Minnesota Wild Rice Research 1985

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

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RESEARCH IN NITROGEN AND FERTILITY OF PEAT SOILS - 1985

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Research during 1985 focused on nitrogen transformations and losses from a peat soil in wild rice paddies and on factors causing increased yield near some paddy ditches.

Lab Research

In 2.5 inch diameter plexiglass columns 133 Kg/ha (120 lb/acre) ammonium chloride fertilizer (as 15N) was mixed homogeneously into 15 cm (6 inches) of peat obtained from a paddy owned by Clearwater Rice Inc. The amount of fertilizer added is two to three times higher than normal. It was necessary to add high amounts for analytical purposes. Some of the peat properties are listed in Table 1.

Table 1. Peat Properties

Classification:	Terric Borosaprist
Bulk Density	0.21 g/cm
Carbon/Nitrogen	16/1
pH	6.9
Ash (500°C)	31%

Results of the study indicate that losses of N to the atmosphere by ammonia volatilization contributes only 5-10% of the nitrogen lost from the soil. The greatest loss of nitrogen to the atmosphere occurred through the process of nitrification-denitrification at the soil water interface. This process converts ammonium nitrogen into N_2 gas.

The experimental results suggest that one-fourth to one-third of the incorporated fertilizer was lost as N_2 gas. Most of the loss occurred in the top two to three inches of the soil. If the nitrogen fertilizer had been applied on the surface or poorly incorporated (as with disking) losses to volatilization and denitrification would have been greater. However, injection of the fertilizer six to eight inches would greatly reduce both losses. Mouldboard plowing would also place the nitrogen at greater depths and reduce loss by volatilization and denitrification.

A nitrification inhibitor, DCD, was investigated as a possible inhibator for nitrification-denitrification losses. The results were negative.

Laboratory results also indicate that algae can cause serious losses of nitrogen. Algae act as a weed and reduce the nutrients available to the wild rice. Approximately one-fourth to one-half of the nitrogen can be lost when algae growth is moderate to severe. Deep placement of fertilizer would keep nutrients away from the algae and reduce their growth.

The Clearwater peat is a well-decomposed sapric peat with high mineral content and a favorable carbon to nitrogen ratio (16/1). It is a net mineralizer of organic nitrogen and produces approximately 35-40 lbs/acre of inorganic nitrogen in a six inch plow layer over a 90 day period. However, a field survey indicates that a healthy high yielding crop of wild rice (approx. 1000 lbs/acre) will extend its roots 18 inches into a deep sapric (well decomposed) peat. This results in approximately 100-120 lbs/acre of nitrogen available to the plant. Studies by Grava and Raisanen indicate that a high yielding wild rice requires about 100-120 lbs/acre of nitrogen.

Field Studies

from dredging of the ditches. Conditions in the center of the paddy were strikingly different than along the ditch. A layer of well-decomposed sapric type peat approximately six inches deep overlay a peat that was fibric (poorly decomposed) in character. Most importantly, the roots of the wild rice extended only six inches into the soil (into the sapric peat only) with no growth into the fibric peat. The yield in the center of the paddy was very poor compared to the edge near the ditch. Deep sapric peat has a much greater potential to supply the nitrogen, potassium, phosphorous and other nutrients required by the wild rice plant than does a fibric peat.

Analysis of the poorer (fibric) peat indicates that it had a carbon to nitrogen ratio of 30/1, an ash content of 9% and very low potassium, only 9 lbs/acre in six inch plow layer. Low ash can often indicate low potassium. The sapric layer had a carbon to nitrogen ratio of 16/1, an ash content of 19% and 80 lbs/acre of potassium. Studies by Grava indicate that wild rice requires approximately 250 lbs/acre of potassium. Furthermore, peats with a higher carbon to nitrogen ratio generally have less capability to produce inorganic nitrogen by mineralization of organic matter.

Table 2 presents the results of plant tissue analysis from along the ditch (the edge) and the center of the paddy.

Table 2. Plant Tissue Analysis (Stems and Leaves) from the Edge and Center of the Paddy.

	Edge	Center	High yielding wild rice*
Nitrogen (N) %	1.46	1.42	1.5
Potassium (K) %	3.6	3.0	3.5
Calcium (Ca)	0.36	0.44	0.3
Magnesium (Mg) %	0.13	0.16	.24
Sulfur (S)	0.14	0.17	--
Phosphorus (P) %	0.34	0.35	.42
Silicon (Si) %	3.7	2.7	--
Manganese (MN) ppm	197	145	250
Copper (Cu) ppm	1.5	1.0	2 to 5
Zinc (Zn) ppm	43	61	63
Boron (B) ppm	15	21	8

*Grava and Raisanen, 1978

The soil analysis and plant tissue analysis (Table 2) suggests that potassium may be deficient in this paddy. However, it is possible that other elements are deficient, such as nitrogen (due to the high carbon to nitrogen ratio), copper, maganese, and silicon. Copper tested adequate in the soil, but was low in the plant tissue. Grava and Raisanen (1978) found copper levels several times this concentration in studies in high yielding plots located on the Kosbau Brothers' farm. Silicon is not considered an essential plant nutrient. However, it may be important for stem strength and disease resistance.

Studies have been started to try to determine the nitrogen supplying ability of various peats and identify the factors responsible for the lack of root growth into fibric type peat.

ACKNOWLEDGEMENTS

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REFERENCE

Grava, John and K. A. Raisanen. 1978. Growth and Nutrient Accumulation and Distribution in Widle

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1985 WILD RICE SEASON

The 1985 growing season started out warm during May but was cool during the rest of the summer. The number of growing degree days (GDD) was considerably more in May compared to 1984 and the normal (long-term) average for Aitkin, Grand Rapids and Itasca locations (Table 1).

Table 1. Growing degree days* comparisons for 1984 and 1985.

Month	Aitkin		Normal	Grand Rapids		Normal	Itasca		Normal
	1985	1984		1985	1984		1985	1984	
April (15-30)	196	109	---	172	101	---	168	86	---
May	740	456	414	526	378	380	502	326	375
June	582	784	677	527	711	635	493	686	645
July	847	976	871	824	880	816	782	843	833
August	716	950	785	674	912	734	657	898	759
September (1-15)	291	227	---	283	206	---	255	183	---
Total	3372	3502		3006	3188		2857	3022	

* $\frac{\text{Maximum temp.} + \text{Minimum temp.}}{2} - 40°$ F; data from University of Minnesota and U.S. Dept. of Commerce.

However, for the rest of the season the number of GDD was less for each month compared to the 1984 or normal average, except for July at Grand Rapids. The number of GDD at Grand Rapids was slightly higher in July than the normal but not the 1984 average. In Aitkin County approximately 470 GDD are required for plants to reach the floating leaf stage, 1,400 to jointing (when the nodes in the base of the stem begin to separate), 1,850 to flowering and 3,000 to maturity.

Harvest was later than in 1984 because of the cooler temperatures and rains during August which caused some fields to be very wet for harvest (Table 2). The high amount of rainfall also contributed to brown spot infection in some fields; however, generally, the cooler temperatures slowed the development of the disease. The infestations of wild rice worm were not very severe this year and many growers did not have to treat for control.

Table 2. Precipitation (inches) comparison for 1984 and 1985.

Month	Aitkin		Normal	Grand Rapids		Normal	Itasca		Normal
	1985	1984		1985	1984		1985	1984	
April (15-30)	4.04	1.74	----	4.13	1.06	----	2.39	1.11	----
May	3.77	2.18	3.39	6.11	3.24	3.16	8.54	1.50	2.80
June	4.31	8.14	3.83	4.03	7.44	3.79	5.62	5.93	4.33
July	6.03	1.36	4.79	3.84	1.32	4.12	4.39	1.67	3.34
August	5.00	1.14	4.19	2.96	1.51	3.38	4.50	4.85	3.47
September (1-15)	1.44	1.06	----	1.30	0.90	----	1.26	0.80	----
Total	24.59	15.62		22.37	15.47		26.70	15.86	

from cultivated acres in Minnesota was about 10 percent higher than in 1984.

RESEARCH

Our research during 1985 focused on weed control, reducing wild rice plant population with chemicals, plant growth regulators for reducing plant height, drying of wild rice seed before storage and the effect of combine harvesting on wild rice seed storability. The research was conducted on University plot land in St. Paul and Grand Rapids and in growers' fields near Aitkin. A glass house and growth chambers at St. Paul were also utilized for some of the research.

WEED CONTROL RESEARCH

Effect of Giant Burreed Density on Wild Rice Growth

Giant burreed corms were planted at 4 densities (0, 0.6, 1.0 or 2.25 corms/ft^2) into wild rice (variety K2) at the Grand Rapids Experiment Station. The experimental design was similar to 1984 (see 1984 Wild Rice Research Report). Wild rice panicles/ft^2 and grain yield were significantly reduced with densities as low as 0.6 corms/ft^2 (1.8 plants/ft^2 at harvest) (Table 3). Yield per panicle was reduced at 1.0 and 2.25 corms/ft^2 densities. The results were similar to those reported in 1984. In a controlled field experiment, yield loss from giant burreed densities as low as 0.6 corms/ft^2 were 64 and 30% for 1984 and 1985, respectively. Yields were reduced by 70 and 60% at 2.25 giant burreed corms/ft^2 in 1984 and 1985, respectively. Giant burreed is a very competitive weed when present in wild rice and needs to be controlled even at densities as low as 0.6 corms/ft^2.

Table 3. Effect of giant burreed densities on wild rice growth and yield, Grand Rapids, MN-1985.

Giant Burreed Density	Giant Burreed Plants	Giant Burreed Dry Weight	Wild Rice Plants	Wild Rice Panicles	Wild Rice *Yld/Pan	Wild Rice Yield*
corm/ft^2	/ft^2	lb/A	/ft^2	/ft^2	g/panicle	lb/A
0.6	1.8	1425	2.6	4.8	0.83	381
1.0	2.6	1622	2.8	4.3	0.75	304
2.25	3.6	2376	2.5	3.6	0.62	227
Check (0)	0	0	2.8	6.3	0.88	532
LSD (0.05)	0.5	348	NS	1.2	0.12	126

* 7% moisture.

The 1984 experiment where giant burreed was removed by hand after 2, 5 or 14 weeks of growth in wild rice was repeated in 1985. In 1984, when 1.8 corms/ft^2 were interplanted with wild rice, grain yield and the number of wild rice plants and panicles were reduced after 2 weeks of competition. Competition from 2 to 5 weeks did not cause further reductions. However, season-long competition caused a greater reduction than if removal occurred between 2 and 5 weeks. A repeat of the 1984 experiment did not confirm these results. No significant yield differences were obtained when giant burreed was removed after 2, 5 or 14 weeks of growth compared to all season competition. Wild rice plant populations were uneven and this could have resulted in no differences in yield.

Water Management and Temperature Influence on Survival of Giant Burreed Corms

A laboratory experiment on corm survival was continued in 1985 (see 1984 Wild Rice Research Report). Corms were separated into 4 sizes (<12 mm, 12-17 mm, 17-23 mm and >23 mm) and placed at -2° or 2° C in flooded or nonflooded containers with peat soil for 1, 3, or 5 months. Corm size, cold treatment duration, or water management had no effect on corm survival. Corms that were kept at above freezing temperature (+2° C) had a greater survival percentage than those stored at below freezing temperature (Table 4). Corms placed on the soil surface germinated more frequently than those placed in the soil. These results are similar to those reported in 1984.

Table 4. Average giant burreed corm survival at above and below freezing temperature and storage either on soil surface or covered with soil, St. Paul, MN-1984 and 1985.

Temperature	Survival	
	1984	1985
°C	- - % - -	
2	53	55
- 2	8	2
LSD (0.05)	6	15

Position	Survival	
	1984	1985
	- - % - -	
Soil surface	34	32
7 cm	26	25
LSD (0.05)	6	6

Water management practices (fall vs spring flooding) were evaluated in 1984 amd 1985. Giant burreed corms were planted at 5 depths (0, 10, 20, 30, or 40 cm) in a peat soil in plastic-lined soil pits and either flooded or covered with plastic to simulate dry soil conditions. Soil temperatures were recorded from the boxes and also obtained from the St. Paul Monitoring Weather Station. Soil temperatures were lowest the week of January 28 to February 3, 1985 (St. Paul climatological data) when soil temperatures were down to -20° C in the top cm of soil. Boxes were flooded in the spring. Corm viability (production of roots or shoot) was monitored throughout the spring and summer.

A time of flooding by burial depth interaction was significant in this experiment (Table 5). Corms at the 0 and 10 cm depth in the flooded treatments had a lower survival rate than those at the 20 and 30 cm depth. Depth of burial in the nonflooded treatments did not affect corm survival. These results differed from 1984 (see 1984 Wild Rice Research Report) in which corms at the 0 and 10 cm depth had the highest survival rate and water management was not a significant factor in corm survival.

Table 5. Giant burreed corm survival in the spring after burial in the soil at different depths and water treatments, St. Paul, MN-1985.

Burial depth	Survival
cm	(%)
0	48
10	65
20	76
30	84
40	75
LSD (0.05)	21

Water Treatment	Burial Depth	Survival
	(cm)	(%)
Flood	0	18
	10	59
	20	80
	30	85
	40	70
Non-flood	0	79
	10	71
	20	72
	30	84
	40	79
	LSD (0.05)	30

Areas with giant burreed were rotovated in the fall to a depth of 6 inches or left as no-till areas. Giant burreed numbers and dry weight were reduced in plots receiving the fall tillage treatment (Table 6). Wild rice plants/ft^2, dry matter production/A and panicles/ft^2 increased with fall tillage. Yield of wild rice grain was not affected by fall tillage. Fall tillage in the 1984 season reduced both number and dry weight of giant burreed (see 1984 Wild Rice Research Report). Wild rice yield in that production year was significantly increased with fall tillage treatments. Fall tillage appears to be a useful cultural control method for giant burreed. Wild rice yield may be increased in tilled areas depending on the season's climatic conditions, control of giant burreed realized and other production practices employed (i.e., water depth, disease control, thinning, etc.).

Table 6. Fall tillage influence on giant burreed and wild rice, Aitkin, MN-1984 and 1985.

Tillage Treatment	Giant Burreed				Wild Rice			
	1984		1985		1984		1985	
	Plants	Dry Weight	Plants	Dry Weight	Panicles	Yield*	Panicles	Yield*
	/ft^2	lb/A	/ft^2	lb/A	/ft^2	lb/A	/ft^2	lb/A
No Till	2.0	962	2.7	1914	3.2	257	4.7	977
Fall Rotovate	0.8	236	0.8	370	8.2	563	6.7	958
LSD (0.05)	0.3	336	1.6	974	2.7	128	NS	NS

* 7% moisture.

Spring Bentazon Treatment

A bentazon trial to define rates and dates of application which give acceptable giant burreed control was continued in 1985. Bentazon in 3 formulations (granular, liquid, and liquid + crop oil) and at 3 application dates (preemergence, 2-, or 5-leaf stage of wild rice growth) was applied in 5-foot diameter metal rings to minimize bentazon movement between plots (see 1984 Wild Rice Research Report). Giant burreed dry weight was reduced with liquid at 1 or 2 lb/A applied at the 2- or 5-leaf stage of growth and liquid + crop oil at 0.5 or 1.0 lb/A applied at the 5-leaf stage of growth (Table 7). Granules did not reduce giant burreed dry weight in 1985 in contrast to 1984 results. Grain yield was not increased from the weedy check with any herbicide treatment. Wild rice injury may have resulted from liquid applications at 2 lb/A applied at either 2- or 5-leaf stage of growth. Results from the 1984 and 1985 field seasons suggest that bentazon applied at the 2-leaf stage at 1 lb/A or 5-leaf stage at 2 lb/A give acceptable control of giant burreed. Applications with crop oil may injure wild rice depending on climatic conditions.

rice yield, Aitkin, MN-1985.

Treatment	Stage*	Rate	Giant Burreed		Wild Rice		
			Plants	Dry Weight	Plants	Panicles	Yield**
		lb/A	/ft^2	lb/A	/ft^2	/ft^2	lb/A
Granule	Preemerge	1.0	3.8	2271	3.2	6.7	242
Granule	Preemerge	2.0	2.0	2420	2.5	4.7	215
Granule	2 leaf	1.0	2.7	1062	3.3	4.7	248
Granule	2 leaf	2.0	1.9	1734	3.2	6.4	212
Liquid	2 leaf	1.0	1.5	359	3.5	6.5	318
Liquid	2 leaf	2.0	2.4	704	1.8	4.3	126
Liquid + crop oil	2 leaf	0.5	1.6	1636	3.1	4.9	244
Liquid + crop oil	2 leaf	1.0	2.7	1947	3.8	7.2	296
Liquid	5 leaf	1.0	1.9	706	2.7	5.8	310
Liquid	5 leaf	2.0	1.5	260	3.0	5.4	153
Liquid + crop oil	5 leaf	0.5	2.9	1049	3.1	6.1	304
Liquid + crop oil	5 leaf	1.0	2.2	369	3.3	5.9	162
Weedy Check			3.6	2276	3.1	6.5	243
Handweeded Check***			0.1	34	3.4	8.2	362
	LSD (0.05)		NS	1120	NS	NS	139

* Stage of wild rice development when treatments were applied.
** 7% moisture. *** Weeded at 2-leaf stage.

Spring Herbicide Trial

Herbicide trials for control of giant burreed were continued in 1985 near Aitkin, MN. Herbicide treatments included bentazon, MCPA, propanil, and 2,4-D amine applied at 1, 2 or 4 lb/A at the 5-leaf stage of wild rice development. The experimental design was a randomized complete block with 4 replications. Giant burreed numbers were not reduced by any herbicide treatment in 1985 (Table 8). This is contrary to the 1984 results in which all treatments reduced giant burreed numbers when compared to the weedy check. Dry weight of giant burreed was reduced in 1984 by all treatments except propanil applied at 1 lb/A. In 1985, however, dry weight of giant burreed was highly variable within plots and treatments had no effect on this parameter at the 5% level of significance. Bentazon and 2,4-D at 1 lb/A and propanil at 2 lb/A increased grain yield when compared to the weedy check in 1984. Grain yield in herbicide treatments was not different from the weedy check in 1985. MCPA at 2 and 4 lb/A, and 2,4-D + crop oil at 4 lb/A severely injured wild rice in both years. Climatic conditions were cooler and wetter in 1985 than in 1984. This may have caused this year's poor herbicide performance; a photosynthetic inhibitor such as bentazon is especially likely to be affected. Studies on herbicide methods for giant burreed will continue in 1986 to define rates that give consistent control.

wild rice, Aitkin, MN-1984 and 1985.

Treatment	Rate	Giant Burreed				Wild Rice	
		1984		1985		1984	1985
		Plants	Dry Weight	Plants	Dry Weight	Yield*	
	lb/A	$/ft^2$	lb/A	$/ft^2$	lb/A	- - lb/A - -	
Bentazon	1	0.7	198	1.4	1257	126	32
	2	1.2	348	0.5	270	69	60
	4	1.6	526	1.2	837	20	59
MCPA	1	0.1	27	0.6	263	28	138
	2	0.4	60	0.7	261	23	65
	4	0.4	63	0.9	529	0	19
Propanil	1	2.5	940	0.8	551	88	158
	2	1.9	574	1.1	460	123	154
	4	2.0	837	0.6	241	79	190
2,4-D	1	1.1	109	1.4	1147	105	70
	2	0.6	53	1.5	783	91	147
	4	0.4	37	0.9	645	52	80
2,4-D + crop oil	1	0.8	188	0.9	556	78	70
	2	0.7	27	1.4	1114	79	38
	4	0.2	9	1.1	593	13	9
Weedy Check		3.9	1179	1.4	877	35	90
Handweeded Check		0.2	24	0.3	20	140	174
LSD (0.05)		1.1	245	NS	466**	67	95

* 7% moisture. ** LSD (0.30).

Ropewick Herbicide Trial

Giant burreed emerges earlier from the water and is taller than the wild rice until mid-July. This height differential allows a ropewick application of herbicide to the weed without treating the wild rice plant. Therefore, a ropewick herbicide trial was initiated in 1985. Herbicides including bentazon, MCPA, Roundup and Rodeo + surfactant (0.01% v/v) were mixed with water (1:2 v/v) and placed in a ropewick applicator. The herbicides were applied in one pass at the 2-leaf stage of wild rice growth; giant burreed was at the 5-leaf stage, approximately 1 foot above the wild rice plants. A weedfree and weedy check were included in the treatments. Roundup and Rodeo + surfactant reduced giant burreed biomass production when compared to the weedy check (Table 9). These treatments also reduced the number of wild rice panicles/ft^2 when compared to the handweeded check. Wild rice yield with herbicide treatments was not increased over the weedy check. Handweeded plots produced the highest yield for this trial.

Aitkin, MN-1985.

