Minnesota Wild Rice Research 1988

Miscellaneous Publication 59-1989
Minnesota Agricultural Experiment Station
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St. Paul, Minnesota

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CONTENTS

WILD RICE PRODUCTION RESEARCH - 1988

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The 1988 growing season was one of the warmest and driest on record, especially in the northwestern part of the state. At all 3 locations, Aitkin, Grand Rapids and Crookston, the total growing degree days (GDD) during April through August in 1988 were considerably higher than normal, reflecting the warmer temperatures (Table 1). The total GDD were also higher at Grand Rapids and Crookston but were lower at Aitkin than for 1987.

Table 1. Growing degree days[a] comparisons for 1987, 1988 and normal.

Month	Aitkin			Grand Rapids			Crookston		
	1987	1988	Normal	1987	1988	Normal	1987	1988	Normal
	- - - - - - - - - - - - - - - - GDD - - - - - - - - - - - - - - - -								
April	345	120	114	311	99	107	349	166	132
May	632	642	414	520	620	381	661	702	438
June	900	792	677	765	826	634	878	954	710
July	981	943	871	938	970	817	1053	1034	900
August	812	816	785	751	810	733	801	980	850
Total	3670	3314	2861	3285	3325	2672	3742	3836	3030

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

Total precipitation during April through August was below normal at all 3 locations with the greatest difference at Crookston (Table 2). April was especially dry at all 3 locations. Aitkin was the wettest location with actually more moisture than in 1987 during the growing season. The dry winter of 1987-88 and the dry 1988 spring resulted in a shortage of flood water, consequently some fields were not flooded in 1988. This was the same situation as in 1987.

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

Table 2. Precipitation comparisons for 1987, 1988 and normal.

Month	Aitkin			Grand Rapids			Crookston		
	1987	1988	Normal	1987	1988	Normal	1987	1988	Normal
	- - - - - - - - - - - - - - - inches - - - - - - - - - - - - - - -								
April	0.15	0.15	2.27	0.31	0.40	1.99	0.29	0.00	1.39
May	2.72	3.16	3.39	4.90	1.18	3.16	4.37	1.61	2.20
June	1.00	3.19	3.83	1.16	3.06	3.79	0.89	1.52	3.61
July	4.36	3.96	4.79	8.46	1.66	4.12	5.20	1.84	3.17
August	3.98	7.08	4.19	2.83	10.03	3.38	3.08	1.56	3.04
Total	12.12	17.54	18.47	17.66	16.33	16.44	13.83	6.53	13.41

Total wild rice produced in 1988 was nearly the same as in 1987 (Table 3). Thus, the production has been lower during the last 2 years compared to the record production of 1986. Wild rice acreage was down again in 1988 as it was in 1987 due to lack of water for flooding. In addition, some acreage in 1988 was planted to other crops due to declining prices for wild rice. Acreage in production in 1988 was estimated to be about 18,000 compared to 20,000 in 1987.

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

Year	Production	Year	Production
1968	36	1978	1761
69	160	79	2155
70	364	80	2320
71	608	81	2274
72	1496	82	2697
73	1200	82	3200
74	1036	84	3639
75	1233	85	5172
76	1809	86	5313
77	1031	87	4200
		88	4200[a]

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

Research

The 1988 research focused on weed control, residue removal-nitrogen fertilization-disease incidence interactions and effects of drying wild rice seed before storage on seed viability and storability. The research was conducted on University plot land at Grand Rapids and St. Paul and on the newly established research area near Aitkin. Some of our research plots at Grand Rapids were lost due

to the very warm water temperatures in May which caused many seedlings to die resulting in very poor stands.

Weed Control Research

Growth and Development of Giant Burreed

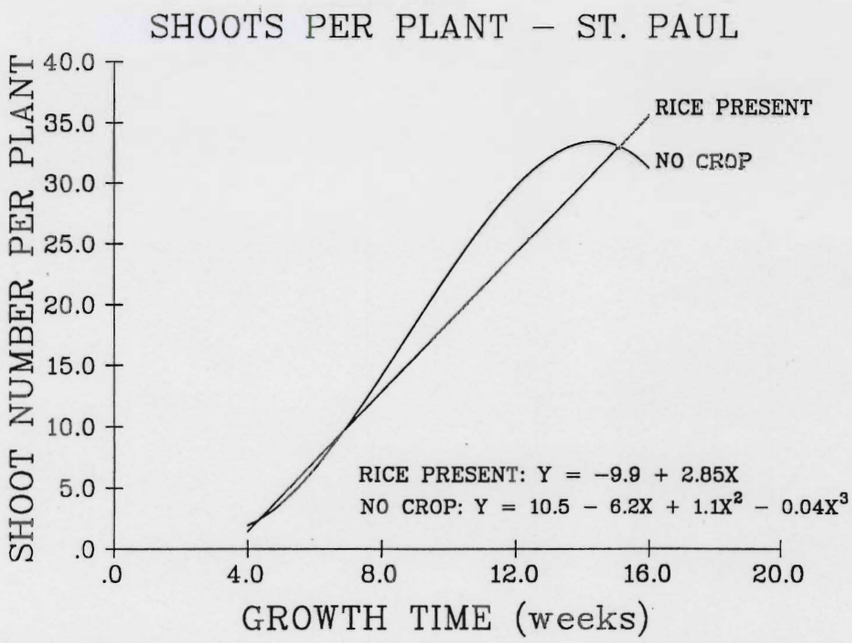
Field experiments were conducted in 1988 to examine the growth and development of giant burreed throughout the growing season. The experiment was conducted in 4-ft by 4-ft boxes at the St. Paul campus, and 4-ft diameter pools at the North Central Experiment Station at Grand Rapids. Three giant burreed corms were planted in each box or pool (May 13 at Grands Rapids, and May 20 at St. Paul), and were grown under flooded conditions for 16 weeks. The entire box or pool was kept in either a crop free environment or had wild rice growing in competition with giant burreed. Enough boxes or pools were planted so that each treatment (wild rice competition vs. no competition) could be harvested 7 times during the 16 week season. The experimental design was a randomized complete block with 3 replicates of each treatment by harvest-date combination.

The height of each giant burreed shoot and wild rice plant was measured at weekly intervals throughout the experiment. Plots were harvested at biweekly intervals, beginning 4 weeks after planting. Shoot number per plant and rhizome buds per plant were measured for all plots at their respective harvest dates. Shoot, root, and rhizome dry weight per plant were also measured.

In general, wild rice competition had little influence on giant burreed growth throughout the growing season. The number of giant burreed shoots per plant produced at the St. Paul location was somewhat higher in the no crop environment at 12 weeks, but the difference disappeared by the end of the season. There were no differences in giant burreed shoots per plant at the Grand Rapids location (Figure 1).

