescence emerged (GS 55) (Table 1), when compared to plants grown in $CaSiO_3$ amended peat soil. Plants grown in unfertilized peat did not develop beyond the 4th aerial leaf emerging (GS 17) and only 25 % of the plants were alive at harvest.

The percent silicon concentration in wild rice plants in fertilized Minnesota peat soil containing silicon was increased by an average of 4.1, 5.8, 4.2 fold when compared with those grown in fertilized peat only (Table 7).

Wild rice development in a fertilized Canadian peat, as in Minnesota peat (Table 6), resulted in increased plant height total main stem dry wt, and advanced plant development when compared with plants grown in fertilized peat alone (Table 8). Average plant height and main stem dry weight in the silicon amended peat were increased 1.6 and 1.4 fold, respectively when compared with plants grown in unamended silicon Canadian peat. Again, as in the case of the silicon amended Minnesota peat (Table 7). The plants in the silicon treated Canadian peat were undergoing stem elongation (GS 31) while those in the fertilized peat containing no additional silicon were still in the seedling and leaf stage of development (GS 19) (Table 8). Wild rice plants failed to survive when grown in Canadian peat soil without silicon.

Wild rice plants grown in Canadian peat containing silicon, regardless of the formulation had increased percent silicon concentration in their flag leaves, main stems, and remaining bulk tissue (Table 9).

B. Field Study

Refer to Soil Science Report

Fungal brown spot incidence and severity. Disease incidence in 1987 at the Atkin, MN test site was 100% by July 15 th.; while disease severity on the flag, second, and third leaves was considered as being trace (10 - 25 lesions/leaf). However, by July 22nd disease severity had increased to aproximatley < (less than) 1 percent (25 lesions/leaf) regardless of treatment (Table 10). The period between July 29th and Aug. 8th was characterized by high day (+32 C) and night (+21 C) temperatures and high relative humidities (70 -90%). Fungal Brown Spot became epidemic during this period. The lime pH controls

TABLE 6. THE GROWTH AND DEVELOPMENT OF WILD RICE CULTIVAR K-2 IN PEAT SOIL (HEDSTROM) AMENDED WITH SILICON

TREATMENT (HEDSTROM)	PLANT[X/] HT(CM)	TOTAL MAIN[Y/] STEM DRY WT/G	GROWTH[Z/] STAGE
PEAT + FERT	62	282	45
PEAT + FERT + $CaSiO_3$	70	592	50
PEAT + FERT + $Na_2SiO_3 \cdot 5H_2O$	87	721	55

X,Y,Z/ AVERAGE HEIGHT (CM), TOTAL MAIN STEM DRY WT (G), AND GROWTH STAGE, RESPECTIVELY FROM 20 PLANTS.

TABLE 7. THE EFFECT OF SILICON AMENDED PEAT (HEDSTROM) SOIL ON THE PERCENT SILICON CONCENTRATION IN WILD RICE CULTIVAR K-2

TREATMENT (HEDSTROM)	PERCENT SILICON/G DRY WEIGHT[X/]		
	FLAG LEAF	MAIN STEM	BULK
PEAT + FERT	0.75	0.34	0.39
PEAT + FERT + $CaSiO_3$	3.40	1.97	1.41
PEAT + FERT + $Na_2SiO_3 \cdot 5H_2O$	2.81	2.00	1.83

X/ AVERAGE PERCENT SILICON CONCENTRATION FROM 20 PLANTS.

TABLE 8. THE GROWTH AND DEVELOPMENT OF WILD RICE CULTIVAR K-2 IN PEAT SOIL (CANADIAN) AMENDED WITH SILICON

TREATMENT (CANADIAN)	PLANT[X/] HT(CM)	TOTAL MAIN[Y/] STEM DRY WT/G	GROWTH[Z/] STAGE
PEAT + FERT	54	212	19
PEAT + FERT + $CaSiO_3$	87	255	31
PEAT + FERT + $Na_2SiO_3 \cdot 5H_2O$	81	323	31

X,Y,Z/ AVERAGE HEIGHT (CM), TOTAL MAIN STEM DRY WT (G), AND GROWTH STAGE, RESPECTIVELY FROM 20 PLANTS.

