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Minnesota Wild Rice Research—1999/2000

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WILD RICE PRODUCTION RESEARCH - 1999

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Growing Season and Production

The total number of growing degree days was lower in 1999 compared to 1998 at all locations except Aitkin (Table 1 and 2). However, the total was higher than the long-term average (normal) at Aitkin, Grand Rapids and Waskish, but lower at Crookston. Overall the season was somewhat later than in 1998 but still relatively earlier than the long-term average. Generally, April and May were cooler at all four locations in 1999 than 1998, while June was warmer. July was also warmer in 1999 compared to 1998 at Aitkin, Grand Rapids and Waskish but not at Crookston. August was cooler in 1999 compared to 1998 at all four locations. Compared to the long-term average all months were warmer at Aitkin, Grand Rapids and Waskish. At Crookston, April, June, July and August were warmer in 1999 compared to the long-term average while May was warmer.

Table 1. Growing degree days[a] comparisons for 1998, 1999, and normal (61-90).

	Aitkin			Grand Rapids		
Month	**1998**	**1999**	**Normal**	**1998**	**1999**	**Normal**
	----------GDD----------					
April	148	146	127	206	151	130
May	619	550	417	620	431	434
June	639	661	646	652	702	674
July	806	1004	779	854	924	858
August	823	770	683	882	773	768
Total	3035	3131	2652	3214	2981	2864

[a] $\frac{\text{Maximum + minimum temp.}}{2}$ - 40°F; data from Mark Seeley, Department of Soil, Water and Climate, U of MN.

Table 2. Growing degree days[a] comparisons for 1998, 1999, and normal (61-90).

	Waskish			Crookston		
Month	**1998**	**1999**	**Normal**	**1998**	**1999**	**Normal**
	----------GDD----------					
April	146	126	103	230	150	151
May	516	416	369	614	510	488
June	572	608	518	661	718	743
July	793	829	642	932	918	926
August	814	664	563	937	800	867
Total	2814	2643	2195	3374	3096	3175

[a] $\frac{\text{Maximum + minimum temp}}{2}$ - 40°F; data from Mark Seeley, Department of Soil, Water and Climate, U of MN.

Total precipitation during the 1999 growing season at all four locations was higher than in 1998 and the long-term average (Tables 3 and 4). The growing season total precipitation in 1999 compared to 1998 was 8.1 inches more at Grand Rapids, 5.47 inches more at Aitkin, 2.30 inches more at Waskish and 1.54 inches more at Crookston. At Aitkin and Grand Rapids, July and August were particularly wet making harvest difficult especially in Aitkin. At Crookston, July and August were wet in 1999 compared to 1998 making harvest more difficult near this location also.

In 1999 the weather was generally favorable for wild rice production but the wetter conditions made it more difficult to harvest while in 1998 the late summer was very favorable for harvesting. As was the situation in 1998 many growers observed a slow filling of kernels plus a high incidence of empty kernels. Yields were good but may have been higher if more filling of the kernels had occurred.

Table 3. Precipitation comparisons for 1998, 1999, and normal (61-90).[a]

	Aitkin			Grand Rapids		
Month	**1998**	**1999**	**Normal**	**1998**	**1999**	**Normal**
	inches					
April	2.56	2.33	2.30	0.47	1.84	2.10
May	2.52	6.85	2.88	4.29	4.95	3.04
June	7.80	3.58	4.09	6.60	2.56	4.11
July	3.49	5.07	4.14	1.82	9.35	3.89
August	2.53	6.54	3.83	1.24	3.82	3.59
Total	18.9	24.37	17.24	14.42	22.52	16.73

[a]Data from Mark Seeley, Department of Soil, Water, and Climate, U of MN.

Table 4. Precipitation comparisons for 1998, 1999, and normal (61-90).[a]

	Waskish			Crookston		
Month	**1998**	**1999**	**Normal**	**1998**	**1999**	**Normal**
	inches					
April	1.08	1.57	1.70	0.93	1.22	1.45
May	4.93	6.34	2.33	6.04	3.38	2.45
June	4.07	2.82	4.25	5.76	3.96	3.44
July	3.19	4.37	3.42	2.12	3.16	2.77
August	4.73	5.20	3.32	1.36	6.03	2.88
Total	18.00	20.30	15.02	16.21	17.75	12.99

[a]Data from Mark Seeley, Department of Soil, Water, and Climate, U of MN.

The total amount of processed wild rice produced in Minnesota was the highest its ever been with a production of 6.2 million pounds in 1999 (Table 5). However, it was only 100,000 pounds over the second highest production which was in 1996. Even though it was quite wet, especially during harvest, no severe storms occurred except toward the end of the harvest season. California produced its largest crop ever in 1999 of 15,575,000 processed pounds. The amount was 6,575,000 more than that produced in the years of 1986 and 1997. California experienced no significant yield reductions due to weather except some late hail storms in the northern valley area of Shasta and Modoc counties.

Table 5. Minnesota and California paddy wild rice production[a] (1000 processed pounds).

	Production			Production	
Year	Minnesota	California	Year	Minnesota	California
1968	36	0	84	3600	2500
69	160	0	85	4200	7900
70	364	0	86	5100	9000
71	608	0	87	4200	4200
72	1496	0	88	4000	3500
73	1200	0	89	3978	4000
74	1036	0	90	4800	4200
75	1233	0	91	5500	5500
76	1809	0	92	6100	7500
77	1031	0	93	5300	7500
78	1761	100	94	5300	5000
79	2155	200	95	4500	6440
80	2320	400	96	6000	7600
81	2274	500	97	6002	9000
82	2697	880	98	5,840	8800
83	3200	2500	99[b]	6,200	15,575

[a]1968-1982 Minnesota values from Winchell and Dahl and 1983-1998 from Minnesota Department of Agriculture; California values from Marcum, Cooperative Extension Service, University of California.
[b]Estimated.

The estimated value of the Minnesota crop to producers was $9.61 million which was slightly higher than in the previous six years. Part of this was due to the slightly higher production in 1999.

Table 6. Processed wild rice harvested and value from cultivated fields in Minnesota.

Year	Production	Price to Producer	Value
	1,000 lb	$/lb	$ Millions
1968	36	3.30	0.12
1969	160	2.55	0.41
1970	364	2.80	1.02
1971	608	2.70	1.64
1972	1,496	2.30	3.44
1973	1,200	2.05	2.46
1974	1,036	2.37	2.46
1975	1,233	2.50	3.08
1976	1,809	2.70	4.88
1977	1,031	4.35	4.48
1978	1,761	5.10	8.98
1979	2,155	5.01	10.80
1980	2,320	4.47	10.37
1981	2,274	3.79	8.62
1982	2,697	3.41	9.20
1983	3,200	3.35	10.72
1984	3,600	3.30	11.88
1985	4,200	2.97	12.47
1986	5,100	2.60	13.26
1987	4,200	1.50	6.30
1988	4,000	1.65	6.60
1989	3,978	1.65	6.56
1990	4,800	1.70	8.16
1991	5,300	1.70	9.01
1992	6,100	1.70	10.37
1993	5,300	1.65	8.74
1994	5,300	1.65	8.74
1995	4,300	1.50	6.45
1996	6,000	1.50	9.00
1997	6,002	1.50	9.00
1998	5,840	1.55	9.05
1999[a]	6,200	1.55	9.61

[a]Estimated values for 1999.

Wild Rice Plant Population and Nitrogen Fertilization

Introduction

The introduction and widespread use of the variety Franklin coupled with a general increase in the amount of nitrogen applied as topdresses by growers has lead to a need for reexamining the agronomics of cultivated wild rice in Minnesota. In particular, there is considerable interest in whether higher plant densities are advisable under a higher nitrogen regime. Past research has demonstrated that 2-4 plants/ft^2 are necessary for optimum yields. These experiments are the second year of a study begun in 1997. In 1998, as in 1997, the experiments were conducted at two separate locations: the North Central Experiment Station near Grand Rapids, MN and the Clearwater Rice Farm near Clearbrook, MN. These experiments were done in conjunction with Dr. Paul Bloom who contributed his knowledge about nitrogen response in peat soils. Dr. Raymie Porter also contributed by providing seed and helping to plant the study. Dr. Robert Nyvall also checked the plots for disease incidence.

Materials and Methods: North Central Experiment Station

As in 1997, the experiment consisted of 6 plant densities and 3 fertilization levels for a total of 18 treatments. The experiment was replicated 6 times. The treatments were as follows:

Target Plant Density (plants/ft^2)	Nitrogen Fertilization Levels
1) 0.5	1) 75 lbs/A basal
2) 1.0	2) 75 lbs/A basal + 60 lbs/A topdress
3) 2.0	3) 75 lbs/A basal + 60 lbs/A topdress + 40 lbs/A topdress
4) 4.0	
5) 8.0	
6) 16.0	

The plots were planted on May 6 and flooded on May 7, 1998. Nitrogen fertilizer at a rate of 75 lbs/A was applied at planting. Soil samples were taken on June 8, 1998. The plots averaged 29 lbs/A of inorganic nitrogen. Plots consisted of 8 rows, 6 inches apart and 10 ft. long. The 4 rows in the center were reserved for harvest, the outer rows for borders, and those between the harvest and border rows for plant sampling. To reach the desired plant densities, the plots were thinned by hand at the aerial leaf stage. Topdresses were applied at boot and flowering. The boot stage topdress, 60 lbs/A of nitrogen (urea), was applied on July 13, 1998. The flowering stage topdress, 40 lbs/A of nitrogen, was applied on July 21, 1998. Plant samples were taken at 4 times during the season: boot, 7-13; flowering, 7-21; flowering + 10 days, 7-31; and harvest, 8-25. Each sample consisted of whole plants taken from a 4 ft. section of the sampling rows. Plants were bagged, dried, and stored for future nitrogen analysis. SPAD meter readings were taken on all plots at the boot stage. Stem diameters were measured on all plots the day before harvest. Stems were chosen from the center rows and measured at the first internode below the flag leaf. All plots were harvested on August 25, 1998. An 8 ft. section of the center 4 rows was taken from each plot for grain and straw data. Ten

panicles were taken at random from this section and bagged separately prior to harvesting the remainder of the section. After harvest, plant counts were made on all plots to determine the actual plant densities.

Results and Discussion

Yield Characteristics

Germination of high density plots (8 and 16 plants/ft^2) was erratic in 1998, and consequently actual plant densities were lower than in 1997. Since target densities were not reached in the high density plots in 1998, we decided it was more realistic to present the data on the basis of the actual plant populations that we had at harvest time for 1998. Consistent with data from 1997, the highest yields were obtained with plant densities of 2-4 plants/ft^2 (Figures 1, 2, and 3). Because we did not reach the higher plant densities in 1998, we were unable to corroborate the slow decline in yields observed in 1997 as plant densities increased above 5 plants/ft^2. Wild rice worm damage was less in 1998 than in 1997. This may be reflected in the somewhat higher yields obtained in 1998. All plant densities except two exhibited increased yields with topdress nitrogen (Figure 4). This poor response to topdressing at lower densities was also observed in 1997. An examination of yield components reveals panicles per plot and yield per panicle decreasing as plant densities increase (Figures 5 and 6). This is consistent with data from 1997; however, at lower plant densities, 1997 data suggests a lower yield per panicle than observed in 1998 (Figure 7). The number of panicles per plant exhibits a weak response to topdressing (Figure 8); lower densities again are relatively unaffected. The yield per panicle was unresponsive to nitrogen topdressing. Panicles per square foot increased as plant densities increased and reached 8-10 panicles/ft^2 at high yielding plant densities (Figure 9). Stem diameters were not affected by nitrogen levels, but as in 1997 they showed an inverse relationship to plant density (Figure 10).

Panicle Characteristics

In an attempt to refine our understanding of the components involved in the yield per panicle, the experiment in 1998 was expanded to include an accounting of such factors. Work is ongoing; however, some preliminary results are presented here. The number of kernels per panicle - both dark mature kernels and green immature kernels - is unaffected by nitrogen levels and fairly constant over the range of 1-4 plants/ft^2 (Figure 11). The weight of dark kernels is unaffected by nitrogen levels and slowly decreases as plant densities increase (Figure 12). Data obtained in 1997 by weighing dehulled kernels supports this result (Figure 13). Though analysis is hampered by a lack of data at higher plant densities, it appears that both kernel weight and the number of kernels per panicle are responsive to changes in plant density. Kernel weight slowly decreases with increasing plant densities. As data from both years shows the yield per panicle dropped substantially as densities increased, the number of kernels per panicle must also have decreased. Field observations in both years (especially 1997) support this hypothesis. Panicles from the highest density plots are substantially shorter and smaller than those from lower densities.

Nitrogen Economy

In both years of this study, whole plants were sampled throughout the season and analyzed for nitrogen content. Data for 1998 is not yet available; data from 1997 which was not presented in last year's research report is presented here. Plant samples were analyzed using Near Infrared Reflectance Spectroscopy (NIR) which was calibrated to micro-kjeldahl results. An equation was successfully produced for predicting nitrogen content based on infrared reflectance patterns from ground plant material. Examination of the data reveals two major trends. First, plant nitrogen content decreases throughout reproductive growth for all treatments (Figure 14 as an example). Second, for any given growth stage, increasing plant densities decreased plant nitrogen content (Figure 15 as an example). At boot stage, prior to topdress, plant biomass varies from 500-2500 lbs/A and plants have already taken up 10-45 lbs/A of nitrogen (Figures 16 and 17). At harvest, subsample data indicates a total nitrogen uptake of 60-90 lbs/A while actual plot biomass data indicates an uptake of 40-55 lbs/A (Figures 18 and 19). The actual biomass data is a more reliable figure as it is based upon a larger sample. Thus at harvest topdressed plants contain 10-15 lbs/A more nitrogen than non-topdressed plants. Data from 1998 will be used to test and if necessary to adjust the NIR equation developed from the 1997 experiment. A fairly steady relationship between NIR results and nitrogen levels would prove useful for both growers and researchers.

Summary and Conclusions

The grain yield data for 1997 and 1998 confirmed earlier experiments that the plant population in Minnesota wild rice fields should be in the range of 2-4 plants/ft^2. This optimum plant population did not change even when applying extra nitrogen during the boot and flowering stages of plant growth. However, applying the extra 100 lbs/A of nitrogen above the initial 75 lbs/A on clay soils at the Grand Rapids Experiment Station gave the highest yields. Changes in plant population dramatically changed the number of panicles per plant; as the population increased so the number of panicles per plant decreased. However, they remained constant at about two per plant at the higher plant populations. Kernel number per panicle decreases slightly at higher plant populations but losses in yield at the higher plant populations comes mainly from reduced kernel weight. Kernels per panicle range from 80 to 90 per panicle while kernel weight ranges from 21 to 26 mg per kernel.

Materials and Methods, Clearwater Rice Farm

As in 1997, this experiment was conducted in a grower's field. Sections of the field were thinned to three different plant densities:

Plant Density

1) Not thinned
2) Thinned once by airboat
3) Thinned twice by airboat

Each thinning block was approximately 4.5 acres. The field was managed in accordance with the grower's usual practices. Soil samples were taken on June 22, 1998. The blocks averaged 29.0 lbs/A of inorganic nitrogen. Three topdresses were applied for a total of 105 lbs/A of nitrogen. A

boot stage topdress, 40 lbs/A of nitrogen, was applied on June 12, 1998. A flowering stage topdress, 40 lbs/A of nitrogen, was applied on June 27, 1998. A late flowering stage topdress, 25 lbs/A of nitrogen, was applied on July 20, 1998. Four strips were harvested with a wild rice combine out of the center of each block and the yields averaged. The blocks were harvested on August 11, 1998. Prior to harvest each block was sampled to determine the number of tillers per plant. After harvest each block was sampled to determine plant densities. Don Barron and Rod Skoe did the thinning, topdressing, and harvesting with their equipment.

Results and Discussion

Results from both 1997 and 1998 are presented in Table 1. In 1998 early season algae produced conditions in which thinning would not normally be advisable. Consequently, the thinned plots yielded much less than in 1997 when they were the higher yielding blocks. Based on 1997 results, the one thinning block from 1998 at 1.7 plants/ft^2 should have yielded 1600-1800 lbs/A of grain. It produced approximately half that amount. The ability of algae to reduce stands to clumps, is evidently affecting plant growth responses and yields. Uniformity of stand is thus important for consistently high yields. Data from both years indicates that a range of 2.5 - 4.5 plants/ft^2 is optimal. This compares well with data from the experiments at the North Central Experiment Station.

Table 1 - Plant Thinning Study at Clearwater Rice Farm

Number of Thinnings	Plant Density (plants/ft^2)	Tillers/ plant	%Moisture	Yield at 40% Moisture (lb/A)	%Recovery	Finished Yield (lb/A)
			1997			
0	5.7	1.6	36.0	1293	46.1	558.3
1	2.8	2.7	36.7	1853	43.9	770.8
2	1.1	5.5	38.5	1655	42.9	692.0
			1998			
0	4.4	2.6	36.7	1425	47.0	635.0
1	1.7	4.2	41.1	789	43.3	347.8
2	0.7	8.0	43.6	517	40.2	221.0

WILDRICE BREEDING AND GERMPLASM IMPROVEMENT

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Variety Trials

Introduction

Variety trials in 1999 were carried out to assess yield, shattering, and other traits of released varieties and breeding populations.

Materials and Methods

Although variety trials were planted in three locations, only the trial on the Rennemo farm northwest of Waskish had sufficient stand density to harvest for yield and shattering data. The Godward farm near Aitkin had enough plants to obtain some data, but not yield. The Waskish location was planted October 29, 1998 on a peat soil. Aitkin was planted on May 21, 1999 on a mineral soil. At Waskish, phosphorus and potassium were applied and incorporated by the grower at each location in accordance with soil tests and normal practices. Nitrogen was applied by researchers at planting at a rate of 50 lb of N per acre as urea under the rows of seeds. At Aitkin, researchers applied 40 lb/A of potassium and 75 lb/A of nitrogen at planting under the rows of seeds.

At each location, the same twenty entries (released varieties and breeding populations) were planted in 4 replicates in a randomized complete block design. Plots consisted of four 10-foot rows, 12 inches apart, with 3 feet between adjacent plots and 6-foot alleys between ranges of plots. Franklin seed was unintentionally left out of the Waskish planting, so Franklin data from three previous trials was standardized relative to the average of K2, Petrowske Bottlebrush, and Voyager in those earlier trials, then estimated relative to the average of those three varieties in the 1999 trial. This was thought to provide a reasonable estimate for comparisons. Voyager did not appear in the Aitkin trial, but estimates for it were not calculated.