The number of rhizome buds per plant was not significantly influenced by wild rice competition. As with shoot number at the St. Paul location, the number of rhizome buds per plant was somewhat higher in the no crop environment but the differences disappeared at the end of the season. There were no significant differences in the number of rhizome buds per plant at Grand Rapids (Figure 2). The data for plant-part dry weights followed the same trend as the number of shoots and rhizome buds per plant for both locations.

Giant burreed shoots emerged from the water approximately 2 weeks after planting. Wild rice germinated about 2 1/2 weeks after planting and stayed in the floating leaf stage until 4 weeks after planting. All giant burreed shoots were taller than wild rice plants at 3 weeks, and the percentage of giant burreed shoots taller than wild rice plants, decreased to less than 10% by 10 weeks (Table 4). Some methods of herbicide application, such as



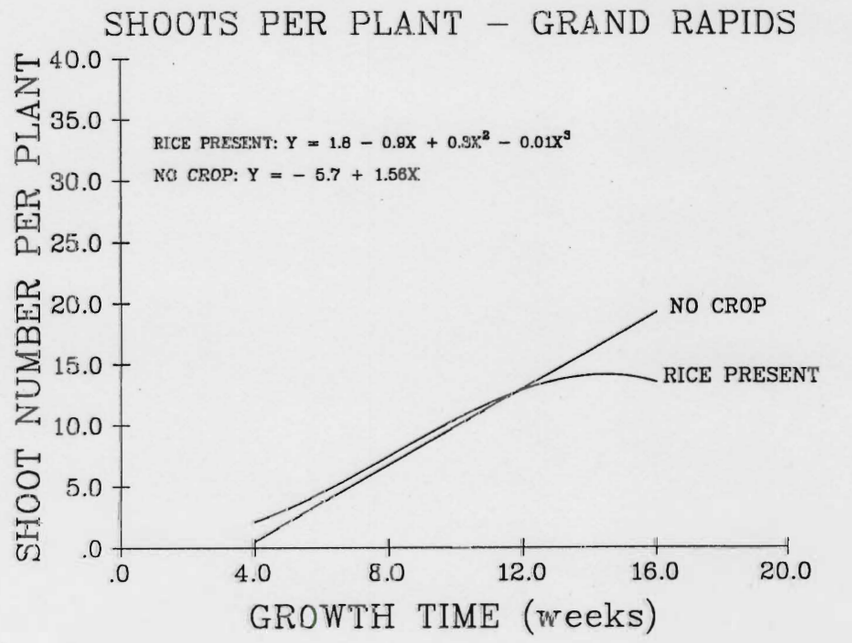


Figure 1. Number of shoots per giant burreed plant throughout the growing season

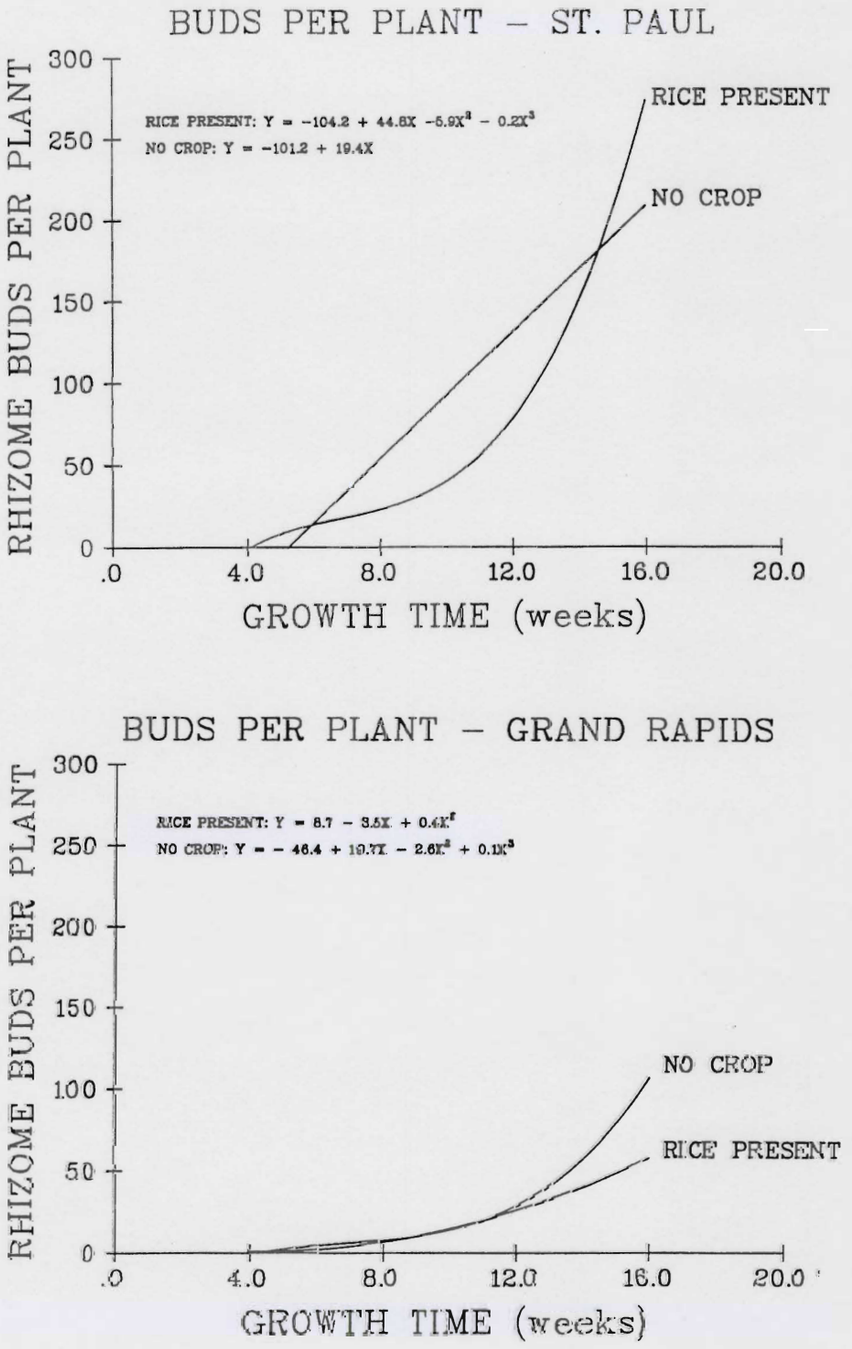


Figure 2. Number of rhizome buds per giant burreed plant throughout the growing season.

pipewick applicator, require a minimum height differential between the weeds and crop of 8 inches to give selective weed control. The percentage of giant burreed shoots 8 inches or more above the wild rice plants was highest at 3 weeks and decreased to less than 10% by 8 weeks (Table 4). All emerged giant burreed shoots were above this differential while wild rice was in the floating leafstage, but the number of shoots above this differential decreased 30% to 60% by the time wild rice was in the 2-aerial-leaf stage (4 weeks).