Treatment	Giant Burreed		Wild Rice	
	Plants	Dry Weight	Panicles	Yield*
	$/ft^2$	lb/A	$/ft^2$	lb/A
Bentazon	2.4	798	3.1	171
Glyphosate (Roundup)	0.4	112	2.3	108
MCPA	2.2	953	3.4	151
Rodeo +	1.0	336	2.9	118
Weedy Check	2.2	1192	2.5	128
Handweeded Check	0.4	61	5.3	298
LSD (0.05)	1.5	603	1.5	91

* 7% moisture.

PLANT POPULATION

Reducing Wild Rice Plant Population with Chemicals

Glyphosate (Rodeo) was applied in strips to wild rice with a modified pipewick at Grand Rapids and in a grower's field (Godward) at Aitkin with an airboat which had a special boom with felt squares (10 inches wide by 8 inches high) attached to it. The pipewick had two ropewicks placed in alternate 10-inch spacings leaving 10-inch rows of plants untreated. The felt squares were supplied with glyphosate by plastic tubing attached to a small pump. The boom was constructed by Tom Godward. The glyphosate solution consisted of 1 gallon of glyphosate mixed with 2 gallons of water plus X-77 spreader (1 qt/100 gal).

The applications of glyphosate with the airboat when the felt squares were spaced 10 inches apart and the pipewick numerically reduced the plant population and yields were slightly higher compared to the check (Table 10). However, the differences were not statistically significant. Rows of dead plants were visually evident.

Table 10. The number of wild rice plants and yield after thinning with an airboat wick and hand ropewick applicator which contained glyphosate (Rodeo), Aitkin, MN-1985.

Method of Application	Wild Rice	
	Plants	Yield
	ft^2	lb/A*
Airboat** (8-inch space untreated)	8.0	384
Airboat** (10-inch space untreated)	5.8	408
Ropewick	5.8	432
Check	7.1	336
LSD (0.05)	NS	NS

* 7% moisture. ** Felt applicators were 10 inches wide.

but yields were numerically lower (Table 11). Some injury [illegible] remaining plants probably causing the lower yields.

Table 11. Wild rice plant population and characteristics as influenced by application of glyphosate (Rodeo) with a modified pipewick applicator to thin wild rice, Grand Rapids, MN-1985.

Treatment	Wild Rice		
	Stems	Plants	Yield
	ft^2	ft^2	lb/A
Thinned	5.7	3.2	463
Check	8.4	4.6	695
LSD (0.05)	1.4	1.3	NS

Thinning wild rice with chemicals when applied with a wick system may have some possibility with further refinement of the system for application.

PLANT GROWTH REGULATORS

Experiments on the use of plant growth regulators to reduce plant height and lodging in small grains were continued in 1985. Ethephon (Cerone®) which is cleared for use in the U.S. for wheat and barley was tried again even though the 1984 results were not very positive. Ethephon was applied at 3/4 and 1 1/2 lb/A at the late tillering stage (July 2) and when the flag leaf was out (July 16) at Grand Rapids. No statistical differences in plant height, lodging or grain yield were obtained; however, visually there appeared to be a little less lodging in the later treatments compared to the control plots. We will continue to search for other growth regulators which might reduce plant height and lodging in wild rice.

SEED STORAGE

Fall Seed Handling and Storage

Experiments were initiated in the fall of 1984 to determine if allowing wild rice seed to remain out of water either spread out or in bags on a table before storage for a period of time would decrease viability of the seed the following spring. Immediately after harvest, seed of the variety K2 was spread out on a laboratory bench and samples taken periodically for the first 6 hours of air drying and then after 18, 44 and 116 hours. Percent grain moisture was obtained and some seed was immediately put into water at each sampling. The seed in water was stored in a cooler at 2° C and germination checked the following spring (1985). Table 12 lists the moisture percent of the grain after drying in the fall and the germination percentage obtained the following spring.

room temperature for various lengths of time before storage in cold (2° C) water.

Length of drying period on labortory bench	Grain moisture	Germination
hr	%	%
0	39	37
0.5	39	47
1.0	37	59
1.5	37	47
2.0	37	43
3.0	36	45
4.0	35	52
5.0	34	52
6.0	29	50
18.0	24	47
44.0	12	37
116.0	8	17
LSD (0.05)	5	13

Allowing the seed to dry on a laboratory bench up to 44 hours and down to 12% moisture before storage in water did not affect germination the following spring. However, drying the seed longer and below 12% moisture significantly reduced germination. It appears that some air drying of the seed at room temperature before storage in water will not reduce viability if the seed doesn't dry down below 12% moisture. Previous work indicated that drying seed below 30% moisture in the spring after storage in water and dormancy was broken reduced germination substantially. This experiment was repeated in the fall of 1985 and germination will be checked in the spring of 1986.

Some of the same seed was also allowed to remain in plastic mesh bags (15 lbs each) on the laboratory bench and seed samples were removed every 3 days for grain moisture determination and some seed samples were stored in water until the following spring. The temperature in the center of the bags went up to 48° C (118° F) after 6 days (Table 13). These temperatures did not appear to hurt germination; however, in larger bags the temperature may be substantially higher and could affect seed viability. Seed moisture in the bags did not drop as readily nor as low as the seed in a thin layer on a bench. Seed moisture only decreased to 22-24% after 18 days in the bags. A considerable amount of mold growth was evident on the seed after 6 days in the bags. If seed is to be kept in bags for even a short while the seed should be immediately cooled and kept wet.

mesh bags for various lengths of time at room temperature before storage in cold (2° C) water.

Length of time in mesh bags on laboratory bench	Room temperature	Temperature of seed in bag	Seed moisture	Germination
days	C° (F°)	C° (F°)	%	%
0	27 (81)	30 (86)	39	37
3	27 (81)	37 (99)	38	37
6	27 (81)	48 (118)	28	30
9	24 (75)	44 (111)	32	22
12	22 (72)	29 (84)	23	36
15	24 (75)	29 (84)	22	23
18	23 (73)	27 (81)	24	43
		LSD (0.05)	8	NS

In the fall of 1985, seed samples were hand harvested from 12 different fields of the K2 variety. In addition, seed samples from the grower's combine in the same fields were collected. All of the samples were immediately put into water and taken to St. Paul to store in a cooler at 2° C. Seed germination in the spring of 1986 will be compared for the hand and machine harvested samples. In addition to the 12 fields of the K2 variety, both hand and machine harvested seed samples were collected from 3 fields of the variety Voyager. Germination in the spring of 1986 of these samples will be compared to the K2 variety samples.

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WILD RICE BREEDING--1985

R.E. Stucker, G.L. Linkert, P.M. Hayes, G.G. Wandrey and Tri Hutomo[1/]

Results from 1985 wild rice breeding experiments are in varying stages of analysis ranging from near completion for the tiller synchrony research carried out by P.M. Hayes as part of his Ph.D. program, to just beginning for seed size research initiated by the project and G.W. Wandrey as part of his Ph.D. research. Tri Hutomo is nearing completion of a selection program (in the population cross of Dwarf x Johnson) which is part of his Master of Science degree requirements. The genetic shift experiments may be considered in a preliminary stage of analysis.

The 1985 season can be considered a success by wild rice standards since none of our experiments were a complete loss. On the other hand, we were generally disappointed by the quality of several of the experiments at Excelsior. We find this particularly frustrating in view of the intensive inputs and care given to those experiments. We prefer to blame the effect of the location, late planting and paddy variation. None-the-less, we must begin serious consideration of abandoning the breeding research in the Minneapolis/St. Paul area in favor of a more northerly site.

The dwarf population released as 'Meter' is continuing in increase by Minnesota Crop Improvement. The first increase of approximately 5 acres resulted in around 800 lbs of green seed. It will be used to seed another 15 acre site from which seed should be available to other growers in the fall of 1986. The variety continues to be very early, short and low in yield. Early bird damage is likely to be a severe problem.

SELECTION FOR TILLER SYNCHRONY

(P.M. Hayes)

In an effort to increase recoverable yields of wild rice, we have selected for tiller synchrony, the uniform within-plant development of tillers and mainstem. Our rationale is that mainstems mature and shatter before tillers mature; reducing the opportunity for mainstem shattering would allow the producer to recover a greater percentage of the actual yield.

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selection because of the difficulty encountered in selecting for shattering resistance beyond that conferred by the two gene system present in 'non-shattering' cultivars. Such selection can be effective, as demonstrated by the research of Everett, Boze, and Stucker, reported in previous Wild Rice Research Bulletins. However, concerns regarding the efficiency of the tensile strength meter selection process prompted our tiller synchrony selection effort.

Synchrony of heading date was chosen as our measure of tiller synchrony based on the assumption that within-plant differences in heading date would reflect comparable differences in maturity. This assumption will require validation. However, heading date is a stage of plant development in wild rice that can be more objectively scored than maturity date.

Observation and published research indicated that there is variation for heading date synchrony in wild rice populations, but this variation has not been quantified nor has the inheritance of tiller sychrony been determined. Our first step was to characterize heading date synchrony, estimate its heritability, and predict what gain we would make selecting for the trait. We also determined its association with other agronomic traits. We have completed two cycles of characterization and selection (1984 and 1985). The second stage of our research involved evaluating the progress from one cycle of selection and determining the impact of plant density on synchrony expression. One cycle of evaluation (1985) was completed.

The study was initiated in replicated sets of half-sib families derived from the cultivar Voyager. One of these sets, or populations, has been selected for synchrony and will here-in be referred to as the synchronous (SYN) population. A second population has been maintained without selection and will here-in be referred to as the control (CONT) population. A third population, developed through one cycle of visual mass selection for asynchrony, will be referred to as the asynchronous (ASYN) population.

Two indices of heading date synchrony that have been discussed in the literature, synchrony range (SR) and synchrony measure (SM), were used. Synchrony range is computed as the difference in heading date between the last tiller measured (in our case the third tiller) and the heading date of the mainstem. Synchrony measure takes into account the values for intervening tillers, and is defined as the number of cumulative days between the heading date of the mainstem and the third tiller. In 1984 we measured heading date synchrony at two stages in the development of the protogynous wild rice inflorescence. The female stage (F) was considered the date of first pistillate spikelet emergence; the male stage (M) was considered the date of complete panicle extrusion from the boot. These indices will here-in be referred to as female synchrony range (FSR), male synchrony range (MSR), female synchrony measure (FSM), and male synchrony measure (MSM). Based on 1984 data, we determined the male stage was most suitable for assessing synchrony and did not measure heading date at the female stage in 1985.

The SYN and CONT populations were planted in separate four-replicate blocks-in-replicates designs at Rosemount in 1984. The SYN population m long plot. Within each plot, the heading dates of the mainstem and first three tillers of two randomly chosen plants were recorded. The aforementioned synchrony indices were then computed for each plant, and subsequent analyses calculated on plot means.

Based on heading date synchrony indices, the ten most synchronous families were selected from the 1984 SYN population for evaluation in a gain from selection experiment. Among and within family selection was then practiced to develop 100 half-sib families for the next cycle of characterization and selection. Families and then plants within families were chosen at random from the CONT population, giving a total of 50 half-sib families for characterization in 1985. Bulks of the 1984 SYN, CONT, and ASYN populations were formed as balanced composites of seed from each family within each population; these bulks were included in the gain from selection experiment.

Mean values for synchrony indices in the 1984 and 1985 SYN and CONT populations are given in Table 1. These populations exhibit considerable asynchrony of heading date when compared to published values for domesticated cereals. For example, five tiller synchrony range values for barley, wheat and oats ranged from two to four days; three tiller synchrony range values for these wild rice populations are all in excess of 11 days.

The amount of heritable variation for heading date synchrony in these populations is encouraging; we can expect to make progress by selecting for greater synchrony. Heritability estimates for heading date synchrony indices, and associated 90% confidence limits, for the 1984 and 1985 SYN populations are given in Figure 1. The moderate size of the heritability estimates indicates that response to selection would be modest, a conclusion borne-out by estimates of predicted gain from selection. These gain estimates indicate that one cycle of selection could lead to a 0.5 day reduction in the difference between the heading date of the third tiller and mainstem. A long term selection effort without a reduction in genetic variance would thus be required to achieve complete synchrony in these populations.

As mentioned earlier, an underlying assumption of our research was that within-plant differences in heading date would reflect comparable differences in maturity. The differences in tiller and mainstem maturity were recorded, on a plot basis, in the 1985 SYN and CONT populations. Mean maturity synchrony ranges in these populations were 10.7 and 12.1 days, respectively. The close correspondence of these values with the heading date synchrony ranges given in Table 1 suggests that the difference between heading date and maturity is relatively constant for mainstems and tillers. Heritability estimates for maturity synchrony were comparable to those for heading date synchrony. However, different families were identified as synchronous at the two stages of development, as indicated by the low correlations (Table 2) between indices at the two stages. Further research is thus needed to document the relationship of heading date synchrony with maturity synchrony and increased recoverable yield.

2) are consistently low. If synchrony were correlated with yield per se, the correlation would be negative; a low synchrony index value indicates a high degree of synchrony. In most cases, heading date indices at a given stage of inflorescence development accounted for about half the variation observed in indices at the other stage. The very high correlations between indices at a given stage of inflorescence development were not surprising, given the common basis of the indices, and they indicate the more readily obtained synchrony range may be as effective as synchrony measure in evaluating and selecting for tiller synchrony.

GAIN FROM SELECTION

The ten most synchronous families from the 1984 SYN population, the SYN, ASYN, and CONT bulks, and Meter, an early short-stature cultivar (formerly evaluated under the name Dwarf), comprised the entries in the gain from selection experiment. The experiment was planted at two locations, Grand Rapids and Excelsior. A split plot restriction of a randomized complete block design was used in order to examine the effect of plant density on tiller synchrony expression. Within-row spacings of 15, 20, 25, and 30 cm (approximately 6, 8, 10 and 12 inches) were considered whole-plot treatments. The fourteen populations were considered sub-plot treatments. Two plants per sub-plot were chosen at random, and the heading dates at the male stage of panicle development were recorded for the mainstem and third tiller (Grand Rapids) and mainstem and first three tillers (Excelsior).

Heading date synchrony was not affected by the plant density treatments; mainstem yield, which declined in a linear fashion with increasing density, was the only trait significantly affected. There were no population x density interactions.

Population differences in heading date synchrony range and other agronomic traits considered in this experiment were examined through orthogonal contrasts, because variation rather than mean performance was of the greatest interest.

Differences in synchrony range between selected populations and bulks were highly significant but small, an expected finding in view of the low predicted gain. The most synchronous population was Meter, at 9.8 days difference between main stem and third tiller. Synchrony range values for the selected populations ranged from 10.4 to 12.1 days. The most asynchro-

The low correlations between heading date synchrony and other agronomic traits encountered in the characterization and selection experiments were substantiated in this evaluation. Substantial variation for plant height, mainstem yield and total yield was retained in the selected populations. Phenotypic correlations among traits (Table 3) are comparable to those in Table 2, giving us some confidence in our assertion that heading date synchrony is not associated with other agronomic traits.

Mainstem yield accounted for 30% of the total grain yield at Excelsior and 14% at Grand Rapids, a reflection of reduced tillering at the former

YEAR

Synchrony index	1984 Population SYN	CONT	1985 Population SYN	CONT
	- days -		- days -	
FSR[1]	12.7±1.9[2]	14.2±1.6	--	--
MSR	13.5±1.3	14.1±1.6	11.9±0.9	12.8±1.0
FSM	30.3±2.7	33.5±3.2	--	--
MSM	32.6±3.0	33.7±3.3	29.3±2.1	31.1±1.4

[1] FSR, female synchrony range; MSR, male synchrony range; FSM, female synchrony measure; and MSM, male synchrony measure.
[2] Standard error of the mean.

Table 2. Phenotypic correlations in the SYN populations[1] (above diagonal) and CONT populations[2] (below diagonal) in 1984 and 1985. 1985 values in parentheses.

	FSR	MSR	FSM	MSM	Maturity synchrony	Height	Yield
FSR[3]		0.69 (-)	0.95 (-)	0.67 (-)	- (-)	0.18 (-)	-0.21 (-)
MSR	0.74 (-)		0.65 (-)	0.94 (0.94)	- (0.21)	0.06 (0.02)	-0.28 (0.01)
FSM	0.87 (-)	0.53 (-)		0.69 (-)	- (-)	0.19 (-)	-0.27 (-)
MSM	0.68 (-)	0.94 (0.95)	0.57 (-)		- (0.21)	-0.08 (0.02)	-0.29 (0.03)
Maturity synchrony	(-)	(0.21)	(-)	(-)		(0.16)	(0.04)
Height	0.11 (-)	0.02 (0.28)	0.15 (-)	0.02 (0.27)	- (0.40)		0.18 (0.67)
Yield	0.17 (-)	-0.06 (0.26)	0.26 (-)	-0.04 (0.25)	- (0.23)	0.62 (0.24)	

[1] 98 df: 1984, 1985.
[2] 38 df: 1984; 48 df: 1985.
[3] FSR, female synchrony range; MSR, male synchrony range; FSM, female synchrony measure; and MSM, male synchrony measure.

	MSM[1]	Plant height	Mainstem yield	Tiller yield	Total yield
MSR[3]	0.96[2]	-0.14	0.19	0.19	0.20
MSM		-0.23	0.28	0.03	0.07
Plant height			0.68	0.66	0.68
Mainstem yield				0.86	0.89
Tiller yield					0.99

[1] Excelsior only.
[2] df=11, cv. Meter deleted.
[3] MSR, male synchrony range; MSM, male synchrony measure.

Figure 1. Narrow sense heritability estimates and their 90% confidence intervals for heading date synchrony indices in the SYN populations in 1984 (above axis) and 1985 (below axis).

```
                 ------------- 42.4 -----          FSR
            ------------- 31.9 ------              MSR
1984                            --- 56.4 -----     FSR
                 --------- 41.7 ------             MSM
 %    0 -- 10 -- 20 -- 30 -- 40 -- 50 -- 60 -- 70 -- 80 -- 90 -- 100
1985           ---------- 40.0 -----               MSR
                 ---------- 42.9 ------            MSM
```

FSR, female synchrony range; MSR, male synchrony range; FSM, female synchrony measure; and MSM, male synchrony measure.

increased shattering resistance.

CONCLUSIONS

The wild rice populations examined in this study exhibit considerable asynchrony when compared with reported values for domesticated cereals. The presence of heritable variation indicates that heading date synchrony is under genetic control, but progress from selection is likely to be modest.

A question raised by this research is whether selection for synchrony represents an appropriate allocation of resources in our continuing effort to domesticate wild rice. Synchrony range and synchrony measure are labor intensive selection criteria to implement, and limited sampling can pose problems in estimation of genetic variances. The ideal criterion would be one that measures maturity synchrony on a family basis rather than on a plant basis.

The lack of correlation between synchrony indices and other agronomic traits indicates that variation for other traits can be retained in a synchrony selection program; conversely, synchrony will not be achieved through continued selection for plant height or yield per se.

GENETIC SHIFT EXPERIMENTS

Because of an apparent change in maturity of K2 relative to Voyager and Netum in 1984 in our trials, I wondered if the grower source of a variety was an important factor in its performance. In order to evaluate how much a variety may change because of where it is grown, I collected samples of seed from growers' combines in the fall of 1984 and evaluated the performance of the samples in an experiment in 1985 called the genetic shift trial. Samples were stored in our cold room over winter.

Fourteen entries were evaluated in a randomized complete block design at three locations. A test was fall-planted at Dick Brink's paddies at Deer River and tests were spring-planted at Grand Rapids and Excelsior on May 1 and May 22, respectively. We noted large differences in percent germination following storage over winter, differences that were not apparent in the trial at Brinks. The fourteen entries were comprised of 8 K2 sources, 3 Netum sources, 2 Voyager sources, and M1. The results from the Grand Rapids and Excelsior tests are presented in Tables 4 and 5, respectively. The two tests do not compare well although a combined analysis of variance indicated that the entry times location interaction was not significant. The Excelsior data were of poorer quality than the Grand Rapids data and until more thorough analyses have been completed, the Grand Rapids data will be emphasized. Based on the % dry weight at harvest, the trial was harvested too early; close to 65% dry weight is desirable at harvest.

The LSD (.05) value indicates that two varieties which differ by more than that amount are likely to be significantly different in performance.