TABLE 9. THE EFFECT OF SILICON AMENDED PEAT (CANADIAN) SOIL ON THE PERCENT SILICON CONCENTRATION IN WILD RICE CULTIVAR K-2

TREATMENT (CANADIAN)	PERCENT SILICON/G DRY WEIGHT[X/]		
	FLAG LEAF	MAIN STEM	BULK
PEAT + FERT	1.09	1.05	0.64
PEAT + FERT + $CaSiO_3$	1.44	1.14	1.06
PEAT + FERT + $Na_2SiO_3 \cdot 5H_2O$	1.83	1.61	1.27

X/ AVERAGE PERCENT SILICON CONCENTRATION FROM 20 PLANTS.

had little effect on disease severity. However, the slag treatments appeared to enhance disease resistance to some extent, particulary in the 15,500 kg/ha treatment (Table 11). Plants grown in the highest slag were aprox. 66 cm taller, had more tillers, structurally contained more biomass, and had greener flag leaves and panicles. The lesions were generally smaller and fewer in number. The importance of silica in barley and rice resistance to foliar fungal pathogens has been reported (2,6). Future work will be directed to role (s) silicon plays in wild rice resistance to fungal brown spot.

Table 10. Percent leaf area infected with Bipolaris oryaze on wild rice cultivar K-2 when grown in peat soil amended with various rates of lime and silicon.

Treatment (Tons)	Average Percent Leaf Area Infected				
	7/22/87	7/28 87	8/12/87	8/18/87	8/26/87
Slag					
1	<1/<1/1[z]	1/1/5	15/19/34	22/44/50	29/36/50
3	<1/<1/1	1/1/5	11/18/24	17/29/45	22/28/50
6	<1/<1/<1	1/1/5	10/15/22	14/30/45	12/25/40
Lime					
1	<1/<1/1	1/5/10	22/35/50	30/50/75	46/46/75
3	<1/<1/1	1/5/10	22/30/50	24/30/75	46/46/75
6	<1/1/1	1/5/10	25/26/50	19/26/50	50/50/85
Control	<1/1/1	1/5/10	25/25/47	40/50/80	50/50/100

[z] Average percent leaf area infected on the flag/second/third from the top from 20 plants.

Conclusion

Preliminary laboratory, greenhouse, and field research indicates that silicon amendments to low silicon peat soils affected wild rice cultivar K-2 in the following ways:

1. It is a required plant nutrient.
2. Acclerated plant growth and development.
3. Significantly increased yields by increasing the number panicles.
4. Increased silicon uptake and enhanced its incorporation into

structural plant tissue.

5. May play a role in resistance to fungal brown spot.

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Progress in Tissue Culture of Wild Rice

Introduction

Successful production of callus from tissues of cereals has lagged behind the achievements in tissue culture of many other crops. Cereals typically respond poorly to the same conditions that produce vigorously growing morphogenic cultures from dicotyledonous plants. Although callus initiation has been achived with most cereals, morphogenesis and regeneration have proven more difficult (Evans et al., 1981). In some cereals, most notably corn (*Zea mays* L.) and rice (*Oryza sativa* L.), callus initiation has been accomplished and plants are routinely regenerated via organogenesis or embryogenesis (Green and Phillips, 1975, Nishi et al., 1968).

In wild rice (*Zizania palustris* L.) the initiation and maintenance of callus cultures has been difficult and no reports of success with this system have been published. As with many cereal cultures, wild rice callus is prone to slow growth, production of non-regenerable cell types and necrosis. The necrosis of cultured tissue is particularly severe in wild rice, and its causes are unknown.

An efficient culture system must be developed before *in vitro* techniques and somaclonal variation can be used for improvement of wild rice. The ability to initiate callus from organized plant tissue and regenerate plants from callus is a basic requirement, and must become routine before advanced selection schemes can be applied. The rate at which cultures grow and regenerate plants is also important because somaclonal variation continues to occur as long as cells are in culture. In older cultures the accumulation of mutations eventually results in deleterious variation (eg: albinism, sterility or lethality). It is therefore necessary to identify and maximize the factors promoting efficient initiation and rapid growth of callus.

Successful culture of cereals has often been the result of subtle modifications, such as changes in the culture medium or methods of selection and preparation of tissue. Many variables are known to affect initiation and growth of callus, and often only certain combinations of factors will produce satisfactory results. In this study, several of the most important factors have been investigated.

Explant Tissue

Introduction.

In the Gramineae immature embryos are often the best explant tissue for induction of callus (Cummings et al., 1976, Dale, 1980). Other tissues, such as root tips, intercalary meristems, and immature inflorescences have been successfully cultured in a few systems (Wernicke and Brettell, 1980). In all cases the frequency of callus initiation and overall quality of the cultures were dependent on the type of explant and the age and morphological development of the tissue. The effects of explant source and morphological development on callus initiation by wild rice explants were investigated.