Table 4. Wild rice plant height and percentage of giant burreed shoots taller than wild rice throughout the growing season[a].

Weeks after planting	Wild rice height (in)	Burreed shoots taller than W.R. (%)	Burreed shoots at least 8 inches taller than W.R. (%)
- - - - - - - - - - - - - - - -	Grand Rapids	- - - - - - - - - - - - - - - -	
3	Floating	100	100
4	13	96	69
6	23	58	29
8	31	55	9
10	48	5	0
12	57	0	0
14	57	0	0
16	57	0	0
- - - - - - - - - - - - - - - -	St. Paul	- - - - - - - - - - - - - - - -	
3	Floating	100	100
4	11	75	40
6	21	45	33
8	31	20	4
10	49	0	0
12	56	0	0
14	56	0	0
16	56	0	0

[a]Means are averages across competition levels.

The environmental conditions probably played a major role in the differences between locations. The temperature was cooler in Grand Rapids than in St. Paul, and Grand Rapids had more rainfall (and thus more cloudy days), than did St. Paul. Cooler temperatures and less photosynthetically active radiation have been shown to change the growth of perennial plants by increasing leaf size and decreasing underground reproductive structure development. This may be the cause for many of the differences in giant burreed growth between the Grand Rapids and St. Paul locations.

Each shoot has the potential to form a productive corm and each rhizome bud has the potential for forming a new plant the following year. These data suggest that one giant burreed plant could produce as many as 300 new plants the following year. Although seeds are produced on one or two shoots of each plant (data not presented), they are not considered an immediate concern because they will usually remain dormant for 5 to 10 years.

A second experiment was conducted in 1988 to determine the percentage of giant burreed corms and rhizomes that would produce new plants the following year, and to determine if there is an association between time of emergence and corm viability. Giant burreed corms were planted at Grand Rapids and St. Paul in a manner similar to the previous experiment. The experimental design was a randomized complete block with 3 replicates of each treatment (wild rice competition vs. no competition).

The plants were grown for 16 weeks, and the emergence date of each shoot was recorded. At the end of the growing season the plants were harvested, and the developed corms were separated by the emergence date of their respective shoot. It was not possible to accurately separate rhizome buds into date of formation. The corms and rhizomes were placed in a cold room (34 F) for 4 months. They were planted in the greenhouse and grown for 30 days, at which time the number of emerged plants was counted.

There was no association between date of emergence and the viability of the subsequent corm. Although the number of corms and rhizomes produced per plant was higher at the St. Paul location, the percentage of viable corms and rhizomes produced was similar at both locations (Table 5). Although the viability of corms and rhizomes was no more than 15% of the maximum reproductive potential of the plant, a single giant burreed plant in this experiment could have produced 30 to 45 new plants the next growing season.

Table 5. Percent giant burreed corm and rhizome viability at the Grand Rapids and St. Paul locations[a].

Location	Corm viability (%)	Rhizome viability (%)
Grand Rapids	15.4	8.7
St. Paul	13.5	10.0
LSD (0.05)	2.7	3.4

[a]Means are averages across competition levels and date of shoot emergence.

These experiments showed the ability of giant burreed to grow and spread throughout the growing season, regardless of the presence or

absence of wild rice. This indicates the competitiveness of giant burreed with wild rice, and conversely, the poor competitiveness of wild rice with giant burreed. The fast early season growth of giant burreed makes it necessary for the producer to control the weed early, as is the case for most perennial weeds. The differential growth of giant burreed and wild rice offers opportunities for control of giant burreed with herbicides applied through pipewick applicator.

Giant Burreed Control With Glyphosate (Rodeo™) Applied Through A Pipewick Applicator

Field experiments were conducted in 1987 and 1988 to examine the effects different combinations of Rodeo concentrations and surfactant concentration (X-77™) have on the control of giant burreed when applied through a pipewick applicator. The experimental area was a fallow (non-flooded) wild rice paddy which had a heavy infestation of giant burreed. The experiment was conducted near Aitkin, MN in 1987 on a peat soil, and at the North Central Experiment Station at Grand Rapids, MN in 1988 on a mineral soil.

The treatments in 1987 were Rodeo at 0, 5, 10, or 30%, applied in combination with X-77 at 0, 0.15, 0.3, 0.6, 1.2, or 2.4%. In 1988, Rodeo concentrations were 0, 5, or 30% applied in combination with X-77 at 0, 0.15, 0.3, 0.6, or 1.2%. In addition, each Rodeo by X-77 combination was applied with or without ammonium sulfate (AMS) at 2% in 1988.

Treatments were applied June 23 of both years to 8- to 10-inch tall giant burreed. Treatments were applied with a hand held pipewick applicator by making a bi-directional application (one pass in each of two opposite directions) at a ground speed of 4 MPH. Each treatment was applied with a separate set of wicks to avoid contamination from other treatments. Plot size for each treatment was 4 ft by 10 ft. The experimental design was a randomized complete block with 4 replicates.

Visual injury ratings were taken 30 days after treatment (DAT). Shoots, corms, and rhizomes were harvested from a 2 ft by 2 ft area in the center of each plot. Shoots were dried at 105 F for 7 days and weighed. Corms and rhizomes were washed, weighed, and put into cold storage (34 F) for 4 months. They were then planted in a greenhouse and grown for 30 days to test for viability.

A second experiment was conducted in 1988 which included the same treatments and application methods as in the previous experiment, except that treatments were applied to 25-inch tall giant burreed that was grown under flooded conditions. Treatments were applied on June 17.

Visual estimation of stand reduction was used as a measure of long-term giant burreed control. Stand reduction ratings were taken 65 DAT. Giant burreed harvest was not done due to encroachment of

plants from adjacent control plots at the end of the growing season.

Under non-flooded conditions giant burreed injury was highest with 30% Rodeo, regardless of X-77 or AMS concentration (Table 6). This was observed in both 1987 and 1988. Giant burreed shoot dry weight was reduced by both 5% and 30% Rodeo concentrations in 1987 but there was no dry weight reduction by Rodeo in 1988 (Table 6). The lack of dry weight reduction in 1988 was probably due to the warm temperatures that were present after application.

Table 6. Effects of Rodeo concentration on giant burreed visual injury, and shoot weight when Rodeo was applied through a pipewick in non-flooded conditions[a].