4. Genetic shift evaluation test, Grand Rapids 1985.

/	Source[1/] code	Plant height	% Dry weight	Flowering[2/] date	Harvest[2/] date	Plants per plot	Stems per plot	Yield[3/] (green)	Yield (dry)	% Germin
								--lb/A--		
	1	190	59.2	50	87	48	169	1,870	1,121	33.
	2	185	57.1	52	87	48	158	1,462	877	43.
	3	186	56.0	53	86	32	135	1,270	762	46.
	5	186	54.5	54	87	36	157	1,390	833	26.
	6	185	58.6	49	87	31	133	1,438	862	79.
	7	181	54.4	55	87	22	110	1,143	685	21.
	9	187	58.5	49	83	64	190	1,230	738	12.
	11	184	58.2	53	87	50	153	1,702	1,020	70.
	4	189	61.6	44	83	28	138	1,454	872	41.
	10	182	63.1	41	83	38	155	1,518	910	20.
	12	178	60.0	48	83	41	145	1,326	795	78.
:	8	170	59.7	47	83	44	163	1,502	901	19.
:	13	179	56.7	51	87	23	102	1,214	728	1.
	14	187	54.5	54	87	46	132	1,183	709	15.
)5)		11	2.3	3	--	14	33	396	238	

.es from different fields.
after June 1.
ı weight yield at 40% moisture.

ible 5. Genetic shift evaluation test, Excelsior 1985

iriety	Source code[1/]	Plant height	% Dry weight	Flowering date[2/]	Harvest date[2/]	Plants per plot	Stems per plot	Yield[3/] (green)	Yi (d
								--lb/A--	
[illegible]	1	132	64.2	53	88	36	125	903	5
[illegible]	2	122	63.2	53	90	37	149	943	5
[illegible]	3	134	63.5	53	89	30	120	879	5
[illegible]	5	133	62.0	52	87	33	144	983	5
[illegible]	6	136	62.3	52	86	30	144	1,047	6
[illegible]	7	128	61.8	55	89	21	86	679	4
[illegible]	9	122	60.9	50	84	44	161	791	4
[illegible]	11	131	62.9	54	86	41	142	1,087	6
etum	4	118	62.6	45	86	25	80	583	3
etum	10	108	64.1	45	87	27	83	503	3
etum	12	124	63.6	50	84	30	110	767	4
oyager	8	115	64.4	46	86	37	139	927	[illegible]
oyager	13	124	63.5	52	87	26	95	727	[illegible]
1	14	138	63.1	56	91	28	109	879	[illegible]
SD (.05)		13	NS	2	--	8	33	293	[illegible]

1/ Samples from different fields.
2/ Days after June 1.
3/ Green weight yield at 40% moisture.

the remaining sources are similar in performance. However, the pattern of significant differences is much more complex. Source 1 was significantly better than all other K2's except source 11. Source 11, on the other hand, was significantly better than sources 3, 7, and 9. Differences in height among the K2 sources were not significant, but maturity differences measured at flowering were significant. Source 7 was the latest K2 and sources 6 and 9 were the earliest.

The differences among yields of the Netum sources were not significant but height and flowering date differences were significant. Similarly, the two sources of Voyager had significantly different flowering dates. Based on % dry weight at harvest, I suspect that Voyager 13 was much later in maturity than was Voyager 8. Similar differences in maturity were indicated in the Excelsior results. A logical conclusion from the results is that in as little as 2 generations, significant genetic shift for maturity has occurred in Voyager. The K2 sources had been grown for at least 3 generations after their original source; significant shift has occurred there as well. The results of this experiment need additional consideration before definite conclusions are developed. Nevertheless, I believe the message is clear for growers seeking seed sources; we as an industry need certified seed producers. Even so, a generation or two from the original seed source can make significant changes in the genetic potential of the variety. Unlike other annual crops, the genetic shifts can occur in your own paddy due to shattering losses. The % germination values in Table 4 are also particularly disturbing but require greater research before additional comment.

INHERITANCE OF SEED LENGTH

(G.G. Wandrey)

Two aspects of variation for seed length in wild rice will be considered by G.G. Wandrey. In the first experiment, he is evaluating seed length in half-sib families to obtain estimates of genetic and environmental variation and to complete a cycle of bi-directional selection for seed length. One hundred and forty-five half-sib progenies of K2 were grown in a sets-in-replicates design at Excelsior. Measurements of seed length have been completed and analyses are in progress. A second experiment will involve estimates of variation in seed length among four cultivars of wild rice. The first year of that portion of the research will involve evaluation of the materials in the genetic shift experiment. In addition to evaluating variation in seed length in different sources of the same variety, we will obtain estimates of genotype x environment interaction. Some crosses have been made between shattering and non-shattering materials to provide a basis for some longer term experiments on seed length research. The bi-directional selection approach can result in short seed length cultivars for seed mix markets and longer seed length selections for pure rice markets. Estimates from the above experiments will be used to plan the longer-term selection work.

(Tri Hutomo)

The plant breeding project at the Minnesota Agricultural Experiment station has selected for early maturity in attempts to minimize harvest losses. Good progress has been made for increased earliness, which has been found to be associated with short plant height (see 1983 Wild Rice Breeding Progress Report). However, early maturing and short plant height cultivars, as in the newly released wild rice 'Meter' (1984 Wild Rice Progress Report), yield less than late maturing and tall cultivars. In 1980, a cross of the short early variety Meter and tall late variety 'Johnson' was made with the objective of combining the early short attributes of Meter with the better yield of Johnson. The wild rice breeding program made visual selections for a series of sub-populations from the random mated population cross.

The objective of this study was to determine if visual selection for plant height-maturity combinations could be effective in changing population means for plant height, maturity, and primarily yield. Half-sib families from within the population cross sub-populations were evaluated to characterize the effectiveness of the visual mass selection for plant height maturity combinations, and to provide a basis for deciding which sub-populations would continue in the breeding program.

The experimental material consisted of 150 half-sib families selected from the population cross between Dwarf (released as Meter) and Johnson (a tall cultivar). The Dwarf population was developed by mass selection for short plant height in 1980 in a population of short plants. Dwarf is characterized as having very early maturity (57 to 69 days to harvest), short plant height (95 to 140 cm), reduced foliage in the canopy, and low yield. The Johnson cultivar was visually selected for less shattering characteristics in 1963 in Mr. Johnson's paddy in Minnesota. Johnson is generally described as having late maturity (77 to 93 days to harvest), tall plant height (195 to 213 cm), and harvestable yield comparable to that of the Dwarf cultivar.

The population cross was randomly mated for three generations without selection. Appreciable variation in plant height and maturity was observed within the random mated population. In the summer of 1983, visual mass selection was used to develop three phenotypic sub-groups of families, i.e. 42 families of short plant height and early maturity (DJ-SE), 48 families of short plant height and medium maturity (DJ-SM), and 60 families of medium plant height and medium maturity (DJ-MM). The families, individually and as a group of families (three sub-populations) were evaluated in two separate experiments, both conducted at the North Central Experimental Station, Grand Rapids, Minnesota in summer 1984.

For the first experiment in 1984, the Preliminary Yield Trial (PYT), the three sub-populations (DJ-SE, DJ-SM, and DJ-MM) were formed by bulking a few seed from each family in the respective groups. The Dwarf x Johnson population cross and a random control population were included, but the populations were lost due to seed storage problems. The Johnson population available. The Voyager variety and the Dwarf (Meter) population were used as checks. A randomized complete block design with six replicates was used in the PYT. The entries were hand planted in two-row plots 3.0 m long with 0.6 m between rows in paddies on mineral soils.

In the second experiment, the Family Evaluation Trial (FET), the performance of each family within the three sub-populations was evaluated in a sets-in-replicates design with four replicates. There were 3 sets of 14 families from the DJ-SE sub-population, 3 sets of 16 families from the DJ-SM sub-populations, and 4 sets of 15 families from the DJ-MM sub-population. The families were hand-planted in single-row 1.8 m plots with 0.6 m between rows. Plots were fertilized with 15 kg of nitrogen in form of urea.

The characters measured in both experiments were plants per plot, stems per plot, stems per plant, height, grain yield, and percent seed dry weight. Harvest date was recorded in the PYT, whereas scoring systems for maturity, flowering, and plant stand were used in the family evaluation trial. In the PYT, plant height measurements were taken on ten random plants, whereas in the FET plant height was measured on five random plants. Yield in the PYT was measured as dry grain yield (included hulls), after drying the wet grain at $60^{o}C$ for 96 hours. In the FET, the yield of families was expressed in wet grain weight; the grain was weighted immediately after harvest and no drying was done in order that the seeds could be used for planting the next generation. Percent seed dry weight was calculated using the formula % dry weight = (dry weight/wet weight) x 100. Weights for this calculation in the FET were obtained from a sub-sample of seed from each plot. The sample was weighed (wet weight), dried at $60^{o}C$ for 96 hours and weighed to get dry weight. In the PYT, percent seed dry weight was calculated from dry grain weight over grain weight of each plot. Harvest date in the PYT was recorded as days after June 1 to the date of harvesting.

The general performance of the two experiments and growing conditions were acceptable. However, some sets of the half-sib families in the Family Evaluation Trial (FET) showed lower vigor than the other sets in the same sub-population, probably because of variation in soil texture within the paddy. Low germination percentage and limited seed supply of a few half-sib families resulted in very poor plant stand, and a few plots had no surviving plants.

The results of the Preliminary Yield Trial (PYT) in 1984, designed to compare the performance of the DJ-SE, DJ-SM, and DJ-MM sub-populations to other selected entries, primarily to Voyager and Meter, are presented in Table 6. The three sub-population on the average were 35 to 45 cm taller than Meter; they were later in maturity and considerably better in yielding ability. The DJ-SE sub-population was significantly shorter than Voyager and yielded less, but the other two sub-populations were not significantly different from Voyager in plant height and yield. The reduction in plant height and increase in earliness of DJ-SE compared to Voyager along with yielding ability similar to Voyager were three important features sought from the Dwarf x Johnson cross population. The similarity of DJ-MM and DJ-SM to Voyager is encouraging; reasonable progress appears to have been

Table 6. Results of the 1984 Preliminary Yield Trial (PYT) at Grand Rapids (6 replicates).

Entry	Characteristics						Harvest 1/ date
	Plants per plot	Stems per plot	Stems per plant	Plant height (cm)	Dry weight yield (lb/A)	% Dry weight	
Voyager	27	173	6.5	168	798	62.7	77
DJ-MM	70	199	2.9	165	869	64.2	76
DJ-SM	69	239	3.5	163	956	64.2	76
DJ-SE	71	223	3.2	155	742	66.2	72
Meter 3/	24	133	5.9	120	479	76.1	69
LSD (0.05) 2/		32	1.0	10	149	1.5	

1/ Days after June 1.

2/ Other entries in the PYT resulted in error d.f. of 45.

3/ The Dwarf population (experimental name) was released in 1984 under the name Meter.

mass selection for plant height-maturity combination was effective in changing population means for plant height and maturity (DJ-SE). The difference in number of plants per plot (low for Voyager) makes yield comparisons of questionable value.

The results of the Family Evaluation Trial (FET) are presented in Table 7. Apparently, the DJ-MM sub-population was significantly taller and later in maturity than the DJ-SE and DJ-SM sub-populations. However, the difference in wet grain weight (yield) between the DJ-MM and DJ-SM sub-populations was not significant. The lower plant stand score in the DJ-MM sub-population indicated better plant stand relative to the other sub-populations. DJ-SM sub-population means for plant height, maturity and yield were intermediate between the DJ-SE and DJ-MM sub-populations. The results in the PYT (Table 6) differed somewhat for yielding ability of the DJ-SM sub-population. There, the DJ-SM yielded more than the DJ-MM sub-population although the difference was not significant. The discrepancy between the two experiments could be due to paddy differences and/or chance variation. As in the PYT, the results in the FET showed that the DJ-SE sub-population flowered and matured earlier than the other two, but was substantially the lowest in wet grain weight (yield) and was the shortest in plant height.

The variance components estimates are presented in Table 8. Estimates of error variance (σ^2_e) were higher than estimates of genetic variance ($\sigma^2_{F(S)}$) for stems per plant, plant height, flowering score, maturity score, and percent seed dry weight (except in DJ-MM). The larger magnitude of σ^2_e for these characters could be attributed to a large sampling error and lack of uniformity in the paddy. The data provided evidence of significant genetic variation for characters tested and implied that improvement through selection is possible.

Estimates of heritability were calculated as the ratio of family genetic variance to phenotypic variance of family means (Table 9). Heritability estimates appeared to be high (0.75 or greater) for plants per plot, stems per plot, plant stand, and wet grain weight (yield) and indicate that continued selection should be effective. High heritability estimates for wet grain weight (yield) in wild rice was also reported by Stucker et al. (1984 Wild Rice Breeding Progress Report) who suggest that the high heritability estimates for grain yield in wild rice is due to the fact that wild rice is relatively unselected for grain yield.

Heritabilities for stems per plant, plant height, and flowering differed in three sub-populations and were generally lower than those for four characters previously mentioned. The lower than expected heritability estimates for plant height in the three sub-populations may be an indication that genetic variation for plant height was reduced somewhat by mass selection for plant height in the previous generation. Even though mass selection may have reduced the genetic variance relative to that in the unselected population, there still appears to be ample genetic variance for additional height selection to be effective. Apparently, reasonable progress in improving this character could be made through half-sib selection.

Table 7. Means for characters studied in the DJ-MM, DJ-SM, and DJ-SE sub-populations in the Family Evaluation Trial (FET) in 1984.

Sub-population	Characteristics								
	Plants per plot	Stems per plot	Stems per plant	Plant Height (cm)	Wet grain weight (g)	% seed dry weight	Flowering score	Maturity score	Plant stand score
DJ-MM	10.6 a[1/]	47 a	5.1 a	157 a	100 a	67.0 a	2.2 a	3.1 a	2.7
DJ-SM	10.2 ab	50 a	6.1 b	147 b	93 a	68.6 b	1.9 b	2.7 b	3.0
DJ-SE	8.9 b	37 b	4.4 c	138 c	74 b	68.3 ab	1.5 b	2.3 c	3.3

1/ Means followed by different letters are significantly different based on a t-test ($\alpha = 0.05$).

Table 8. Estimates of among half-sib family and error components of variance for traits measured in the DJ-SE, DJ-SM, and DJ-MM sub-populations.

Traits	DJ-SE		DJ-SM		DJ-MM	
	$\hat{\sigma}^2_{F(S)}$	$\hat{\sigma}^2_e$	$\hat{\sigma}^2_{F(S)}$	$\hat{\sigma}^2_e$	$\hat{\sigma}^2_{F(S)}$	$\hat{\sigma}^2_e$
Plants per plot	10.7 ± 2.9	8.7 ± 2.9	27.8 ± 6.4	10.1 ± 1.3	17.0 ± 3.6	7.4 ± 0.8
Stems per plot	114.1 ±34.6	148.5 ±19.7	268.6 ±69.0	228.3 ±28.5	138.4 ±32.4	128.6 ±14.2
Stems per plant	0.4 ± 0.2	2.3 ± 0.9	3.1 ± 0.9	3.9 ± 0.5	1.3 ± 0.4	2.8 ± 0.3
Plant stand	0.7 ± 0.2	0.6 ± 0.1	1.3 ± 0.3	0.6 ± 0.1	1.2 ± 0.3	0.7 ± 0.1
Plant height	50.0 ±19.9	141.4 ±18.7	34.1 ±11.0	68.6 ± 8.6	26.2 ± 8.8	76.1 ± 8.4
Flowering	0.2 ± 0.1	0.4 ± 0.1	0.1 ± 0.1	0.5 ± 0.1	0.2 ± 0.1	0.4 ± 0.0
Maturity	0.1 ± 0.1	0.5 ± 0.1	0.1 ± 0.0	0.3 ± 0.0	0.1 ± 0.0	0.2 ± 0.0
Wet grain weight (yield)	604.0 ±183.7	794.7 ±105.3	861.1 ±235.9	992.2 ±124.0	1097.5±247.1	818.9 ±90.4
% seed dry weight	1.4 ± 0.9	7.2 ± 1.5	1.7 ± 1.1	12.3 ± 1.8	2.6 ± 1.0	9.8 ± 1.2

Table 9. Heritability estimates for characters evaluated in the DJ-SE, DJ-SM, and DJ-MM sub-populations.

Characters	Sub-populations		
	DJ-SE	DJ-SM	DJ-MM
Stems per plot	0.75 ± 0.23	0.82 ± 0.21	0.81 ± 0.19
Stems per plant	0.39 ± 0.21	0.76 ± 0.22	0.65 ± 0.20
Plant height	0.59 ± 0.23	0.67 ± 0.21	0.58 ± 0.19
Flowering	0.61 ± 0.33	0.47 ± 0.44	0.64 ± 0.33
Wet grain weight (yield)	0.75 ± 0.23	0.78 ± 0.21	0.84 ± 0.19

medium to tall plant populations rather than in short plant population.

1985 PRELIMINARY YIELD TRIALS

In 1985 we had a number of experimental populations to evaluate and did so in a replicated experiment at Grand Rapids and Excelsior. We used 2-row plots 12 feet long. The rows were spaced 1 foot apart without skip rows. A high seeding rate was used and plants were removed at about first aerial leaf stage to achieve a reasonable stand of about six plants per linear foot of row. The trials were arranged in a randomized complete block design with six replicates at each location; Grand Rapids was planted May 1 and Excelsior on May 22. The plots looked good at both sites.

The results of the trials are presented in Tables 10 and 11. Variation among the entries was significant for all traits except date of harvest. Decision procedures on when to harvest prevented a proper analysis and tests of significance for harvest dates. A more thorough interpretation of the data will be presented elsewhere. This report will focus on the variation among the sub-populations from the Dwarf x Johnson population crosses. Based on information from the Tri Hutomo 1984 experiments, superior families for high yield, listed as DJ-SE(Y), DJ-SM(Y) and DJ-MM(Y), and families with short plant height, listed as DJ-SM(S) and DJ-MM(S) were identified. The SE, SM, and MM letters refer to short-early plants, short plants with medium maturity and medium height plants with medium maturity, all selected in 1983. To be brief, the yields of the sub-populations tend to be competitive with Voyager and M3 x Netum, but not M3E, an experimental selection out of M3, or K2, when evaluated at Excelsior. At Grand Rapids, the DJ-MM populations were somewhat better in performance relative to M3E and even K2. However, all of the short height of the Dwarf (Meter) parent, and most all of the earliness was lost. Additional evaluation will be required, but for now, we made progress only in that we recovered yield at the expense of the other desirable attributes of the Dwarf population.

The Voyager populations (Asyn and Syn) were evaluated here in addition to the trials reported earlier in this description of the breeding work. Selection for synchrony of maturity did not decrease yield or maturity or significantly change plant height at Grand Rapids, (Table 10). At Excelsior, the selected populations both appeared better yielding than Voyager itself. This is undoubtedly more a function of seed source differences than a result of genetic changes.

The other notable entry in these trials is Dwarf (Meter). It consistently yields low, is very short and of course is very early at harvest, 18 days earlier than K2 at Excelsior and 20 days earlier at Grand Rapids.

Acknowledgements:

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ble 10. Preliminary yield test, Grand Rapids 1985[1/]

try	Plant height	% Dry weight	Flowering[2/] date	Harvest[2/] date	Plants per plot	Stems per plot	Yield (green)[3/]	Yield (dry)
							--lb/A--	
I-SE(Y)	150	61.9	41	82	56	185	946	567
I-SM(S)	152	60.1	44	82	62	184	972	583
I-SM(Y)	155	62.2	44	82	66	187	1,066	638
I-MM(S)	154	61.0	44	82	68	199	1,285	770
I-MM(Y)	155	60.4	46	82	69	178	1,032	618
I Bulk	152	60.4	43	82	61	172	959	575
3E	158	58.4	48	82	64	184	1,112	666
oyager Asyn	157	59.5	48	82	39	131	1,052	630
oyager Syn	160	61.3	46	82	51	161	1,312	786
oyager	156	60.7	46	82	45	153	1,092	654
2	173	58.6	52	87	48	160	1,452	870
warf (Meter)	124	64.8	35	67	64	220	946	567
3 X Net	155	61.3	46	82	64	191	1,265	758
3 X Net (Bulk)	157	61.3	44	82	57	172	1,119	670
3 X Net (Reject)	154	61.7	44	82	65	198	1,205	722
SD (.05)	10	1.9	3	--	11	26	276	166

/Reps 3 and 4 of this trial lodged and were discarded.
/Days after June 1.
/Green weight yield at 40% moisture.

able 11. Preliminary yield test, Excelsior 1985

ntry	Plant height	% Dry weight	Flowering[1/] date	Harvest[1/] date	Plants per plot	Stems per plot	Yield[2/] (green)	Yield (dry)
							--lb/A--	
J-SE(Y)	136	62.6	44	77	62	161	879	527
J-SM(S)	144	62.0	45	72	64	170	1,151	690
J-SM(Y)	149	64.3	45	82	76	195	1,230	738
J-MM(S)	153	60.2	46	69	64	146	991	594
J-MM(Y)	153	59.9	48	77	65	176	1,358	814
J Bulk	148	63.6	45	82	67	172	1,055	632
3E	155	64.9	48	78	67	208	1,726	1,035
oyager Asyn	145	62.9	46	75	52	175	1,630	977
oyager Syn	143	63.9	45	78	53	165	1,470	881
oyager	144	63.0	46	77	48	140	1,071	642
2	159	63.0	52	82	60	200	2,053	1,231
warf (Meter)	105	69.0	38	64	65	162	783	469
3 X Net	152	62.8	44	73	69	195	1,438	862
3 X Net (Bulk)	144	62.8	44	76	64	180	1,175	704
3 X Net (Reject)	141	64.5	44	80	68	186	1,294	776
LSD (.05)	10	3.5	1.0	--	10	31	370	222

/ Days after June 1.
/ Green weight yield at 40% moisture.