Materials and Methods

Embryos, immature inflorescences and root tips of cultivar K2 were used as explants. For embryo culture, seeds were surface sterilized in 1% sodium hypochlorite for 5-7 minutes and rinsed in sterile distilled water. Embryos were excised, surface sterilized for 3-5 minutes with 0.5% sodium hypochlorite, rinsed twice in sterile distilled water, and soaked for 2-4 minutes in a 5% aqueous solution of Penicillin G (Parke-Davis, Detroit, Mi., 48232). The embryos were categorized by size (in mm) as follows:

a)	large-mature	8-11mm
b)	large-immature	8-11mm
c)	medium	5-8mm
d)	small	2-5mm
e)	micro	2mm or less

Immature inflorescences (5-15mm) and root tips (2-4mm) were excised from seedlings at growth stages 33 and 10, respectively (Percich et. al, 1988), sterilized in 2.5% sodium hypochlorite for 10 minutes and rinsed twice in sterile distilled water. Immature inflorescences were categorized as small (5-10mm) or large (10-15mm). Root tips were not categorized by size. All explants were cultured in 20 x 60mm petri plates containing 25 ml of medium. The culture medium consisted of Murishige-Skoog (MS) basal salts (Gibbco laboratories), MS vitamins, and sucrose (3% w/v) (Murishige and Skoog, 1962) supplemented with 1.0 mg/l 2,4-dichlorophenoxy acetic acid (2,4-D) and solidified with agar. Two-hundred explants (40 plates with five explants per plate) were used for the immature inflorescences, root tips and for each size category.of embryos. Callus initiation was observed after eight weeks.

Results

Embryos from the large-immature and large-mature size categories initiated the greatest number of calli (Table 11). There were no observable differences in the quality of callus derived from different embryo sizes. None of the immature inflorescence or root tip cultures showed any growth. These cultures were therefore discarded and the data omitted from Table 11. Success with mature embryos indicates that stored seed can be used as a source of explant material. This is a great advantage since supplies of immature embryos depend on the availability of living plants at a particular growth stage.

Table 11
Effect of embryo size on callus initiation from wild rice embryos.

Size	Number of calli	% initiation	Mean/plate
large-mature (8-11mm)	65	32.5	1.625 A
large-immature (8-11mm)	59	29.5	1.475 A
medium (5-8mm)	24	2.0	0.600 B
small (2-5mm)	11	5.5	0.275 BC
micro (< 2mm)	2	1.0	0.050 C

Means followed by the same letter do not differ significantly (P=.05) according to Duncan's multiple range test.

Exogenous Hormones

Introduction

Substances with plant hormone activity must be added to tissue culture media to induce or promote the desired type of growth. Auxins and cytokinins are the two classes of hormones most often used in plant tissue culture (Evans et al., 1984). The hormones selected, their concentrations and the combinations in which they are used determine the type of growth exhibited by the culture. The effects of each hormone differ greatly between plant species, making it necessary to establish the optimum hormone balance for each system by trial and error. The effects of hormone concentration and some combinations of hormones on callus initiation were tested in cultures of wild rice.

Materials and Methods

Three auxins were tested; 2,4-D (2,4-dichlorophenoxy acetic acid), NAA (naphthlene acetic acid), and Picloram (4-amino 3,5,6-trichloro-picolinic acid). The auxins 2,4-D and NAA were also tested in combination with the cytokinin BAP (benzyl-amino purine) Large-immature embryos of cultivar K2 were cultured (using the methods described previously) on standard MS media with various hormone concentrations. Forty embryos (eight plates with five embryos/plate) were cultured for each hormone treatment. Callus initiation was observed after eight weeks.

Results

The greatest number of calli were initiated on medium with 0.5 mg/l 2,4-D (Table 12). Picloram induced fewer calli by comparison and promoted slower callus growth with a greater tendency for necrosis. NAA concentrations up to 5 mg/l failed to initiate callus, but concentrations of 2-5mg/l were effective for regenerating plants from whole embryos without an intervening callus stage. BAP was detrimental to callus initiation when combined with 2,4-D and inhibited regeneration of plants from embryos when combined with NAA.

Table 12
Effects of various hormone levels and combinations on callus initiation from immature embryos of wild rice.

Hormones	Concentration mg/l	#calli	% initiation	Mean/plate
2,4-D				
	0.5	17	42.5	2.25 A
	1	7	17.5	0.88 B
	5	4	10.0	0.50 B
2,4-D + BAP				
	1; 0.1	2	5.0	0.25 B
Picloram				
	1	1	2.5	0.12 B
	2	3	7.5	0.38 B
	5	7	17.5	0.88 B
NAA				
	1	0	0	0
	2	0	0	0
	5	0	0	0
NAA + BAP				
	1; 0.1	0	0	0

Means followed by the same letter do not differ significantly (P=.05) according to Duncan's multiple range test.