Glyphosate concentration	Visual injury[b]		Shoot weight (g 0.4 m^{-2})	
	1987	1988	1987	1988
0%	0.0	0.0	142.2	23.0
5%	19.5	13.7	106.3	26.4
30%	71.0	51.7	107.9	21.0
LSD (0.05)	6.7	6.2	28.1	5.6

[a]Means are averages across surfactant concentrations in 1987 and averages across surfactants and AMS concentrations in 1988.
[b]Injury ratings were made 30 DAT. 0=no injury, 100=complete kill.

Reduction of percent corm and rhizome viability was used as a measure of long-term control of giant burreed. Percent corm and rhizome viability was reduced with Rodeo at 30% in 1987. However, no differences were detected for corm or rhizome viability in 1988 (Table 7). The poor giant burreed control in 1988 was probably due to decreased translocation of Rodeo to the rhizomes because of the warm dry weather. This has been observed in other perennial weeds, such as quackgrass and milkweed.

These experiments show that Rodeo, applied through a pipewick at 30% gave the best giant burreed control of the Rodeo concentrations tested. Control was also influenced by the growing conditions after application. These experiments also show no evidence that X-77 or AMS enhanced Rodeo activity when applied to giant burreed through a pipewick applicator. Rodeo toxicity to many annual and perennial weeds is increased with addition of AMS and/or surfactants. It is possible that, as an aquatic plant, giant burreed may not have a well developed cuticle, as do many terrestrial plants. The absence of a developed cuticle could explain the lack of X-77 influence, since one of the functions of X-77 is to enhance the movement of some herbicides across the cuticle.

Table 7. Effects of Rodeo concentration on giant burreed root weight, % viable corms, and % viable rhizomes when Rodeo was applied through a pipewick in non-flooded conditions[a].

Glyphosate concentration	Root weight (g 0.4 m^{-2})		% Viable corms		% Viable rhizomes	
	1987	1988	1987	1988	1987	1988
0%	637	167	49.7	10.3	20.0	6.4
5%	470	160	45.3	11.5	20.8	5.0
30%	432	142	23.4	8.0	13.2	4.5
LSD (0.05)	121	41	12.9	4.1	5.3	2.1

[a]Means are averages across surfactant concentrations in 1987 and averages across surfactant and AMS concentrations in 1988.

Under flooded conditions, long term giant burreed control was highest with 30% Rodeo and decreased as X-77 concentration increased (Figure 3). AMS did not influence Rodeo toxicity to giant burreed. Some leaf tissue necrosis was observed with the 0.3, 0.6, and 1.2% X-77 concentrations 3 to 5 DAT.

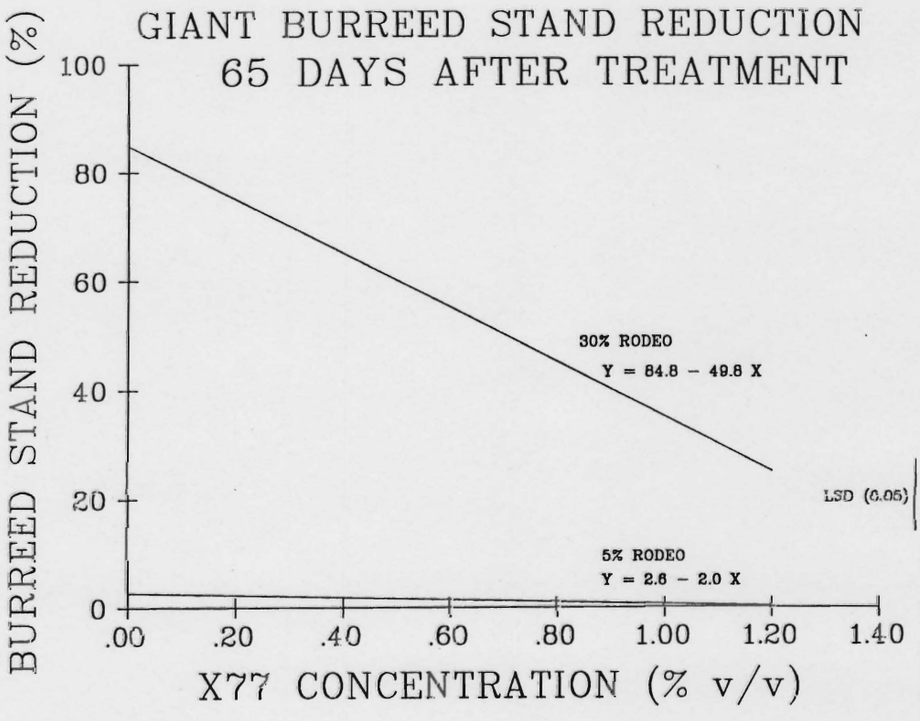


Figure 3. Effect of Rodeo concentration and X77 concentration on the control of giant burreed with Rodeo applied through a pipewick in flooded conditions.

The flooded conditions allowed for more active growth of giant burreed and thus perhaps facilitating translocation of Rodeo into rhizomes. The addition of X-77 did not enhance Rodeo toxicity to giant burreed. This response was similar to the response under non-flooded conditions. The decrease in long term control at the higher X-77 concentrations is consistent with reports on other perennial species. The leaf tissue necrosis observed at those X-77 concentrations indicates that leaf tissue adjacent to the site of herbicide application may be damaged, thus decreasing Rodeo translocation to the rhizomes.

Rate and Method of Nitrogen Fertilizer Application and Residue Removal on Second Year Peat Fields

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

In the summer of 1986, five 2-acre and one 1.3-acre paddies were constructed so each could be flooded and drained separately. The six paddies are being used for this three year study to investigate the influence of removing the residue on nitrogen fertilizer requirements and on disease incidence. All paddies were fertilized in the spring of 1987 with a broadcast application of 40 lb/A P and 60 lb/A of K fertilizer. This fertilizer was incorporated with a rotovator. The five larger paddies were divided into four 42 x 500 ft strips while the smaller one was divided into four 42 x 300 ft strips. The four nitrogen treatments in each paddy were granular urea applied at 30 and 60 lb N/A. After nitrogen fertilization the paddies were seeded with the K2 variety at 40 lb/A. The seed was incorporated with a harrow.

In the fall of 1987, the paddies were harvested with a combine. The straw spreader was incapacitated in 3 of the paddies while the straw was spread out with the straw spreader in the other 3 paddies. The straw was removed with a dump rake in the 3 paddies that had the straw in windrows. After residue removal, all 6 paddies were rotovated. On October 26, 30 lb/A of P_2O_5 and 40 lb/A of K_2O were applied and incorporated into all paddies. In addition, 30 or 60 lb/A of N were applied by injection or broadcast and then incorporated with a rotovator. Granular urea was used for broadcasting and incorporation while aqua ammonia was used for injection. In the spring of 1988 the paddies were all flooded. The fungicide, Tilt, was applied on July 30 when the plants were flowering. Some brown spot was evident already on the plants when the fungicide was applied. The paddies were harvested on August 5 with a combine. A 16 x 200 ft strip was harvested from each

treatment.