WILD RICE DISEASE RESEARCH-1985

January 24, 1986

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INTRODUCTION

The 1985 research efforts have been directed toward the initiation of two new research projects, involving the possible biological control of waterplantain and the various factors affecting wild rice seed storage and subsequent germination. Also, in 1985 studies were continued on the possible use of the systemic fungicide Tilt^{TM} alone or in combination with the protectant fungicide Dithane M-45 for the control of fungal brown spot, caused by Bipolaris oryzae. An effort towards developing new laboratory and greenhouse techniques for the screening of plant material for sources of possible resistance to fungal brown spot will be attempted during 1986.

CHEMICAL CONTROL

A. Tilt Rate Study

Introduction. Propiconazol (Tilt) is a systemic fungicide having both eradicative and protective properties. It has been proposed that this fungicide be registered for use in the management of *Bipolaris oryzae* (Breda de Haan) Shoem. the causal organism of fungal brown spot of wild rice. In 1985, a study at Grand Rapids, MN, was initiated to determine the effects of differing rates of this fungicide on disease development and subsequent plant yield.

Experimental Methods. The paddy was prepared by rototilling and amending the soil with 22.5 kg/ha (20 lbs/A) of nitrogen in the form of urea. Volunteer seed was eliminated by fumigation of the soil with methyl-bromide the previous fall. Experimental design was a completely randomized block consisting of six treatments replicated six times. Each treatment was planted in a 12.19 by .9144 m (40 x 3 ft) row. The wild rice cultivar utilized was K2.

Inoculum of *B. oryzae* was prepared one month in advance of the growing season. Galvanized trays (30 by 20 by 10 cm) were covered with aluminum foil. A mixture of 150 ml of corn meal plus 300 ml of 1% PDA was added to the trays. After 15 minutes, 700 ml of rinsed perlite was added and mixed thoroughly. Trays were then covered with two layers of aluminum foil and autoclaved for 1 hour. After cooling 2-4 hrs., each tray was inoculated with 2-3 PDA plates containing 1-2 week old cultures of *B. oryzae* diced into 1 cm squares. After 3 weeks at room temperature, the inoculum was air-dried at room temperature. Once dried, the inoculum was stored in brown paper bags and kept under refrigeration until use.

Wild rice plants were inoculated on July 8 and July 15 at the boot stage of plant development. The inoculation process was as follows: Approximately 1 liter of the dried inoculum was mixed with 3 liters of water immediately prior to inoculation. The resulting spore suspension was sieved through a 300 micron (U.S. Standard Sieve Series No. 50, W.S. Tyler Co.,Mentor, Ohio) screen. This procedure was repeated 4 times. Each row was inoculated using a backpack sprayer (Hudson Stainless Steel Suprema 67367, H.D. Hudson Mfg. Co., Chicago, IL). Immediately following inoculation, plants were misted every 15 minutes for 2 minutes up until the fungicide was applied. Fungicides were applied with a hand-held CO_2 pressurized sprayer (20 lbs of pressure). Application volume was 1/3 l per plot. The fungicide treatments were as follows:

Formulated oz/A(g ai/A)	Plant Growth Stage	Spray Schedule
Tilt 4 (50)	Boot and Heading	07/10 & 07/25
Tilt 6 (75)	Boot and Heading	07/10 & 07/25
Tilt 8 (100)	Boot and Heading	07/10 & 07/25
Tilt 8 (100)	Boot	07/10
Tilt 10 (125)	Boot	07/10
Control	---------------	-------------

The plants located within .9144m (3 ft) of the north and south end of each row were not harvested. The remaining plants were harvested by hand on August 27. Plants were counted, threshed and the seed dried at 90 C. The grain was then dehulled, sized and weighed. Wild rice seed greater than 1.245 mm in diameter was used to determine final yields. Treatment means were compared by Duncan's New Multiple Range Test at the p=.10 level of significance.

Disease severity ratings were recorded throughout the growing season in each plot. If the level of disease was below 1%, lesions were categorized according to size (Figure 1) and counted on each of the three upper leaves of the plant. As the disease level increased, and lesions coalesced, disease severity was assessed by determining the percent leaf area infected for each of the three uppermost leaves.

Results and Discussion. Plants treated with two 8 oz ai/A applications of propiconazol at boot and heading, resulted in significantly (p=.10) higher yields than untreated plants, plants treated with one application of propiconazol at 8 oz ai/A or 10 oz ai/A at boot, and plants treated with two applications of propiconazol at the rates of 4 or 6 oz ai/A at boot and heading (Table 1). While one application of propiconazol at 8 oz ai/A resulted in yields significantly lower than that obtained from two applications at the same rate; yields from this treatment were significantly higher than untreated controls, plants treated with two applications of either 4 or 6 oz ai/A , and plants treated with one application at 10 oz ai/A. No significant differences in yield were found between untreated controls, plants treated with two applications of either 4 or 6 oz ai/A, or plants treated with one application of propiconazol at the rate of 10 oz ai/A at boot.

Disease ratings were lowest for the plants receiving one or two 8 oz ai/A applications of propiconazol at boot and boot and heading, respectively (Table 2).The trace levels of disease (<1%) recorded on July 24 and August 5 for plants receiving two 8 oz ai/A applications, have been shown not to cause detectable reductions in yield (Kohls and Percich, 1984a.; Kohls and Percich, 1984b.). On August 5, for the 4, 6, 10 oz and control treatments, mean disease readings of 1.5, 1.4 and 1.8 % were recorded for the flag, 2nd and third topmost leaves, respectively. When this level of disease is present at the milk stage of plant development, noticeable reductions in yield can occur (Kohls and Percich, 1984a.; Kohls and Percich 1984b.). Furthermore, the lower disease ratings recorded for the plants receiving two 8oz ai/A applications of propiconazol corresponded to the higher yields observed for these treatments compared to others (Tables 1 and 2). The disease ratings were low for plants treated with one 10 oz ai/A application of propiconazol at boot. The yield from this treatment did not reflect the low disease ratings. This may have been due to the phytotoxic effects of this fungicide noted at this high application rate. Leaves of plants from this treatment exhibited purple discoloration, chlorosis and/or bleached spotting. These symptoms are typical of spray injury. As mentioned, disease ratings for the remaining treatments were moderate. It should be noted that disease initiating from the milk stage of plant development on, has no effect on the final yield. Thus, high disease ratings at the end of the season do not reflect the yield reductions that the amount of disease present earlier in the season would.

The results of this preliminary study,indicate that the best control of fungal brown spot can be obtained with two applications of propiconazol at 8 oz ai/A during both boot and heading. Further conclusions can be made when the study is repeated in 1986.

Literature Cited

Kohls, C.L. and J.A. Percich. 1984a. Epidemiology and yield losses associated with fungal brown spot of wild rice. Phytopathology 74: 809.

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B. Tilt Residue Study

If propiconazol (Tilt) is to be registered for use in the management of Bipolaris oryzae (Breda de Haan) Shoem., the causal organism of fungal brown spot of wild rice, the phytotoxicity of the compound must be determined. In 1984, a three year study in conjunction with Ciba-Geigy Corporation, Greensboro, N.C., was undertaken to determine residue levels of Tilt TM in soil, grain and water. This study is outlined below.

In Grand Rapids, MN, one 152.4 m (500 ft) long paddy was divided into nine equal sections. On May 18, 1984, all nine sections were rototilled and fertilized with 45 kg/ha (40 lbs/A) of nitrogen and 45 kg/ha (40 lbs/A) of potash. On May 22, cultivar K2 seed was broadcast over a 12.2m by 12.2m (40 ft by 40 ft) area in each of the nine sections. The seed was raked in and the paddy flooded. The spray schedule for these nine plots was as follows:

Section (plot)	Treatment (g ai/A)	Plant Growth Stage	Spray Schedule
1	Control	-----	-----
2	Tilt 100	Boot	07/10/84
3	Tilt 200	Boot	07/10/84
4	Tilt 100	Boot and Heading	07/10 & 07/24
5	Tilt 200	Boot and Heading	07/10 & 07/24
6	Tilt 100	Boot	07/10/84
7	Tilt 200	Boot	07/10/84
8	Tilt 100	Boot and Heading	07/10 & 07/24
9	Tilt 200	Boot and Heading	07/10 & 07/24

The fungicide was applied with a hand-held CO_2 pressurized canister sprayer (20 lbs psi). Application volume was 4L/plot. All residue samples were taken in duplicate from the plots sampled. Approximately 2 lbs of soil and grain per replication was collected. Water samples were collected in 1 qt bottles. After collection, all samples were packed in ice and transported to the laboratory. Samples were then maintained at 0 C. All samples were eventually sent in dried ice to Ciba-Geigy Corporation, Greensboro, N.C. for chemical analysis.

To determine the base level of Tilt present, flood water samples and soil samples [0-15.24 cm (0-6 in) below the surface], from treatments 1-8 were taken just prior to the first spray application. Immediately following the first spray application, flood water samples were taken from plots 1-8 and soil samples [0-15.24 cm (0-6in)] from plots 1 and 2. On the 3rd, 7th, 10th and 14th day following the first spray application of Tilt, flood water and soil [0-15.24cm (0-6in)] samples from plots 1, 2, 4, 6, and 8 were collected. The sampling sequence was the same for the second application of Tilt.

During paddy draining, canal water from plots 1,2 and 4 was collected at 0 (0), 15.24 (50), 60.96 (200) and 121.92 m (400 ft) down stream. After drainage was completed soil samples from plots 1,2,6 and 8 were collected at depths of 0-15.24 (0-6) and 15.24 -30.48 cm (6-12 in). At harvest, grain and soil were collected from all plots. Soil sample depths included: 0-15.24 (0-6), 15.24-30.48 (6-12), 30.48-45.72 (12-18), and 45.72-60.96 cm (18-24 in). Soil samples were to be taken after fall tillage. However, the soil was too wet to till and no samples were collected.

On May 2, 1985, K2 seed was added to all nine plots and the paddy flooded. On July 11 urea was added. Spray applications were on July 15 and July 25. The procedures and sampling sequence were the same as in 1984. Again, the soil was too wet to fall till.

In 1986, the paddy will be left fallow. Soil samples at depths of 0-15.24 (0-6), 15.24-30.48 (6-12), 30.48-45.72 (12-18),and 45.72-60.96 cm (18-24 in), from plots 1,2,4,6 and 8, will then be collected in early spring, mid-summer and the fall.

C. Chemical Control of Sclerotium oryzae with BAY NTN

Introduction. Stalk rot of wild rice is caused by Sclerotium oryzae Cav. Symptoms appear initially in the form of small oval lesions at the water level. As the growing season progresses and the fields are drained, infected stems become necrotic and brittle which may lead to lodging. These lodged plants can account for a reduction in yield. Current control methods recommend the removal of plant residue or tilling it into the soil, use of disease free seed, and crop rotation with a non-susceptible crop to reduce survival of overwintering sclerotia. There is no effective chemical control available.

In this study, BAY NTN 19701 (Mobay Chemical Corporation, Kansas City, MO), an experimental fungicide, was tested for control of S. oryzae. This fungicide is a non-systemic, protective fungicide that has been shown to control Rhizoctonia spp. on field crops vegetables, ornamentals, turf and rice. Rhizoctonia spp., like S. oryzae, form sclerotia.

Experimental Methods. The paddy was prepared by rototilling and amending the soil with 22.5 kg/ha (20 lbs/A) of nitrogen. Volunteer seed was eliminated by fumigation of the soil the previous fall with methyl-bromide.

Experimental design was a completely randomized block consisting of four treatments replicated four times. Each treatment was planted in a 1.22 by 1.22 m (4 x 4 ft) plot. The wild rice cultivar utilized was K-2. The treatments, fungicide application schedule and inoculation schedule are described in Table 3.

The fungicide, BAY NTN, was applied with a hand-held CO_2 pressurized canister sprayer (20 psi). The application volume was 1/3 l (0.09 gal)/plot. The recommended rate of 4 oz ai/A was applied at boot and again at heading. The procedure for inoculum increase and application is the same as that described for the Tilt Rate Study. A needle attached to a syringe was used to inoculate plants with approximately 35 sclerotia/ml at the base of the plant.

At harvest, 20 plants per plot were collected by hand for analysis. Panicles were counted, threshed and the seed dried at 90 C. Grain was then de-hulled, graded and weighed. Treatment means were compared by Duncan's New Multiple Range Test. Disease severity was determined, at harvest, by rating the tillers according to the method of Krause and Webster (Table 4).

Results and Discussion. No significant differences among treatments were found (Table 5). The disease index was statistically the same regardless of treatment. Non-inoculated controls receiving no sprays had the same level of disease as the inoculated non-spray treatment. This may represent natural infection, or contamination from neighboring plots. The spray applications of BAY NTN failed to increase yields or grain quality above that obtained from non-spray treatments (Table 5). Similarly, disease severity was not reduced below that obtained from non-spray and control treatments (Table 5).

These preliminary results indicate that while BAY NTN is effective in controlling some diseases caused by Rhizoctonia spp., it is not effective in controlling stalk rot of wild rice. Time of spray application may be part of the reason for the lack of control observed. Currently, 4 oz ai/A is recommended at boot and heading; by this time (boot) the pathogen has already established itself within the plant. Thus, a systemic fungicide with some eradicative properties may be more effective than a protectant fungicide like BAY NTN in controlling stalk rot of wild rice. The effects of applying BAY NTN earlier in the season have not been determined.

D. Tilt-Dithane M-45 Study

Introduction. Until September 1984 (personal communication with Minnesota Department of Agriculture), mancozeb (Dithane M-45, Rohm and Haas Co.,Philadelphia, PA) was the only fungicide registered for use on wild rice in Minnesota to control fungal brown spot caused by Bipolaris oryzae (Breda de Haan) Shoem. Dithane M-45 is a protective fungicide with a recommended spray application interval of 7 to 10 days on wild rice. Propiconazol (Tilt by Ciba Geigy Corp., Greensboro, N.C.) is a systemic fungicide having both eradicative and protective properties. During the 1984 growing season, an emergency use permit (section 18) was submitted to the Minnesota Department of Agriculture and the Environmental Protection Agency (EPA), for use of

Tilt on wild rice. Thus, the purpose of this study was to evaluate the use of Tilt and Dithane M-45 in sequential application combinations for control of fungal brown spot. Also investigated, was the possibility Tilt had a depressing effect on yield.

Experimental methods. In 1984, in Excelsior, MN, wild rice seed, cultivar K2, was planted on May 31 into 2.13 by 3.05 m (7 x 10 ft) plots. The paddy was previously prepared by rototilling and amending the soil with nitrogen at the rate of 22.5 kg/ha (20 lbs/A). A second application of nitrogen at a rate of 8 kg/ha (7 lbs/A) was applied at the early grain elongation stage of plant development. Volunteer seed had been previously eliminated in the fall by fumigation of the soil with methyl bromide. The experimental design was a completely randomized block consisting of nine treatments, and six blocks. In 1985, in Grand Rapids, MN, wild rice seed cultivar K2, was planted on May 2 into 1.5 by 2.13 m (5 x 7 ft) plots. Preparation of the paddy was the same as described for the 1984 growing season. The experimental design was a completely randomized block consisting of ten treatments and six blocks.

Fungicides were applied with a hand-held, CO2 pressurized canister sprayer. For both fungicides the application volume was 0.3 l (0.09 gal)/plot. Dithane M-45 was applied at the recommended rate of 2.25 kg/ha (2 lbs/A) and Tilt at the rate of.28 kg ai/ha (50 g ai/A) in 1984, and .1 kg ai/ha (100 g ai/A) in 1985.

The treatments, fungicide application schedule and inoculation schedule are described in tables 6 and 7. Treatments were coded with three letter descriptors which indicate the pattern of fungicide use. The letter °M' indicates an application of Dithane M-45 whereas °P' refers to an application of Tilt. Control treatment descriptors begin with a °C' whereas inoculated treatment descriptors contain an°I'. The second and third letters of the descriptor indicate whether the treatment was an individual fungicide used twice - both letters the same, a single fungicide used once - the last letter an °I', or the two fungicides used in sequence - an °M' and °P'.

The CMM treatment received five applications of Dithane M-45 at a 7-day interval. The CPP treatment received two applications of Tilt at a 17-day interval in 1984 and a 10-day interval in 1985. The CPM and CMP treatments received two applications of Dithane M-45 at a 7-day interval and one application of tilt, 10 to 17 before the first Dithane M-45 application or 3 to 10 days after the last Dithane M-45 application depending on the year, respectively. The IPP treatment received the same fungicide applications as the CPP treatment but was also inoculated. The IPI treatment was similar to the IPP treatment, but did not receive the second application of Tilt. The IPM and CPM treatments were similar, except that those plants receiving the IPM treatment were inoculated and did not receive a second application of Dithane M-45. The second application of Dithane M-45 was applied when most plants were in the mid-milk stage of development. An application of Dithane M-45 at this time does not affect yield loss but will reduce disease severity. The MIP and IMP treatments resembled the CMP treatment except that both were inoculated and each received only one of the two early

Dithane M-45 applications of inoculum. In 1985, an additional treatment of an unprotected control (I) was added (Table 7). This was done to see if Tilt did infact increase yields compared to unprotected disease controls. Treatments that were inoculated received 5 and 2 applications of inoculum, respectively, in 1984 and 1985. The procedure for inoculum increase and application is the same as that described for the Tilt Rate Study.

It should be noted that the healthy control treatments were used to determine if the fungicides were phytotoxic. Decreased yields in non-diseased treatments would indicate phytotoxicity. The controls also allowed for a comparison between healthy and diseased treatments with similar but unchallenged fungicide protection.

Panicles in 1984 and plants in 1985 were harvested from the inner 1.22 by 1.83 m (4 x 6 ft) area of each plot by hand. Plant material was counted, threshed and dried at 60 C. Grain was then de-hulled, graded and weighed. wild rice seed greater than 1.26 mm in diameter (grade # 3) was used to determine final yields. Treatment means were compared by Duncan's New Multiple Range Test.

Disease severity readings were recorded throughout the growing season in each plot. If the level of disease was below 1%, lesions were categorized according to size (Figure 1) and counted on each of the uppermost leaves of the plant. As the disease level increased and lesions coalesced, disease severity was assessed by determining the percent leaf area infected for each of the three uppermost leaves.

Results. In both 1984 and 1985, disease severity varied depending on the treatment (Table 8). Non-inoculated controls had disease levels of 1% or less throughout the growing season. The trace levels of disease determined on August 10, 1984 and August 5, 1985 in the non-inoculated controls has been shown not to cause detectable reductions in yield (Kohls and Percich, 1984a.; Kohls and Percich, 1984b.. More disease was present in the inoculated treatments throughout the growing season compared to non-inoculated controls. By August 10, 1984, mean disease severity levels of 2, 3 and 4 % on the flag, second and third top-most leaves, respectively, were recorded. Similarly, on August 5, 1985, mean disease severity levels of 2, 2 and 2 % on the flag, second and third top-most leaves, respectively, were recorded. When this level of disease is present at the milk stage of plant development, noticeable reductions in yield can occur (Kohls and Percich, 1984a.; Kohls and Percich, 1984b.).

The treatment yield means are shown in Table 9. In 1984, significant differences between treatments were observed at the p=.05 level as determined by Duncan's New Multiple Range Test. The yield of the CMP treatment was significantly higher (Table 9) than either of the two control treatments (CPP and CPM) receiving the first application of Tilt on July 16. Application of Tilt at the full boot stage of plant development decreased yields compared to the non-diseased CMP treatment. However, the CMP treatment yield was not significantly higher than the IPM treatment yield. The IPM treatment was inoculated and also received the July 16 application of Tilt. The CMP treatment yield was significantly higher than the yields from the IMP and MIP treatments, indicating that disease did significantly decrease yields (Table 9). CMM and CMP treatment yields were not significantly different at the 5% level. This indicates that an application of Tilt at the early grain elongation stage of wild rice development does not decrease yield in the absence of disease.

The IMP and MIP treatment yields were not significantly different from the IPP treatment yield, at the 5% level. The application of Tilt at full boot, does not seem to significantly decrease yield when comparing treatments with yields already reduced by disease. The IPP treatment yield is not significantly different from the IPI treatment yield (Table 9). This indicates that the Tilt application at the grain elongation stage did not significantly increase yield under the low level of disease present in this study. Because the CMM and CMP treatment yield comparison does not show significant differences, the comparison of IPP and IPI is not confounded by a yield reduction due to the Tilt application at early grain elongation. However, the comparison of IPP and IPI may be inappropriate because of the confounding effects of a Tilt application both received at the full boot stage. This application of propiconazol decreased yields significantly in non-inoculated treatments (Table 9).