Variety

Introduction

In most tissue culture systems, the explant genotype has been shown to have a significant effect on the induction of callus and the ability to regenerate plants (Green and Phillips, 1975). Differences in culturability between varieties are often distinct. In many cases, especially with open pollinated crops, there are also differences in culturability within varieties. In most systems it has been useful to first determine which varieties are most suitable for tissue culture and then make selections for best callus type within that variety . Varieties of wild rice were compared for their ability to induce callus.

Materials and Methods

Two-hundred mature embryos (40 plates with five embryos/plate) from each of the varieties K2, Voyager, Netum and M3 were cultured on MS medium supplemented with 0.5mg/l 2,4-D using the methods described previously. Callus initiation was observed and recorded after six weeks of culture.

Results

Numbers of calli derived from each variety were not significantly different (P=.05). The variety Netum initiated the most calli and and these calli suffered the least amount of necrosis. The results are summarized in Table 13.

Table 13
Effect of variety on callus initiation from mature embryos of wild rice.

Variety	Number of calli	Percent initiation	Mean/plate
K2	48	24.0	1.20
Voyager	39	19.5	1.00
Netum	54	27.0	1.35
M3	45	22.5	1.15

Gelling Agent.

Introduction

There are few gelling agents which can be used to solidify tissue culture medium. Agar is the most commonly used gelling agent. It has been satisfactory for many plant species, but has proved to have toxic effects in a few cases. Agarose is a more refined and much more expensive type of agar. It has been used in cases where a more purified gelling agent was necessary for plant tissue growth. Gelrite is a relatively new product which has not yet been widely used, but has some promise as an alternative to agarose. The effects of different gelling agents on the initiation of wild rice callus were compared.

Materials and Methods

Four batches of medium utilizing different gelling agents were prepared. Standard MS medium supplemented with 1mg/l 2,4-D was solidified with Bacto-agar (Diffco), Phyt-agar (Gibbco Laboratories), Sea-palque agarose (FMC Corporation), or Gelrite (Scott Laboratories). Two- hundred mature embryos (40 plates with five embryos/plate) of cultivar Netum were cultured (using the methods described previously) on each of the four media. Callus initiation was observed and recorded after six weeks.

Results

The greatest number of calli were initiated on medium solidified with agarose (Table 14). Agarose and Gelrite media initiated significantly more calli than Bacto-agar. Also, those calli initiated on medium solidified with Bacto-agar or Phyt-agar were more prone to tissue browning and necrosis.

Table 14
Effect of culture medium gelling agents on callus initiation from mature embryos of wild rice.

Gelling agent	Number of calli	Percent initiation	Mean/plate
agarose	121	60.5	3.03 A
Gelrite	117	58.0	2.92 A
Phyt-agar	105	53.0	2.62 AB
Bacto-agar	88	44.0	2.22 B

Means followed by the same letter do not differ significantly (P=.05) according to Duncan's multiple range test.

Carbon Source

Introduction

Plant cells require a carbon source when grown in culture and this need is generally met by the addition of sucrose (2-3% w/v) to the medium

(Gamborg, 1984). The use of carbon sources other than sucrose has been beneficial in some tissue culture systems. Combinations of sucrose and maltose, dextrose, ribose or lactose have sometimes promoted greater callus initiation and more rapid growth as compared with sucrose alone (Evans et al., 1984). The effects of different carbon sources on the initiation of wild rice callus were compared.

Materials and Methods

Six types of medium were prepared. Five of the media were amended with dextrose, lactose, glucose, maltose, or ribose. The media contained standard MS ingredients, 1 mg/l 2,4-D, half the normal amount of sucrose (1.5% w/v) and an equimolar amount of one of the other sugars. The sixth medium was the same except that it contained only sucrose (3% w/v) as a carbon source. Using the methods described previously, 100 mature embryos (20 plates with five embryos/plate) of cultivar Netum were cultured on each of the six media. Callus initiation was observed after six weeks.

Results

Media ammended with maltose or dextrose initiated significantly more calli than medium ammended with any of the other sugars or with sucrose alone (Table 15). Lactose, glucose and ribose-ammended media did not differ significantly from sucrose alone.

Table 15
Effect of carbon source on callus initiation from mature embryos of wild rice.