In 1988 the N fertility treatments were not as evident as in 1987. In 1987 the plants in the 60 lb/A N rates were greener most of the year while in 1988 this was not the case. Lodging also occurred more in the higher N rates while in 1988 lodging did not follow the nitrogen treatments.

When no fungicide was applied, the highest yield was obtained when 60 lb/A N were applied dry and incorporated into plots where the residue was removed (Table 8). When a fungicide was applied, the highest yield was obtained when 60 lb/A N were injected as a liquid again when the residue was removed. Generally in the fungicide treated strip of the plots, the 60 lb/A N yielded slightly higher than the 30 lb/A N. This was not as evident in the non-treated strip. Part of this may be due to more lodging which occurred in the untreated (no fungicide) half of the research paddies. The average yield for the fungicide treated half of the paddies was not statistically different than the untreated half. There was also no difference in yield between the residue removal vs. no residue removal. From the 1988 results on 2 year old paddies, it appears that 60 lb/A N was somewhat better than the 30 lb/A rate. Application method did not seem to make much difference. In 1987, which was the first year of the paddies, the 30 lb/A of N rate seemed to be best and injection was somewhat better than dry applications and then incorporating the fertilizer. This experiment will be conducted one more year. We also plan to do some tissue analyses of the plants we sampled during 1987 and 1988.

One year's result on the benefit of removing the residue (straw) showed little benefit both from the yield perspective and brown spot infection. Yields were not different statistically whether the residue was or was not removed. We will have a second-year's data at the end of 1989.

The plants were generally healthy until about mid-July when leaf diseases began in some spots. Tilt was applied onto half of all plots when leaf disease was evident. Tilt appeared to reduce leaf brown spot some but it was not very evident based on leaf disease ratings on August 2 (Table 8). Maybe an earlier application would have been more beneficial. There also was no difference in yield for the Tilt treated plots compared to the untreated ones.

Table 8. Wild rice disease ratings taken on August 2 and dehulled grain yield in response to nitrogen and fungicide application and residue removal at Aitkin - 1988.

Treatment			Brown spot infection on upper 3 leaves			Dehulled grain yield[a]
Nitrogen rate	Application method	Residue removal	Flag	One below	Two below	
lb/A			- - - -	%	- - - -	lb/A
- - - - - - - - - - - - - No Fungicide - - - - - - - - - - - - -						
30	Injected	Yes	27	45	63	247
60			20	42	83	217
30	Incorporated		22	42	83	220
60			28	50	83	170
30	Injected	No	30	62	88	278
60			15	31	50	220
30	Incorporated		38	62	100	260
60			5	20	50	283
		LSD .05	15	22	27	110
- - - - - - - - - - - - - Fungicide (Tilt) - - - - - - - - - - - - -						
30	Injected	Yes	27	50	75	161
60			23	58	83	177
30	Incorporated		28	58	100	213
60			18	50	83	181
30	Injected	No	13	42	67	240
60			13	23	58	280
30	Incorporated		13	30	55	191
60			8	42	67	265
		LSD .05	27	34	39	94

[a]Dry weight; grain was hulled after drying at 105° F for 7 days.

Soil variability showed up more in 1988 than in 1987 at the Aitkin site. Figure 4 is a copy of an aerial color photograph taken on July 13 showing a dark circular pattern; this pattern represents darker-green and maturity-delayed wild rice plants. Soil cores taken in the fall after harvest indicated deeper peat in these areas (see 1988 Soil Science Report). Figure 5 is a copy of a computer enhanced, color photograph when a filter was used on the camera to absorb the wavelengths of light that Chlorophyll A absorbs. The photograph is of the first 3 paddies and the dark areas are similar to the dark circle in Figure 4. This dark area is where the plants are absorbing more of the wavelengths that Chlorophyll A absorbs indicating greener or less mature plants. The plants tended to lodge more in some of the darker circle area

compared to the lighter areas. All of the paddies have a layer of peat on the surface, thus they look fairly uniform after tillage in the fall. However, the depth of the peat varies and this could influence the variability in growth.

Figure 4. A copy of a color, aerial photograph of the 6 paddies at Aitkin. The darker oblong-circle in the 4 paddies on the left is a darker green in the color photograph.

Figure 5. A copy of the computer-enhanced, color photograph which was taken with a filter to adsorb the wavelengths of light that chlorophyll A adsorbs. The photograph is of the first 3 paddies on the left of Figure 4. The dark area is where the plants were greener.

Seed Storage and Handling

A seed storage experiment was conducted to determine if wild rice seed germination is affected by drying seeds before storing them in water at 34 F for 180 days. The experiment was conducted over a 3-year period (1985 - 87). Immediately after wild rice harvest, seed (variety K2) was spread out on a laboratory bench and allowed to air dry at 70 - 74 F and 40% relative humidity for 7-12 days.

These random samples (300 ml) of seed were taken from the laboratory bench 10-12 times during the 7-12 day period. Each sample was divided into 2 subsamples; moisture content at the time of sampling was determined with 1 subsample and the other subsample was immediately placed into 34 F water at each sampling time. Moisture content was determined by drying the subsample for 7 days

in a forced air oven at 150 F. Germination for each subsample was determined by placing 100 seeds into a 250 ml beaker (1985 and 1986) or a petri dish (1987) filled with water and kept at 70-74 F. Germinated seeds were counted and removed from the beaker after 1, 2, and 3 weeks. Seeds were determined to be germinated when the coleoptile had grown longer than the length of the seed.

Seed moisture declined about 2.5% per day from 32% down to 10% (Figure 6). Wild rice seed germination declined as seed moisture declined in 1985 and 1987, but some germination occurred even at a seed moisture as low as 10% (Figure 7). However, in 1986 seed germination increased as seed moisture decreased from 30% to 23%, and then decreased steadily as seed moisture decreased to less than 10% (Figure 7).