All plots were inoculated at flowering with spore suspensions of Bipolaris oryzae, the causal agent of Fungal Brown Spot (FBS) disease. Approximately 100 ml of spore suspension were sprayed on all four rows of each plot with a CO_2 sprayer, for a total of 1,000,000 spores/plot. Approximately 35 lb/A of N as urea were topdressed three times during flowering.

The center two rows of each plot were used for measurements-- namely, flowering, height, panicle length, foliar disease rating, and lodging. On the same day as harvest, the plots were rated for disease and lodging. The center two rows of each plot were trimmed to a net length of 8 feet and harvested with a Yanmar binder. Bundles were immediately carried to a Kincaid raspbar thresher for threshing. Seed was weighed before drying, placed in a drying oven for at least one week at 130°F, and then weighed again to determine percent moisture.

Results and Discussion

The three highest yielding entries at Waskish were pistillate breeding populations (Table 1). FY-C6 also yielded well, and PBR-C4, the population being increased for possible release in 2000, was in the middle of the pack. The least shattering entries were PBR-C4, PBM-C6, and K2PiH-C1 at 11%. PBR-C4 also had the lowest FBS and lodging ratings, confirming its superiority in disease and lodging resistance. It was near the average in height and panicle length. These characteristics were also seen in the Aitkin data (Table 2). In both trials, PBM-C6 was almost as good as PBR-C4. FSSR-C10 had low FBS ratings at Aitkin, but not at Waskish.

When 1999 data were included in a multi-year average (Table 3), PBR-C4 ranked third in yield, and first in shattering, and lodging, and second in FBS rating, supporting its superior performance for these characteristics. However, PBM-C6 also looks promising.

Other Activities

In 1999, Franklin was increased and 15,000 lb. were made available to growers in Minnesota. This seed increase was carried out on the Imle farm north of Gully. Also on the Imle farm, PBR-C4 completed its first on-farm increase, providing 720 lb of seed to plant on 48 acres for the final 2000 increase. If approved by the Crop Variety Review Committee, approximately 40,000 lb. of this variety should be available in September of 2000. In addition, a synthetic line made from intercrossing nonshattering progeny of a nursery family (96F-111) was increased in the growth room to provide seed for yield testing in 2000. This line is putatively fixed for at least one nonshattering gene, and should be more stable with respect to retaining its shattering resistance over time, barring contamination by seed or pollen from shattering genotypes.

Eighteen breeding populations were subjected to recurrent selection for a number of traits, including shattering resistance, FBS resistance, lodging resistance, yield, earliness, medium plant height, and pistillate panicles.

In 1999, the project obtained a McGill sample huller to begin gathering data on hulled yield, a rough estimate of processed yield. The first try with variety trial samples resulted in data which had more variability than the raw (green) yield, indicating the need to further refine the sample hulling protocol in order to reduce error from the hulling procedure. Still, it was a good beginning for improvements in breeding for the end product.

Table 1 Yield, shattering, and other varietal characteristics for 1999 Waskish trial

Entry	Yield	Shattering	Shattering	Grain moisture	FBS rating	Lodging score	Plant height	Panicle length
	lb/A[1]	lb/A[1]	%[2]	%	units[3]	units[4]	in	in
Franklin (est.)	*1698*	*311*	*16*	*39*	*5.1*	*2.1*	*75*	*8.4*
FSP5-C2	1692	263	13	42	4.9	1.2	73	7.3
FSSR-C10	1270	215	14	40	5.1	1.3	74	6.8
FY-C5	1864	269	12	40	4.4	1.4	76	7.4
GIB-C9	1770	325	15	39	5.1	2.0	75	7.6
K2-C8	1699	302	15	40	5.0	1.6	74	7.0
K2F-C7	1541	219	13	40	5.4	1.0	74	7.6
K2F-C8	1416	225	13	40	4.8	1.7	75	7.1
K2-Godward	1787	270	14	41	5.0	1.3	74	7.5
K2-Lyneta	1070	191	15	45	6.0	2.3	74	7.3
K2PiH-C1	2298	264	11	46	4.7	2.0	72	7.1
K2PiP-C2	2028	289	13	45	4.6	1.7	76	8.0
NACH-B	1401	292	18	36	6.7	1.9	70	6.6
P2BR-C3	1445	259	16	41	4.0	1.2	74	7.4
PBM-C6	1586	199	11	43	3.8	1.2	75	7.4
PBR-C4	1585	178	11	42	3.5	1.0	75	7.3
PLAR-C4	1528	355	19	45	4.5	2.0	73	7.0
PM3E-C8	2019	278	12	45	4.4	1.2	73	7.7
PS-C4	1522	344	18	43	5.7	2.0	78	7.9
Petrowske BB	1439	387	22	41	6.3	2.3	69	7.5
Voyager	1667	331	18	41	5.7	2.0	73	8.2
Mean	1632	273	15	42	5.0	1.6	74	7.4
LSD.05	473	89	5	2	2.0	0.8	4	1.0
CV	20%	23%	26%	4%	28%	33%	4%	9%

[1] Adjusted to 40% moisture.

[2] Expressed as a percentage of shattered seed plus grain yield per unit area.

[3] Using a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead).

[4] Using a 1-5 scale where 1 = stems completely erect, 3 = stems averaging 45° angle, 5 = stems prostrate.

Table 2 Varietal characteristics for 1999 Aitkin trial

Entry	FBS rating units[1]	Lodging score units[2]	Plant height in	Panicle length in
Franklin	5.1	2.6	59	7.6
FSP5-C2	3.8	1.8	62	8.1
FSSR-C10	2.4	1.6	57	6.6
FY-C5	3.8	1.5	62	7.5
K2-C8	3.8	1.3	62	7.2
K2F-C7	3.3	1.3	64	7.1
K2F-C8	4.1	2.1	64	7.0
K2-Godward	4.5	1.7	62	7.5
K2-Lyneta	4.1	1.9	61	7.3
K2PiH-C1	4.0	2.5	59	7.5
K2PiP-C2	4.2	2.3	62	7.5
NACH-B	7.4	3.2	58	7.0
P2BR-C3	3.7	1.4	62	7.2
PBM-C6	3.2	1.0	66	7.3
PBR-C4	3.0	1.2	59	7.8
PLAR-C4	4.7	2.3	63	7.5
PM3E-C8	4.4	2.2	58	7.5
PS-C4	5.7	2.0	61	8.2
Petrowske BB	6.2	2.7	60	8.2
Mean	4.3	1.9	61	7.5
LSD.05	1.5	0.8	6	0.8
CV	25%	29%	6%	8%

[1] Using a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead)

[2] Using a 1-5 scale where 1 = stems completely erect, 3 = stems averaging 45° angle, 5 = stems prostrate.

Table 3 Yield, shattering, and other varietal characteristics of variety trial entries, 1997-99.

Entry	Yield	Shattering	Shattering	FBS severity	FBS rating	Lodging score	Plant height	Panicle length
environments: [1]	a b c d f	a b d f	a b d f	a	c d e f g	a b c d e f g	a c d e f g	a c d e f g
	lb/A[2]	lb/A[2]	%[3]	%[4]	units[5]	units[6]	in	in
FY-C5	1335	251	15	13	4.1	2.1	75.4	7.8
Franklin	1239	290	19	24	4.8	2.6	73.7	8.0
K2F-C7	1390	199	12	11	4.3	1.9	74.9	7.5
K2-C8	1315	185	12	15	4.0	1.8	74.4	7.8
K2PiP-C2	1507	315	17	19	4.8	3.1	73.7	8.0
K2 Godward	1324	279	17	33	4.8	2.1	74.3	7.4
NACH-B	1196	355	24	28	6.7	2.6	71.3	7.5
P2BR-C3	1141	224	16	14	3.9	1.7	73.6	7.6
PBM-C6	1474	170	11	11	3.4	1.7	75.0	7.7
PBR-C4	1440	179	11	11	3.6	1.6	73.3	7.6
Petr. BB	1100	284	21	28	5.8	2.5	70.6	7.5
Voyager	1113	398	27	20	5.3	2.5	72.7	7.9
avg means	1295	249	16		4.4	2.2	73.3	7.8
LSD.05	151	46	3		0.6	0.3	2.1	0.4
CV	20%	29%	26%		21%	25%	5%	8%

[1] Environments represented are a=Waskish 97; b=Gully 97; c=Grand Rapids 97; d=Waskish 98; e=Gully 98; f=Waskish 99; and g=Aitkin 99.

[2] Adjusted to 40% moisture.

[3] Expressed as a percentage of shattered seed plus grain yield per unit area.

[4] Estimated percentage of leaf area covered by lesions on a per-plot basis.

[5] Using a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead).

[6] Using a 1-5 scale where 1 = stems completely erect, 3 = stems averaging 45° angle, 5 = stems prostrate.

Acknowledgments

We thank Ross Rennemo, John Gunvalson, and Tommy Godward for providing space and support for our on-farm variety trials. Thanks to Paul Imle for increasing potential varieties, partially at his own expense. This research was funded through USDA-ARS Cooperative Agreement No. 58-3640-9-119, secured largely through the efforts of the Minnesota Cultivated Wild Rice Council and University of Minnesota representatives.

RESEARCH RESULTS ON DISEASES OF CULTIVATED WILD RICE, 1999

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Field Trials

Cooperative work with Paul Bloom - Interaction of fertility and disease

Effect of N topdress compared to Tilt fungicide on the control of disease. This is a continuation of studies completed in 1996 and 1998. The 1997 research plots were abandoned due to an error in aerial application of fertilizer.

A wild rice paddy with a uniform stand of wild rice and moderate soil fertility was selected in early June at the Tom Godward farm in Aitkin, Minnesota. The treatments included topdress once with 40 lb./A of N, two topdresses with 70 and 30 lb./A of N, one 40 lb./A topdress with N followed by one or two applications of Tilt at 6 oz/A and a control that received no topdress or Tilt. Treatments were replicated 6 times in 6 ft. x 10 ft. plots. Disease was measured by harvesting 5 flag leaves per plot and rating percentage of leaf diseased. Incidence of scab and grain yield were also measured.

			Recovery of Bipolaris spp.[4]		
		Scab[3]	B. oryzae	B. sorokiniana	Yield[5]
Treatment[1]	Disease Rating[2]	%	%	%	(lb./acre)
40 lb. N mid boot	50 a	8 a	31 a	3 a	146
70 lb. N mid boot + 30 lb. early flower	55 a	7 a	36 a	1 a	175
40 lb. N mid boot + 1 early application Tilt	59 a	17 b	80 b	2 a	132
40 lb. N mid boot + 1 late application Tilt	44 b	19 b	56 c	0 a	144
40 lb. N mid boot + 2 applications Tilt	41 b	13 b	41 c	2 a	188
Control	54 a	13 b	51 c	1 a	113

[1]Data were analyzed by analysis of variance with mean separations by Duncan's test (P=0.05) using Statview Version 4.02. Ratings followed by the same letter within a column were not significantly different (P=0.05).
[2]Disease rating is based on five flag leaves per plot, replicated six times for a total of 30 leaves. Rating is estimated using Clive James Key for percentage of leaf area diseased.
[3]Based on number of seed Fusarium spp. (scab) recovered of 100 seeds.
[4]Based on recovery of Bipolaris spp. from 100 leaf fragments.
[5]Dry weight in pounds per acre.

Evaluation of Stratego, Tilt (Propiconazole) and Quadris (Azoxystrobin) Fungicides on Cultivated Wild Rice

Locations:

Rod Skoe farm in Clearbrook and Ray Berger farm in Waskish, Minnesota.

Experimental Protocol:

Experiment design was a randomized complete block.
Five replicates per treatment per location.
Each treatment was a plot 7 ft. x 6 ft.
Fungicides were suspended in water and applied with a hand held pressure type garden sprayer so that a measured amount of active ingredient was delivered to each plot.
Five flag leaves were randomly selected from each plot at harvest.
Isolations of Bipolaris spp. were made from 100 leaf spots from each replicate.
Isolations of Fusarium spp. were made from 100 whole seeds from each replicate.
Yields was obtained by harvesting all seed in one square meter per plot, dried to approximately 5% moisture content and weighed.

Treatments:

1. Tilt 4 oz/A at heading
2. Tilt 6 oz/A at heading
3. Tilt 6 oz/A at boot
4. Stratego 8 oz/A at boot and 14 days later (heading) and 14 days later (heading)
5. Stratego 8 oz/A at heading
6. Stratego 8 oz/A at boot and 14 days later (heading)
7. Stratego 10 oz/A at boot
8. Stratego 10 oz/A at heading
9. Stratego 10 oz/A at boot
10. Quadris12.8 oz/A at heading
11. Control

Disease Data:

	Disease Reading			% Recovery of Bipolars spp. from spots					
				Waskish Location 1		Clearwater Location 2		Ave	
	Waskish Location 1	Clearwater Location 2	Average	B.o	B.s	B.o.	B.s.	B.o.	B.s.
Treatment	%	%	%	%	%	%	%	%	%
1	7.9	11.5	9.7	46	4	17	6	32	5
2	5.6	12.5	9.1	15	8	29	4	22	6
3	8.6	7.4	8.0	52	0	35	16	44	8
4	6.2	16.4	11.3	22	1	39	25	31	13
5	19.3	14.1	16.7	54	3	41	18	48	11
6	3.7	9.6	6.7	14	3	19	18	17	11
7	11.8	13.2	12.5	64	6	24	16	44	11
8	7.9	9.6	8.8	25	5	24	20	25	13
9	7.5	13.0	10.3	19	3	48	13	34	8
10	7.6	10.0	8.8	31	4	27	15	29	10
11	14.8	19.2	17.0	53	22	46	19	50	21

B.o. = Bipolaris oryzae, causal organism of fungal brown spot.
B.s. = Bipolaris sorikiniana, causal organism of spot blotch.

Disease readings were estimated using Clive James Key for percentage of leaf area diseased.
One hundred leaf spots were selected randomly from each replicate for a total of 500 spots per treatment per location and placed on sterile filter paper and incubated for 10-14 days. Fungi were identified at this time. Average is the result of 1,000 spots.

Scab data:

Isolation or Fusarium spp. (scab) from seed collected from Fungicide Trials.

Treatment	Percent of seed yielding Fusarium spp. Waskish Location 1 %	Clearbrook Location 2 %	Average %
1. Tilt 4 oz/A at heading	1	49	25
2. Tilt 6 oz/A at heading	0	32	16
3. Tilt 6 oz/A at boot and 14 days later (heading	1	59	30
4. Stratego 8 oz/A at boot	3	45	24
5. Stratego 8 oz/A at heading	6	46	26
6. Stratego 8 oz/A at boot and 14 days later (heading)	0	48	24
7. Stratego 10 oz/A at boot	5	59	32
8. Stratego 10 oz/A at heading	5	31	18
9. Stratego 10 oz/A at boot and 14 days later(heading)	3	52	26
10. Quadris12.8 oz/A at heading	0	66	36
11. Control	5	66	36

Yield data:

Treatment	Yield Waskish Location 1 (lbs./acre)	Clearbrook Location 2 (lbs./acre)	Average (lbs./acre)
1. Tilt 4 oz/A at heading	533	864	699
2. Tilt 6 oz/A at heading	544	783	664
3. Tilt 6 oz/A at boot and 14 days later (heading)	621	900	761
4. Stratego 8 oz/A at boot	509	987	748
5. Stratego 8 oz/A at heading	517	821	669
6. Stratego 8 oz/A at boot and 14 days later (heading)	674	906	790
7. Stratego 10 oz/A at boot	582	1,034	808
8. Stratego 10 oz/A at heading	633	1066	850
9. Stratego 10 oz/A at boot and 14 days later(heading)	522	966	744
10. Quadris12.8 oz/A at heading	644	893	769
11. Control	597	981	789

Effect of Infested Residue on Fungal Brown Spot Incidence and Severity

Dry wild rice field residue, infested with Bipolaris oryzae, was stuffed into 20 lb. plastic mesh potato sacks. Sacks were tied onto poles, either above the water surface, or on the water surface. One pole, with bag of residue attached, was placed at the center of each 6 ft. x 7 ft. plot. Plots were separated by 4 ft. alleys. Control plots were marked, but no treatment applied. Each treatment was replicated 12 times. Grain was harvested from 1 square meter per plot, air dried and weighed. Located at Clearwater Farms in Clearbrook, Minnesota.

Results:

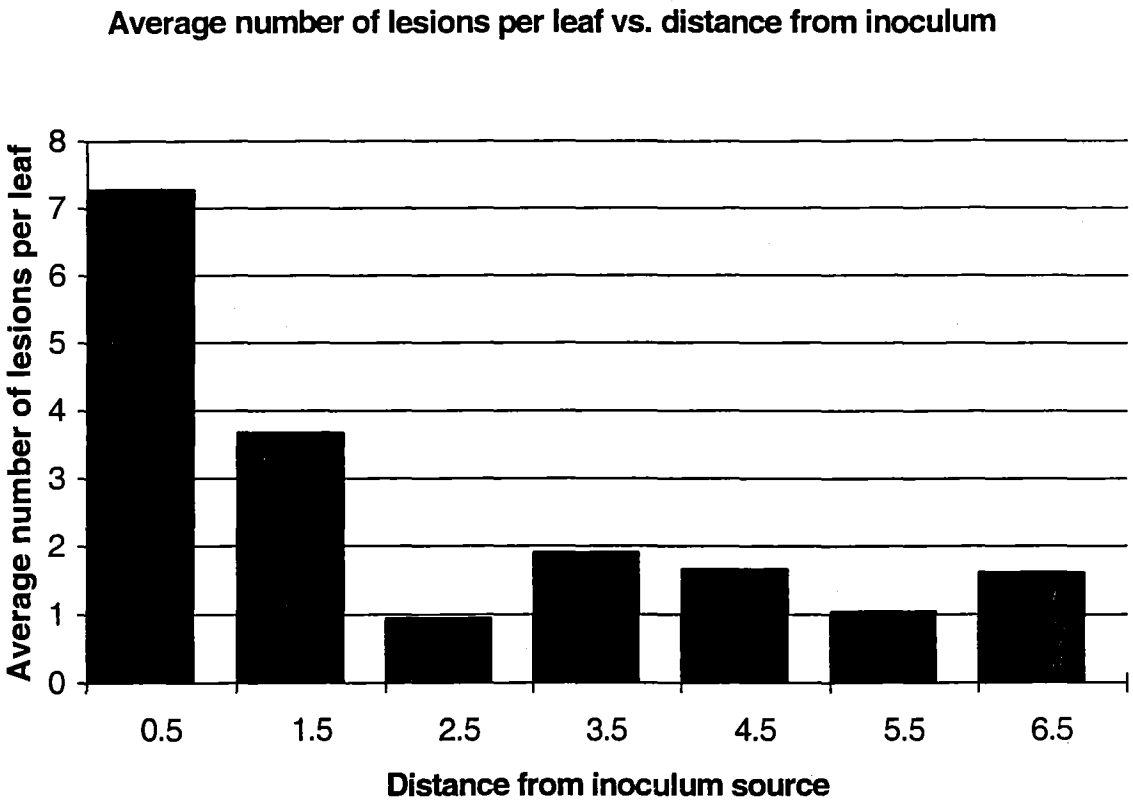
Treatment	Yield (lb./acre)
Residue placed above water surface	720
Residue placed on water surface	760
Control	820

Green House Projects

Simulated Wind Conditions

Preliminary results from our study conducted in 1997-1998 indicate that B. oryzae is airborne but not a large distance from the source of inoculum. This experiment was repeated in 1998-1999 with similar findings and will be repeated again in 1999-2000.