Carbon source	Number of calli	Percent initiation	Mean/plate
maltose + sucrose	30	30	1.65 A
dextrose + sucrose	28	28	1.60 A
sucrose	22	22	1.10 B
lactose + sucrose	20	20	1.00 B
ribose + sucrose	20	20	1.00 B
glucose + sucrose	19	19	0.95 B

Means followed by the same letter do not differ significantly (P=.05) according to Duncan's multiple range test.

Conclusion

Initiation and growth of morphogenic callus from mature embryos of wild rice can now be routinely accomplished. Modifications of the culture medium, particularly the hormone and gelling agent components, have had dramatic effects on the initiation, growth and re-differentiation of callus. In comparison with other systems, the growth rate of wild rice callus is slow. It is hoped that further refinements of the culture medium and selection of vigorously growing callus tissues will increase the growth rate of wild rice calli.

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Procedures for Optimizing Combine Harvest Profitability and Evaluating Kernel Size Distribution

C. E. Schertz, J. J. Boedicker and M. C. Lueders

Wild rice harvest research has continually emphasized the development of methods to quickly evaluate samples. Recently, effort has been directed toward the quick on-site evaluation of green grain samples to calculate percent recovery and size distribution of the processed grain. The method for evaluating grain samples has facilitated the development of a procedure for assessing the profitability of specific combine adjustments. Having the ability to quickly evaluate green grain samples is useful for on-the-spot evaluation of quality and for establishing value.

Wild rice harvest research in 1987 was conducted in the following specific areas:

1) Further development of procedures for comparing combine adjustment effects on harvest profitability as influenced by amount and quality of harvested grain.

2) Further evaluation of bulk density as a predictor of percent recovery.

3) Assessment of the accuracy of combine net yield sample analysis in predicting amounts of processed grain by size category.

4) Investigation of the relationship between mechanical length sorting and manual-visual sorting for evaluating the extent of broken kernels in a green sample.

1. Procedures for comparing combine adjustment effects on harvest profitability

An objective in harvest research over the last two years has been to develop a method for use by growers for determining proper combine adjustments to maximize harvest profitability. This year's investigation followed the method developed, used, and reported on last year.

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Combine adjustment is a compromise, between attempts to maximize both the quality and quantity of the harvested yield. In adjusting for optimum performance of the sieve system, for example, the desire to minimize the loss of grain from the sieve must be balanced with the desire to minimize the amount of non-grain material going into the grain tank. The method that was developed involves determining a relationship between the amount of the net green yield (NGY) and the associated amount and kernel size distribution of the net processed yield (NPY). From this relationship, the cost of processing an incremental change in net green yield can be compared to the anticipated value of the incremental change in net processed yield.

The procedures used are applicable to any combine and set of harvest conditions. A series of test runs was made with each test run consisting of two end-to-end trips (2240 ft for each test run) in the field. After each run, the harvested grain was transferred from the combine grain tank to a weigh-wagon for weighing. During each run, a composite sample was made of the grain coming into the grain tank. From this sample, subsamples were taken for: a) on-site field laboratory analysis and b) freezing and subsequent campus laboratory analysis. The sample analysis procedures included: heating at 217 F for 2 hours, dehulling, fanning, sorting by length on oscillating pocket plates, and weighing grain in each length category. The length categories were: 1 & 2 [>20/64"], 3 [<=20/64" & >12/64"], and 4 to 7 [<=12/64"] as specified by the International Wild Rice Association, May 1984. The grain was not sorted for kernel width.

The results of net processed yield by grade category are shown plotted in Figure 1. As expected, with the exception of run "C", the graph shows that as net green yield is increased by combine adjustment to permit more material to go to the grain tank, net processed yield increases as well.

Data like those shown in Figure 1 form the basis for determining the effect of specific combine adjustments on profitability. At time of harvest, cost per acre for processing the current year's crop is the only cost the grower can control. In the profit analysis, this cost per acre is considered to be directly proportional to the weight of material delivered to the processing plant. Information of the type shown in Figure 1 can be used to determine the economic effect of adjusting the combine to change net green yield from one level to another and the profitability of making such an adjustment. Such a determination also requires pricing information on a) the processing charge per pound of green wild rice and b) value per pound of processed wild rice by grade category.