Comparison of the disease intensity ratings for the IPM and IMP treatments with the IPP treatment indicates that two applications of Tilt did not control fungal brown spot as well as a combination of one application each of Dithane M-45 and Tilt. The disease ratings of the IPP, IPI and MIP treatments were similar at the milk and ripe stages. This level of protection is satisfactory for control of fungal brown spot and reduces the associated reduction in yield to desirable levels (Table 8).

In 1985, no significant differences among treatments were found (Table 9). Because of poor germination (< 5%), seedlings were transplanted into all plots. This may have resulted in non-uniformity with regards to the age of the plants within the plots; and the stage of plant development at the time of fungicide application is important in the control of fungal brown spot. Consequently, all plants may not have reached the various stages of plant development at the same time, and this may have in turn affected disease development, disease control with fungicide applications and final yield.

Although the treatments did not differ significantly from one another in 1985, trends similar to those observed for the 1984 growing season can be noted (Table 9), with the higher yields being obtained from the CMM, CPP and IPM treatments. In general, plants treated with tilt did result in less disease severity (Table 8) and higher yields (Table 9) compared to the unprotected disease control.

Discussion. Both Dithane M-45 and Tilt control fungal brown spot of wild rice. Dithane M-45 is a protectant whereas Tilt has the additional attribute of being able to eradicate disease. An eradicative fungicide such as Tilt will offer a grower additional flexibility in the disease management of fungal brown spot. The 1984 results showed that Tilt applied at the full boot stage, in the absence of disease, can decrease yields by 16%. If disease was present prior to the application of Tilt, no significant decrease in yield occured. One or two applications of Tilt with inoculations throughout the growing season had significantly lower yields when compared to only one Tilt application at the full boot stage followed by Dithane M-45 at early grain elongation. However, resulting yields from an application of Tilt at full boot on inoculated plants with or without a second application at grain elongation, was not significantly different from one application at early grain elongation followed by a single Dithane M-45 application at either full boot or early flowering stages. The contrasting results obtained between the inoculated and non-inoculated treatments, in both 1984 and 1985, do not support the theory that Tilt applied at full boot has a depressive effect on yield.

This study will be repeated in 1986. The problem of little or no seed germination in 1985 and for the past several years has stimulated the need for a research effort into the areas of seed storage and seed borne pathogens. Such an effort will begin in 1986 and is described below.

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SEED GERMINATION

Laboratory determination and evaluation of various environmental parameters affecting seed storage, germination and subsequent seedling growth of wild rice.

During the past four years, an increasing decline in the percent germination of stored wild rice seed has been observed. To date there appears to be little definitive information concerning the best conditions both biologically or economically to store seed, thus, insuring the highest possible seed germination and subsequent seedling growth. Also, there is no available information to predict with accuracy, the percent germination of stored seed during various storage periods. The fact that a decline in percent seed germination can occur among various cultivars stored under similar conditions, further complicates the problem. The roles of seed-borne microorganisms in seed storage, germination and subsequent seedling growth, needs to be determined.

Recently, the project purchased a microprocessor pH/mv/Ion meter to examine parameters such as oxygen concentration, temperature and pH at selected periods during storage. Similarly, a variety of microbial media has been obtained to plate the seed of various cultivars, and thus, determine the microorganisms present throughout storage. Also, the percent germination and subsequent seedling growth will be monitored at selected sampling intervals. It is hoped that from this data germination trends will be observed. In the future we may have ways of manipulating one or all of these factors to increase or maintain seed germibility under defined storage conditions. Thus, the objectives will be:

1) Conduct a laboratory investigation of various chemical, biological, and physical parameters that influence wild rice seed storage, germination, and subsequent seedling growth and vigor (i.e. water depth, pH, salt content [Mg^{++},Ca^{++}], Co_2 concentration, O_2 concentration, seed coat thickness, temperature, cultivar, and microorganisms).

2) To identify those biologically and economically feasible chemicals and/or procedures that will help ensure high quality seed storage as well as subsequent seed germination and seedling growth.

3) Establish standardized percent germination response curves for wild rice seed in storage under defined conditions. Thereby, giving the grower a rapid and accurate method of assessing the present and future state of wild rice seed germination during storage.

BIOLOGICAL CONTROL

Biological control of common waterplantain (Alisma triviale Pursh) in cultivated wild rice.

Introduction. Wild rice (Zizania palustris L.) is an annual aquatic cereal that grows naturally in many lakes and rivers in Minnesota, Wisconsin and Canada (Steeves, 1952). Domestication of wild rice began in 1950 and is presently cultivated on approximately 11,000 ha. in Minnesota (Oelke, 1982). Continuous monoculture of wild rice has led to the establishment of several pest weed species. (Ransom and Oelke, 1982). These weeds include; burreed (Sparganium latifolia Englem), cattail (Typha latifolia L.), common arrowhead (Sagittaria latifolia L.), common waterplantain (Alisma triviale Pursh), cursed crowfoot (Ranunculus scleratus L.), small pondweed (Potamogeton pusillus Fern.), and water starwort (Callitriche heterophylla Pursh).

Common waterplantain (A. triviale Pursh) is the most destructive weed present in wild rice fields (Oelke, 1982). One plant per square foot from rootstocks can result in a yield reduction of 43% (Oelke, 1982; Ransom and Oelke, 1982). Effective weed control is usually the result of both cultural and chemical methods. Cultural control consists of planting weed free seed in the spring, rotovating in the fall after harvest, and in heavily infested areas it may be beneficial to fallow the field for a year. The only herbicides recommended for weed control in cultivated wild rice are 2,4-D(amine) and M-CPA. These herbicides do not give complete weed control and when not applied at the proper rate or time, serious injury to the wild rice plant can occur.

The use of plant pathogens or the chemical products of these organisms as microbial herbicides can be an effective component of weed control programs (Wilson, 1969). Plant pathogens as weed control agents have several advantages over synthetic chemicals. The organisms are specific, there is no hazard to the applicator, no residue, no accumulation of toxins in the soil or ground water, less costly, and there is less disturbance of other plants and animals in the environment (Wilson, 1965).

If bioherbicides are to be applied to the foliage, it is necessary to understand what organisms are already present, and the potential interactions that may occur. Thus, the objectives of this study were to make a detailed survey of the microorganisms present on the phylloplane of common waterplantain, and from this identify possible biological control agents.

Material and Methods. Common waterplantain was sampled from three locations at the following stages of growth development: five aerial leaves, early flowering, late flowering, and seed set. The locations sampled included, Manomin and Kosbau's farms in Aitkin county Minnesota, as well as a research paddy in Grand Rapids, Minnesota. Leaf samples were collected aseptically and placed into autoclaved containers for transport to the laboratory. The phylloplane microflora was determined through leaf prints, leaf washings, and direct isolation. Leaf prints lead to the isolation of both transient and resident microorganisms. Leaf washings identify only resident microorganisms, and direct isolation reaffirms the presence of resident pathogens. These techniques are described below.

Leaf Prints. Leaves were printed adaxially and abaxially, aseptically, onto a wide range of media (Dickenson, 1971). For each print, the quantity and quality of identifiable bacteria, filamentous fungi, yeasts, and yeast-like organisms will be recorded. Bacterial isolates were identified through the use of differential media and the gram stain (Schaad, 1980; Figure 2). All microorganisms were maintained on appropriate slants throughout the growing season.

Leaf Washes. The leaves were washed in tap water ten times, each washing being ten minutes in length. After the tenth washing, using a number 6 corkborer, 8 leaf discs per leaf were aseptically punched out and plated onto various culture media. After five to seven days of incubation at 22 C, the resident microorganisms were identified (Dickenson,1971).

Direct Isolation. Tissue from the advancing margins of necrotic lesions was plated aseptically onto various nutrient media.

Results. At the five-aerial leaves stage of development, five microoranisms were isolated consistently from Aitkin County, Minnesota; and three microorganisms from the Grand Rapids site (Table 10). Lesions on the leaves were first noted at this stage of development. Symptoms consisted of dark brown to black spots that were circular in shape. Upon examination of the leaves with a dissecting microscope, pycnidia were detected in the spots. It was from these lesions that direct isolations were made. Tissue from the advancing margins of the lesions was aseptically plated onto acidified water agar and acidified potato dextrose agar. After incubation at 24 c for 7 days, a dark black mycelial mat was observed. Examination with the compound microscope at 43x revealed long, septate conidia borne on short conidiophores. These cultural and microscopic characteristics are typical of the genus Septoria (Agrios, 1978; Barnett and Hunter, 1972). From

Aitkin County, Epicoccum spp., Septoria spp., [illegible] [illegible]
spp., and Xanthomonas spp. were isolated from all five leaves using the leaf print technique (Table 10). None of the microorganisms isolated were unique to a particular leaf or location on the leaf. In Grand Rapids, MN, with the exceptions of Erwinia spp. and Xanthomonas spp., Epicoccum spp., Septoria spp., and Pseudomonas spp. were detected by the leaf print method (Table 10). At all locations, leaf washings and direct isolations yielded a species of Septoria (Table 10).

When waterplantain reached the early and late stages of flowering, the results from the three isolating techniques, at all locations, were the same as those obtained during the five-aerial stage of development (Table 10).

At seed set, three additional organisms were recognized at both Aitkin County and Grand Rapids (Table 10). These microorganisms were: Alternaria spp., Penicillium spp., and Rhizopus spp.. These fungi were isolated through leaf prints and leaf washings, but not through direct isolations.

Discussion. Since Epicoccum spp., Pseudomonas spp., and Xanthomonas spp. could not be detected through leaf washings or direct isolations, they are probably existing epiphytically on the leaf surface. Furthermore, there were no symptoms present to indicate these organisms play a role in disease of this plant.

Alternaria spp., Penicillium spp., and Rhizopus spp., were detected late in the season through leaf prints and leaf washings. Direct isolations from lesions on the leaves did not yield these organisms. Thus, it would seem likely that these microorganisms are not the cause of the symptoms observed, but are in fact secondary pathogens attacking when the plant is weak and senescing.

Of the microorganisms isolated, Septoria spp. seems to be the most likely choice for use as a possible biological control agent of common waterplantain in wild rice paddies. This microorganism was isolated consistently throughout the growing season by all three techniques, indicating it is a resident of the leaf flora. In addition, Septoria spp. is known to be pathogenic and produce the symptoms that were observed on the leaves of common waterplantain (Agrios, 1978).

In the fall of 1985, weed corms of common waterplantain were collected from Aitkin county, cleaned and stored at 0 C. After a two month dormancy period at this temperature, the corms can be planted in the greenhouse and inoculation-infection tests with this isolate of Septoria spp. begun.

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RESISTANCE

Greenhouse Screening for Resistance to Bipolaris oryzae.

In the winters of 1984 and 1985, a study in conjunction with the wild rice breeders was initiated to screen plants for resistance to Bipolaris oryzae (Breda de Haan), the causal agent of fungal brown spot of wild rice. The wild rice cultivar Voyager was utilized in this study. Three to five seedlings per pot were planted in a greenhouse mix (3/4 soil: 1/4 sand). Plants were inoculated with B. oryzae at the boot stage of development. inoculum preparation and application were the same as described for the Tilt Rate Study. Approximately three weeks following inoculation, plants were read for disease severity (Figure 1). No differences among plants were found with regards to lesion number and size. Thus, no differences with regards to resistance in this cultivar were detected. Similar studies with other wild rice cultivars will be conducted during 1986

Fungal Brown Spot Disease Key For Lesion Size

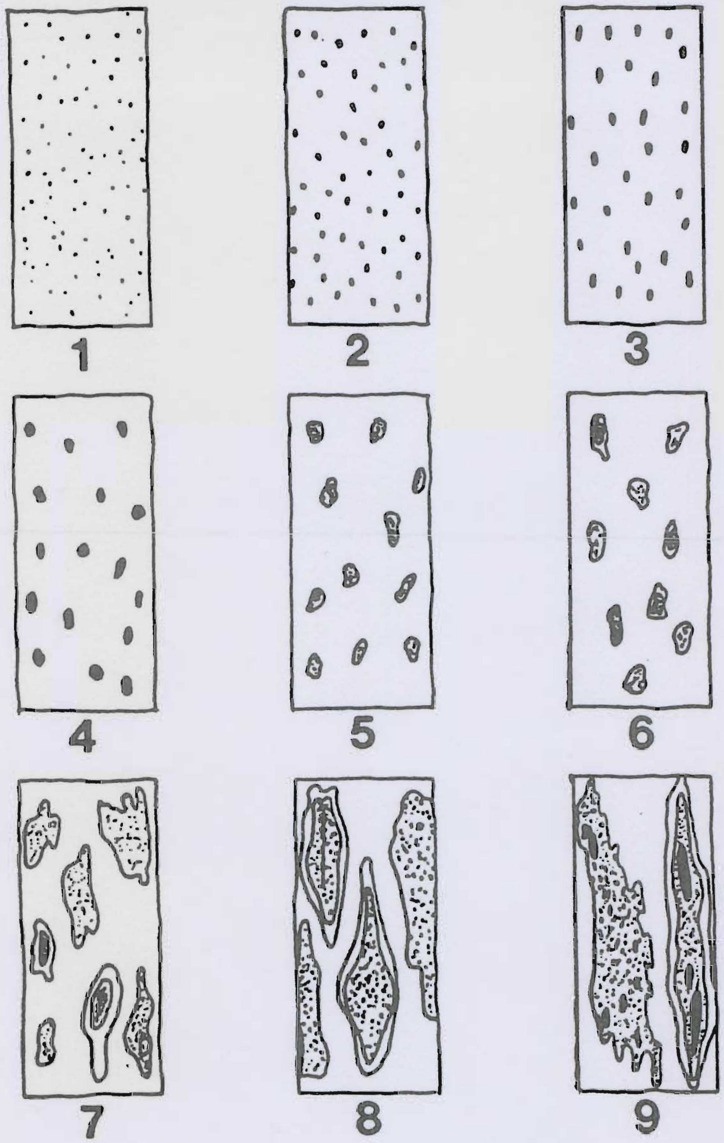
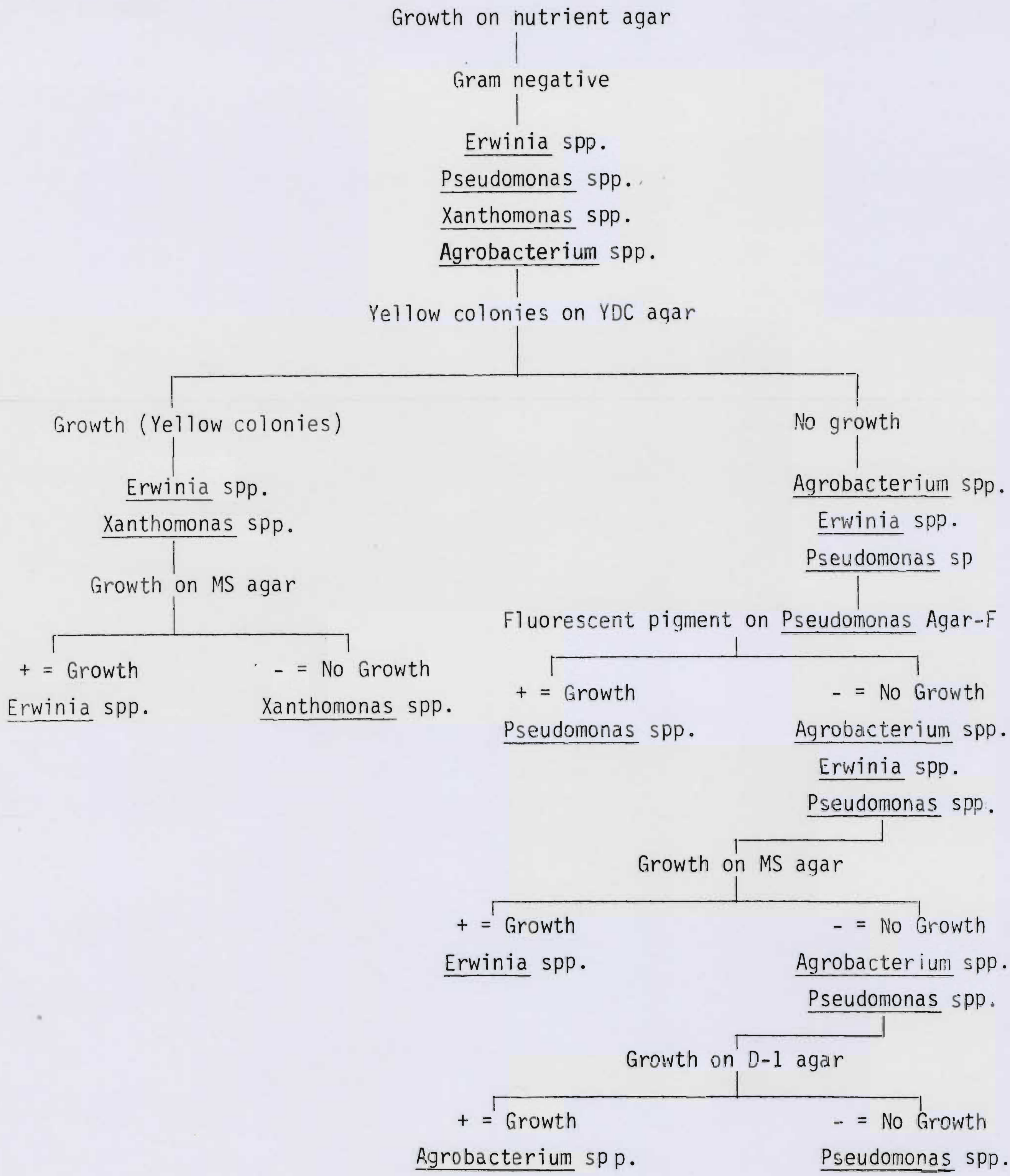


Figure 1 . Fungal brown spot of wild rice key to lesion size. Based on the work of Dr. David Punter, University of Manitoba, Winnepeg, Manitoba, Canada (unpublished). Leaf sections contain lesions coded by a number beneath each leaf. Lesions smaller than 1 are considered to be size 0; those larger than 9 are also considered to be lesions of size 9. The leaf sections are 2.5 x 5.7 cm. Lesion size categories 1, 2, 3, 4, 5, 6, 7, 8 and 9 are approximately 0.5, 1.0, 2.0, 3.0, 5, 7, 15, 30 - 40 and >50 mm long and have areas of approximately 0.005, 0.01, 0.02, 0.06, 0.12, 0.21, 0.5, 2.4 and 3.5 sq. cm, respectively.

Figure 2. Differentiation of bacterial isolates (Schaad, 1980).



with *B. oryzae*.

Rate oz/a	Stage of Plant Development	Yield lb/a
4	Boot and Heading	281.19 a*
6	Boot and Heading	277.66 a
8	Boot and Heading	447.87 c
8	Boot	358.87 b
10	Boot	292.82 a
Control		317.41 a

* Means followed by the same letter are not significantly different at the P = .10 level according to Duncan's New Multiple Range Test.

Table 2. Mean disease ratings of plants inoculated with B. oryzae and then treated with propiconazol (Til· at varying rates.

Rate oz/a	Stage of Plant Development	Disease Severity Ratings[a/] 7/8	7/24	8/5	8/22
4	Boot and Heading	0%	6#1, 2#2, 1#3, 1#5/ 5#1, 5#2, 1#3/ 6#1, 3#2, 6#3	1.5/2.0/2.0	2.5/5.0/2.0
6	Boot and Heading	0%	30#1/30#1/25#1, 10#2, 3#5	1.5/2.0/2.0	2.5/10.0/25.1
8	Boot and Heading	0%	3#1/8#1/2#1	4#1/8#1, 2#2/ 3#1	1.0/5.0/25.0
8	Boot	0%	7#1/5#1/2#4	1.0/1.0/1.0	1.0/10.0/25.0
10	Boot	0%	10#1/1#1, 2#3/10#1, 8#3, 5#6	1.0/1.0/1.0	1.5/5.0/30.0
Control		0%	6#1, 3#2/12#1, 5#2, 20#5/ 22#1, 4#3, 6#5	2.0/3.0/4.0	2.0/5.0/50.0

a/ On July 24, disease readings (n#s) on each of three leaves (leaf 1/leaf 2/leaf 3) indicate the number of lesions (n) of various size categories (s) for the top, second and third leaves, respectively. On Augu 5 and 22, most of the disease ratings represent the percent leaf area affected with fungal brown spot for the top, second and third leaves, respectively.

Treatment	Date July 8	July 11	July 19
1	I	Bay NTN	Bay NTN
2	I	-	-
3	C	Bay NTN	Bay NTN
4	C	-	-

I = Inoculated with *Scelorotium oryzae*.

C = Non-inoculated

Bay NTN = Spray application of Bay NTN at 4 oz ai/a.

Table 4. Disease index scale for stalk rot according to the method of Krause and Webster.