Pots of wild rice at flowering stage of development were placed at increasing distances from a source of inoculum, at one meter intervals from 0.5 to 6.5 meters. Inoculum source consisted of infested wild rice residue spiked with a suspension of B. oryzae spores at a concentration of 1.5×10^4 spores per milliliter. Plants were enclosed in a mist chamber and relative humidity kept at 95% to encourage favorable conditions for disease development. A box fan was placed behind the inoculum source and directed toward the plants. Airflow was maintained for 24 hours and then discontinued. Leaves were collected 5 weeks after inoculation and all visible lesions were counted.


Average number of lesions per leaf vs. distance from inoculum
Average number of lesions per leaf
8
7
6
5
4
3
2
1
0
0.5
1.5
2.5
3.5
4.5
5.5
6.5
Distance from inoculum source

Laboratory Studies

Cooperative work with Raymie Porter

We continue to cooperate with Dr. Porter by supplying B. oryzae inoculum to be used in wild rice variety trials to determine relative resistance or susceptibility to fungal brown spot.

Mycoherbicide development for Water Plantain

We continue to culture isolates of Rhyncosporium spp. obtained from diseased water plantain to be used as a potential biological control of water plantain in growers' fields

Work In Progress

1. Simulated wind conditions in the green house.
2. Chronology of disease.
3. Inoculation of Reed Canary grass.
4. Mycoherbicide development on water plantain.
   a) grow water plantain.
   b) culture Rhyncosporium spp.

EFFICACY OF FOUR *BACILLUS THURINGIENSIS* FORMULATIONS IN SUPPRESSING FEEDING DAMAGE BY RICE WORM, *APAMEA APAMIFORMIS* (GUENEE)

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In Minnesota, under 50 farms commercially grow wild rice, *Zizania aquatica* L. on 16,000-20,000 acres annually producing about 6 million pounds. The annual value of commercially produced wild rice is estimated at $ 41 million. Insect species associated with wild rice in Minnesota include the rice worm, rice stalk borer, rice leaf miner, rice midge, rice stem maggot, rice water weevil, English aphid and birdcherry-oat aphid. Of these 6 species, the rice worm is considered the most important economic insect pest causing 10% of crop loss (D. M. Noetzel, unpublished report). All the other species were reported causing less than 1% crop loss. The riceworm, *Apamea apamiformis* (Guenee) is the larva of a noctuid moth that has traditionally been a pest of natural wild rice stands (Moyle 1944, MacKay and Rockburne 1958, Melvin 1966). The adults of *A.apamiformis* emerge from overwintering sites and oviposit as soon as they emerge during July-August. Eggs are laid in recently opened florets, and each floret may harbor from 3-64 eggs (Johnson 1975). There could be as high as 84% of heads with eggs, and about 6 florets/head with eggs. A greater percentage of eggs are laid around the paddy edges, and the number of infested heads decreases from the field edge to the interior. Egg mortality is less than 5% indicating lack of any adverse impact by natural enemies. Newly hatched larvae feed inside the floret and emerge within 2 days. These young larvae are difficult to find because of their nocturnal feeding habits, and it is believed that they disperse to other paddy plants or unknown alternate hosts in this stage (Johnson 1975). Larvae are not apparent until the third instar. Older larvae of *A. apamiformis* damage the developing kernels, but are capable of boring into the wild rice stalks causing them to break (Melvin 1966, Johnson 1975). In severe infestations, 10-16% crop loss is not uncommon (Peterson et al. 1981). Fully-grown larvae (presumably 7^{th} or 8^{th} instars) leave the head and spend sometime in the leaf sheaths after which they move to the base of the plant. Larvae overwinter by burrowing into the ground at the base of the plant or near the dikes around September-October, and continue their development the following May. Thus, there is only one generation of *A. apamiformis* per wild rice growing season.

Malathion is the only insecticide registered for use on wild rice to control both the rice worm and midge. Currently, there are two formulations of malathion that have a Special Local Need (Section 24 C) registration in Minnesota (**Malathion 5E**, Micro Flo Company, Lakeland, Florida and **Malathion 57 EC**, Platte Chemical Company, Fremont, Nebraska). On commercial paddies, malathion should be applied by air. For rice worm a single application is recommended, but the label does not restrict the number of applications as long as no application is made 10 days prior to harvest.

* Current location: Kansas State University.

On August 3, 1996, the United States Congress passed the Food Quality Protection Act (FQPA) [Public Law 104-170] amending both the Federal Insecticide, Fungicide, and Rodenticide and the Federal Food, Drug, and Cosmetic Acts and this legislation has been implemented by the EPA. The FQPA revises tolerances of registered pesticides on raw and processed agricultural commodities using nine criteria. These criteria include assessing tolerances based on dietary consumption of adults, children, and infants; cumulative effects of pesticides, hormonal effects of pesticides, and combining exposures from pesticides with a similar mode of action. These stringent criteria have resulted in manufacturers supporting their pesticide products for use for the most part only in major crops, while dropping minor uses. A minor use pesticide is one used on 300,000 acres or less. Malathion use on wild rice is certainly a minor use. Incentives exist in FQPA to support minor use pesticides, especially where no other alternatives exist, and to expeditiously register reduced-risk pesticides At best, malathion's future is uncertain. Therefore, it is important to explore effective reduced-risk pesticide alternatives to malathion for *A. apamiformis* control.

Bacillus thuringiensis, *Bt*, is a naturally occurring bacteria which produces an insect toxin, different varieties of which are effective only against certain orders of insects and is very safe for mammals. The bacteria are raised by a number of companies and the toxins extracted through a process in which the bacteria are killed. The toxins are then incorporated into insecticide formulations. Because commercial *Bt* formulations do not include living bacteria, are highly specific and very safe for mammals, they are considered 'safe' pesticides by the EPA, and are therefore fast-tracked for registration on agricultural crops. The variety *Bt* Kurstocki (*Btk*) is specifically toxic only to lepidoptera (butterflies and moths). It is available in a number of formulations and may provide some control for rice worm. We conducted field trials to evaluate four different *Bt*K formulations for their effectiveness in controlling rice worm.

Methods & Materials

Twenty small plots (8'x4') were established in the experimental rice paddies at the North Central Research & Outreach Center in Grand Rapids, MN. Rice was planted and maintained using standard production techniques. All plots were located in the vicinity of a population source of wild rice worm. Four formulations of *Bacillus thuringiensis* with different toxins (Cry 1 and Cry 2) that are specific for larvae of Lepidoptera were selected from commercially available products (Cutlass, Condor, Crymax, and Lepinox) by Ecogen, Inc. All formulations must be ingested by larvae to exert any biocidal activity. Formulations were mixed according to and applied at label directions and rates (Table 1). Plots were sprayed on Aug 22, 1999 with a backpack sprayer and 3' boom. Even coverage was obtained and plants were sprayed to drip. Each replication included one application each of the

Treatment	Formulation	Rate
1	**Cutlass**	1.5 lbs/ac
2	**Condor**	1.5 lbs/ac
3	**Lepinox**	3.0 lbs/ac
4	**Crymax**	1.5 lbs/ac
5	Untreated Check	N/A

Table 1. Application rates for *Bt* formulations.

four *Bt* formulations and an untreated check. A comparison application with Malathion was intentionally excluded; it was known beforehand that the *Bt* formulations would be significantly less effective than any of the *Bt* formulations and the authors considered this to be an unfair comparison.

Because the larvae feed at night and spend little time in the kernel, it was decided to use damage to kernels as a measure of rice worm population and feeding activity. Prior to spraying, ten plants were randomly selected in each plot by selecting stalks at water level and following the stalk up. This practice prevented unintentionally selecting either heavily or lightly infested panicles. Although 10 heads per plot is a relatively low sample size, the number of stalks per plot limited a more aggressive sampling program. The panicles of each plant were collected, placed in a zip-lock plastic bag and stored in a cooler for transport to the laboratory at the Northwest Research and Outreach Center. In the laboratory, the panicles were visually examined under a dissecting microscope and the number of rice worm damaged kernels was recorded. Because of the variation in panicle size, comparing the absolute number of damaged kernels per panicle would be misleading; it would be very difficult using this raw data to ascertain if the *Bt* application had any effect on the rice worm populations. We therefore decided to use the proportion of kernels damaged as an indicator of riceworm population and activity. We counted the number of kernels in each panicle and calculated the proportion of kernels in each head damaged by riceworm feeding. Ten days after spraying, 10 more heads were selected in the same manner and the proportion of damaged kernels was again assessed. The difference between the proportion of kernels damaged prior to application and the proportion of kernels damaged after application was then calculated for each plot. This difference between pre and post-treatment damage was used to evaluate how effective the *Bt* formulations had been in suppressing riceworm populations or feeding. These proportions were arcsine transformed and differences between the treatments compared using an Analysis of Variance (ANOVA). The arcsine transformation is necessary when using parametric statistics, like ANOVA, to compare proportions or percentages.

Results & Discussion

There was a trend for all four *Bt* treatments to have less mean post-treatment damage than the untreated check (Fig 1). However, only the Condor and Lepinox formulations were statistically different from the untreated check; both formulations showed less damage post treatment than the check. There was no significant difference in post-treatment damage between any of the treatments. It should be noted that the formulation with the least post-treatment damage was Lepinox, the label of which recommends a rate twice that of the other formulations (Table 1).

We found that Bt formulations may have some potential for use against rice worm, although results will not be comparable with the control achieved with Organo-Phosphate insecticides. Of the formulations tested, Lepinox and Condor can significantly decrease damage from rice worm as compared with untreated checks.

Reference Cited

Johnson, C. B. 1975. The life history of *Apamea apamiformis* (Guenee) on wild rice in Minnesota. M. S. Thesis, University of Minnesota, 81 pages (unpublished).

MacKay, M. R. and E. W. Rockburne. 1958. Notes on life-history and larval description of *Apamea apamiformis* (Guenee), a pest of wild rice (Lepidoptera: Noctuidae). Can. Entomol. 90: 579-582.

Melvin, J. C. E. 1966. Observations on insects attacking wild rice in Manitoba. Proc. Entomol. Soc. Manitoba 22: 6-11.

Moyle, J. B. 1944. Wild rice in Minnesota. J. Wildlife Mgmt. 8: 177-184.

Peterson, A. G., D. M. Noetzel, J. E. Sargent, P. E. Hanson, C. B. Johnson, and A. T. Soemawinata. 1981. Insects of wild rice in Minnesota. Miscellaneous Report 157. Agricultural Experiment Station, University of Minnesota, 15 pp.

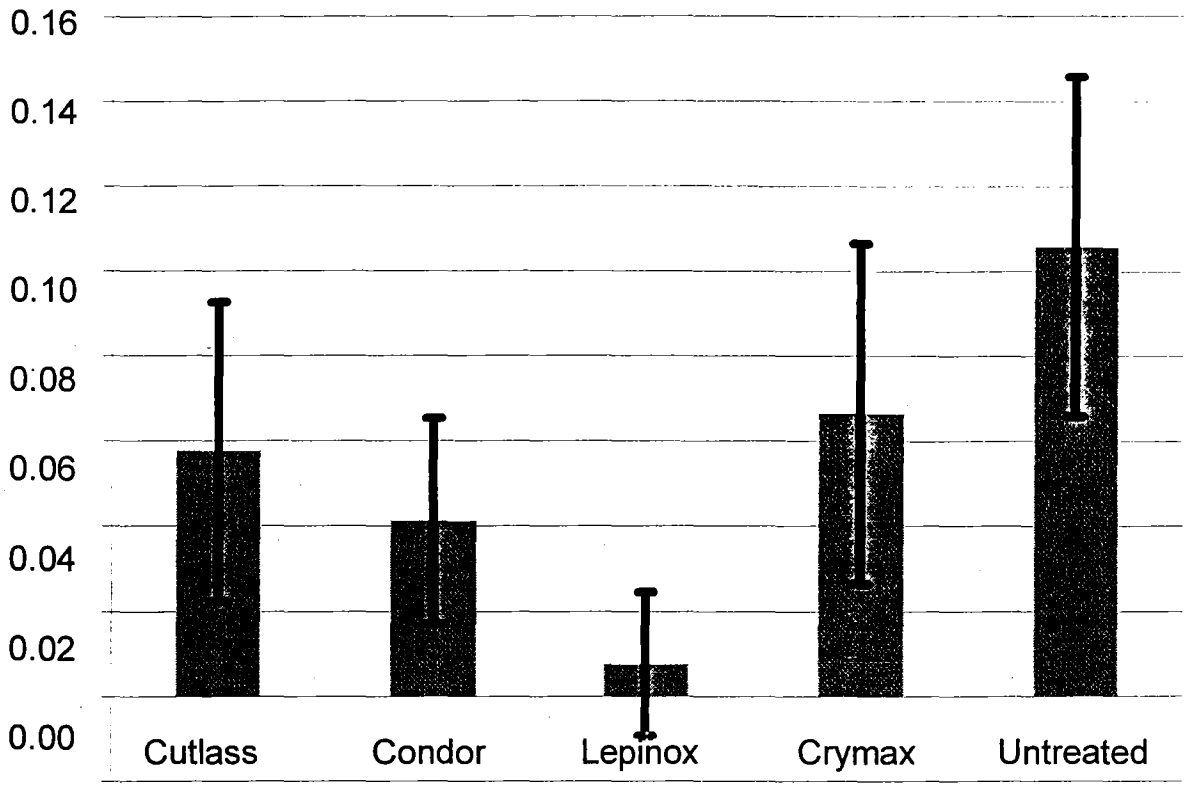

Figure 1. Comparison of rice worm damage. Solid bars represent the mean difference between the percent of kernels damaged by riceworm before and percent of kernels damaged by riceworm after *Bt* treatments. Vertical lines represent 95% Confidence Intervals (CI's). The formulations Lepinox and Condor had significantly less post-treatment damage from rice worms than did the untreated checks.

FERTILITY AND INTERACTION OF FERTILITY WITH TILT IN CONTROL OF BROWN SPOT

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Low fertility is known to contribute to the severity of brown spot disease. In 1999 we continued the field studies of the interaction of N fertility and Tilt® (propiconazole) in the incidence and severity in brown spot in cultivated wild rice.

A previous study in 1998 suggested that, 1) topdress K on a field with sufficient basal K has no effect, 2) topdress N reduces disease incidence and increases yields, 3) topdress combined with one Tilt ® application further reduces disease incidence and may result in a small increase in yield over N only, and 4) when combined with topdress N two applications of Tilt ® are no better than one.

In the 1999 study, problems with poor general plant health were encountered despite application of N and sufficient K and N. Because the plants did not grow well brown spot disease incidence was high in all treatments.

The 1999 study was conducted on the Tom Godward farm in a second year paddy with the Franklin variety. The experimental design was changed from 1998 to eliminate the investigation of the effects of topdress K. The paddy had been thinned by airboat before the experiment was initiated.

Research Design

A wild rice paddy with a uniform stand of wild rice and moderate soil fertility was selected in early June and the following topdress treatments were applied:

a) 40 lb urea N/ac at mid boot (1 topdress),

b) 70 lb N/ac at mid boot and 40 lb N/ac at early flower (2 topdresses),

c) 40 lb urea N/ac at mid boot plus one application of Tilt® at 6 oz/ac (1 early Tilt),

d) 40 lb urea N/ac at mid boot plus two applications of Tilt at 6 oz/ac (2 Tilt)

e) 40 lb N at mid boot, one late application of Tilt® at 6 oz/ac, and (1 late Tilt)

f) control with no topdress applications (control).

The plants were monitored for disease and late in the season flag leaves were taken from each plot for pathological analysis. This included the following disease data: a) the percentage of

spots from which were *bipolaris* spp. were isolated; b) the number of spots per leaf; c) the area of diseased flag leaf tissue. The chlorophyll in the plant leaves was monitored using a SPAD® chlorophyll meter and plant tissue was taken for analysis of N, S, and inorganic elements. Soil samples for extractable NH_4^+ were taken at the beginning of the experiment and at the time of addition of the last fertilizer topdress. The grain and biomass yields were measured at harvest time.

Results

The major finding was that, despite sufficient available soil N as measured in mid June and adequate SPAD readings in late June, and mid July straw and grain yields were very low (Table 1). The panicle count at harvest showed a range from 3.1 to 4.2 per ft^2. This should have been sufficient to produce a reasonable yield.

Table 1. Harvest air dried green grain yield, oven dried straw yield, and plant N.

Treatment	N content at harvest	Straw lb/ac	Grain yield, lb/ac
Control	1.36 ab #	1720 a	122 a
1 topdress	1.35 ab	2020 ab	144 a
2 topdress	1.46 b	2190 b	172 ab
1 topdress 1 early Tilt	1.32 a	2160 b	130 a
1 topdress 1 late Tilt	1.36 ab	2050 ab	115 a
1 topdress 2 Tilt	1.27 a	2130 b	186 b

Different letters indicate significant differences at the 10% level.

In mid June the soil contained 28 ±15 lb/ac of available N in the top 10 inches and at boot (June 29) there was still 15 lb/ac remaining. The soil K was not determined in mid June but samples from June 29 show a 115 lb/ac of available K. Initial available soil N in the range of 35 to 50 lb/ac normally is sufficient to get the plants off to a good start. The samples at the boot stage were taken 4 days after the first top dressing of all topdress plots. Growth at this stage was robust and the plant N contents of the topdressed plots were satisfactory and significantly greater than the control plots. The SPAD readings of the topdressed plots were statistically greater than the control plots. The values obtained, however, were somewhat less than we usually obtained from well-fertilized wild rice at the boot stage.