To illustrate a procedure for assessing the anticipated change in profit resulting from a change in combine adjustments, consider the following question: Which is the more profitable setting--- that used for run "B" or that used for run "D"? Letters to

identify the runs are shown on Figure 1. The data and associated calculations for these two runs are as follows:

Run Identification	NGY, lb/ac	NPY (grades 1 thru 7), lb/ac
Run "B"	517	213
Run "D"	563	223
incremental change (B to D)	+ 46	+ 10
incremental processing cost @ $ .17/lb	+ $ 7.82	
incremental crop value @ $ 1.00/lb		+ $ 10.00
incremental crop value @ $ 1.25/lb		+ $ 12.50

In this example the adjustments for run "D" are more profitable than the adjustments for run "B" for either assumed values of processed grain. This analysis makes use of an assumed charge for processing of $.17/lb and assumed values of $1.00 & $1.25/lb for the processed grain. The above simplified analysis did not differentiate in value of crop for different grade categories. For a more realistic analysis, a different value could be assigned to each grade category of processed grain.

As a second example, consider for runs "B" & "D" the incremental change in the total in grade categories 1&2 and 3. (In this example, the grain in the other grade categories is assumed to be of no value.) The data and associated calculations for this example are as follows:

Run Identification	NGY, lb/ac	NPY (grades 1,2&3), lb/ac
Run "B"	517	202
Run "D"	563	209
incremental change (B to D)	+ 46	+ 7
incremental processing cost @ $ .17/lb	+ $ 7.82	
incremental crop value (grades 1,2&3 only) @ $ 1.00/lb		+ $ 7.00
incremental crop value (grades 1,2&3 only) @ $ 1.25/lb		+ $ 8.75

In this comparison, the adjustments for run "D" are more profitable if the price is $1.25/lb but not if it is $1.00 /lb.

The primary intent of the investigation was to develop and demonstrate a procedure for making combine adjustment decisions based on profitability. For wild rice growers to implement this procedure, they must do three things: 1) make net green yield measurements corresponding to selected combine settings in a field with uniform crop conditions, 2) determine percent recovery and preferrably also processed grain size distribution from representative samples of harvested grain for each combine setting and 3) calculate incremental costs and values using anticipated price structure(s).

2. Estimating percent recovery from bulk density by vibrating the container

The use of bulk density measurements to help estimate percent recovery and to help make harvest decisions is not new. Our 1986 harvest season, report provided results for three different methods, namely, loose fill, jostle fill and pack fill. In the 1987 season, samples of wild rice were measured for bulk density

by use of a vibrating surface stand for the container during filling. It was anticipated that the vibration might provide for a more uniform fill of the container. Also for comparisons, bulk density measurements were made by the loose fill method. The results for both methods are shown on Figure 2. The fill method employing the vibrating surface, as expected, produced higher bulk densities than the loose fill method. However, because of similar scatter in the data points there appears to be no advantage of one method over the other.

3. Predicting amounts of processed grain by size category from combine net yield sample analysis

A study was made to determine the accuracy of combine net yield sample analysis in predicting the amounts of processed grain by size category. One reason for conducting this study was to determine the validity of using sample analysis results directly in determining preferred combine adjustments for maximum profitability. The study utilized subsamples from a composite of a group of individual load samples taken at the processing plant. The results obtained by sample analysis were compared to the results obtained by a processing plant for the respective load groups. This composite sample procedure was necessary because of the inability to maintain identity of individual load lots through the processing plant. This study was performed on the grain from three wild rice growers. The composite samples, from which subsamples were taken for analysis, were made up of grain from load samples taken at the time of delivery of each load to the plant. The contribution of each load sample to the composite sample was in proportion to the weight of the load from which it had been obtained. Of necessity, the load samples were frozen until all load samples had been collected.

Sample analysis procedures included: 1) heating the sample at 217 F for 2 hours, 2) dehulling, 3) fanning, 4) categorizing the kernels by length on oscillating pocket plates, 5) categorizing the kernels by width in rotating slotted cylinders and 6) weighing the grain in grouped grade categories. The grain was weighed without further drying. It's moisture content ranged from 4 to 7 % Mwb. The length and width categories employed corresponded to the Grading Standards of the International Wild Rice Association and as grouped by the cooperating processing plant. The summarized results from this study are tabulated in Table 1. The sample analysis results are shown in columns 3 & 4 and the results from the processing plant are shown in columns 5 & 6. The following observations are made:

1. Sample analysis and processing results are similar for the wild rice from each grower.

2. The results from processing showed a higher portion of grain in the 1 & 2 kernel length categories than did the results of the sample analysis.

3. The sample analysis procedure retained as graded grain a larger portion of the original green weight than did the procedures of processing.

Some of the reasons that sample analysis resulted in a higher portion of the green weight being retained as graded grain are:

1. The sample analysis treats all grain kernels independent of size; whereas, the processing plant procedures included an air separation step to remove the extremely light kernels.

2. Freezing of the samples for later analysis essentially stopped respiration; whereas, respiration continued to occur in the grain during the curing process. In the respiration process some dry matter is consumed.