1 = Healthy (H)	-	No visible symptoms.
2 = Light (L)	-	Infection on leaf sheaths only.
3 = Medium (M)	-	Infection on outer culm surface.
4 = Moderate (MO)	-	Infection penetrating to inner culm surface.
5 - Severe (S)	-	Culm shriveled from weakened disease tissue; fungus, mycelial growth on inner culm; sclerotia often present.

$$\text{Disease Index} = \frac{1(\#H) + 2(\#L) + 3(\#M) + 4(\#MO) + 5(\#S)}{\text{Total number of tillers examined}}$$

Treatment	Disease index	Yield[1/] lb/a	Grain quality[3/] 4	3	2
1	1.22 a[2/]	73.6 a[2/]	48 a[2/]	45 a[2/]	7 a[2/]
2	1.02 a	76.2 a	49 a	43 a	8 a
3	.9 a	75.8 a	50 a	42 a	8 a
4	.8 a	79.4 a	53 a	44 a	3 a

1/ Yield of dehulled, dry (7% moisture) grain.

2/ Means in each column followed by the same letter are not significantly different at the p = .05 level according to Duncan's New Multiple Range Test.

3/ Grain quality refers to seed size. The numbers 4, 3 and 2 refer to seed with a diameter of 4/64th of an inch, 3/64th of an inch, and 2/64th of an inch respectively.

MN.

Date	Non-inoculated				Inoculated				
	CMM	CPP	CPM	CMP	IPP	IPI	IPM	MIP	IMP
July 14					I	I	I	I	I
July 16	M	P	P	M	P	P	P	M	
July 20					I	I	I	I	I
July 23	M			M					M
July 30	M				I	I	I	I	I
August 2		P	M	P	P		M	P	P
August 6	M				I	I	I	I	I
August 9			M		I	I	I	I	I
August 13	M								

I = Inoculation with <u>Bipolaris oryzae</u>.

M = Mancozeb application.

P = Propiconazol application.

Table 7. Fungicide application and inoculation (I) schedule for the comparison of Propiconazol (Tilt[TM]) and Mancozeb (Dithane M-45) for the control of fungal brown spot on wild rice cultivar K-2 in 1985 at Grand Rapids, MN.

Date	Non-inoculated				Inoculated					
	CMM	CPP	CPM	CMP	I	IPP	IPI	IPM	MIP	IMP
July 8					I	I	I	I	I	I
July 10		P	P			P	P	P		
July 11	M			M					M	
July 15					I	I	I	I	I	I
July 19	M			M						M
July 25	M	P	M	P		P		M	P	P
July 31	M									
August 6			M							
August 13	M									

Table 8. Incidence and severity of fungal brown spot on the flag, 2nd and 3rd top most leaves of wild rice cultivar K-2.

Chemical treatment	Disease severity ratings[a]						
	7/24/84	7/8/85	7/24/85	8/10/84	8/5/85	8/20/84	8/22/85
CMM	0/0/0	0/0/0	0/0/0	0/0/0	0/0/1#1	tr/<1/<1	<1.0/<1.0/<1.0
CPP	0/0/tr[b]	0/0/0	0/0/0	tr/tr/tr	6#1/2#2/2#2	0.6/1.0/1.3	<1.0/<1.0/<1.0
CPM	0/0/tr	0/0/0	0/0/0	tr/tr/tr	5#1,1#2/2#3/ 6#1,3#2/1#3	0.3/0.5/0.7	1.0/1.0/1.0
CMP	0/tr/tr	0/0/0	3#1/8#1/2#1	tr/tr/tr	7#1,8#2/8#2,2#2/ 3#1,8#2,1#3	0.2/0.4/0.5	1.0/1.0/1.0
I	-	0/0/0	7#1/5#2/6#1	-	2.0/2.0/2.0	-	10.0/15.0/30.0
IPP	tr/tr/tr	0/0/0	10#1/5#1/5#1	1.0/3.0/5.0	1.5/2.0/1.0	7.0/15.0/42.0	1.0/5.0/10.0
IPI	tr/tr/tr	0/0/0	5#1/6#1/4#1	3.0/4.0/5.0	1.0/2.0/1.0	0.8/11.0/33.0	10.0/10.0/20.0
IPM	tr/tr/tr	0/0/0	3#1/3#1/4#2	1.0/2.0/3.0	1.5/1.5/2.0	5.0/7.0/10.0	10.0/15.0/20.0
MIP	tr/tr/tr	0/0/0	4#2/2#1/5#1	2.0/3.0/5.0	2.0/1.0/3.0	7.0/14.0/39.0	10.0/15.0/25.0
IMP	tr/tr/tr	0/0/0	3#1/2#1/3#1,2#2	1.0/3.0/2.0	1.5/2.0/3.0	9.0/11.0/13.0	15.0/20.0/50.0

a/ Disease readings (n#s) on each of three leaves (leaf 1/leaf 2/leaf 3) indicate the number of lesions (n) of various size categories (s) for the flag, 2nd and 3rd top most leaves, respectively. From August 10 through August 22 for both 1984 and 1985, most of the disease ratings represent the percent leaf area affected with fungal brown spot for the flag, 2nd and 3rd top most leafes, respectively.

b/ tr = trace disease-no associated yield loss (individual lesions).

cultivar K-2 in inoculated and non-inoculated plots.

Treatment		Yield(lb/a)	
1984	1985	1984	1985
CMP	CMP	805 a[1/]	405.28 a[1/]
CMM	CPP	749 ab	400.92 a
IPM	IPM	737 abc	387.02 a
CPP	IMP	691 bcd	382.37 a
CPM	CMM	669 bcde	380.15 a
IMP	MIP	635 bcde	371.79 a
MIP	I	623 cde	348.02 a
IPP	IPI	590 cd	337.22 a
IPI	CPM	545 e	313.32 a
	IPP		300.78 a

1/ Means followed by the same letter are not significantly different at the *P* = .05 level according to Duncan's New Multiple Range Test.

Microorganisms detected on the leaf surface of common waterplantain at the plant growth stage indicated.

	Microorganisms isolated	Leaf Prints			Leaf Washings			Direct Isolations		
		Manomin	Kosbau's	Grand Rapids	Manomin	Kosbau's	Grand Rapids	Manomin	Kosbau's	Grand Rapids
	Epicoccum spp.	+	+	+	-	-	-	-	-	-
	Septoria spp.	+	+	+	+	+	+	+	+	+
leaves	Erwinia spp.	+	+	-	-	-	-	-	-	-
	Pseudomonas spp.	+	+	+	-	-	-	-	-	-
	Xanthomonas spp.	+	+	-	-	-	-	-	-	-
	Epicoccum spp.	+	+	+	-	-	-	-	-	-
	Septoria spp.	+	+	+	+	+	+	+	+	+
wering	Erwinia spp.	+	+	-	-	-	-	-	-	-
	Pseudomonas spp.	+	+	+	-	-	-	-	-	-
	Xanthomonas spp.	+	+	-	-	-	-	-	-	-
	Epicoccum spp.	+	+	+	-	-	-	-	-	-
	Septoria spp.	+	+	+	+	+	+	+	+	+
ering	Erwinia spp.	+	+	-	-	-	-	-	-	-
	Pseudomonas spp.	+	+	+	-	-	-	-	-	-
	Xanthomonas spp.	+	+	-	-	-	-	-	-	-
	Epicoccum spp.	+	+	+	-	-	-	-	-	-
	Septoria spp.	+	+	+	+	+	+	+	+	+
	Erwinia spp.	+	+	-	-	-	-	-	-	-
ible	Pseudomonas spp.	+	+	+	-	-	-	-	-	-
	Xanthomonas spp.	+	+	-	-	-	-	-	-	-
	Alternaria spp.	+	+	+	+	+	+	-	-	-
	Penicillium spp.	+	+	+	+	+	+	-	-	-
	Rhizopus spp.	+	+	+	+	+	+	-	-	-

and
SPIKE TOOTH/RASPBAR CYLINDER PERFORMANCE COMPARISON

J. J. Boedicker, C. E. Schertz,
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Combine harvest research in 1985 consisted of (1) a field test to evaluate the effects of rotor speed and feed rate on overall performance of a rotary type combine and (2) an experiment with a stationary combine test set-up to compare performance of a spike tooth cylinder to that of a raspbar cylinder, both as affected by cylinder speed, concave setting and crop feed rate.

Rotary Combine Performance Test

The rotary combine was tested in a grower's field under actual harvest conditions. The test was conducted one day before harvesting officially got underway at the farm. The combine, an IH 1460, was the same one used in the 1984 performance comparison test of a rotary and a conventional (IH 915) combine. We greatly appreciate the grower's cooperation in again allowing us to work with the rotary combine in 1985.

The grower had made the following modifications to the IH 1460 combine in preparation for the 1985 harvest season:

1. The 16' wide header used on the combine in 1984 was replaced with a 22' wide header. This change permitted reduction in travel speed without reducing plant material feed rates to the combine.

2. The angle of deflector vanes on the left side of the rotor cage was changed, so as to reduce the rearward speed of plant material in the cage. This increased the detention time of material in the cage. (The optimal setting of these deflector vanes for harvest of wild rice is not known.)

3. Bolts (and nuts), used in 1984 to plug holes in the longitudinal plates of the concave where the wires were removed, were replaced with caulking. This change resulted in a slightly more open concave. (Left unplugged, straw had been found to catch in these holes, thus reducing concave openness.)

The field test was designed to investigate the effects of both rotor speed and feed rate on overall combine performance. Feed rate in the tests was varied by operating the combine at different travel speeds. The following three rpm and travel speeds--1.7, 2, and 3 mph. Nine test runs, were performed, one for each of the nine (3x3) possible treatment combinations of the two variables. Three test runs were made in each of three successive passes with corresponding runs in the passes being nearly side-by-side. Treatments were assigned randomly to the runs but in a manner that would tend to minimize the effects on results from possible differences in crop conditions in the field. Limitations in time and available labor prevented test replication. In conducting the test, concave, sieve and fan adjustments were taken as set by the combine operator and were not changed during the test.

Prior to conducting the test, the rotational speed for the straw chopper at the discharge end of the rotor cage was reduced in an attempt to permit assessment of rotor threshing performance. This change was made by interchanging the two pulleys on the straw chopper drive, resulting in a speed reduction of about 75%. The high rotational speed of the chopper (2736 rpm) and the supplemental threshing it no doubt caused, prevented realistic assessment of threshing performance of this combine in 1984. Fortunately, the reduced chopper speed was still sufficient to propel discharge material well beyond the end of the sieve. (Also, as in 1984 the chopper concave blades were removed during the test runs to further minimize supplemental threshing and straw break-up.)

Test procedures were similar to those used in previous years. Net yield in each test run was based on the amount of grain conveyed to the grain tank over a 100' distance. Combine discharge losses were based on analysis of discharge samples collected over a 30' distance within the same 100'. Discharge collection equipment (two catch cloths carried on a frame mounted on an ATV hitched to the rear of the combine) permitted the rotor and sieve discharge material to be collected separately.

An additional procedure used in 1985 was sampling of the returns (tailings). Returns were collected in a specially designed sampler (with a flap to divert the material either into the sampler or back into the combine) installed at the upper (front) end of the returns conveyor. Collection was made over a portion of each 100' test run distance, and the time required for returns to fill the sampler recorded.

Discharge and returns samples were partially analyzed on-site by water-bath separation. Preliminary estimates of rotor and sieve separation loss were available the following day. All material was saved for laboratory analysis to determine threshing loss, rotor and sieve separation loss, Another aspect of the rotary combine field work in 1985 was the testing of a "drop box" method to determine its usefulness in quickly assessing combine performance in the field. Rectangular plywood boxes were towed (with light chain) beneath the combine and released by pulling a rod on one side of the combine. Combine discharge material fell into the box as the rear of the combine passed over it.

The drop box method was tested in three test runs adjacent to Run No.'s 85107, 108 and 109 and at the same corresponding combine operation settings as those runs. Immediately after the test runs, the boxes were placed side-by-side for ease of visual comparisons. Nine observers then individually examined the contents of the boxes and ranked them according to levels of a) separation loss and b) threshing loss (1 = highest to 3 = lowest). Individual rankings were then totaled. Material in each box was then saved for laboratory analysis.

Rotary Combine Test Results

On-site and laboratory results of the rotary combine performance test are contained in Tables 1 & 2.

Except for test run No. 85104 where the crop was obviously lighter than for other runs, variation in crop conditions in the test area was higher than appeared to be the case when the test was conducted. This variation, indicated by differences in the total MOG per acre (rotor + sieve MOG/acre) among different test runs, no doubt contributed to the scatter evident in the data. These differences illustrate the difficulty in attempting to perform meaningful combine performance tests in the field without considerable replication. Despite variation in the performance data, the following observations can be made with reasonable confidence:

1. Threshing loss percentage, while being somewhat higher than generally desired, was practically independent of MOG rate within the 380 to 675 lb/min range. Also, threshing loss was expectedly higher at the 550 rpm rotor speed than at the two higher rotor test speeds.

2. Rotor separation loss percentage varied directly with MOG rate but appeared to be independent of rotor speed.

rate.

4. Sieve loss percentage varied inversely with total MOG rate, sieve discharge MOG rate and total sieve loading rate. These results are opposite to what would normally be expected, unless air speed was excessive making grain more likely to be blown out at low sieve loading rates.

5. Returns (tailings) rate, like sieve MOG discharge rate, varied directly with both rotor speed and total MOG rate.

6. Percent broken grain varied from about 2 percent at 550 rpm rotor speed to about 6 percent at 950 rpm rotor speed.

Spike Tooth/Raspbar Cylinder Performance

An experiment was conducted in 1985 to compare performance of a spike tooth cylinder and concave to that of a raspbar cylinder and grate concave in a conventional type combine. The experiment was done at Grand Rapids with the same stationary combine test set-up described in the last two annual reports. Briefly, the equipment consists of a specially modified combine (IH 303) with sieves removed and replaced with a partitioned tray to permit separate collection of grain separated at the concave and grain separated beyond the concave. The combine remains stationary and is fed with plant material preloaded onto a flight conveyor. Performance is evaluated based on the following criteria:

- unthreshed grain, %
- threshed grain separated at the concave, %
- broken (<1/4" length) grain, %

The experiment included an additional variable not tested previously, crop feed rate. Three feed rate levels were tested, these being equivalent to 125, 250 and 500 lb/min for a 4'-0" cylinder. To accommodate the addition of this variable while holding the experiment to a manageable size, it was decided to limit the numbers of test concave settings and cylinder speeds for both cylinder/concave types to two and three, respectively. The experiment consisted of 36 test runs, 18 for each cylinder/concave type. All tests runs employed a feed time to the combine of three seconds. All material was partially analyzed at an on-site laboratory using water-bath separation. Material was then saved for laboratory analysis to determine the results on a dry, dehulled basis.

Results of this experiment are contained in Figures 1 - 4. Despite the lack of replication in the experiment, results were quite consistent with little apparent data scatter.

A comparison of Figures 1 and 2 shows that unthreshed grain percentage:

1. Varied inversely with cylinder speed but directly with concave spacing for both cylinder/concave types. (Results simliar to 1984.)

2. For the raspbar type cylinder was more sensitive to concave spacing than for the spike tooth cylinder. (Results similar to 1984.)

3. Appeared to be relatively independent of crop feed rate over the range tested for both cylinder/concave types.

A comparison of Figures 3 and 4 shows that percentage of threshed grain separated at the concave:

1. Varied directly with cylinder speed but inversely with concave spacing for both cylinder/concave types. (Results similar to 1984.)

2. Was more sensitive to cylinder speed for the raspbar than for the spike tooth cylinder/concave over the range tested. (Results similar to 1984.)

3. Varied inversely with crop feed rate for both cylinder/concave types.

Results for percent broken grain in the experiment are not included in this report. These results had been expected to follow patterns similar to those from experiments in past years, but unfortunately, due perhaps to improper storage or laboratory analysis procedures, the broken grain percentage was unrealistically high for all treatments. Breakage was even high for samples of grain that had been hand stripped and not fed through the combine. The reason high breakage occurred is not yet known.

Table 1. Data from on-site analysis[a] of samples.

Run No. 85-	Travel speed mph	Rotor speed rpm	Net Yield green lb/ac	MOG discharge (Mat'l other than grain) rotor lb /min	rotor lb /ac	sieve lb /min	sieve lb /ac	Separation losses[b] rotor lb/ac	rotor % of net	sieve lb/ac	sieve % of net	Re-turns (tai-lings) lb/min
101	2.0	750	550	259	2790	18	203	13.1	2.4	16.2	2.9	14.3
102	2.0	550	753	360	4180	20	236	11.4	2.3	13.9	1.8	11.5
103	2.0	950	664	415	4740	35	402	22.5	3.4	15.7	2.4	14.5
104	1.6	950	259	71	980	10	138	8.5	3.3	15.8	6.1	6.7
105	1.6	750	643	184	2630	22	312	10.3	1.6	22.3	3.5	11.2
106	1.7	550	745	385	5270	19	254	33.1	4.4	26.1	3.5	9.5
107	2.9	550	736	571	4500	23	181	31.8	4.3	11.5	1.6	17.5
108	2.9	950	724	464	3660	50	392	25.2	3.5	13.1	1.8	28.4
109	2.8	750	624	644	5210	30	246	39.7	6.4	10.2	1.6	25.7

Data from discharge collected in drop boxes:

		Rotor and sieve discharge in drop boxes lb/ac	Rotor and sieve separation losses, "sinker" portion lb/ac
201	550	2240	36.3 [18][bb]
202	950	1670	30.8 [20]
203	750	4024	42.5 [16]

a) On-site analysis made use of water separation for rotor and sieve discharge samples

b) As evaluated at completion of on-site processing ("sinker" portion, partially dried, not dehulled and compared to net yield on green weight basis).

bb) Numbers in brackets are loss rank totals by observer team in the field. (highest number = lowest observed loss)

Table 2. Data from lab analysis of samples.

Run No. 85-	Net yield: % Recovery[c]	Net yield: Processed[c] lb/ac	% Broken[d]	Discharge loss[e] — Separation loss, rotor: lb/ac	rotor: % of net	sieve: lb/ac	sieve: % of net	Threshing loss: lb/ac	Threshing loss: % of net	Total: lb/ac	Total: % of net
101	42.9	236	3.4	NA	NA	12.2	5.2	NA	NA	19.6	8.3
102	43.8	330	2.2	14.0	4.3	11.2	3.4	13.9	4.2	39.2	11.9
103	40.8	271	6.0	16.2	6.0	11.0	4.0	9.7	3.6	36.9	13.6
104	37.9	98	7.8	6.4	6.5	12.0	12.1	2.3	2.4	20.6	21.0
105	41.2	265	3.7	9.2	3.5	17.1	6.4	5.9	2.2	32.2	12.2
106	45.5	339	4.4	21.8	6.4	19.0	5.6	22.5	6.6	63.3	18.7
107	46.0	339	1.9	22.7	6.7	8.7	2.6	17.9	5.3	49.3	14.6
108	38.8	281	6.9	18.4	6.5	8.8	3.1	9.6	3.4	36.8	13.1
109	43.8	273	3.2	27.5	10.0	7.5	2.8	15.2	5.6	50.2	18.4

Data from discharge collected in drop boxes:

	Total rotor and sieve separation loss (lb/ac)	Threshing loss lb/ac	Total loss lb/ac
201	27.2	4.4 [16.5][f]	31.7
202	24.8	11.0 [25.0]	35.8
203	30.2	11.0 [12.5]	41.2

c) By dehulling, sorting for over 2-1/2/64" width, drying, weighing, calculating at 7% Mwb and comparing to green weight.

d) Percent by weight of kernel pieces 1/4" or less in length in a dehulled sample.

e) By dehulling, sorting for over 2-1/2/64" width, drying, weighing and calculating at 7% Mwb. (Separation loss results include both the "sinker" kernels and the "floater" kernels.)

f) Numbers in brackets are loss rank totals by observer team in the field. (highest number = lowest observed loss)

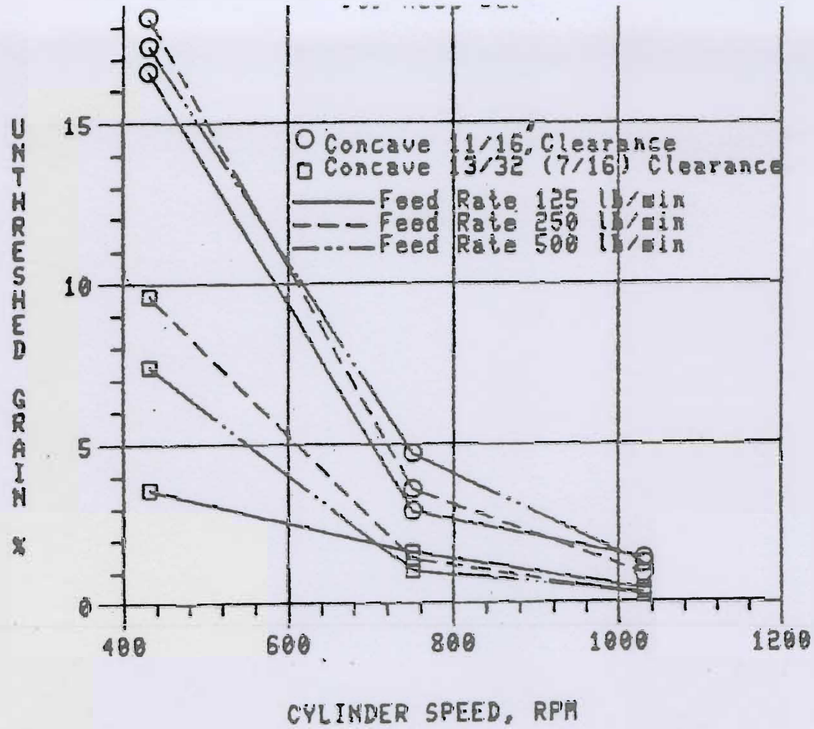

Figure 1.