The experiment was on soil that transitioned from a shallow to deeper peat. The shallow peat transitioned to a mineral soil a short distance from the experiment. In the mineral soil area the plants were visibly deficient in N and had a SPAD reading of only 23.8, an extremely low value.

The plant K (data not shown) was greater than 4% ,a high value that is more than sufficient for good growth. The mean available soil N was 15 lb/ac, which indicates a small amount of residual N. Thinning damage was observed in 3 of the six rows of the experiment. At this stage the plants were growing well and we expected good yields.

Table 2. Plant data at boot stage (June 29)

Treatment	N content June, 29 NS	SPAD June 29	Soil N NS
Control basal N	3.31	32.8 a	12
1 topdress	ND	ND	
2 topdress	3.6	34.4 b	21
1 topdress 1 early Tilt	ND	NA	
1 topdress 1 late Tilt	3.63	34.4 b	15
1 topdress 2 Tilt	ND	ND	

Different letters indicate significant differences at the 10% level.

We sampled on July 15 at flower (after the second topdress). Growth after the boot stage was not as vigorous as we expected, but we did find significantly greater plant N and SPAD readings for the plots that had been topdressed twice (Table 3). The plant N was slightly lower than we would like to see at this stage and the SPAD readings were several units lower than expected for the top dressed plots. The SPAD reading in the adjacent mineral soil was only 29.3 and the plants contained only 1.28% N. The plant content of most of the other elements was in the normal range (data not shown). The data for S (Table 3), however, seem to suggest possible S deficiency and the magnesium contents, mean of 1200 ppm, were also lower than we typically see.

In 1989 Mike Meyer reported a results form a greenhouse experiment and field sampling that suggested possible S deficiency for peat soils from Aitkin. His data suggest our S tissue concentrations in mid July were less than the 0.16% needed for good growth.

Table 3. July N, SPAD and S

Treatment	SPAD, July, 15	N content July, 15	S content July, 15 NS
Control basal N	36.2 a	1.63 a	0.143
1 topdress	38.8 ab	ND	ND
2 topdress	40.2b	2.15b	0.155
1 topdress 1 early Tilt	37.4a	ND	ND
1 topdress 1 late Tilt	38.0ab	1.76 ab	0.146
1 topdress 2 Tilt	37.7 ab	ND	ND

Different letters indicate significant differences at the 10% level.

The yields of grain and total biomass were very low (Table 1). We had hoped green grain yields from the topdressed plots in the range 700 to 1000 lb/ac. The 2 topdress treatment is the only treatment with significantly higher grain yields than the no topdress control. The 2 top dress treatment also had the highest tissue N content. The 2 top dress and the topdress plus Tilt, except for the late Tilt treatment, had significantly higher biomass yields than the control. We saw somewhat better growth toward the northwest corner of the experiment corresponding to a deepening of the peat in the northeasterly direction. However, even in the better parts of the experiment growth was not robust.

Tissue analysis for S and other elements has not yet been completed for the straw at harvest. These data may help us gain an understanding of the reasons for the very low yields we observed in this experiment.

The disease assessment data show that the disease ratings were significantly less for the tilt late Tilt and 2 Tilt treatments (Table 4). It appears that one late Tilt and two Tilt applications were equally as effective and the one early application of Tilt was not effective. The differences seen for scab infected seeds and the relative infection with *Bipolari oryzae* or *Bipolaris Sorokniana* are difficult to interpret. Scab was present and not insignificant. Very many of the leaf spots are *Bipolaris oryzyae*. These data likely reflect the very poor plant health that became evident after the boot stage.

Table 4. Disease response

Treatment	Disease rating, % of leaf surface	Scab, % infected seeds	% B.oryzae	% B.soroknian a
Control basal N	54a	13b	51c	1
1 topdress	50a	8a	36a	3
2 topdress	55a	7a	36a	1
1 topdress 1 early Tilt	59a	17b	80b	2
1 topdress 1 late Tilt	44b	19b	56c	0
1 topdress 2 Tilt	41b	13b	41c	2

Different letters indicate significant differences at the 10% level.

The cause of the generally poorer plant health in paddies in the Aitkin area is still an unsolved puzzle. In an effort to try and solve this puzzle we hope to pursue the possibility of S deficiency with greenhouse and field studies.

INSECT ASSESSMENT OF CULTIVATED WILD RICE PADDIES

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North Central Research and Outreach Center

Introduction

Wild rice (Zizania *palustris*) has been a cultivated crop from the middle 1960's to the present. During this time improvements have been made in disease resistance, insect resistance and total yield. Despite these improvements, very little is known about the aquatic insects that live in wild rice fields, which are large, temporary, shallow environments. This project will inform growers and entomologists about insects that grow in these fields.

Wild rice is unique from other small grains in northern Minnesota because it requires shallow water for its growth. This basic requirement forces growers to build and maintain permanent rice paddies. To grow cultivated rice on a large scale, growers construct irrigation and dike systems that flood in the spring and drain in the fall. Fields are of uniform water depth, usually less than 3 feet. Due to crop rotation, some fields may lay fallow for 2-3 years before being flooded again for another growing season.

These agronomic practices provide for a unique opportunity to study insects. The lentic environments are void of larger predators such as fish and due to the heavy canopy of rice, are difficult for avian predators to hunt effectively. The stagnant conditions of the paddies cause the water temperature to be much warmer than "natural" situations. All of these factors combine to make an extremely confined system where trends in the population dynamics of insects can be observed.

This project was done to demonstrate paddies are important not only from an agricultural and financial standpoint, but also as a research opportunity. These paddies are created and maintained only for the production of wild rice, but the habitat they provide to aquatic insects is unlike that found in any other natural environment.

Insects are excellent indicators of the health of the environment and are superior mechanisms of controlling undesirable insects. These paddies afford the entomologist with a way to study predator/prey relationships and the reproductive potentials of aquatic insects in an environment that has never been studied before. This will be a qualitative as well as quantitative assessment of two cultivated rice paddies located in northern Minnesota.

Materials and Methods

Sampling Locations

Samples were taken within paddies at two locations, Waskish and Grand Rapids. Waskish is approximately 150 miles northwest of Grand Rapids. These sites were chosen due to their differences in bottom sediment and total growing degree days. Waskish has a predominantly peat substrate while Grand Rapids has a clay and mineral substrate. Waskish, in a normal year,

has 2195 growing degree days while Grand Rapids has 2864 growing degree days (30% more than Waskish). The differences in substrate and total degree days may affect insect variety and abundance.

Methods

A dip net, large cooler, waders, strainer, forceps, and shallow pan were used to collect, store, and separate insects. Large scoops through submerged vegetation and bottom sediment yielded large amounts of debris that would be cleaned later. Approximately 10 liters of debris were sampled and stored in a cooler. Insects were than separated from debris and placed in 75% ethanol for preservation.

Collection dates in 1999 for each location were as follows:
Waskish-6/30, 7/13, 7/27, 8/10
Grand Rapids-7/6, 7/20, 8/3, 8/17

Four samples were taken from each location during the growing season, alternating between sites every other week. This was done to sample insect genera and populations during a growing season. This length of time was thought to be adequate to allow for univoltine genera to emerge and be sampled.

All insects were identified to genus, if possible, and organized according to collection date and location. Data was compiled after separation, preservation, identification and labeling was complete.

Results

Summary of Insects Sampled in Waskish

A total of seven orders were collected while at the Waskish site. Orders ranged from small, herbivorous invertebrates, like Diptera, to aggressive hunters, like Odonates. The wide array of insects collected, suggest conditions in these paddies are favorable for many types of insects.

Population fluctuations of orders indicate definite trends throughout the sampling season. Populations of herbivorous and smaller predaceous genera peaked early in the season. These orders flourish in an environment with few dominant predators and high food content. Two predaceous orders, Odonata and Coleoptera, had a gradual increase throughout the summer. (See Figure 1). These orders are relatively large, aggressive predators.

Once Odonata and Coleoptera had established themselves, all other orders declined in numbers. These orders were the only insects collected that maintained their high numbers throughout the sampling period. Temperature regimes throughout the sampling period ranged from 17-20 ° Celsius. This slight variation is not substantial enough to cause such wide population fluctuations.

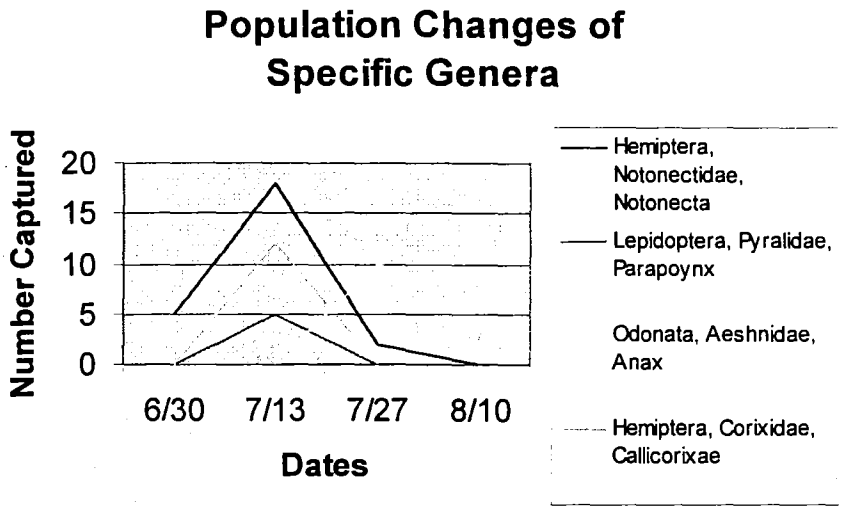
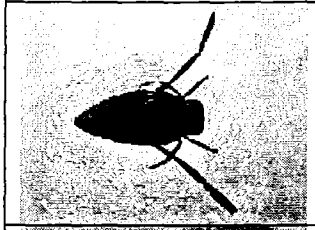
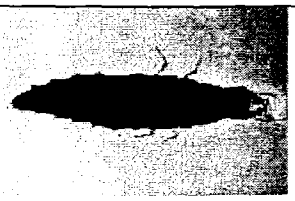


Figure 1. Populations of genera captured in cultivated wild rice fields in Washkish, Mn-1999 (See photos below).

	O: **Hemiptera** F: Corixidae G: *Callicorixae*	Common Name: "Water Boatman" Univoltine, herbivorous Number Sampled: 12
	O: **Hemiptera** F: Notonectidae G: *Notonecta*	Common Name: "Backswimmer" Univoltine, predaceous Number Sampled: 18
	O: **Odonata** F: Aeshnidae G: *Anax*	Common Name: "Dragonfly" Univoltine, predaceous Number Sampled: 10
	O: **Lepidoptera** F: Pyralidae G: *Parapoynx*	Common Name: "Aquatic Caterpillar" Univoltine, herbivorous Number Sampled: 5

Summary of Insects Sampled in Grand Rapids

A total of five orders were sampled at Grand Rapids. Families sampled included large predators like Belostomatidae and Aeshnidae to smaller, herbivores like Baetidae. Most orders sampled were of a predaceous nature. The wide array of insects collected suggests that these paddies are well suited for many types of insects.

Seasonal population fluctuations showed definite trends. Populations of predominantly herbivorous and smaller predaceous genera peaked early in the season. With a lack of larger, dominant predators, these genera were able to flourish in the nutrient rich paddies. (See Figure 2). Populations of Odonata and Ephemeroptera steadily increased throughout the sampling period. This is somewhat surprising since Ephemeroptera are a herbivorous order.

Temperature regimes throughout the sampling period ranged from 19 to 23 Celsius. This slight variation is not substantial enough to cause such wide population fluctuations.

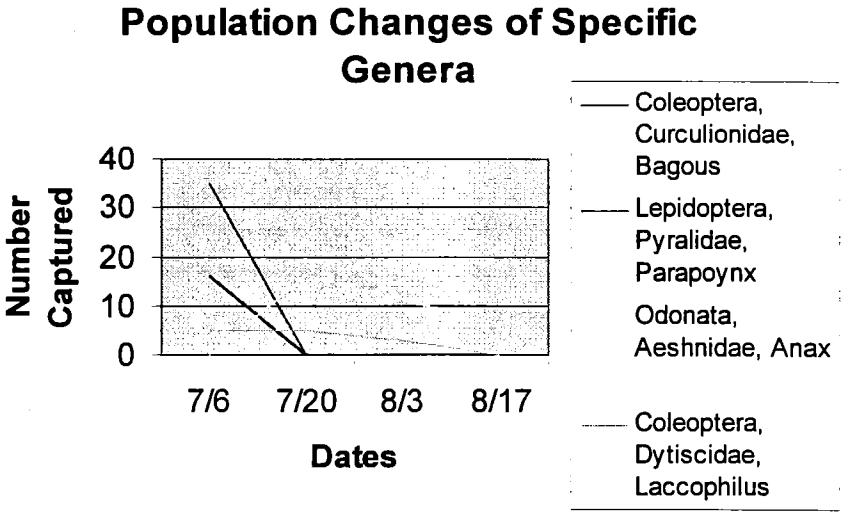
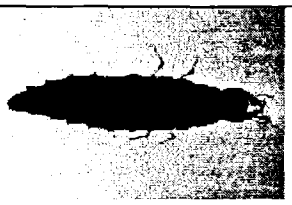
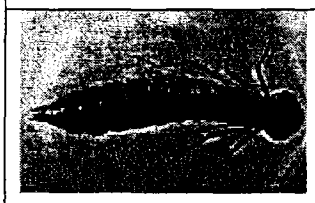


Figure 2. Populations of genera captured in cultivated wild rice paddies in Grand Rapids, Minnesota-1999 (See photos below).

	O: **Coleoptera** F: Curculionidae G: *Bagous*	Common Name: "Weevils" Univoltine, herbivorous Number Sampled: 16
	O: **Lepidoptera** F: Pyralidae G: *Parapoynx*	Common Name: "Aquatic Caterpillar" Univoltine, herbivorous Number Sampled: 35
	O: **Odonata** F: Aeshnidae G: *Anax*	Common Name: "Dragonfly" bivoltine, predaceous Number Sampled: 16
	O: **Coleoptera** F: Dytiscidae G: *Laccophilus*	Common Name: "Predaceous Water Beetle" Univoltine, predaceous Number Sampled: 3

Discussion

A total of 8 orders of aquatic insects were found in wild rice paddies at Waskish and Grand Rapids. In the 8 orders identified 56 genera were represented. These genera varied widely in feeding habits, reproductive characteristics, and body size, but there was consistent populations of both herbivorous and predaceous genera. This variability suggests cultivated rice paddies are extremely well suited for many types of aquatic insects.

Grand Rapids had 7 orders totaling two hundred five specimens; whereas Waskish had 6 orders totaling two hundred thirty five specimens. The two sites were similar in total numbers and variety of insects. Although short-term population changes of certain genera take place at different times, overall trends during the sampling period of the two sites were consistent with each other. However, some genera that occurred in high numbers at one site did not occur at the other site. This is to be expected considering the differences in bottom sediment and total number of growing degree-days.

Habitat and feeding requirements of some genera may be better suited to a peat substrate while some may prefer a day substrate. Habitat preferences of soil type, and temperature by genera is outside the scope of this project.

Herbivorous orders were at their highest numbers early in the sampling season, for both the Waskish and Grand Rapids site. Ephemeroptera was the exception as numbers increased during the sampling period in Grand Rapids. No Ephemerals were sampled in Waskish. As the season progressed in Waskish, herbivore numbers declined steadily until none were found on the last sampling date. This decline in herbivore numbers was likely due to heavy predation by the orders Odonata and Coleoptera. These orders consistently increased in numbers throughout the sampling season. The most dramatic increases in populations took place immediately following population peaks of herbivorous orders.

Grand Rapids had slightly different sampling results. Odonata was the only predatory order to increase consistently throughout the season. At both sampling sites, Aeshnidae Anax was the dominant predator. These results suggest that Odonates, particularly Aeshnidae Anax, are adaptable to different kinds of environments.

This entomological inventory of two rice paddies is the first study of this aquatic environment. This project has demonstrated these paddies contain a rich and diverse aquatic community. Sampling insects is an inexpensive, non-intrusive method of accurately assessing the productivity of aquatic systems. A diverse insect community is an indication of a healthy environment.

Although informative, this project has raised more questions than it has answered. The study of the aquatic fauna in these paddies is still in the early stage. The potential for studying topics, such as reproduction, development rates, distribution throughout paddies, specific predator/prey relationships, etc. is enormous. Wild rice paddies are an unique environment and offer an opportunity to study insects in an environment unlike any other.

Acknowledgements

I would like to thank the North Central Research and Outreach Center and Ross Rennemo for the opportunity to sample insects in their wildrice fields, and Dr. Raymie Porter, for his generosity and help throughout the project. I would also like to thank Dr. Robert Nyvall, for the use of his equipment and advice, without them, this project could not have been done. And I must thank Jenna, for everything else.

References

Stover, T.; Usinger, R.; Stebbins, R.; Nybakken, J., 1943: General Zoology, Fifth Edition: McGraw-Hill, Inc. pp. 555-607

Needham, J.; Needham, P., 1962: A guide to the study of Freshwater Biology, Fifth Edition: McGraw-Hill, Inc. pp.30-65

Hilsenhoff, W., 1991: Diversity and Classification of Insects and Collembola: Academic Press, Inc. pp.593-620

Hilsenhoff, W., 1995: Aquatic Insects of Wisconsin: Publication number 3 of the Natural History Museums Council, University of Wisconsin-Madison. pp.1-79

Oelke, E.; LeGare, D.; Schumer, H., 1996: Wild Rice Production Research: Minnesota Wild Rice Research, University of Minnesota, Miscellaneous Publication. 89. pp 1-22

WILD RICE GROWING SEASON AND PRODUCTION – 2000

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The total number of growing degree days (GDD) were lower in 2000 compared to 1999 at all Locations (Tables 1 and 2). However, the total was higher than the long-term average (normal) at Aitkin, Grand Rapids and Waskish, but lower at Crookston. Generally, May was warmer than normal at all four locations, whereas, June had fewer GDD than normal. July was about normal at Aitkin, Grand Rapids and Crookston, with Waskish reporting over 180 GDD above normal. Crookston recorded about normal temperatures for August, but the other three locations all reported above normal.

Table 1. Growing degree days[a] comparisons for 1999, 2000 and normal (61-90).

	Aitkin			Grand Rapids		
Month	**1999**	**2000**	**Normal**	**1999**	**2000**	**Normal**
			GDD			
April	142	146	127	174	141	130
May	489	477	417	514	489	434
June	670	594	646	733	590	674
July	1012	(779)[b]	779	957	892	858
August	776	800	683	811	820	768
Total	3089	2796	2652	3189	2932	2864

[a] $\frac{\text{Maximum + minimum temp.}}{2}$ - 40°F; data from Mark Seeley, Department of Soil, Water and Climate, U of MN.