3. Lower losses may have occured in the analysis of the small samples than occured in processing the large lots.

From these results, modifying or correcting factors have been developed so as to more closely predict the results from plant processing. It is not known if these modifying factors will be useful at other processing plants or for that matter at the same plant in another season. To be useful, such modifying factors should be based on data over the range of grain parameters that can be expected for delivery at a processing plant. In this particular study, the making of a composite sample from individual load samples provided an averaging effect. The inability to maintain identity of individual load lots through the processing plant in 1987 precluded any comparisons of sample analysis and processing results for loads over the expected range in quality parameters.

Other potential uses for green sample analysis results are: a) to quickly test for excessive kernel damage which can be reduced through appropriate combine adjustment and b) to permit on-the-spot evaluation for quality. In 1987, a number of samples were analysed for growers from a number of different combines. Excessive kernel damage was not detected in any of those samples.

4. Mechanical length sorting and manual-visual sorting for evaluating the extent of broken kernels in green samples

A study was conducted to compare the results of on-site mechanical length sorting with results of manual-visual sorting for evaluating the extent of broken kernels in a green sample of wild rice. The mechanical length sorting procedure involved heating the sample, dehulling, fanning, sorting on an oscillating pocket plate for length, and weighing to determine the percentage of dried dehulled grain < 12/64" in length. The manual-visual sorting used a back lighted work surface on which a sample of

green wild rice grain was placed for sorting. The purpose of the light was to aid in visually detecting and sorting out any fractured kernels, otherwise undetectable, within the hulls. The mass ratio in percentage of fractured kernels to total mass was calculated. A comparison of the results from the two methods showed no correlation.

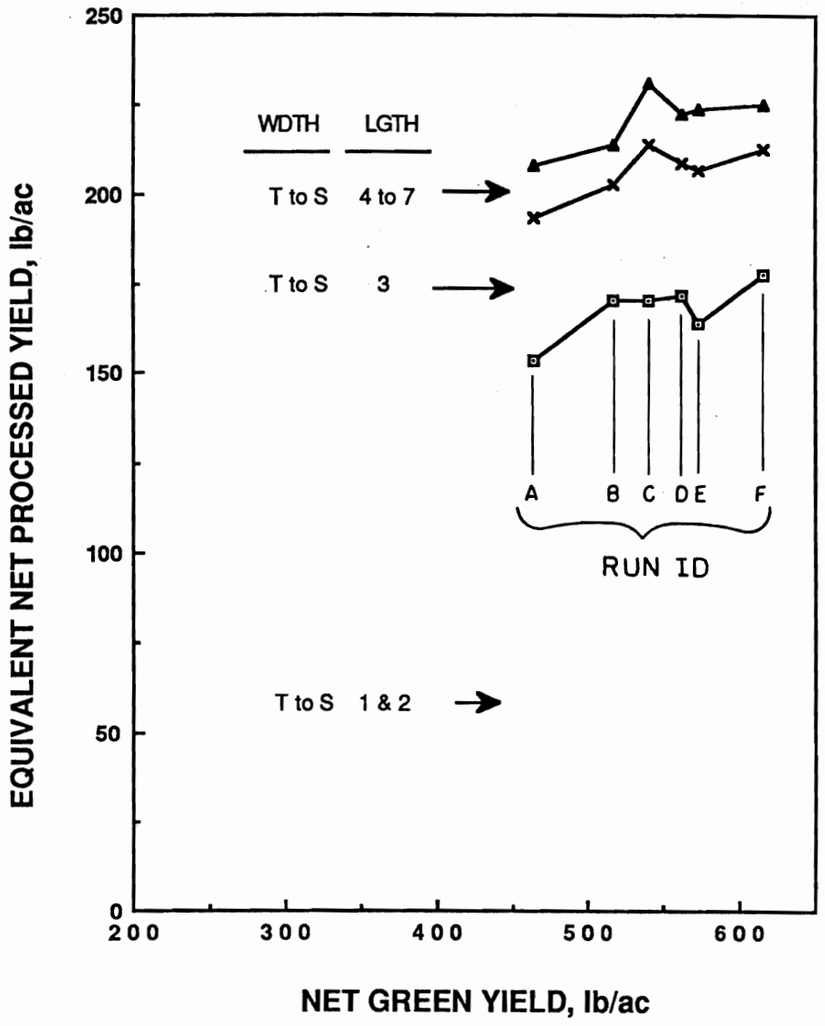

Fig. 1 Equivalent net pocessed yield by grade vs. net green yield.