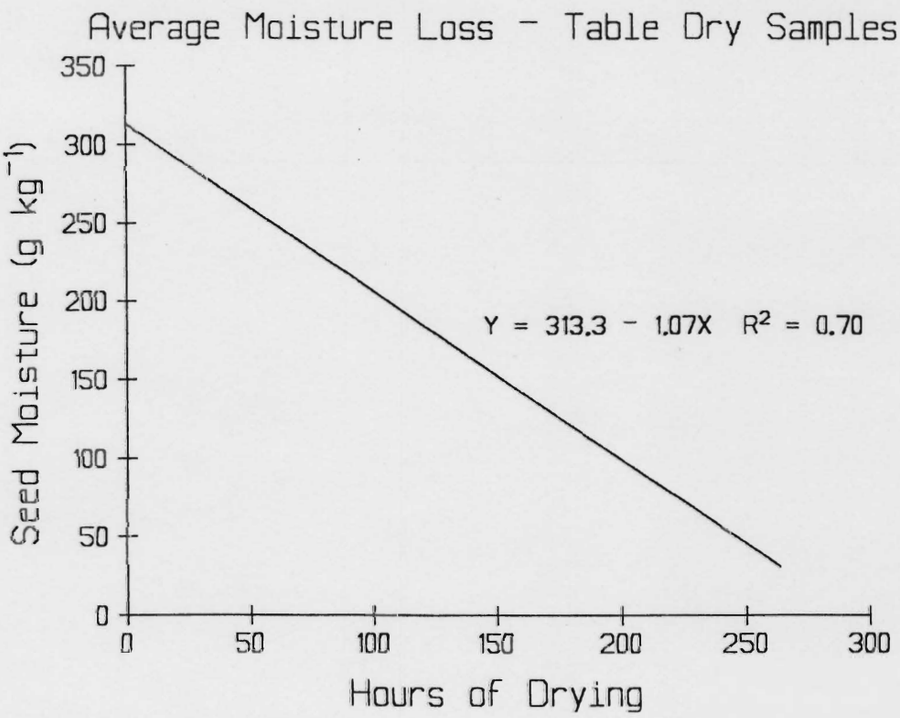


Figure 6. Wild rice seed moisture[a] loss over time when seeds were air dried on a laboratory bench.

[a]% seed moisture = (g kg^{-1}) x 0.1

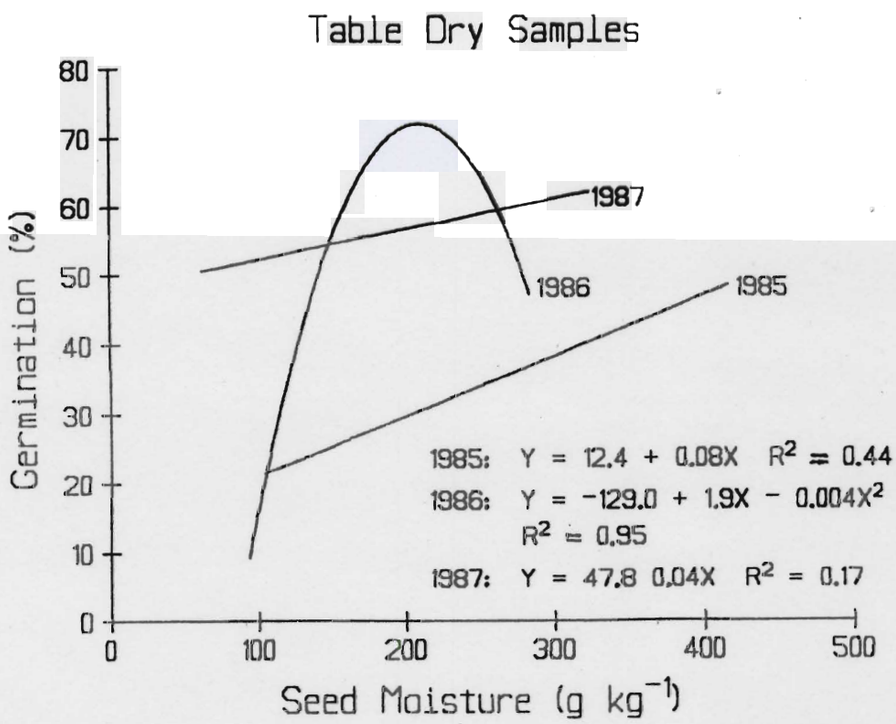


Figure 7. The effects of seed moisture[a] on wild rice seed germination when air dried and immediately placed in water.

[a]% seed moisture = (g kg^{-1}) x 0.1

This experiment showed that wild rice germination was affected by loss of seed moisture. Seed germination generally was reduced as seed moisture fell below 30%. However, some seed germination did occur when seed moisture was low. The results from 1986 did not correspond with the 1985 and 1987 results. Differences in seed quality or handling of the seed lot in 1986 may be responsible for the differences between the 1986 data and those of the other years.

A second seed storage experiment was initiated in 1987 to determine if wild rice seeds could be stored out of water for extended periods of time and still remain viable. Seeds were air dried for 12 days and sampled in the same manner as in the previous experiment. One third of the seeds at each sampling date were treated with a 50:50 mixture of Dithane and Captan fungicides. Instead of immediately placing a subsample into water, 100 g of

seeds were placed into small glass bottles at each sampling time and covered with a metal cap and sealed with silicone. The fungicide treated samples, and some of the untreated samples were stored at 34 F. The remainder of the untreated samples were stored at 30 F. Seeds were removed from the bottles after 3, 6, or 9 months and placed into 34 F water. Germination was measured immediately after seeds were taken out of the bottles and after 90 days in water in the same manner as in the previous experiment. No seeds germinated when tested immediately after removal from the bottles (data not presented). There was no association between germination and seed moisture when seeds were treated with fungicides and stored at 34 F (Figure 8). Germination of non-fungicide treated seeds stored at 34 F was dependent on seed moisture when stored out of water for up to 6 months. Germination increased as seed moisture decreased from 35% to 25%, and then decreased as seed moisture decreased to 20%. However, there was no relationship between germination and seed moisture in seeds stored out of water for 9 months (Figure 9).