[b] Missing data, substituting with normal GDD

Table 2. Growing degree days[a] comparisons for 1999, 2000 and normal (61-90).

	Crookston			Waskish		
Month	**1999**	**2000**	**Normal**	**1999**	**2000**	**Normal**
			GDD			
April	174	142	151	132	113	103
May	532	499	488	421	418	369
June	748	659	743	623	481	518
July	954	927	926	838	825	642
August	832	890	867	672	724	563
Total	3240	3117	3175	2686	2561	2195

[a] $\frac{\text{Maximum + minimum temp.}}{2}$ - 40°F; data from Mark Seeley, Department of Soil, Water and Climate, U of MN.

Total precipitation during the 2000 growing season was lower than in 1999 at all locations and very close to the long-term normal range (Tables 3 and 4). During the growing season there were some noteworthy deviations from the normal. In May, Aitkin had 2.5 inches over average, whereas, Crookston had about 1.5 under normal. June was about normal at all locations except for Crookston which received 2.25 inches above average. Precipitation in July was below normal at Aitkin, Grand Rapids and Waskish; with Crookston reporting above average. During August, the harvest month, records show: Aitkin with normal precipitation, Grand Rapids with about an inch over, Waskish with 2.25 inches over and Crookston about 1.5 inches below normal.

Table 3. Precipitation comparisons for 1999, 2000, and normal (61-90).[a]

	Aitkin			Grand Rapids		
Month	**1999**	**2000**	**Normal**	**1999**	**2000**	**Normal**
			inches			
April	2.33	2.55	2.30	1.84	2.64	2.10
May	6.85	4.31	2.88	6.02	3.34	3.04
June	4.59	4.14	4.09	3.89	4.23	4.11
July	4.44	1.99	4.14	9.35	1.80	3.89
August	5.89	3.77	3.83	3.98	4.52	3.59
Total	24.10 ~~18.9~~	16.76 ~~24.37~~	17.24	25.08 ~~14.42~~	16.53 ~~22.52~~	16.73

[a]Data from Mark Seeley, Department of Soil, Water and Climate, U of MN.

Table 4. Precipitation comparisons for 1999, 2000 and normal (61-90)[a] .

	Crookston			Waskish		
Month	**1999**	**2000**	**Normal**	**1999**	**2000**	**Normal**
			inches			
April	1.22	1.03	1.45	1.57	1.47	1.70
May	3.38	1.08	2.45	6.34	2.25	2.33
June	3.96	5.72	3.44	2.82	4.39	4.25
July	3.16	3.22	2.77	4.37	2.71	3.42
August	6.03	1.38	2.88	5.20	6.06	3.32
Total	17.75	12.43	12.99	20.3	16.88	15.02

[a]Data from Mark Seeley, Department of Soil, Water and Climate, U of MN.

The total amount of processed wild rice produced in Minnesota in 2000, estimated at 5.4 million pounds, was the lowest since 1995 (table 5). Production was down 800,000 lbs from 1999 and 440,000 lbs less than 1998. The reduction in total production is likely linked to the storms which hit in mid-late August and possibly a reduction in acreage.

Table 5. Minnesota and California paddy wild rice production[a] (1000 processed pounds).

	Production			Production	
Year	Minnesota	California	Year	Minnesota	California
1968	36	0	84	3600	2500
69	160	0	85	4200	7900
70	364	0	86	5100	9000
71	608	0	87	4200	4200
72	1496	0	88	4000	3500
73	1200	0	89	3978	4000
74	1036	0	90	4800	4200
75	1233	0	91	5500	5500
76	1809	0	92	6100	7500
77	1031	0	93	5300	7500
78	1761	100	94	5300	5000
79	2155	200	95	4500	6440
80	2320	400	96	6000	7600
81	2274	500	97	6002	9000
82	2697	880	98	5840	8800
83	3200	2500	99	6200	15575
			2000[b]	5400	13035

[a] 1968-1982 Minnesota values from Winchell and Dahl and 1983-1999 from Minnesota Department of Agriculture; California values from Mel Androus, California Rice Marketing Board.

[b]Estimated.

The estimated value of the Minnesota crop to Producers was $7/67 million which is the lowest crop value since 1995 (table 6). This five year low is due to a reduction in both components of total crop value, the price/LB dropped from $1.55/lb to $1.42/lb and total production was down.

Table 6. Processed wild rice harvested and value from cultivated fields in Minnesota.

Year	Production	Price to Producer	Value
	1,000 lb	$/lb	$ Millions
1968	36	3.30	0.12
1969	160	2.55	0.41
1970	364	2.80	1.02
1971	608	2.70	1.64
1972	1496	2.30	3.44
1973	1200	2.05	2.46
1974	1036	2.37	2.46
1975	1233	2.50	3.08
1976	1809	2.70	4.88
1977	1031	4.35	4.48
1978	1761	5.10	8.98
1979	2155	5.01	10.80
1980	2320	4.47	10.37
1981	2274	3.79	8.62
1982	2697	3.41	9.20
1983	3200	3.35	10.72
1984	3600	3.30	11.88
1985	4200	2.97	12.47
1986	5100	2.60	13.26
1987	4200	1.50	6.30
1988	4000	1.65	6.60
1989	3978	1.65	6.56
1990	4800	1.70	8.16
1991	5300	1.70	9.01
1992	6100	1.70	10.37
1993	5300	1.65	8.74
1994	5300	1.65	8.74
1995	4300	1.50	6.45
1996	6000	1.50	9.00
1997	6002	1.50	9.00
1998	5840	1.55	9.05
1999	6200	1.55	9.61
2000[a]	5400	1.42	7.67

[a]Estimated values for 2000.

WILDRICE BREEDING AND GERMPLASM IMPROVEMENT

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Variety Trials

Introduction

Variety trials in 2000 were conducted for several purposes: 1) to assess the performance (yield and other traits) of released varieties and breeding populations, 2) to determine whether and how much the application of Tilt® affected the yield and FBS ratings of variety trial entries, and 3) to begin to assess varietal differences in several traits not previously measured on a routine basis, namely a) hulled yield, b) seed size, and c) seed hydration.

Materials and Methods

In 2000, variety trials were planted in three locations: on the Clearwater Wild Rice farm near Clearbrook, on the Rennemo farm northwest of Waskish, and on the Godward farm near Aitkin, east side (former Kosbau farm). The Waskish location was planted September 23, 1999; Clearbrook, October 20, 1999; and Aitkin, April 26, 2000. The Clearbrook trial was planted on a mineral soil, while the other two trials were on peat soils. At Waskish and Clearbrook, phosphorus and potassium were applied and incorporated by the growers at each location in accordance with soil tests and their normal practices. Nitrogen was applied by researchers at planting at a rate of 50 lb of N per acre as urea under the rows of seeds. At Aitkin, researchers applied 40 lb/A of potassium and 75 lb/A of nitrogen at planting under the rows of seeds. Approximately 65 lb/A of N as urea were topdressed at early flowering and again 13 days later.

At each location, the same twenty entries (released varieties and breeding populations) were planted in 4 replicates in a randomized complete block design. Each block (rep) was 10 plots long, end-to-end, and 2 plots wide. Blocks were placed parallel to each other and parallel to the nearby ditch or dike. This arrangement minimized variability due to the edge effect (or ditch effect), since plots within any given rep a similar distance from the edge of the paddy. Plots consisted of four 10-foot rows, 12 inches apart, with 3 feet between adjacent plots and 6-foot alleys between ranges of plots.

In order to observe the effect of Tilt® on the variety trial entries, two of the four replicates at each location were sprayed once with propiconazole at a rate of 8 oz. per acre on July 10 and 11. Three days later, all plots were inoculated with spore suspensions of Bipolaris oryzae, the causal agent of Fungal Brown Spot (FBS) disease. Approximately 100 ml of spore suspension were sprayed on all four rows of each plot with a CO_2 sprayer, for a total of 750,000 spores/plot. This essentially converted the design to a split-plot design, with Tilt® application as the main plot and variety trial entries as the subplots. The analysis was initially done based on a split-plot design.

The center two rows of each plot were used for measurements-- namely, flowering, height, foliar disease rating, and lodging. The dates each entry reached 50% flowering, along with estimates of percentage of heads with dark seed, were used to group entries for three separate harvesting dates. At harvest, the plots were rated for disease and lodging. The center two rows of each plot were trimmed to a net length of 8 feet and harvested with a Yanmar binder. Bundles were immediately carried to a Kincaid raspbar thresher for threshing. Seed was weighed before drying, placed in a drying oven for at least one week at 130°F, and then weighed again to determine percent moisture. Later, samples were re-dried by heating to approximately 200°F overnight, then passed through a McGill sample huller twice, and weighed again. A 1-teaspoon (5 ml) sample of hulled seed was removed from each plot-sample, weighed, and counted in a Agriculex ESC-1 seed counter. The samples from the Waskish location were then scanned on a flatbed scanner and analyzed for seed size measurements using WinSeedle version 5.1a (Regent Instruments, Inc., Quebec, Canada). The other two locations will be scanned and analyzed at a later time. Hydration tests will be carried out subsequently on these small samples.

Results and Discussion

A number of Aitkin plots were flattened by strong winds, but later recovered. A similar event occurred at the Clearbrook location, where some plots were apparently flattened at random by swirling winds. An analysis of the lodging ratings revealed no significant differences among varieties, indicating that the lodging occurred at random. Therefore plots that were flattened were thrown out and only 61 of the 80 plots were harvested or included in the final analysis. Shattered seed was collected at each location, but was not significant enough to merit analyzing. NACH-B and Voyager were harvested 2-3 days earlier than the next group of 10, which were harvested 4-6 days prior to the last 8 entries. At Aitkin, however, GIB-C9 and PM3E-C9 were harvested with the second group, not with the third as was done at the other two sites.

Tables 1-3 give the results for each location, and Table 4 the averages over all three locations. Overall, Clearbrook was the most productive site (yield and hulled yield), followed by Waskish. Plant heights and panicle length followed the same trend. Similarly, FBS ratings were lowest at Clearbrook, followed by Waskish and Aitkin. Lodging ratings were all minimal at Waskish, so the analysis at that site was not shown. Overall, the effect of applying Tilt® on half the plots at each site was not large enough to be statistically significant using this experimental design, so all the data reported were based on analyses using the original randomized complete block design, ignoring the Tilt® treatments in the analyses.

PBM-C6, a bottlebrush selection was the highest yielding entry at Clearbrook (almost 3500 lb/A at 40% moisture, or more than 1500 lb/A hulled), Aitkin, and overall. However, GIB-C9 (Gunvalson-Imle Bottlebrush) was highest at Waskish. A number of advanced entries received low lodging scores at Aitkin. Entries with 2.0 or greater scores included NACH-B, Petrowske Bottlebrush, two pistillate entries (K2PiP-C3 and K2PiH-C2), and Voyager. In several cases, these higher lodging scores corresponded to higher disease ratings. Although Petrowske Purple yielded relatively less than it had done in previous years, it maintained its superiority in lodging and disease resistance. The two earliest entries, NACH-B and Voyager, also had the highest FBS and lodging scores.

Table 1 Yield and other varietal characteristics for 2000 Aitkin trial

Entry	Yield lb/A [1]	Moisture % [2]	Hulled yld. lb/A [3]	Lodging score [4]	FBS disease score [5]	Height in.	Panicle in.
NACH-B	843	36	320	2.5	8.1	64.3	7.0
Voyager	817	43	287	2.0	6.6	73.8	7.6
FSSR-C10	1166	41	486	1.5	3.8	74.6	7.6
FY-C6	1729	40	645	1.0	3.8	77.1	7.7
Franklin	1401	41	523	1.7	4.7	77.7	7.9
K2-C9	1444	39	587	1.0	3.7	74.7	7.3
K2F-C9	1469	40	539	1.8	3.5	75.3	7.5
K2	1337	42	523	1.8	3.8	77.2	7.8
P2BR-C4	1152	42	403	1.5	4.2	76.7	7.5
PS-C5	1323	42	453	1.3	5.4	73.6	8.2
Petr. BB	873	40	295	2.5	7.0	71.5	7.3
Petr. Purple	1316	41	477	1.2	3.7	74.7	7.4
GIB-C9	1788	41	656	1.0	3.4	75.1	7.6
PM3E-C9	1586	41	516	1.2	3.2	72.3	7.3
FSP5-C3	1437	38	645	1.3	5.3	78.5	8.0
K2PiH-C2	1969	42	577	2.2	4.6	78.5	7.9
K2PiP-C3	1504	37	537	2.0	6.6	73.9	7.7
PBM-C6	1993	37	823	1.0	5.4	77.0	7.0
PBM-F4	1622	39	623	1.0	4.6	76.0	7.7
PLAR-C5	1826	42	579	1.6	6.0	75.7	7.5
Mean	**1430**	**40**	**525**	**1.6**	**4.9**	**74.9**	**7.6**
LSD.05	**435**	**2**	**159**	**0.8**	**1.2**	**3.9**	**0.7**
CV	**21%**	**4%**	**21%**	**34%**	**17%**	**4%**	**6%**

[1] Adjusted to 40% moisture.

[2] Percent moisture in grain at harvest, fresh weight basis.

[3] Hulled, unsorted seed at 0% moisture.

[4] Using a 1-5 scale where 1 = stems completely erect, 3 = stems averaging 45° angle, 5 = stems prostrate.

[5] Fungal Brown Spot disease rating on a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead)

Table 2 Yield and other varietal characteristics for 2000 Clearbrook trial

Entry	Yield lb/A [1]	Moisture % [2]	Hulled yld. lb/A [3]	FBS disease score [4]	Height in.	Panicle in.
NACH-B	2038	34	960	4.9	83.4	7.6
Voyager	1248	39	489	3.6	89.4	8.6
FSSR-C10	2277	38	973	3.3	91.7	7.8
FY-C6	2586	37	1105	3.6	91.8	8.2
Franklin	1870	40	712	3.1	91.8	8.5
K2-C9	2423	37	1045	3.3	90.9	8.2
K2F-C9	2513	38	1056	3.5	92.9	7.8
K2Godw	1801	39	754	4.0	89.6	7.8
P2BR-C4	2016	39	783	3.1	90.8	8.3
PS-C5	1542	40	650	3.5	88.7	8.8
Petr. BB	2015	36	898	4.6	91.3	8.1
Petr. Purple	1974	38	874	3.1	90.3	8.1
GIB-C9	2795	34	1195	3.6	95.1	8.8
PM3E-C9	3245	37	1196	2.8	89.6	9.1
FSP5-C3	2358	36	1039	4.1	95.5	8.1
K2PiH-C2	3048	38	1058	3.6	93.6	8.8
K2PiP-C3	2648	36	992	4.0	90.2	8.8
PBM-C6	3450	35	1533	2.6	94.1	8.4
PBM-F4	2615	36	1104	3.1	91.9	8.2
PLAR-C5	2441	39	871	3.3	95.1	9.2
Mean	**2345**	**37**	**964**	**3.5**	**91.4**	**8.4**
LSD.05	**613**	**2**	**265**	**1.0**	**3.9**	**1.0**
CV	**18%**	**3%**	**19%**	**20%**	**3%**	**8%**

[1] Adjusted to 40% moisture.

[2] Percent moisture in grain at harvest, fresh weight basis.

[3] Hulled, unsorted seed at 0% moisture.

[4] Fungal Brown Spot disease rating on a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead)

Table 3 Yield and other varietal characteristics for 2000 Waskish trial

Entry	Yield lb/A [1]	Moisture % [2]	Hulled yld. lb/A [3]	FBS disease score [4]	Height in.	Panicle in.
NACH-B	1430	39	613	6.1	71.2	6.7
Voyager	1107	44	395	5.6	78.3	7.0
FSSR-C10	2159	40	872	3.8	77.8	7.3
FY-C6	1943	40	763	4.6	84.1	7.2
Franklin	1468	42	553	4.7	81.9	7.7
K2-C9	2067	41	758	4.5	80.5	7.4
K2F-C9	1977	40	835	4.6	80.0	7.3
K2Godw	1449	43	535	4.2	79.0	7.0
P2BR-C4	1326	43	545	3.8	80.0	7.6
PS-C5	1479	42	557	4.9	80.2	7.9
Petr. BB	1532	41	572	5.4	77.0	7.8
Petr. Purple	1726	43	579	3.2	80.1	6.8
GIB-C9	2689	37	1066	3.3	81.8	7.2
PM3E-C9	1724	39	790	3.7	80.0	7.9
FSP5-C3	1783	36	741	4.1	81.7	7.8
K2PiH-C2	1332	41	480	4.0	82.3	7.6
K2PiP-C3	2064	38	761	4.1	80.8	7.8
PBM-C6	1925	38	757	3.2	81.6	7.8
PBM-F4	1754	39	728	4.0	79.7	7.2
PLAR-C5	1957	40	753	4.4	80.2	7.6
Mean	**1745**	**40**	**683**	**4.3**	**79.9**	**7.4**
LSD.05	**488**	**2**	**198**	**1.1**	**3.5**	**0.8**
CV	**20%**	**3%**	**20%**	**18%**	**3%**	**8%**

[1] Adjusted to 40% moisture.

[2] Percent moisture in grain at harvest, fresh weight basis.

[3] Hulled, unsorted seed at 0% moisture.

[4] Fungal Brown Spot disease rating on a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead)

Table 4 Yield and other varietal characteristics for 2000 variety trials, 3 locations combined.

Entry	Yield	Hulled yield	FBS disease	Height	Panicle
	lb/A[1]	lb/A[2]	score[3]	in.	in.
NACH-B	1478	630	6.3	73.5	7.0
Voyager	1072	388	5.2	80.4	7.7
FSSR-C10	1907	780	3.5	81.1	7.7
FY-C6	2026	825	4.0	84.9	7.6
Franklin	1602	613	4.2	83.8	8.0
K2-C9	1968	806	3.9	82.2	7.6
K2F-C9	1989	811	3.8	82.4	7.6
K2Godw	1612	622	4.0	82.4	7.7
P2BR-C4	1530	577	3.7	82.6	7.8
PS-C5	1452	558	4.7	80.7	8.3
Petr. BB	1424	588	5.7	79.9	7.7
Petr. Purple	1663	645	3.3	81.5	7.4
GIB-C9	2372	990	3.5	83.9	7.9
PM3E-C9	2230	828	3.3	80.9	8.1
FSP5-C3	1903	817	4.5	84.1	8.2
K2PiH-C2	2017	694	4.1	85.3	8.0
K2PiP-C3	2038	758	4.9	82.0	8.2
PBM-C6	2443	1044	3.8	83.9	7.8
PBM-F4	2022	830	3.9	82.5	7.7
PLAR-C5	2131	729	4.6	83.6	8.1
Mean	**1844**	**727**	**4.2**	**82.1**	**7.8**
LSD.05	**448**	**182**	**1.1**	**2.2**	**0.5**
CV	**29%**	**30%**	**32%**	**3%**	**8%**

[1] Adjusted to 40% moisture.