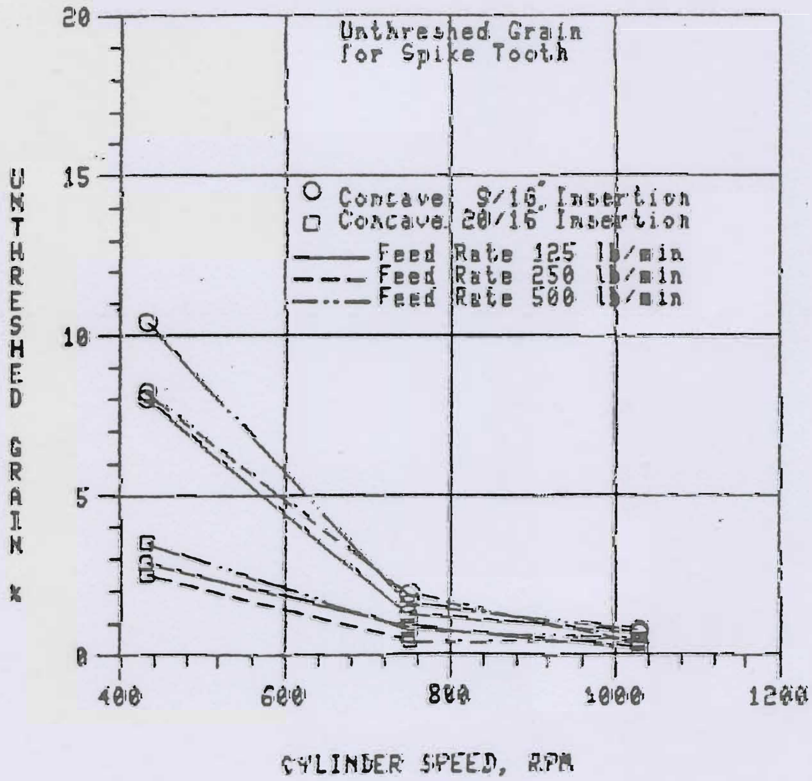

Figure 2.

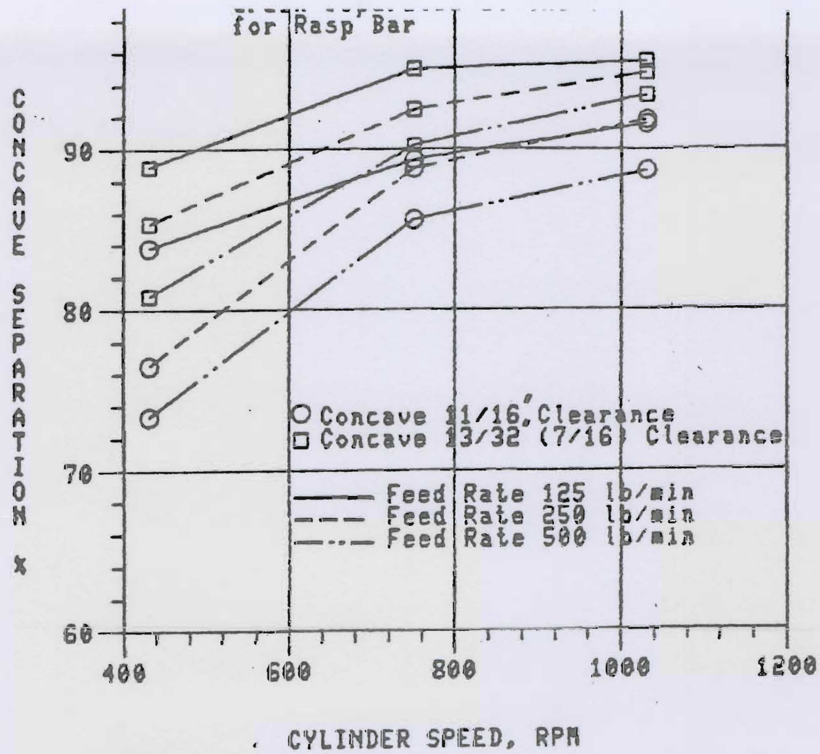

Figure 3.

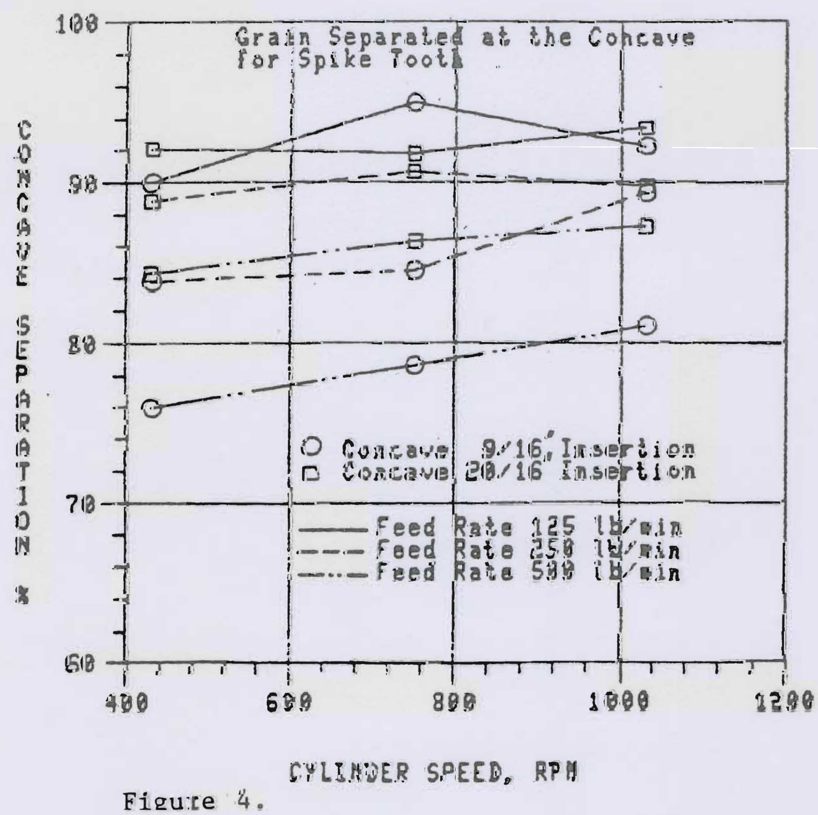

Figure 4.

John Strait, Arni Sigurdsson, Mitchell Voehl, J. J. Boedicker

Wild rice processing research during 1985 was principally concerned with the design and performance of hullers. One M.S. thesis was substantially completed, and preliminary work on a possible Ph.D. research project was started.

Hulling Research

Laboratory Studies

Tests were conducted to compare the hulling characteristics of nitrile and carbox, two buna-N compounds, with neoprene. Three-inch strips of each compound were attached to 10 3/4 inch diameter steel rolls. Each of the compounds was within a hardness range of 70-73 durometer. The rolls were installed in the laboratory test huller which is equipped with a feeder which is movable to feed a particular strip. Frozen wild rice was parched and divided into uniform test lots. The hulled rice was analyzed according to our usual procedures to determine percentages of whole, broken and unhulled kernels.

The results of the laboratory tests indicated that nitrile was approximately equal to neoprene with respect to hull removal and kernel damage. Nitrile is considered to have slightly better resistance to abrasive wear than neoprene. Carbox was not as good as nitrile and neoprene with respect to hull removal.

Processing Plant Studies

Two rolls were covered with 5/8-inch thick 67 durometer nitrile and installed in the experimental huller in Deerwood. The other pair of rolls on the experimental huller was neoprene covered rolls which were used the previous processing season.

Hull removal by the nitrile rolls was poor in comparison to that accomplished with neoprene rolls. Their poor performance was totally unexpected in view of the laboratory tests. Because there has usually been good correlation between laboratory tests and prototype performance, one can only speculate that the nitrile supplied for the laboratory studies was significantly different from the nitrile subsequently used to cover the huller rolls. It would be interesting but probably not worthwhile to repeat laboratory studies with newly acquired materials. Results experienced at the Gibbs plant with nitrile covered rolls were substantially the same as those at Deerwood.

Commercially Built Hullers

Two hullers similar to the experimental huller used at Deerwood were built by Temco for use at the Gibbs plant at Deer River. Some relatively minor design changes were made, and new drawings to incorporate those changes were completed. All the functional components of the experimental huller were retained. The design changes that were made were largely related to clearances and accessibility and collecting the rice as

Some Observations Related to Hullers

There appears to be a complex interrelationship involving the condition of the green rice delivered to the processing plant, the handling of the green rice prior to parching, parching methods and procedures, properties of the finished rice, and the performance of roller type hullers. For example, a sample set collected from the huller discharge at Deerwood on September 20 and analyzed in the laboratory produced the following results: moisture content of hulled kernels = 7.8%, broken (less than 1/4") = 2.2%, unhulled kernels = 8.6%. This is a very low figure for brokens and particularly so considering that likely some were broken by the combine. One would like to see fewer unhulled kernels, but the percentage shown reflects the hulling problems associated with rice parched to higher moisture levels. These results contrast sharply with considerably less favorable results observed at certain other times. Of course, it is well proven that one cannot at the same time achieve both minimum percentages of broken and unhulled kernels.

It is advantageous to accomplish reasonably complete hull removal since processing rerun rice from the gravity tables presents problems. Feeding rerun rice into roller type hullers results in severe damage to the huller rolls. Kernel fragments become imbedded in the rolls and do considerable damage. A modified polishing tube seems to be reasonably well adapted to hulling rerun rice. Additional kernel breakage always occurs each time the rerun rice is passed through a hulling device.

It appears that about 67 durometer neoprene is the best material that we know of for roller type hullers. Neoprene is the best compound we have tested to date with respect to hull removal. The 67 durometer value represents a compromise between completeness of hull removal and achieving low levels of breakage. While an exact durometer value is difficult to achieve, the rubber fabricator should be able to come within 3 or 4 durometer numbers of the exact value specified.

It is essential that the processor pay close attention to roll clearance and condition for optimum huller performance. Effective feeder and roll conditioning systems along with sensitive means for adjusting roll clearance are helpful in achieving continuous high huller performance.

Continuous Flow Parcher

Experimental work with the continuous flow parcher at Deerwood has been terminated. The parcher has been dismantled to make way for rearrangement of the plant.

Data collected and observations made during its experimental use showed that the parcher had both advantages and disadvantages when compared to the rotary drum units. It proved to be very energy efficient. Typically 9 to 10 gallons of propane were required to parch 1000 pounds of green rice. Labor costs with a full scale unit would be comparatively low. Product uniformity is more easily achieved.

Higher first cost and the lack of a dedicated and competent supplier are important disadvantages. Breakdowns, where the processor is depending upon one or two units, could disrupt his schedules with serious consequences. Another disadvantage that has recently surfaced is that the parcher is not capable of producing a uniformly parched product (kernel to kernel) at the higher moisture contents desired by some producers. The basic operating principle upon which the parcher is designed to operate requires that the rice be parched to a moisture content of about 5% if good uniformity of moisture content among kernels is to be achieved.

It has been noted in previous reports that wild rice kernels parched in the continuous flow unit are usually not as strong in bending as those processed in the rotary drum parchers. If hulled with hard rolls, as for example, 95 durometer, kernel breakage would be severe. However, if hulled in the UM experimental huller with neoprene rolls of about 65 durometer, resulting kernel damage was little or no greater than that which occurred when rice from the rotary drum parchers was hulled in the UM huller.

Experience with the continuous flow parcher at Deerwood indicated the need for certain design changes both from a mechanical and product viewpoint. While some of the disadvantages discussed could be somewhat diminished by design changes, it would be difficult to eliminate any of them completely.

Thesis Projects

Mitch Voehl has substantially completed his M.S. thesis which is a study of the aerodynamic properties of wild rice kernels in a moving air stream. Results of this research could possibly serve as the basis for the design of a device to separate hulls and to a certain degree unhulled kernels from wild rice after it has passed through the huller. Arni Sigurdsson has begun preliminary studies to determine if this separation can be accomplished by mechanical or a combination of mechanical and fluid means. Research along this line may be used as his Ph.D. thesis project.

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Wild Rice Market Shows Vigorous Growth

Ronald N. Nelson and Reynold P. Dahl*

Wild rice is native to many lakes and slow-moving streams of northern Minnesota and southern Canada. It was a staple foodstuff in the diets of the native Indians in these areas and was one of the first items traded by the Indians to the French in the New World. Its image as a gourmet food can be traced back to this early period.

Commercial production of cultivated wild rice in Minnesota, however, dates back only to the mid-1960s. Production has expanded rapidly in Minnesota as has production in California where wild rice was introduced eight years ago. Nationwide, the wild rice industry has undergone a dramatic transformation in the last 15 years. Today, wild rice shows substantial promise as a new agricultural crop.

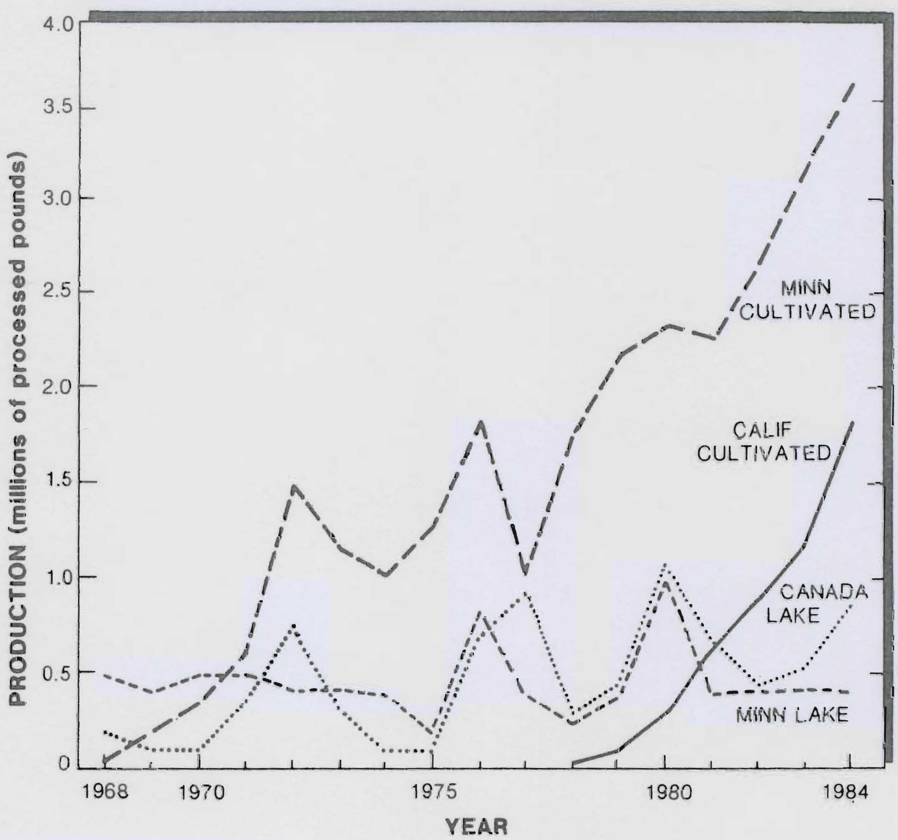
Since 1969, the Minnesota Legislature has provided special funding for wild rice research by the University of Minnesota Agricultural Experiment Station. This research has generated significant advances in wild rice cultivation, including improved varieties and production practices. Yields already have increased by fivefold over early cultivation experiments.[1] But, economic information on the wild rice industry has been sketchy and incomplete.

Three years ago the University of Minnesota Department of Agricultural and Applied Economics began a research study on the economics of marketing wild rice. The first phase of this study was completed with the publication of a research report which provided a historical and modern overview of the economics of wild rice production, prices, and marketing.[2] The objectives of this article are to highlight and update the results and economic data contained in that publication, and to report some results of research currently underway on the consumer demand for wild rice.

Trends in the expansion of consumer demand for wild rice are of crucial importance to the industry. The wild rice industry should make an effort to gear future production expansion to the market's capacity to absorb wild rice at prices that provide a satisfactory return to growers. Prices of such a specialty crop can tumble precipitously if production increases more rapidly than consumer demand.

THE SUPPLY OF WILD RICE

The supply of wild rice for the United States market comes from the harvest of Minnesota and Canadian lakes and the production of cultivated wild rice on farms in Minnesota and California. The trends in production from 1968 to 1984 for each of these sources of supply are shown in Figure 1. The economics of supply and prospects for future expansion are briefly discussed below.



*Ronald N. Nelson is research assistant and Reynold P. Dahl is professor, Department of Agricultural and Applied Economics.

[1] Oelke, Ervin A., ed. *Wild Rice Production Practices in Minnesota*, University of Minnesota Agricultural Extension Service, AG-BU-0546.

[2] Winchell, Elizabeth H., and Dahl, Reynold P. *Wild Rice Pro-*

Ronald N. Nelson, research assistant, and Reynold P. Dahl, professor, Department of Agricultural and Applied Economics.

Lake Wild Rice

Wild rice continues to grow, as it has for thousands of years, along the edges of lakes in northern Minnesota, southern Ontario, and Manitoba. However, production levels vary widely from year to year. Generally, an excellent crop may be expected one year out of four, accompanied by one poor crop and two fair crops. These production variations are due to excessive fluctuations in water levels at critical points in plant development, to wind damage near harvest, and to other factors.

Production data for lake wild rice in both Minnesota and Canada are often estimates subject to error. The trend in production in Minnesota is probably steady to slightly declining. Harvesting on Minnesota Indian reservations and public lakes is restricted to the traditional canoe-and-flail method. Little developmental efforts have occurred on either Indian reservations or state-owned lakes because present policies and practices make no provision for individual production rights and, hence, do not provide incentives to increase production. As the production of cultivated wild rice has increased in Minnesota, the share of lake wild rice in the total supply has declined. In 1984, Minnesota produced 450,000 processed pounds of lake wild rice and 3.6 million processed pounds of cultivated wild rice (Figure 1).

Like Minnesota, the production of lake wild rice in the Canadian provinces of Manitoba and Ontario has not shown a discernible upward trend. Uncertainty over provincial government wild rice policies has, to date, restrained expansion of the industry. Production in Saskatchewan increased from [illegible] to 480,000 pounds in 1984. Saskatchewan, which had no indigenous wild rice, is engaged in an extensive lake seeding program. The provincial government has encouraged the planting of wild rice as a source of income for the native Cree Indians. The keys to the impressive success of this program are provisions for individual production rights on public-owned lakes and more efficient harvesting methods than the traditional canoe-and-flail. Production of lake wild rice in Saskatchewan will probably continue to expand. The supply of Canadian wild rice is important because about 80 percent of the Canadian production is marketed in the United States.

Cultivated Wild Rice

Production of cultivated wild rice in north central Minnesota increased from only 36,000 processed pounds in 1968 to 3.6 million pounds in 1984 (Figure 1). Here previously unused land, often peat bog, has been developed into paddies that can be flooded in the spring and drained in the fall before harvest. Cultivated wild rice production is highly capital intensive due to the cost of land development and the specially designed equipment required.

Production is centered around the Minnesota communities of Aitkin, Clearbrook, Grand Rapids, and Waskish (Figure 2). Acres of productive paddies totaled about 25,000 acres in 1982, not including dikes and ditches. Yields varied from 70 to 200 processed pounds per acre with the median yield about 150 pounds. Currently, median yields are approaching 200 pounds per acre.

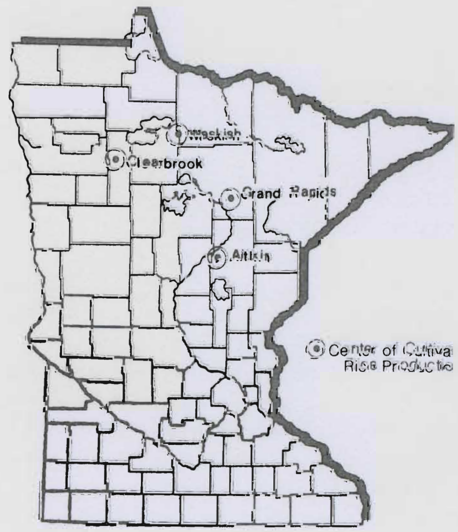
There were 58 wild rice farms in [illegible] cultivated wild rice in Minnesota.