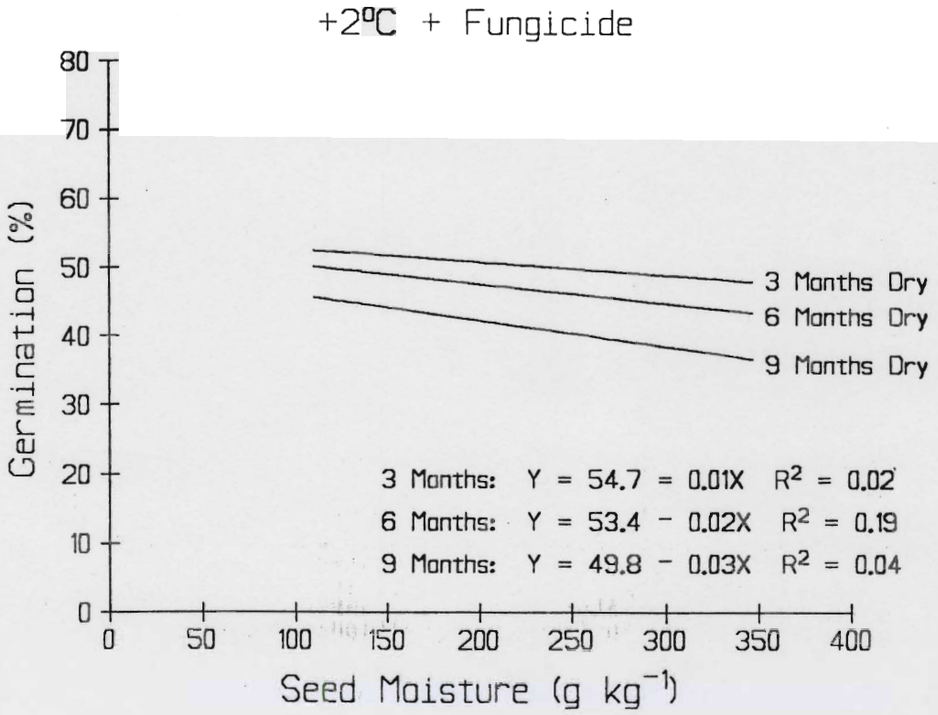


Figure 8. The effects of seed moisture[a] on wild rice seed germination when wild rice was treated with fungicide and was stored out of water at 34 F.

[a]% seed moisture = (g kg^{-1}) x 0.1

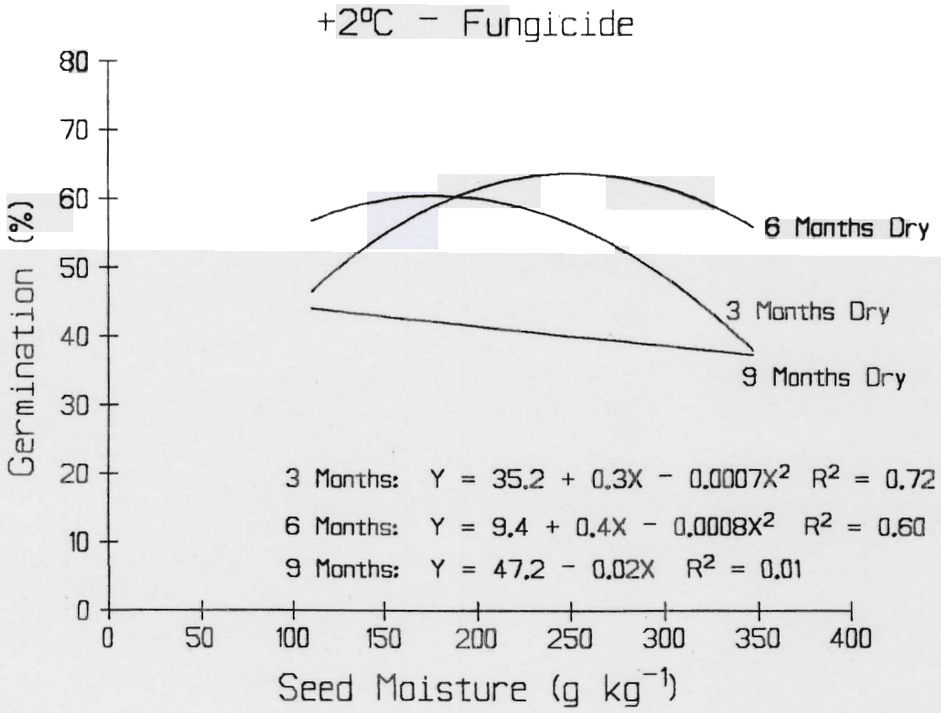


Figure 9. The effects of seed moisture[a] on wild rice seed germination when wild rice was not treated with fungicide and was stored out of water at 34 F.

[a]% seed moisture = (g kg^{-1}) x 0.1

When stored at 30 F, germination increased as seed moisture decreased from 35% to 20%, and decreased as seed moisture decreased to 10%. This relationship was accentuated the longer the seeds were stored out of water (Figure 10). It is possible that water inside the higher moisture containing seeds can damage the seed embryo when exposed to freezing conditions. That may explain the large decrease in germination when seeds containing more than 20% moisture were stored in freezing conditions.

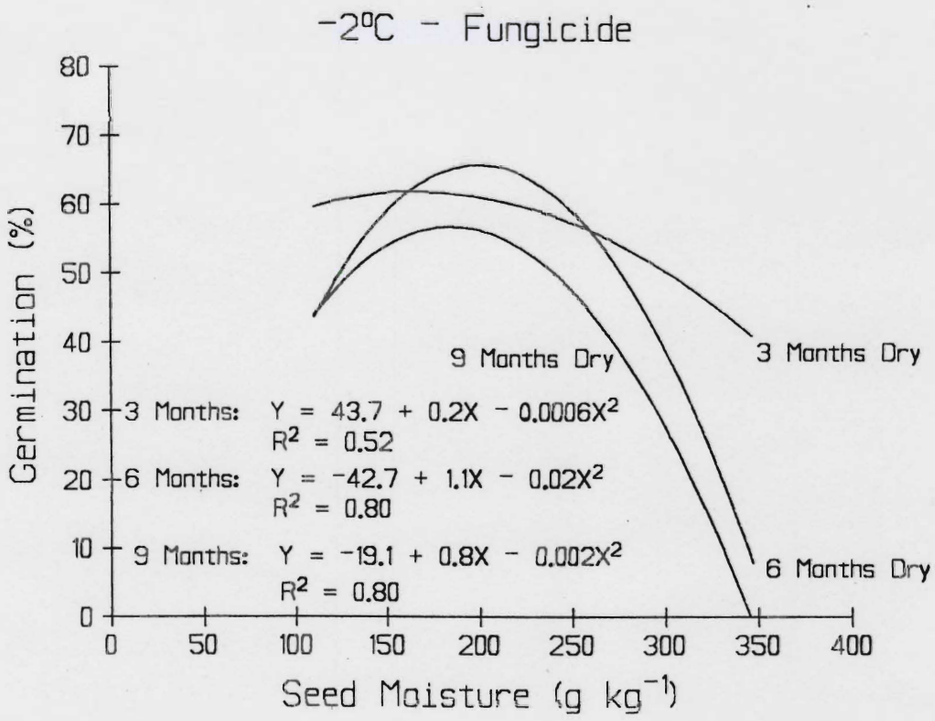


Figure 10. The effects of seed moisture[a] on wild rice seed germination when wild rice was not treated with fungicide and was stored out of water at 30 F.

[a]% seed moisture = (g kg^{-1}) x 0.1

This experiment showed that it was possible to store seeds out of water at 34 F up to 9 months without severely reducing germination. However, it was necessary to store seeds in water at 34 F for 90 days before dormancy was released. Storing wild rice seeds under freezing conditions reduced germination in seeds containing over 20% moisture. Storing seeds out of water for a length of time would allow researchers the capability to store seeds for longer periods of time to aid in breeding and other research activities.