[2] Hulled, unsorted seed at 0% moisture.

[3] Fungal Brown Spot disease rating on a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead)

Table 5 shows the seed characteristics of the Waskish samples. The easiest measurement, 100-seed weight, revealed some significant differences, but was less precise than the measurements derived from the Seedle analysis. Although the range in seed length appears to be narrow (8.5 to 9.4), the measurements are based on many seeds, and the averages are precise enough to distinguish between entries that differ by 0.3 mm in length (LSD = 0.29), which represents only 1/3 of the range of entry means. (By comparison, the LSD of 100-seed weight was about half of the range in measurements, and its CV was higher than that of seedle length.)

Table 5 Seed characteristics for 2000 Waskish trial [a]

Entry	100 seed weight	Seed length	Seed width	Surface area	Seed volume	Width/length ratio
	g	mm	mm	mm^2	mm^3	
NACH-B	1.85	9.2	1.70	41.1	15.7	0.187
Voyager	1.59	9.2	1.53	36.9	12.8	0.168
FSSR-C10	1.92	9.2	1.71	41.2	15.8	0.188
FY-C6	1.86	8.8	1.73	39.8	15.5	0.197
Franklin	1.74	9.1	1.65	39.6	14.9	0.183
K2-C9	1.83	9.3	1.65	40.6	15.1	0.179
K2F-C9	1.84	8.9	1.69	39.5	15.0	0.191
K2Godw	1.67	8.8	1.64	38.3	14.4	0.188
P2BR-C4	1.82	9.1	1.65	39.4	14.7	0.183
PS-C5	1.86	9.4	1.64	40.9	15.3	0.177
Petr. BB	1.83	9.0	1.65	39.1	14.5	0.185
Petr. Purple	1.59	8.7	1.60	36.4	13.2	0.184
GIB-C9	1.62	8.6	1.66	37.5	14.1	0.195
PM3E-C9	1.75	9.1	1.64	39.7	14.8	0.182
FSP5-C3	1.56	8.5	1.66	37.1	14.0	0.197
K2PiH-C2	1.59	9.0	1.58	37.4	13.4	0.177
K2PiP-C3	1.75	9.1	1.63	39.1	14.5	0.180
PBM-C6	1.70	8.8	1.67	38.3	14.5	0.191
PBM-F4	1.69	8.6	1.64	37.3	13.9	0.193
PLAR-C5	1.61	8.9	1.60	37.7	13.8	0.180
Mean	**1.73**	**9.0**	**1.65**	**38.8**	**14.5**	**0.185**
LSD.05	**0.18**	**0.29**	**0.05**	**1.9**	**1.0**	**0.008**
CV	**7%**	**2%**	**2%**	**3%**	**5%**	**3%**

[a] All variables except 100 seed weight were estimated using WinSeedle version 5.1a, software developed by Regent Instruments, Inc., Quebec, Canada. Based on approx. 150-250 whole seeds per replicate.

Both sources of measurement (100-seed weight and Seedle analysis) are consistent with each other in confirming the concerns of processors and growers that seed size, particularly length, in some recent varieties has decreased. GIB-C9 and Petrowske Purple are among the lowest for seed length, while older varieties NACH-B and Voyager are significantly longer. The shortest and longest are experimental populations, FSP5-C3 and PS-C5, respectively.

Wandrey (1988) previously reported the seed length of K2 half-sib families averaging 10.7 mm, with a 100-seed weight of 2.44 g. That was considerably higher than the measurements of the current study, which estimated K2 (Godward seed source) to have a length of 8.8 mm and a 100-seed weight of 1.67 g. One or both of the following reasons could explain this decrease: 1) the genetically-controlled seed size of K2 has shifted since then, or 2) the gains in production due to management have come at the expense of seed size. Although management could be responsible for some of the overall decrease in seed length, genetic shifts are also indicated by the fact that there are significant differences between entries of the present study.

Preliminary Yield Trial

In order to begin yield testing of a 96F-111, a preliminary yield trial was planted in the spring at one location, the research paddies at Grand Rapids. 96F-111 is a synthetic line from a nursery selection which is potentially fixed for at least one nonshattering gene. The plot size and management were similar to what was described for the Variety Trials, except that there were only six entries.

The results shown in Table 5 indicate that 96F-111 is not very high yielding. Stand density of this entry was less than optimal, and there was a great deal of FBS damage to the leaf tissue by harvest time. These may explain the low yield. No shattering plants were observed in any of the plots planted, or in the isolated increase. This entry could still prove if FBS disease is controlled by Tilt®. Further testing will be conducted in 2001, and selection for disease resistance will be initiated in this population, or in the parent lines that were used to construct this synthetic. The entry with the highest raw yield of the six entries was a pistillate entry, K2PiH-C2, but PBM-C6 had the highest hulled yield. The difference in hulling efficiency may be indicated by the higher percent moisture of K2PiH-C2, indicating a slightly larger proportion of immature seeds. Petrowske Purple also yielded well in this trial, exceeded only by the two entries just named. Even Franklin's yield was respectable in this trial, consistent with its performance in other trials as an average to above-average variety.

Table 6 Yield and moisture of six entries at a preliminary yield trial, Grand Rapids.

Entry	Yield	Moisture	Hulled yield
	lb/A [1]	% [2]	lb/A [3]
96F-111	606	39	200
Franklin	1286	39	512
GIB-C9	1280	38	565
K2PiH-C2	1848	42	605
PBM-C6	1706	37	725
Petr. Purple	1400	39	577
Mean	**1354**	**39**	**531**
LSD.05	**501**	**2**	**138**
CV	**26%**	**3%**	**18%**

[1] Adjusted to 40% moisture.

[2] Percent moisture in grain at harvest, fresh weight basis.

[3] Hulled, unsorted seed at 0% moisture.

Variety Releases

Petrowske Purple was released in 2000 under an exclusive licensing agreement with the Minnesota Cultivated Wild Rice Council. Plant Variety Protection is being sought for this variety, which prevents it from being legally sold as anything other than Certified Seed. In early September, 37,000 lb. of Petrowske Purple were distributed to Minnesota growers.

In addition, PBM-C6 has received preliminary approval to be increased for possible release in 2002. Table 6 gives the long-term average of the 11 entries that appeared in variety trials over the past three years. GIB-C9 and PBM-C6 yielded highest. In fact, PBM-C6 yielded substantially higher than Petrowske Purple and Franklin, exceeding them by 31% and 40%, respectively. PBM-C6 had the lowest shattering along with Petrowske Purple. PBM-C6 is also more lodging resistant and disease resistant than all entries except Petrowske Purple. It is tall, similar to GIB-C9 in height, and has a slightly longer seed, but not significantly (see Table 5)--it is still among the shorter-seeded entries. Panicle lengths are not substantially different from any but the shortest variety, NACH-B.

Table 6 Yield and other varietal characteristics for variety trials at 3 locations, 1998-2000.

Entry	Yield	Shattering	Lodging	FBS score	Height	Panicle
	lb/A [1]	% [2]	score [3]	score [4]	in.	in.
	acefg[5]	*ac*	*abcde*	*abcdefg*	*abcdefg*	*abcdefg*
NACH-B	1390	20	2.7	6.7	72.5	7.3
Voyager	1117	26	2.5	5.4	79.1	7.9
Franklin	1471	19	2.5	4.6	79.1	8.2
K2-C9	1786	15	1.6	4.1	78.8	7.7
K2Godw	1499	15	2.0	4.4	78.6	7.5
P2BR-C4	1387	16	1.5	3.9	79.5	7.7
Petr. BB	1352	22	2.6	5.9	75.7	7.7
Petr. Purple	1572	11	1.4	3.5	78.7	7.4
GIB-C9	2062	19	2.2	4.2	82.5	7.7
K2PiP-C3	1980	12	2.5	4.7	78.4	8.1
PBM-C6	2063	11	1.3	3.6	81.3	7.8
Mean	**1670**	**15**	**1.8**	**4.4**	**80.1**	**7.7**
LSD.05	**277**	**4%**	**0.5**	**0.8**	**2.6**	**0.5**
CV	**20%**	**30%**	**32%**	**22%**	**4%**	**9%**

[1] Adjusted to 40% moisture.

[2] Expressed as a percentage of shattered seed plus grain yield per unit area.

[3] Using a 1-5 scale where 1 = stems completely erect, 3 = stems averaging 45° angle, 5 = stems prostrate.

[4] Using a 1-9 scale where 1 = no significant disease lesions and 9= completely susceptible (dead)

[5] Locations included in means: a=Waskish 98; b=Clearbrook 98; c=Waskish 99; d=Aitkin 99; e=Aitkin 00; f=Clearbrook 00; g=Waskish 00.

Population Improvement

In 2000, 23 populations were being improved through recurrent selection for various traits, including shattering resistance, foliar disease resistance, lodging resistance, and short plant height. Among new populations for which improvements were initiated were a K2 population with very early maturity which needs to be reselected for nonshattering plant types; an early NACH-B which was selected for earliness and FBS disease resistance; and a Voyager population which was reselected for earliness and nonshattering plants. In addition, increased seed size was added as a selection criterion in PBM-C8. Two germplasm pools are being maintained under minimal selection for nonshattering. These were assembled several years ago through intermating 20-30 different varieties and wild populations. They are intended to be a future source of genetic variability from which to extract breeding lines which will keep the genetic base of wildrice from becoming too narrow.

In addition to improving populations, maintaining the genetic integrity of populations is needed as well. To that end, we constructed and began using cloth barriers supported by frames which enclose and isolate a number of breeding populations (Fig. 1). This is to allow intra-pollination of each population to produce sufficient seed to continue testing varieties or to maintain previously collected wild germplasm. In addition, new lines can be increased for testing while minimizing pollen contamination from unrelated lines or populations.

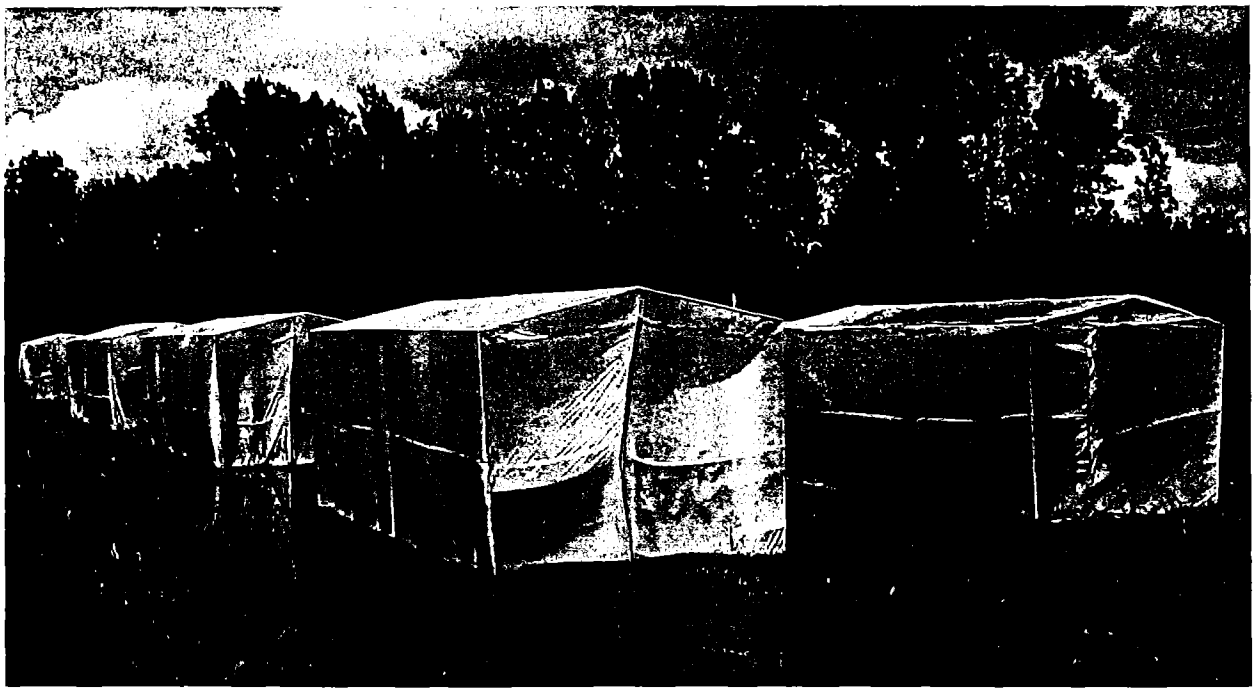

Figure 1 "Pollen tents" used to isolate and increase populations and breeding lines.

Reference

Wandrey, G.G. 1988. Genetic variation in seed length in wild rice (Zizania palustris L.). Ph.D. Thesis. Univ. Minn., St. Paul, MN.

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RESPONSE OF WILD RICE ON POOR SOILS TO SULFUR AND MICRONUTRIENTS

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The wild rice fertility work in 2000 included a study of micronutrients in on problematic soils and a study of the factors controlling wild rice production in a native stand on a lake.

Fertility studies on grower paddies and grower observations have shown that on some soils, even with best practices and adequate NPK, poor yields are obtained. On some fields or areas in fields the growth of rice is consistently very poor. Plant analysis from some of these areas also suggests that micronutrients and/or sulfur may be the problem. In 1999 study in the Aitkin area were not able to get good yields even with high NPK and Tilt®. We concluded that sulfur or micronutrients might be causing the difficulties. Thus, we decided to initiate a trial involving field strips and pot studies to investigate response to sulfur and micronutrients on problematic soils.

In this report we will give some of the results from the field study. Some of the plant data from the harvested plants are not yet available and the pot studies have just been initiated.

In 2000 we also initiated as study to investigate the factors affecting the growth of wild rice on Rice Lake, a highly productive 4200 ac lake located on the Rice Lake National Wildlife Refuge. Wild rice seems to thrive best in environments where perennials are not abundant. When other species become abundant, wild rice may struggle to compete for light, especially during early growth stages and for nitrogen uptake after panicle formation, when it takes up nearly 75% of its total nitrogen accumulation. On Rice Lake, the control structures and dikes have prevented lake flooding, especially in early spring, and have been used to keep the lake at a constant level during summer months. Long term effects of the hydrologic manipulations are unknown.

Observations by the refuge staff corroborate data collected from 1985 to 1995, which suggest that pickerelweed is gradually increasing in abundance and possibly competing with wild rice. Pickerelweed is a perennial aquatic species that spreads slowly through rhizomes, provided that no major disturbances disrupt its growth. Whether wild rice yields are actually decreasing over time, and which factors are most harmful to wild rice production are not known.

Managers of Rice Lake National Wildlife Refuge are concerned how constant water levels may affect the lake's health, specifically related to changes in lake vegetation, genetic variability of wild rice strains, and water quality, as well as other issues. They are concerned whether current management practices have increased the rate of lake eutrophication. Overall, the managers would like to control water levels in such a way that balances conditions producing good production of wild rice and other "desirable" aquatics, with sustaining habitat for fish spawning, fur-bearer populations, waterfowl and other migratory and resident wildlife.

This study is divided into three phases: 1) evaluation of historical data, 2) determination of some of the limiting factors for wild rice production, and 3) development of recommendations for long term monitoring of wild rice production.

The goals for the first year of the study were to 1) characterize the sediment properties and plant mineral nutrition along the lake transects, to identify possible stressors to the wild rice (nutrient deficiency, invasive plant species, etc); 2) to establish a protocol for characterizing plant communities on Rice Lake; and 3) to create a format to record and analyze monitoring results. In this report we will summarize some of the available results

Micronutrient Field Study

Methods

In the summer of 2000 strip trials were conducted on one site in the Aitkin area on the Godward farm and on the Petrowske farm in the Waskish area. Five treatments: S, Mn, Cu, Fe and a combination treatment of all 4 elements plus B, Mo, and Zn were applied to 8 ft x 30 ft strips at the early aerial stage (duplicate strips). Plant tissue was obtained in early boot. At harvest the grain yields and total biomass yield were obtained from two 1 m^2 plots in each treatment strip and from control strips with no treatment. Plant tissue was also obtained for analysis.

In the fall of 2000 two sites were chosen for the 2001 season on the same farms. The design used for the summer of 2000 was repeated with some modification and with application of fertility amendments in the fall. The amendments were incorporated with a rotor tiller. Soil samples were taken for analysis. Soil was obtained from the two fall 2000 plots for pot studies in Grand Rapids.

The treatments 2000 were:

1. 50 lb/ac Mn as a sulfate salt.
2. 34 lb/ac as ironite; or 85 lb/ac as sucrate.
3. 30 lb/ac Cu as sulfate salt.
4. 100 lb/ac S as gypsum.
5. Combination: Mn, Fe, Cu at 1/2 the above plus 2 lb/ac B as borax and 30 lb/as Zn as sulfate. Sulfur is added with the metal micronutrients.
6. Control with no fertilizer added.

Results

The soil test results show that the at the Petrowske site the soil is a highly organic peat and at the Godward site the soil is a mineral soil quite low in organic matter (Table 1). The pH is similar at both sites and the K was similarly low at both sites. The P was lower at the Petrowske site but not at a value that is low enough to be considered problematic for wild rice production.

Table 1. Soil samples obtained from non treated areas at harvest

Site	pH	Bray-P (ppm)	K (ppm)	Organic Matter, %
Petrowske	6.2	23.4	44.4	80.4
Godward	6.2	43.3	54.3	3.3.

Both the total straw yields and hand harvested grain yields were greater at the Petrowske site compared to the Godward site (Table 2). At both sites no response was seen to the treatments. The yields at the Godward site were more erratic because of lodging.

Table 2. Plant yield

	Petrowske		Godward	
Treatment	Straw lb/ac	grain lb/ac	Straw lb/ac	grain lb/ac
Cu	4339	978	3509	589
Mn	4598	958	4013	584
Fe	4455	1018	3991	668
S	4554	938	4103	514
Combination	4335	946	3469	393
Control	4262	857	4018	725

The results of the tissue analysis at boot stage are shown in Table 3 and 4. The chemical data for the plants at harvest are not yet available. These data show that the Cu and Mn treatments did increase the Cu and Mn in the plants (Table 4). The Zn in the combination treatment also increased the tissue contents. The Fe and gypsum did not increase tissue Fe or S nor did the gypsum treatment, which added 125 lb/ac of Ca, increase the Ca content in the plant tissue. Also the B added in the combination treatment was not seen in the tissue. The plant concentration in the Cu treatment is sufficient to be of concern for Cu toxicity but there was no negative yield response of the type that would indicate severe toxicity. The very high Cu uptake is surprising given the strong affinity of soil organic matter for Cu.