Wild rice farms are, for the most part, family farms. Individuals or extended families operated 69 percent of the farms and produced nearly 60 percent of Minnesota's cultivated wild rice crop in 1982. Unrelated owners, commonly neighbors, operated 22 percent of the farms while only 9 percent of the farms have absentee owners with hired operators.

Production expansion of cultivated wild rice in Minnesota will be influenced by wild rice prices and the availability of suitable land and water. In 1982, Minnesota growers reported owning or renting 15,611 acres of land suitable for wild rice development. Most of this land, 10,603 acres, is in the Waskish area.

The production of cultivated wild rice in California began in 1977 and has expanded at a rapid rate reaching 1.8 million processed pounds in 1984. California's wild rice production is divided among three distinct regions each with different climatic conditions: the Sacramento Valley, Lake and Mendocino counties, and Shasta and Lassen counties.

In the Sacramento Valley, which has the largest production of the three regions, rice farmers have shifted some of their acres to wild rice. Yields per acre are almost twice those obtained by Minnesota growers. Wild rice is an attractive alternative crop for rice farmers since they are able to use their existing



Although wild rice and rice are not closely related botanically, the production technology is transferable. Expansion in wild rice production in the Sacramento Valley will largely depend on the price relationship between wild rice and rice. If wild rice prices are favorable relative to rice prices, wild rice production will probably expand. Current rice prices are near an all-time low, so the interest in growing wild rice should be stimulated.

In Lake and Mendocino counties, wild rice production is located along the marshy fringes of lakes. Since much of the suitable land has already been brought into production, further expansion will be minimal.

In the high Sierra Nevada mountain counties of Shasta and Lassen, wild rice is grown along the banks of rivers on what previously was wiregrass pasture. Ranchers here have found wild rice an attractive alternative revenue source because of unfavorable beef prices. If wild rice prices are favorable, expanded production is likely.

Most California growers contract with a processor for production and sale of wild rice before planting. This may inhibit production expansion because processors will probably gear such contracting to the growth in the market for wild rice.

Table 1. Wild Rice Production and Wholesale Prices, 1968-1984.

Year	Total Production[1] (million processed pounds)	Wholesale Prices[2] ($ per processed pound)
1968	.69	3.27
1969	.62	2.66
1970	.94	2.88
1971	1.43	2.71
1972	2.65	2.34
1973	1.92	2.11
1974	1.50	2.37
1975	1.55	2.51
1976	3.39	2.68
1977	2.39	4.25
1978	2.29	5.15
1979	2.96	5.01
1980	4.67	4.47
1981	3.91	3.79
1982	4.39	3.40
1983	5.27	3.35
1984	6.69	3.30

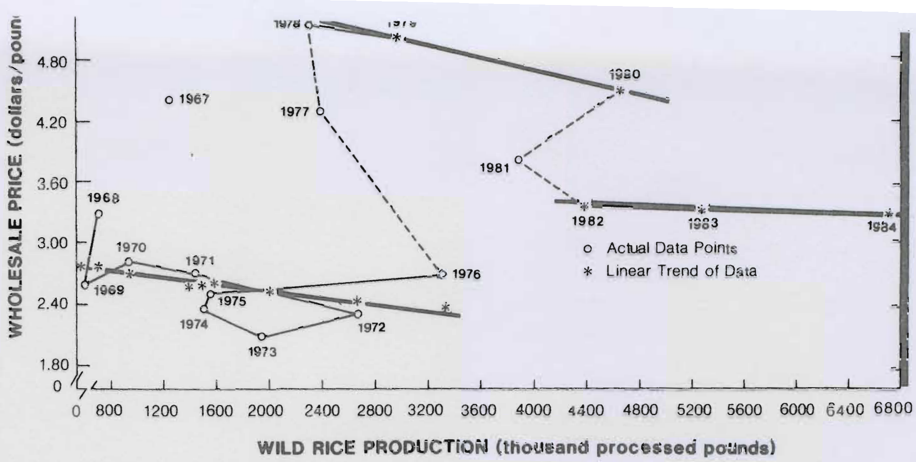


Figure 3. Wild Rice Demand Expansion, 1968-1984.

MARKETS, PRICES AND CONSUMER DEMAND

Production and Demand Expand

When only lake wild rice was produced, prices varied widely from year to year in response to changes in supply. Instability in both prices and supply discouraged major food processing firms from introducing products containing wild rice. These uncertainties created too many unknowns to justify product development and promotion expenses.

To overcome these problems, in 1965 Uncle Ben's contracted for some of the first cultivated wild rice acreage. The continuing success of paddy cultivation has significantly reduced production and price variability. This stability has created conditions favorable for the industry to promote wild rice products.

Total wild rice production in the United States and Canada from 1968 to 1984 is shown in Table 1. While production oscillated in the early years, it has consistently and substantially expanded since 1981, reaching 6.69 million processed pounds in 1984. Most, if not all, production growth is attributable to cultivated wild rice.

The interrelationship between wild rice production, prices, and demand expansion is illustrated in Figure 3, a graphic representation of Table 1 data. Three distinquishable periods are identified. Between 1968 and 1976, wild paddy harvests. Prices fell slightly as the supply of cultivated wild rice expanded fourfold.

An ill-fated attempt by a marketing cooperative to control supply and raise the level of prices resulted in the second period covering the years 1978 to 1980. The withholding of large stocks raised prices to levels of a decade before. However, the price increase was short-lived because it induced an increase in production. Expansion in Minnesota was modest as producers understood the reasons for this price increase. But in California, wild rice took a firm hold with production doubling annually through 1981.

The third period began after high inventory storage costs forced the sale of stocks, and prices returned to market-determined levels. Wild rice production increased 26 percent per year between 1982 and 1984. The market has been able to absorb these large production increases of nearly 1.2 million pounds per year with only a small downward adjustment in wholesale prices.[3] This indicates that the consumer demand for wild rice has expanded at a vigorous rate of approximately 52 percent over the last two years.

What has accounted for the rapid growth in the wild rice market? Some answers to this question emerge from a survey of the market outlets for wild rice.

Sales by Market Outlet

The division of the wild rice supply

Although wild rice and rice are not closely related botanically, the production technology is transferable. Expansion in wild rice production in the Sacramento Valley will largely depend on the price relationship between wild rice and rice. If wild rice prices are favorable relative to rice prices, wild rice production will probably expand. Current rice prices are near an all-time low, so the interest in growing wild rice should be stimulated.

In Lake and Mendocino counties, wild rice production is located along the marshy fringes of lakes. Since much of the suitable land has already been brought into production, further expansion will be minimal.

In the high Sierra Nevada mountain counties of Shasta and Lassen, wild rice is grown along the banks of rivers on what previously was wiregrass pasture. Ranchers here have found wild rice an attractive alternative revenue source because of unfavorable beef prices. If wild rice prices are favorable, expanded production is likely.

Most California growers contract with a processor for production and sale of wild rice before planting. This may inhibit production expansion because processors will probably gear such contracting to the growth in the market for wild rice.

Table 1. Wild Rice Production and Wholesale Prices, 1968-1984.

Year	Total Production[1] (million processed pounds)	Wholesale Prices[2] ($ per processed pound)
1968	.69	3.27
1969	.62	2.66
1970	.94	2.88
1971	1.43	2.71
1972	2.65	2.34
1973	1.92	2.11
1974	1.50	2.37
1975	1.55	2.51
1976	3.39	2.68
1977	2.39	4.25
1978	2.29	5.15
1979	2.96	5.01
1980	4.67	4.47
1981	3.91	3.79
1982	4.39	3.40
1983	5.27	3.35
1984	6.69	3.30

[1]Estimated total wild rice production, United States and

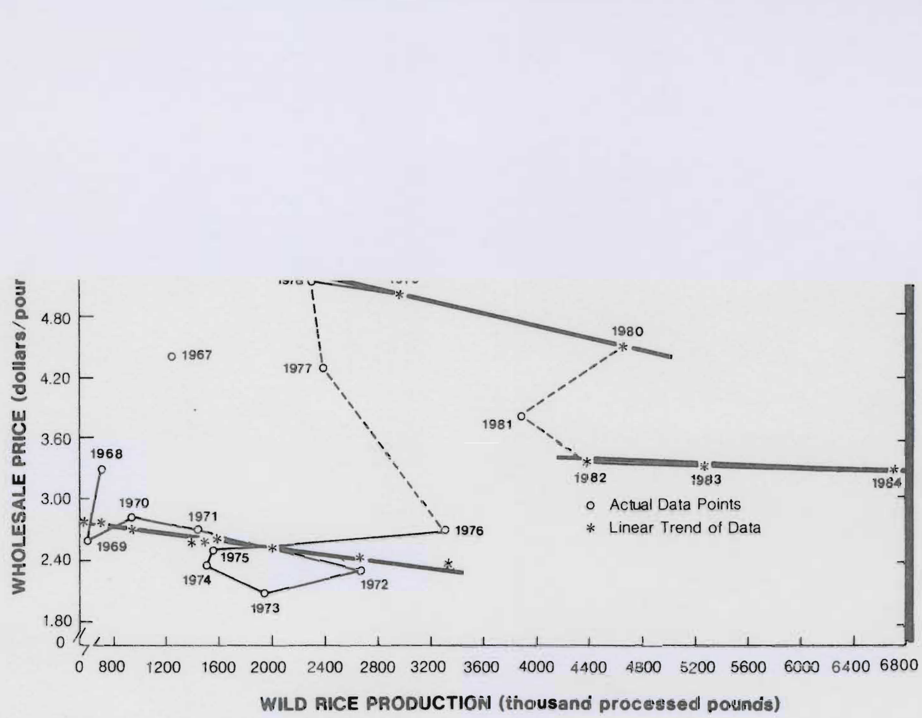


Figure 3. Wild Rice Demand Expansion, 1968-1984.

MARKETS, PRICES AND CONSUMER DEMAND

Production and Demand Expand

When only lake wild rice was produced, prices varied widely from year to year in response to changes in supply. Instability in both prices and supply discouraged major food processing firms from introducing products containing wild rice. These uncertainties created too many unknowns to justify product development and promotion expenses.

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including United Wild Rice, Minnesota Rice Growers Cooperative, and independent growers were estimated to total 3.8 million processed pounds. Food manufacturers accounted for 2.6 million pounds, or nearly two-thirds of total sales. These are mostly firms like Uncle Ben's that prepare, package, and market blends of wild rice and long grain rice. The remaining one-third of total wild rice sales were divided among grocers, restaurants, wholesalers, and other market outlets.

The Wild Rice Blend Market

Uncle Ben's introduced a package blend of wild rice, long grain rice, and herbs in 1961. It was widely accepted by consumers and was a significant factor in expanding the market demand for wild rice. The success of this product encouraged other companies to introduce their own wild rice-rice blends. These included Golden Grain (Rice-a-Roni), General Foods (Minute Rice), and Green Giant. Although blends typically contain only about 10 to 15 percent wild rice by weight, their increased sales have made them the dominant factor in the wild rice market. If blends had not been introduced, the cultivated wild rice industry may not have developed.

The variety of blends now sold in the market has expanded beyond those containing rice. Food manufacturers also market different blend products, such as soup and sidedish mixes, containing wild rice and a variety of vegetables. Convenience foods, such as dehydrated mixes and frozen entrees containing wild rice, have also been developed. The market demand for wild rice blends has expanded by about 15 percent per year since their introduction. This rate may be growing, as previously described, as consumers receive greater exposure to wild rice. One industry source estimates that the wild rice blend market may account for 80 percent of total wild rice sales.

The only exposure many consumers have had to wild rice is as a blend with other ingredients. According to industry estimates, consumer awareness of wild rice increased from 8 percent when blends were first introduced to 30 percent in recent years.

Food manufacturers usually prefer cultivated wild rice over lake wild rice.

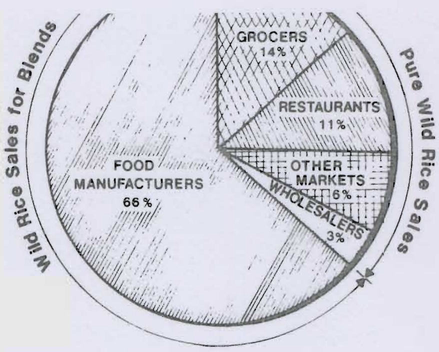

Figure 4. Wild Rice Sales by Market Outlet, 1982 Crop Year.

Cooking time is substantially greater for this rice, and, since there are fewer kernels per pound, mixes of longer grain rice appear more sparse than ones of shorter grains. Therefore, blend producers prefer shorter grain wild rice produced on paddies. The dominance of the blend segment of the market has reduced the premium once commanded by longer-grain, lake wild rice.

The Pure Wild Rice Market

Prior to the development of wild rice blends, pure wild rice was sold exclusively as a gourmet product. Production instability, inventory speculation, and associated high prices helped to support this image. Most consumers were residents of the wild rice producing areas. Concentrations of consumption were centered in Minnesota with as much as 75 percent of wild rice sales, and in the Twin Cities where 50 percent of these sales were made.

Today, the dominance of the blend market is evidenced by the fact that only about one-third of wild rice sales are in the pure form (Figure 4). Even a large portion of these sales eventually reach the consumer in the form of blends prepared by restaurants and other users. Long grain wild rice continues to be the preferred size for the pure market sector. However, some buyers prefer to use shorter or broken kernels—usually available at a discount—for soups and stuffings.

Consumer purchases of pure wild rice are markedly higher in Minnesota than elsewhere due to the greater familiarity and lower prices. Minnesota residents also buy a substantial amount of

gages in its own campaigns to expand demand. The major participant in this program of pure wild rice promotion is the Minnesota Paddy Wild Rice Research and Promotion Council based at Grand Rapids. Promotion funding is based on a checkoff system from growers through their processors.

Since being established in 1969, the council has been actively promoting wild rice worldwide by providing cooking information and recipes and by participating in trade fairs. An annual promotional event is the food editors tour where nationally known writers for food publications are invited to tour grower and processing operations and to sample gourmet meals featuring wild rice. The lobbying of the council prompted the Minnesota Legislature to designate wild rice as "Minnesota's Official State Grain." Promotions labeling wild rice as the "Caviar of Grains" have led to a recent inclusion of wild rice into the menus of formal White House dinners. And, members of the council led a trade mission to Japan in 1982, helping to lift restrictions for importing wild rice and providing the Japanese with their first exposure to its varied uses.

Why haven't higher percentage wild rice blends been introduced by food manufacturers? Consumer preference research indicates that there is a market for blends of perhaps 40 percent, but such products have not been introduced. Furthermore, none of the major food companies offers a pure wild rice product. However, if supply stability and expansion continues, this may encourage the development of these products.

MARKETING WILD RICE

Processing

Wild rice from the lakes and cultivated paddies requires processing before it is sold for consumption. One hundred pounds of unprocessed (green) wild rice typically yield 40 pounds of processed grain. Processing involves two operations.

First, the wild rice is laid in long windrows to cure. The curing process serves the dual purpose of loosening the hull on the grain and storing the wild rice until processing capacity becomes

The second stage of processing is parching. The wild rice is heated to reduce the moisture content from about 40 percent to 7 percent. During the intense heat of parching, contamination introduced during harvesting or curing is largely eliminated. After the hulls are separated from the parched grain, the wild rice is cleaned, sized, and packaged.

In 1982, Minnesota had 22 wild rice processing plants ranging from large operations to small plants in the owner's backyard. California had two processing plants, one of which is operated by a large Minnesota processor with plants in both Minnesota and California.

Processors play an important role in marketing wild rice. They purchase unprocessed Minnesota and Canadian lake wild rice and sell the processed grain to food manufacturers, retailers, and other buyers. Processors also purchase and market cultivated wild rice and/or process wild rice for growers on a custom basis. California processors, unlike those in Minnesota, purchase wild rice solely on contract. Contracts are generally negotiated before spring planting and, in some cases, are forward priced. In other cases, a minimum price is stipulated and upward adjustments are made if warranted by market prices at harvest.

Marketing Cooperatives

Much of Minnesota's cultivated wild rice is marketed through two wild rice cooperatives. These cooperatives, United Wild Rice and Minnesota Rice Growers (MRG), together have 20 Minnesota farm members and marketed an estimated 62 percent of Minnesota's cultivated production in 1982.

MRG, the smaller of the two cooperatives, has seven members and restricts its activities to the pooling and sale of members' wild rice. To date, it has sold mainly to one large food manufacturer. Since MRG owns no facilities, it arranges for custom processing, and members perform most of the managerial and sales duties.

United, in contrast, takes an active role in marketing and product development. It has invested in a processing plant and an instantizing plant that are among the industry's most modern. The cooperative also supports a manager

Marketing by Independent Growers

Two-thirds of all Minnesota wild rice farms are not affiliated with a cooperative, and the farmers must do their own marketing. Together they produce nearly 40 percent of Minnesota's cultivated wild rice.

About half of all independent growers sell exclusively through their processor. The rest are either integrated grower-processors or growers who sell their wild rice through a variety of market outlets.

The terms of sale between independent growers and processors vary substantially. Some fix the price at harvest; others offer a guaranteed base price plus a sliding premium if prices rise above specified levels; still others delay pricing up to seven months after delivery. Contracts establishing prices prior to harvest are rarely available to independent growers.

PRICE DISCOVERY

Wild rice prices are discovered through the interaction of buyers and sellers in the marketing system. Prices are established in a two-tier process. In the early spring large food manufacturers, such as Uncle Ben's, negotiate prepriced contracts with large sellers, locking in prices for much of the annual production. Access to these prepriced contracts is an important advantage to growers who are members of marketing cooperatives.

The remaining wild rice, the exact quantity of which is unknown until after the harvest, is priced after the contracts are fulfilled. Because many contracts are filled in the months following harvest rather than at harvest, the supply and demand situation for the residual wild rice may not clarify until six months after harvest. The absence of reliable price and quantity information tends to extend this period of uncertainty. Many independent growers of cultivated wild rice are forced to sell in the residual market and therefore must wait for the residual price to be determined.

BETTER MARKET INFORMATION NEEDED

The efficiency of price discovery and resource allocation in the wild rice

tant degree, the industry has been the victim of its own history of wild rice speculators, who relied on strict secrecy and even false and misleading market information to insure exploitation of production and price variability. Even though market conditions changed with the introduction of cultivated wild rice, distrust remains and has impeded progress and cooperation in the industry.

A recent study of improving the marketing of California lettuce summarizes the importance of economic information as follows:

> "The need for economic information for marketing food products is widely recognized. It is viewed as the lubricant for the wheels of industry whether for making farming decisions, product marketing decisions by processors, or capital investment decisions by individuals and businesses.
>
> "When the amount, timing, or accuracy of economic information is inadequate, there are often costly misallocations of resources. As the quantity and quality of economic information increases, uncertainty diminishes, and the decision-making process is enhanced."[4]

Lettuce growers in California began a program of exchanging economic information in the early 1970s. Analysis of the program indicated that it reduced uncertainty and price variability and allowed better planning for more efficient production and marketing.

The wild rice industry might profit from the experience of the lettuce industry. Without timely economic information participants in the wild rice industry must make decisions as producers, processors, and buyers that they may not have made if full information were available. Inasmuch as the true market conditions will eventually prevail despite the lack of information, these participants suffer the consequences of acting on inaccurate or incomplete information. The industry as a whole may also suffer from the misallocation of resources; growth of the market consequently would be retarded.

Much basic information on wild rice production, stocks, and prices could be released without harm to indi-

[4]Garvan, Kinney, Pisani, and Skinner, "Lettuce Growers

Statistics Service, that could aggregate data so individuals could not be identified. Such information would reduce uncertainty and costly misallocations of resources in the wild rice industry.

SUMMARY

Evidence of rapid expansion in both the supply and demand for wild rice is impressive. Cultivated wild rice has reduced interyear production variability and also made it possible to expand production. This has stabilized prices and reduced uncertainty. Expanding product development and market promotion have stimulated the demand for wild rice. Wild rice has been changed from a local and gourmet delicacy to an ingredient in mass-marketed foods. most markets.

The dominance of the cultivated wild rice industry is clearly established. This segment will continue to produce 80 percent or more of each year's crop. But this producing sector may not have developed without the introduction of the wild rice blend market. This demand sector is the major market outlet for the supply. However, its future success and profitability cannot be assured without a continued stability in supply and prices.

Thus, the interdependence of the primary producers and users is established. Though the cultivated industry would be much smaller today had it not been for the introduction of wild rice blends, so it is that the future of wild

It is in the best interest of producers to gage their production expansion to the rate of demand expansion. If supply outstrips demand, price will fall precipitously. It is in the best interest of food manufacturers to innovatively develop and market new wild rice products at rates geared to the rate of supply expansion. To do otherwise wastes development and advertising resources better spent elsewhere. Each market segment has a hand in the continued success or future decline of the other. Their intercooperation is essential. Future growth and stability in the wild rice industry will be assisted by improved market information.

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