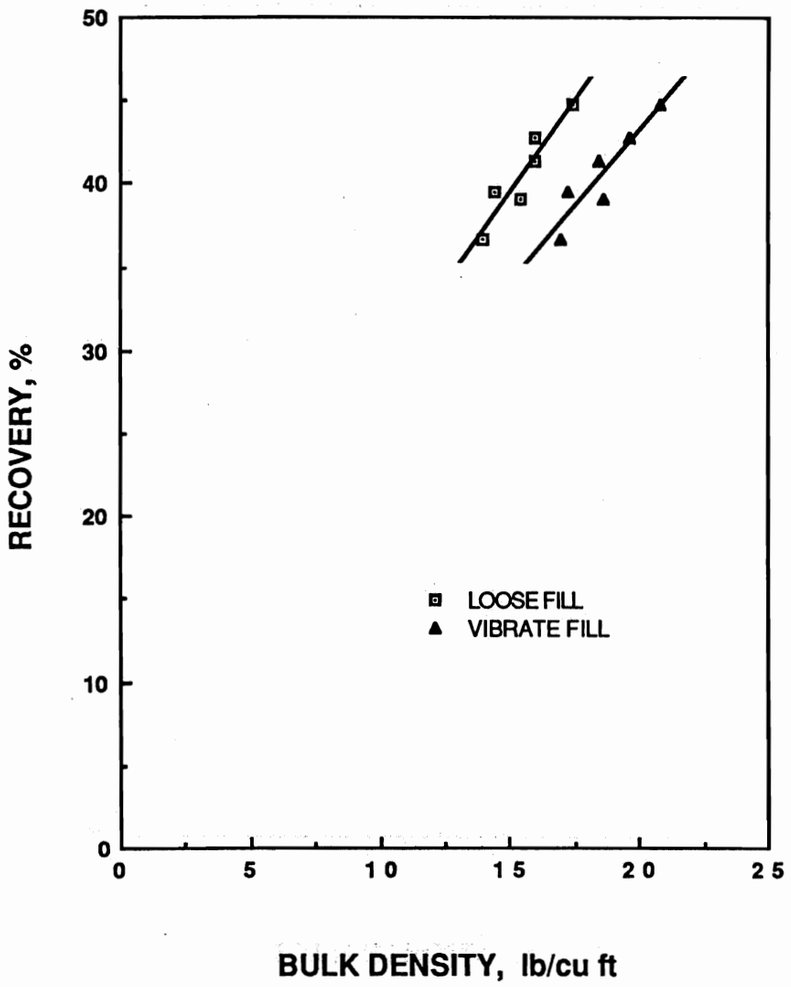

Fig. 2 Bulk density vs. percent recovery.

Table 1. Sample analysis vs. processing plant results.

SIZE DESIGNATION*		SAMPLE ANALYSIS		PROCESSING	
		Percent of Processed Sample Wt.	Percent of Initial Sample Wt.	Percent of Processed Grain	Percent of Green Wt. Delivered
Width (1)	Length (2)	(%) (3)	(%) (4)	(%) (5)	(%) (6)
Grower No. 1					
T O P	1 & 2	41.7	19.8	48.9	19.6
I N	1 & 2	23.8	11.3	30.9	12.4
G S	1 & 2	14.1	6.7	14.5	5.8
T O P	3	4.6	2.2	.8	.3
I N	3	4.6	2.2	1.6	.6
G S	3	6.6	3.1	1.5	.6
T to S	4 to 7	4.7	2.2	1.9	.7
	TOTAL	100.0	47.6	100.0	40.1
Grower No. 2					
T O P	1 & 2	44.7	20.8	49.4	20.0
I N	1 & 2	21.8	10.1	31.4	12.7
G S	1 & 2	11.5	5.3	12.8	5.2
T O P	3	5.8	2.7	.8	.3
I N	3	5.0	2.3	1.6	.6
G S	3	7.0	3.3	1.9	.8
T to S	4 to 7	4.3	2.0	2.1	.9
	TOTAL	100.0	46.5	100.0	40.5
Grower No. 3					
T O P	1 & 2	41.6	19.9	43.5	18.1
I N	1 & 2	22.5	10.7	35.8	14.9
G S	1 & 2	12.6	6.0	15.3	6.4
T O P	3	5.7	2.7	.7	.3
I N	3	5.4	2.6	1.6	.6
G S	3	7.4	3.5	1.5	.6
T to S	4 to 7	4.9	2.3	1.7	.7
	TOTAL	100.0	47.7	100.0	41.5

*International Wild Rice Association, 1984