The N concentration in the plants from the Godward site were in the almost 3%, a value that is thought to be sufficient for wild rice at boot. The plants from the Petrowske site were low in N. This low N may be the reason the higher yields were not obtained. The K and P concentration were adequate at both sites but the P concentrations were higher at the Godward site as would be predicted from the difference soil test values. The S concentrations were similar for both sites and were in the range that is normal for crops like white rice. The concentrations of Ca, Mn, Zn, Cu, and B are in normal rages for these elements except for the Cu in the copper treatment, where the Cu is very high. The concentration of Mg is in the normal rage but on the low end.

The plants from the two sites are very different in Fe and Al contents. The plants from the Godward site have Fe and Al concentrations that would be considered very toxic in white rice. These elements normally accumulate in plants in response to soil acidity and it is very odd to see

elevated Al and Fe in a pH 6.2 soil. Lower concentration in highly organic soils of the same pH is normal because Al and Fe bind to soil organic matter.

The area next to the surface of wild rice roots is acid because a wild rice plant only takes up N in the ammonium form. This acidifies the soil near the root surface. The sandy soil at the Godward site does not provide much buffering of soil pH and it is possible that the soil near the root surface is very acidic. However, our tissue data o 1999 on a nearby sandy peat soil did not show the high Fe seen in 2000.

Tom Godward has seen some positive response of the wild rice crop on the sandy mineral soil to the addition of a wood ash. When we sampled the plants in our plots we also obtained samples adjacent to and in a wood ash strip in the field where our plots were located. The plants in the ash treated soil, when compared to the adjacent non treated soil, were higher for all of the nutrients in Table 3 and 4 with the exception of Cu, Ca, Fe, and Al. The great decrease in Fe and Al is likely due to the liming properties of the ash. The plants on the untreated soil also had N and K at deficiency levels.

We also sampled plants in an adjacent field where there was a gradient in growth from poor growth in the shallow peat to better growth in the deeper peat. The plants in the deeper peat were greener and had more N than in the shallow peat. The main problem here may be N deficiency. However,when N was sufficient, the plants had greater Al and Fe; in the toxic range. This further suggests that the acidification caused by ammonia uptake is important in increasing plant Fe and Al.

Table 3. Plant tissue contents of N. S, P, K, Ca, and Mg. at boot stage.

Treatment	%N	%S	P, ppm	K, %	Ca, ppm	Mg, ppm
Petrowske						
Cu	1.91	0.21	4461	3.26	7321	1782
Mn	1.80	0.19	4373	3.05	5458	1598
Fe	2.06	0.19	4708	2.91	4706	1604
S	1.93	0.19	4541	2.98	5082	1601
Combination	1.97	0.23	4748	3.64	4406	1487
Control	1.90	0.17	4522	3.16	5318	1686
Godward						
Cu	2.16	0.14	4741	2.59	3928	1423
Mn	2.89	0.20	6529	3.37	4146	1515
Fe	2.76	0.16	6005	3.20	3966	1499
S	2.78	0.19	6278	3.24	3990	1577
Combination	2.63	0.18	5973	3.04	4375	1663
Control	2.79	0.18	6189	3.27	4110	1564
Godward same field						
Ash treated	2.52	0.18	4682	3.04	3370	1378
no ash	1.33	0.10	1714	0.67	3312	864
Adjacent field						
Green	2.86	0.25	4256	1.99	6137	1678
Yellow	1.70	0.14	3726	2.73	4311	1225

Table 4. Plant tissue contents of Mn, Al, Fe, Zn, Cu, and B at boot stage.

	Mn, ppm	Al, ppm	Fe, ppm	Zn, ppm	Cu, ppm	B ppm
Petrowske						
Cu	171	419	487	34	57.9	7.4
Mn	353	201	288	42	3.1	6.3
Fe	121	154	238	40	2.8	5.8
S	237	177	263	41	3.0	6.0
Combination	177	114	229	91	7.1	7.0
Control	168	177	255	37	3.1	6.4
Godward						
Cu	157	2254	2538	48	40.3	7.1
Mn	384	1509	2144	61	4.0	7.5
Fe	198	1085	1569	49	3.0	8.0
S	202	1406	1711	50	3.5	7.7
Combination	282	1656	2588	118	21.5	8.0
Control	189	1482	2181	49	3.6	7.8
Godward same field						
Ash treated	122	558	590	46	2.1	6.8
no ash	84	2595	2679	20	2.4	3.5
Adjacent field						
Green	193	1067	3189	44	3.0	8.2
Yellow	340	263	1714	32	2.0	6.0

Treatments for 2001

The design used for the summer of 2000 was repeated with some modification with application of fertility amendments in the fall. The Fe treatment was replaced by Mg. The quantities of Cu and Zn were reduced by a factor of 2.and S was increased by a factor of 3. The amendments were incorporated with a rotor tiller.

1. 50 lb/ac Mn as a sulfate salt.
2. 100 lb/ac Mg as a sulfate salt (epsom salt).
3. 15 lb/ac Cu as sulfate salt.
4. 300 lb ac S as a sulfate salt (gypsum).
5. Combination: Mn, Mg, Cu at 1/2 the above plus 10 lb/ac B as borax and 30 lb/as Zn as sulfate. S is added with the metal micronutrients.
6. Control.

Pot Treatments

Soil was taken from the plots that were prepared in the fall of 2000. Wild rice will be grown in 8 in. pots with one plant per plot. The treatments will include dolomitic limestone (limestone with Mg), S, combination with lime, and control.

Conclusions from summer 2000 results

The treatments did not show any positive response. However, the plant growth and grain yield were better at the Petrowske site despite the better N nutrition at the Godward site. The lower yield at the Godward site was correlated with high tissue Al and Fe. This may be caused by acidification near the root surface. Lime additions may be helpful even though soil pH is 6.2.

Rice Lake Study

Methods

Three persistent wild rice beds and one persistent pickerelweed bed currently exist on Rice Lake. In the past, data were collected on five transects, with only one crossing through a current bed, Bed 2. For this study, four transects were chosen. Transects 1 and 2 traversed thick wild rice beds, while Transect 3 traversed through a bed with mixed plant species and Transect 4 traversed a bed dominated by pickerelweed. Transects 2 and 3 closely follow one of the historical transects, although Transect 3 angles further east, in order to cross a mixed species bed. The transects were marked in mid-June using an airboat and a global positioning system (GPS). Within a transect PVC pipes, located at sites 750 ft. apart, were used to mark the major sampling and observation positions. The area within 16 ft of each pole was characterized by measuring water pH, water temperature and documenting plant species. Lake depth was measured by lowering a Secchi disk until it stopped sinking and measuring the rope length.

In late July, plant species identity and abundance were characterized along each transect. Every 150 ft a 1m x 1m PVC hoop was tossed onto a site representative of the area. At the transect markers, the plants in the hoop were sampled by cutting approximately 1 ft. below the water surface. At the locations between markers the depth, plant number for each species, number of flowers, health and average height of plants were recorded without collecting biomass. At harvest time, only wild rice plants were collected and only at transect sites. Seed heads were harvested separately and all plant materials will be analyzed for nitrogen, sulfur, phosphorus and micronutrients. A set of plots, 3m x 3m, were marked on both sides of a designated marker in each transect. The sets contained a nitrogen plot (N plot) where all plants were removed (rogued) every two to three weeks during the summer, and a control (C plot). One copper and one zinc granular fertilizer treatment were added to additional plots at the south set of Transect 1 and the east set of Transect 2. Sediment samples were collected at the beginning of the season.

The N plots were included to obtain experimental data on the role N might play in the annual fluctuations in wild rice production. The organic matter in the high organic sediments of Rice Lake continues to mineralize organic N to produce available ammonium N, whether or not wild

rice plants are present to take up the ammonium N. We hypothesized that ammonium accumulates in the sediment in years of poor production.

The Zn and Cu plots were included to determine if the Cu and Zn deficiency have any role in limiting production. Preliminary data from the summer of 1999 suggested that wild rice plants in Rice Lake have low Zn and Cu contents.

Some Results

Rice lake is very shallow with a very gently slopping contour to the bottom (Figure 1) The measurements from our transects show a decrease in depth to about 3 ft at about 1/2 mile from shore and then small variations nearer the center of the lake. We did not measure any depth greater than 40 in.

The biomass data for late July (Table 5) were obtained when wild rice was at the late boot to early flower stage for the plants in shallow water but the wild rice plants found greater depths were somewhat earlier in maturity. Germination and early growth of wild rice is greatly affected by water depth and temperature. The immaturity of the wild rice contrasted with pickerelweed, which was in full flower and at maximal biomass. Wild rice plant density was generally greatest in Transect 1. The wild rice on Transect 2 was also dense, but tended to be in clusters nearer the center of the lake. Transect 3 had dense clusters of pickerelweed interspersed with some smaller wild rice beds, but close to shore other species were important (e.g. lilies and bullrush). Pickerelweed was the densest in Transect 4, but wild rice was more prominent than pickerelweed close to shore. The relatively low biomass potential of pickerelweed compared to wild rice suggests that pickerelweed may not be a major competitor for nutrients. At only one site was pickerelweed biomass greater than the total wild rice biomass at harvest.

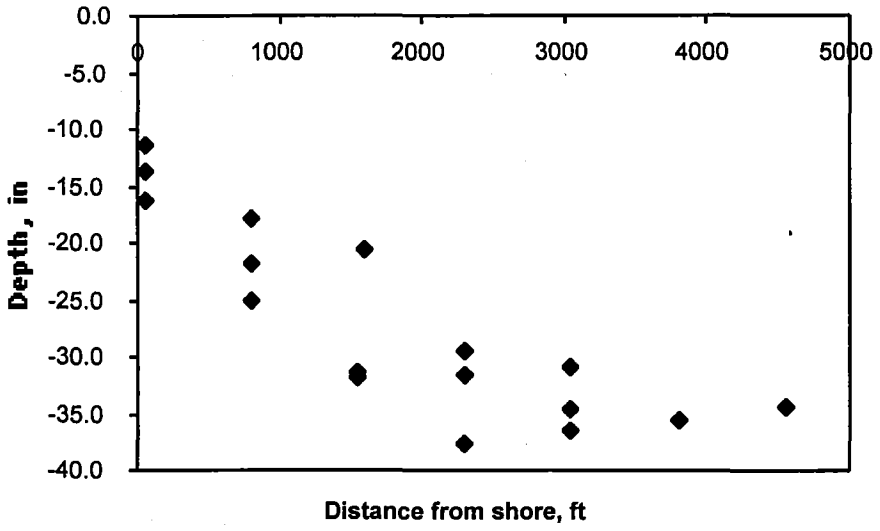

Figure 1. Rice Lake depth profile measure in the transects.

The wild rice biomass along the transects at harvest time, ranged from less that 250 lb/ac to nearly 4000 lb/ac. The higher value is similar to what is seen in growers' fields (Table2). The biomass production has a tendency to decrease in deeper water (Figure 2). The sampling site nearest the shore in Transect 3 is on the south side of the lake where wild rice trash accumulates and greatly inhibits growth. This site was not included in the plot shown in Figure 2. The seed yields in the better growth areas were comparable to yields shown in Table 3 for growers' fields.

The high biomass and seed yields suggests high native fertility in the lake bottom. Our measurements of N, P, K and micronutrients (data not shown) verified that highly organic sediments on the lake bottom are indeed highly fertile. The Bray P data (expressed in micrograms per cubic centimeter of wet sediment) did show an interesting decrease with distance from shore (Figure 3). The low values in the middle of the lake, < 10 μg cm^{-3}, suggest that P may be limiting growth. The high P nearer shore may be due to accumulation of terrestrial P from erosional sediments and leaf litter inputs.

Table 5. Plant biomass along transects in Rice Lake.

Distance from shore, ft	Depth, in	July		September	
		Pickerelweed lb/ac	Wild Rice, Total biomass, lb/ac	Wild Rice, Total biomass, lb/ac	Wild Rice, Seed heads lb/ac
Transect 1					
site 1	9.7		1229	2363	457
site 2	10.4		1724	2288	413
Transect 2, Distance form shore, m					
50	11.4		873	3851	878
800	21.9		509	1217	319
1550	31.3		75	184	37
2300	37.6		131	1989	428
3050	36.5		212	922	183
3800	35.6		138	402	69
4550	34.4	101	199	339	53
Transect 3					
50	16.3		140	245	49
800	25.0	497	1331	1638	356
1550	31.9		202	780	185
2300	31.6		170	1376	358
3050	34.6		139	2532	492
Transect 4					
50	13.7	139	2221	4731	681
800	17.9	157	1748	1246	444
1550	21.1	435	292	280	98
2300	29.4		149	362	33
3050	31.0		12	51	10

Potassium concentration in sediments also showed a tendency to decrease toward the center of the lake, especially in Transect 2 (data not shown). Ammonium N also showed a tendency to decrease nearer the center of the lake (data not shown).

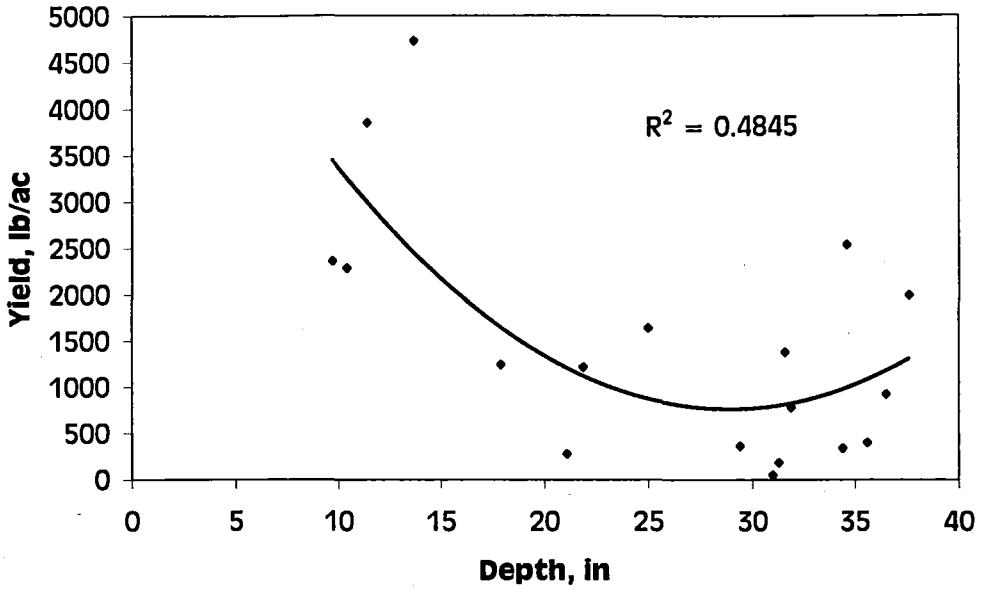

Figure 2 Change in yield with water depth

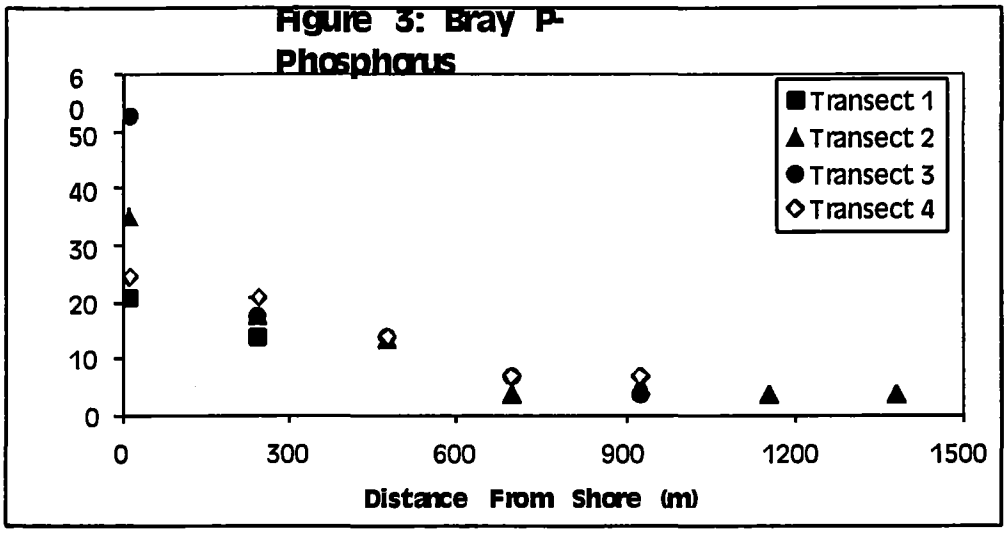

Figure 3. Variation in Bray extractable P with distance from shore.

Plant uptake of ammonium N reduced extractable N contents of the experimental plots in the transects that were dominated y wild rice. When sampled in October the plots with the plants removed had 14.6 ± 8.3 micrograms/cm^3 compared to the plots where the plants were removed which had 5.3 ± 4.0 micrograms/cm^3. This suggests that the anecdotal evidence that years of poor yields are followed by years of good yields may, at least in part, be due to differences in sediment N content. The plots with Cu and Zn added do not show any increase in yield suggesting these nutrients are not limiting in wild rice growth in Rice Lake.

Preliminary Conclusions

We hesitate to conclude much from an incomplete set of data for one season but we will make several preliminary conclusions. The decrease in biomass with depth illustrates the importance water depth in determining production of wild rice. The decrease in available P with distance from the shore is remarkable and P deficiency may have a role in wild rice production. Nitrogen is very important for wild rice production and poor wild rice growth in one season may result in a larger sediment store of readily available N for the following season. Nutrient competition does not seem to be the main mode of pickerelweed competition with wild rice. Pickerelweed is, however, much earlier than wild rice and does compete well for light.

CARFENTRAZONE-ETHYL ACTIVITY ON AQUATIC WEEDS AND WILD RICE TOLERANCE IN MINNESOTA, 2000

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Experiments were carried out at Aitkin, Deer River, and Grand Rapids, Minnesota to determine weed control efficacy and wild rice (*Zizania paulustris*) tolerance to cafentrazone-ethyl. The Aitkin site was a natural reseeded stand of cultivated wild rice that had been thinned on the farm of Tommy Godward. Common water plaintain *(Alisma plantago-aquatita)* was present at this site. The Deer River site was a fallow paddy without wild rice on the farm of Dick Brink. The paddy was not flooded during the 2000 season, yet soils were saturated through the middle of August. Weeds at the Deer River site included arrowhead (*Sagittaria latifolia*), equisetum (*Equisetum arvense*), giant burreed (*Sparganium eurycarpum*), rush (*Scirpus validus*), and sedge (*Carex spp.*). The paddy at the Grand Rapids site was fall tilled in 1999. Four row plots were seeded on May 10, 2000 with a cone seeder at 12 seeds per square foot, thinned to a final stand of 4 plants per square foot. 75 lbs/A of 75-0-40 was applied at planting. All herbicide treatments were applied with a CO_2 backpack type sprayer delivering 20 gpa at 26 psi with 11002 flat fan nozzles. All experiments had a randomized complete block design with four replications and plot size 7 feet wide by 10 feet long. Whole plant and seed yields were measured from the middle two rows at the Grand Rapids site. Application data and results are presented below.

Application Data		**Aitkin**	**Deer River**	**Grand Rapids**
Date		6/22/00	6/27/00	6/27/00
Air Temp (°F)		65	68	60
Soil Temp (°F)		--	61	
Sky		cloudy	partly cloudy	partly cloudy
Wind (mph)		WNW 2-5	W 4-6	W 0-1
Relative Humidity (%)		65	50	68
Water Depth (inch)		0-6	0 (saturated)	10-12
Wild Rice	- Size (inch)	11-16	--	18-24
	- Stage	3-4 leaf	--	early tiller
Equisetum	- Size (inch)	--	12-24	--
	- Stage	--	vegetative	--
Giant Burreed	- Size (inch)	--	24-26	--
	- Stage	--	early bloom	--
Common Water Plantain	- Size (inch)	8-14		
	- Stage	4-8 leaf	--	--
Rush	- Size (inch)	--	12-16	--
	- Stage	--	full bloom	--

Common water plantain pressure was heaviest in the shallow areas of the paddy where the water was 0-6 inches deep at application. Common water plantain scapes were just beginning to emerge at the time of herbicide application. No significant stand reduction was visible on wild rice in the study area (Table 1). Wild rice height was variable and no significant growth reduction was apparent. The highest efficacy of common water plantain was achieved with treatments ≥ 0.2 lb of carfentrazone-ethyl, all applied with 0.25 lbs ai 2,4-D amine/ac. The addition of 2,4-D did improve the efficacy of carfentrazone-ethyl on common water plantain without increasing wild rice injury. Fewer common water plantain seeds were produced on carfentrazone-ethyl or carfentrazone-ethyl + 2,4-D treated plants than on plants treated with 2,4-D alone. The addition of 2,4-D to carfentrazone-ethyl did not always improve plantain seed reduction compared to carfentrazone-ethyl used alone. It appears that the targeted rate for control of common water plantain should be 0.2 lb ai carfentrazone-ethyl + 0.25 lbs 2,4-D.

There was no standing water at the time of herbicide application to giant burreed in the fallowed paddy. Therefore, efficacy may have been greater than expected when lower giant burreed leaves may be covered by standing water at application during wild rice production. The addition of 2,4-D to carfentrazone-ethyl did not appear to consistently improve the efficacy of the carfentrazone-ethyl on giant burreed (Table 2). It appears that carfentrazone-ethyl reduced flower and seed production of giant burreed at all rates tested with or without the addition of 2,4-D. For control of giant burreed, 0.1 lb ai/ac carfentrazone-ethyl gave adequate suppression and the addition of 2,4-D did not appear to improve performance when evaluated on July 19. By September 19, the control with carfentrazone-ethyl treatments had decreased and it is apparent that even the 0.05 lb. rate of carfentrazone-ethyl may be adequate. Control of giant burreed was highest with rates of carfentrazone-ethyl ≥ 0.1 earlier in the season, and trends show that performance was best with 0.2 lb carfentrazone-ethyl by the September 19th rating. Therefore, the target rate of carfentrazone-ethyl should be 0.2 lb ai for suppression of giant burreed. The addition of 2,4-D appears not to be beneficial unless other species are present that are susceptible to 2,4-D. It appears that carfentrazone-ethyl has a low level of activity on broadleaved arrowhead, equisetum, softstemed bulrush, and *Carex* spp. The *Carex* species showed significant necrosis with all carfentrazone-ethyl treatments and were injured more than the other non-target species present. It appears that 2,4-D used alone resulted in little injury on any non-target species. By the September 19 ratings, there was very little injury apparent on these non-target species so the injury would be temporal and likely not cause a long-term reduction in population density of these species.

Wild rice stands and plant height were variable at the time of herbicide application and when rated, typical of cultivated wild rice. There were no visible impacts of any of the herbicide treatments in wild rice stand or height on the July 19 rating (Table 3). Leaf necrosis was present in all wild rice plots. There did not appear to be any significant, long-term leaf necrosis or wild rice injury due to carfentrazone-ethyl. Total yield and grain yield did not show any reductions due to herbicide treatment.

In summary, it appears that the target rate for control of common water plantain would be 0.2 lb carfentrazone-ethyl + 0.25 lb 2,4-D dimethylamine and the target rate for suppression of giant burreed would be 0.2 lb carfentrazone-ethyl with the addition of 2,4-D optional depending on weed species present. Acknowledging the limitations of the single location and environment in which the

tolerance study was conducted, there appears to be no significant concerns for tolerance of wild rice for up to 0.4 lb carfentrazone-ethyl tank mixed with 0.25 lb 2,4-D. (Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul).

Table 1. Carfentrazone-ethyl activity on common water plantain in wild rice at Aitkin, MN - 2000. (Becker et al.)

		July 19		
		Wild Rice	Common Water Plantain	
Treatment	Rate	Growth Reduction	Seedhead Reduction	Control
	(lb ai/A)	(%)		
Carfentrazone	0.2	0	86	68
2,4-D dimethylamine	0.25	0	52	50
Carfentrazone + 2,4-D dimethylamine	0.05 + 0.25	3	96	83
Carfentrazone + 2,4-D dimethylamine	0.1 + 0.25	0	90	78
Carfentrazone + 2,4-D dimethylamine	0.2 + 0.25	0	97	90
Carfentrazone + 2,4-D dimethylamine	0.3 + 0.25	1	99	98
Carfentrazone + 2,4-D dimethylamine	0.4 + 0.25	1	98	94
Untreated		0	--	--
LSD (0.05)		ns	10	10

Table 2. Carfentrazone-ethyl activity on giant burreed in wild rice at Deer River, MN - 2000. (Becker et al.)

		Giant Burreed						
		Flower Inhibition	Control		Nontarget Species Control 7/19			
Treatment	Rate	7/19	7/19	9/19	Arrowhead	Equisetum	Rush	Sedge
	(lb ai/A)	(%)						
Carfentrazone	0.2	100	71	62	2	34	31	69
2,4-D dimethylamine	0.25	64	30	20	0	9	0	18
Carfentrazone + 2,4-D dimethylamine	0.05 + 0.2	100	58	56	1	21	4	66
Carfentrazone + 2,4-D dimethylamine	0.1 + 0.25	97	71	57	0	28	12	81
Carfentrazone + 2,4-D dimethylamine	0.2 + 0.25	100	77	76	21	41	32	80
Carfentrazone + 2,4-D dimethylamine	0.3 + 0.25	99	70	60	14	30	25	81
Carfentrazone + 2,4-D dimethylamine	0.4 + 0.25	95	78	72	16	43	32	78
Untreated		--	--	--	--	--	--	--
LSD (0.05)		16	22	14	18	15	21	28

Table 3. Carfentrazone-ethyl tolerance on wild rice at Grand Rapids, MN - 2000. (Becker et al.)

Treatment	Rate	Wild Rice			
		July 19		September 8	
		Growth Reduction	Necrosis	Total Yield	Grain Yield
	(lb ai/A)	(%)		(lb/A)	
Carfentrazone	0.2	18	8	1557	970
2,4-D dimethylamine	0.25	29	9	1297	779
Carfentrazone + 2,4-D dimethylamine	0.05 +0.25	30	7	1449	898
Carfentrazone + 2,4-D dimethylamine	0.1 + 0.25	31	13	1545	946
Carfentrazone + 2,4-D dimethylamine	0.2 + 0.25	34	12	1264	766
Carfentrazone + 2,4-D dimethylamine	0.3 + 0.25	16	8	1587	994
Carfentrazone + 2,4-D dimethylamine	0.4 + 0.25	39	14	1300	814
Untreated		26	4	1728	1098
LSD (0.05)		ns	ns	ns	ns

MOLECULAR GENETICS OF WILDRICE

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Introduction

Considerable progress has been made in the molecular genetic research of wildrice since this project was initiated 7 years ago. A genetic map consisting of 120 RFLP markers was constructed by previous postdoctoral scientists Wayne Kennard and Al Grombacher (Kennard et al. 2000). Several agronomic traits such as maturity, shattering and flowering have been placed on the map paving the way for a 'molecular breeding' program. Several important populations and breeding lines have been developed in this program that are being characterized by Peter Imle; Alex Kahler is developing new mapping strategies that will benefit the breeding program in Grand Rapids. Scott Jackson has begun to link the chromosomes of wildrice with those of white rice leading the way for the utilization of the DNA sequence data from white rice.

Peter Imle

In addition to the comparative mapping and genomics work, we have been continuing work on the confirmation and integration of QTLs controlling seed shattering in wild rice. Continued RFLP analyses of lines developed from the mapping population have been used to test for the presence of shattering alleles in advanced breeding lines. Preliminary analysis of these results indicate that the majority of the breeding lines tested are fixed for nonshattering. This suggests continued progress toward nonshattering lines by traditional breeding methods.

We are also continuing to test molecular markers for linkage to potential genes controlling shattering. These tests have shown the currently identified markers, identified by Kennard et al. (2000), continue to be polymorphic in successive generations of testing on individuals derived from the mapping population. Recently, two genes were found in white rice that control seed shattering, the location of these genes is collinear with two of the shattering QTLs found in wildrice.

A more complete analysis of this comparative mapping information and the results of the tester line crosses will be available at the annual meetings or by request upon the completion of a M.S. thesis of Peter Imle.

Alex Kahler

To date, all of the mapping and characterization work on wildrice has been completed through the use of RFLP analysis. While RFLPs are still widely used and produce very reliable information, the use of RFLP technology as a primary screening method is being replaced with more effective methods. In addition to harboring slight danger in the required use of radioactive ^{32}P for labeling of probes, the current technology is also quite slow, requiring 5-8 days of labor for each hybridization cycle before any results are observed.

In consideration of time as well as efficiency of using materials, progress has begun to be made in converting the current RFLP-based marker system to a PCR-based system in which results of one DNA amplification cycle may be observed within 1 to 2 days. This upgrade will take wildrice research to the next level and has been proven to be as or more reliable than RFLP analysis in most other small grain crops research. While the PCR-based technology is not yet developed or usable in wildrice, it is hoped that PCR primers for previously identified useful molecular markers will be designed and optimized by mid-year 2001.

Scott Jackson

The genome of white rice will be completely sequenced in the near future and the Monsanto Corporation has already released to the public about 50% of the DNA sequence of white rice. Because of the genetic colinearity found between rice and wildrice, we are very optimistic about the utility of this DNA sequence for the improvement of wildrice. We are preparing comparative physical maps of portions of these two genomes where QTLs for agronomic traits (i.e. shattering) have been found. As the advanced molecular genetics of these traits are elucidated in white rice the data should be directly applicable to wildrice. Thus, this physical map of related regions of the rice and wildrice genomes will facilitate the application of data gleaned from rice to wildrice.

The relationship of wildrice (*Zizania palustris*) and white rice (*Oryza sativa*) has also been more clearly defined by comparing the DNA sequence of genes from both organisms. Based on the comparative genetic map (Kennard et al. 2000), we suspected that these two species were very closely related and other studies have shown that rice and wildrice are in the same Tribe. However, by sequencing genes and comparing the sequence data we have constructed a family tree that clearly shows the relationship of wildrice and rice. Wildrice is more closely related to rice than several other species in the Tribe Oryzeae and its closest relative is *Rhynchoryza subulata* a species that is native to South America. The close relationship of rice and wildrice bodes well for being able to make direct comparison between the genomes of these two species and exploiting the DNA sequence from rice.

Conclusion

We are making considerable progress in the development and application of molecular techniques for genetic research in wildrice. The shift from RFLP to PCR-based markers will make the transition from lab to field research much easier. Using PCR, early generation testing for breeding traits can be done before making crosses. We are also very excited by the research being done in white rice. The white rice genome is being sequenced and functions are being assigned to many of the genes. We plan to use these developments in white rice to assist our efforts in wildrice. Several genes affecting shattering have been cloned in rice and we will be developing markers from these genes to help us elucidate the genetics of shattering in wildrice.

SUMMARY OF PLANT PATHOLOGY RESEARCH ON CULTIVATED WILDRICE IN 2000

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Survival of Bipolaris oryzae (fungal brown spot), B. sorokiniana (spot blotch) and sources of primary inoculum.

It is thought that the fungi survive in infested wildrice residue, only when residue remains dry over the winter. The fungi do not survive longer than a couple of days when exposed to moisture. Therefore, infested wildrice residue may be a source of inoculum in some circumstances where the residue has remained dry during the winter and spring. Examples of this would be wildrice residue that has been baled for bedding or used in dike stabilization or "clumps" of residue that have mostly managed to remain comparatively dry following harvest and through the winter and spring. This research will be published in the refeered journal "Plant Disease" in 2001-2002.

Reed canary grass (Phalaris arundinacea) is the predominant grasss that grows on most dikes surrounding cultivated wildrice fields. Previously we had not thought this grass was a major source of inoculum. Our reason(s) for thinking this was although B. oryzae was frequently isolated from reed canary grass lesions in the fall, the fungus was isolated from only 1 of 12,000 reed canary grass samples taken during the spring of 2000. Therefore, we concluded in our Fall, 2000 report to the Minnesota Cultivated Wildrice Council that reed canary grass was not an important means of overwintering for B. oryzae. However, our subsequent research and review of past data lead us to conclude that reed canary grass may, after all, be a source of primary inoculum to initiate disease the following growing season. A review of past data indicates that B. oryzae was isolated from reed canary grass but at a very low incidence. If we use our 1-years data taken during 1999 and 2000 as an example, B. oryzae was isolated from .045% (4 1/2%) of 2,500 leaf lesions on reed canary grass taken from four locations during the fall of 1999. We have been unable to isolate B. oryzae from reed canary grass stems. In the spring of 2000 B. oryzae was isolated from only 1 of 12,000 leaf lesions on reed canary grass taken from these same four locations or .000083% of lesions. However, we determined that the dry weight of reed canary grass leaves in a square meter (a meter equals 39 inches) varies from 136-197 grams. We assume there is approximately one lesion per square centimeter of reed canary grass leaf tissue. The dry weight of a square centimeter is approximately .001 gram. Therefore, the number of spots per square meter in which B. oryzae may theoretically survive the winter and produce primary inoculum the following growing season varies from 11-16. We know from our past research that the number of conidia (primary inoculum units) that are produced from a single lesion varies tremendously but given proper environmental conditions of high humidity and temperatures the number of conidia that can potentially be produced per lesion may exceed thousands. Therefore we conclude that if reed canary grass remains dry or relatively dry during the winter and spring (we have observed that this commonly occurs), thousands of conidia can potentially be produced per square meter of plant material.

During the summer, isolations were made from stands of wild rice in lakes and rivers. Contrary to previous information that river and lake stands of rice are infected only when plants are under stress, it was found that plants growing in optimum conditions were heavily diseased. These stands will be examined in the spring of 2001 to determine if this is the major source of overwintering for fungal brown spot and spot blotch.

Dissemination of spores.

In 2 years results in the greenhouse, it appears spores of B. oryzae are wind disseminated for at least 18 meters maximum but most spores are only disseminated a couple of meters. Therefore, most disease inoculum is probably of local origin.

Growth stage of plants as related to susceptibility to fungal brown spot and spot blotch.

Symptoms of fungal brown spot of cultivated wildrice caused by Bipolaris oryzae, initially occurred on the flag and lower aerial leaves of wildrice at the boot stage of development, whereas spot blotch symptoms, caused by B. sorokiniana, first occurred at the floating leaf stage of plant development on both the floating leaf and the first aerial leaves. The percentage of B. oryzae isolated from all lesions did not increase significantly until early grain formation. Lesion numbers then increased rapidly until plant maturity when B. oryzae was isolated from 36.9 and 49.3% of all flag and bottom aerial leaf lesions, respectively. On both the flag and lower aerial leaves, the percentage of lesions yielding B. sorokiniana increased slowly until early grain formation, then increased rapidly until plant maturity, 17.6 and 14.1%, respectively. Numerous spots on the floating and first aerial leaves, previously thought to be caused by Bipolaris spp.infections, were caused primarily by Nakataea sigmoidea, Colletotrichum spp., and Phoma spp. The number of conidia of B. oryzae produced per lesion, under laboratory conditions, was greatest from lesions on lower leaves from early-mid flowering until plant maturity. The number of conidia of B. sorokiniana from lesions on both upper and bottom leaves increased until early-mid flowering, then remained relatively constant until plant maturity except that the number of conidia from lesions on bottom leaves declined.

Infection of wild rice seed by Fusarium graminearum (scab).

An extensive effort was made to determine the status of scab-infested seed. Extensive sampling was conducted during all phases of harvest and processing. The results are shown in the enclosed table. Most infected seed "shatters" or is ejected with chaff during harvest. Little effect occurs during the fermentation (in the piles) process but parching and hulling appears to remove the rest of the infected seed. Special thanks to Jule Wraa of Gourmet House and Don Barrons for their help in this study.

Isolation of Fusarium graminearum (scab) from cultivated wild rice seed

Source	Percentage[a]
Soil surface (no Tilt)	42.3
Soil surface (Tilt applied late)	44.6
Passed through combine in chaff (no Tilt)	38.8
Chaff only	0.0
Combine hopper	10.3
Truck used to transport rice to processing plant	
(load 1)	15.1
(load 2)	9.0
Just placed in pile outside processing plant	12.3
Two days in pile outside processing plant	11.1
Before parching/hulling	
(Sample 5 A)	9.1
(Sample 6 A)	12.4
After parching and 86 huller (lighter hulled seed lots)	
(Sample 1 A)	0.0
(Sample 2 A)	0.0
(Sample 3 A)	0.0
(Sample 4 A)	0.0

[a] Based on 1,000 seeds per source with exception of seed collected from soil surface and in chaff.