Acknowledgement

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

SOILS RESEARCH

Paul R. Bloom
Department of Soil Science

On Farm Trials of Silica Slag

Silica slag, a by-product of electric furnace processing of phosphate ore, was evaluated as a soil amendment for wild rice production on peats. Large replicated plots were amended by grower cooperators in the fall of 1987 and spring of 1988. The three cooperators in the Aitkin area were Art Hedstrom, Joe Shetka and Tom Godward. The two cooperators in the Gully area were Paul Imle and Dwayne Erickson of Gully farms.

The trials were designed with 50 ft. wide treatment strips randomly alternating 0, 4 and 8 ton/ac treatments. Whole plant samples were taken at early heading (July 7 and July 8) for elemental analysis. At the Hedstrom site, however, the experiment was more complex with two strips of high Si (uncertain application rate) on paddy 109 and one strip of 10 tons/ac on paddy 108.

In addition to 10 tons/ac slag, other treatments on paddy 108 were 2 tons/ac lime, 5 and 10 tons/ac of Blandin paper mill fly ash, or 50 lb/ac sulfur as gypsum plus lime. Paddy 108 was divided into quarters for application of low NPK (35-20-40) and high NPK (55-30-60) treatments over the other treatments. There was no yield difference for the NPK treatments so the two NPK treatments were treated as replicates. Yield was determined by combine harvest over measured strips of about 200 ft. The grain was collected in bags from the auger feed into the grain bin.

The only site at which a response to silica slag was observed was at the Hedstrom site. The 10 ton/ac silica slag application produced a 70% increase yield (Table 1). In addition, the plant height was significantly increased (see the report of R. Stucker in this publication) and brown spot infection was reduced. The plants in the control strips were severely infected with brown spot, but in the slag-treated plots the infection was less and the leaves were much greener at harvest. The retention of the grain as measured by the tensile strength method was, however, not significantly changed by the slag (see the report of R. Stucker).

Fly ash and gypsum had little or no effect on yield (Table 1), but the ditch edge effect as measured by the yields on a untreated strip near the north ditch appeared to be significant. The results from the gypsum plus lime strip suggested no response, but just north of this strip (in a control strip) the rice was greener. Art Hedstrom said that during lime application there was a very strong south wind. The soil pH measurements in the north of the lime application strip show that the pH in this area (6.2) was higher than in the lime strip

(5.9). Further testing is needed to determine if there may be positive response to lime in this paddy.

The higher yields in the silica slag treatment and the edge strip were associated with higher soil pH (Table 1) and higher plant Si (Table 2). The soil in the control strips is quite acid with a pH of 5.2 This is not surprising for a peat with an ash content of less than 20% (Table 1). The silica slag raised the pH by about one unit. The pH, however, was even higher on the edge strip where enough subsoil had been mixed in to give an ash content of 68%. The pH near the narrow field ditch also was raised to 6.0 suggesting some incorporation of mineral soil.

Table 1. Green Yield of Wild Rice (40% moisture), Soil pH, and Soil Ash Content in 1988 Silicate Slag Trials.

Cooperator	Treatment Si Slag, Tons/Acre	Number of Replicates	Yield lb/acre	Field Soil pH (mean of 3)	Soil Ash Content, % n = 1
Shetka	0	3	1060	6.6	46
	4	3	1080	-	42
	8	3	1040	6.7	36
Imle	0	3	900	-	-
	4	3	900	-	-
	8	3	930	-	-
Gully Farms	0	3	620	-	-
	4	2	690	-	-
	8	3	669	-	-
Hedstrom	0	5	390	5.2	16 (n=2)
	10	2	670	6.3	21
Paddy 108	Near N ditch	2	560	6.9	68
	5 T fly ash (near field ditch)	2	442	6.0	-
	10 T fly ash	2	350	5.1	-
	50 lbs S	1	400	5.5	-
	50 lbs S plus 2 T lime	2	350	5.9	-

Plant silicon was also high in edge strips in paddy 108 (Table 2). Silicon also seemed to be higher in the 10 ton/ac fly ash strip despite the lack of growth response. The other plant elements did not appear to respond to soil amendments (Table 3). For test strips in paddy 109, adjacent to 108, addition of Si slag seemed to increase plant Si, but the concentrations in the controls were higher than in paddy 108. Observations at early heading and harvest suggested a growth response to the Si slag, but no yields were taken on this paddy.

Yields at the Shetka and Imle sites were much higher than at the Hedstrom site (Table 1). These trials were on more fertile soils. The soil pH at the Shetka site was 6.6 to 6.7 with ash contents ranging from 36-46% in the plow layer (Table 1). No ash and pH

measurements were taken at the Imle site, but the plant growth suggests high fertility. At the Shetka site NPK was added at the rate of 75-25-10 lb/ac plus and 15 lb/ac of S was added as Sulfomag. At these sites there was little plant disease and growth was remarkably uniform across treatments.

There was little difference in elemental contents across treatments. At the Imle site, however, plant silica did seem to increase with additions of slag. The increases were not as dramatic as at the Hedstrom site. At the Shetka site, the plants in the control plots already contained 2.48% Si. The plants at this site also had very high K contents.

Table 2. Wild Rice Plant Contents of Silicon (Si), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg) in the 1988 Silica Slag Trials. Sampled at early heading (7 and 8 July). All values reported in percent.

Cooperator	Treatment	Number of Replicates	Si	P	K	Ca	Mg
Shetka	0	3	2.48	0.42	4.3	0.32	0.15
	4 T of Si slag	3	3.00	0.50	4.4	0.37	0.15
	8 T of Si slag	3	2.55	0.48	4.6	0.33	0.14
Imle	0 T of Si slag	3	2.02	0.50	3.6	0.54	0.14
	4 T of Si slag	3	2.54	0.51	3.6	0.48	0.12
	8 T of Si slag	3	2.62	0.44	3.0	0.50	0.14
Gully Farms	4 T of Si slag	2	2.64	0.54	3.9	0.45	0.16
Godward	0 T of Si slag	4	2.71	0.38	2.4	0.37	0.12
	4 T of Si slag	3	2.89	0.35	2.0	0.37	0.12
	8 T of Si slag	3	2.81	0.34	2.1	0.42	0.11
Hedstrom Paddy 108	0	3	1.8	0.37	3.3	0.30	0.15
	10 T fly ash	1	2.60	0.40	3.8	0.27	0.14
	10 T Si slag	1	3.07	0.40	4.0	0.29	0.14
	gypsum	1	1.88	0.41	3.5	0.34	0.15
	gypsum + lime	1	1.78	0.39	3.2	0.30	0.17
	0, near S. ditch	1	2.72	0.36	3.8	0.24	0.16
	0, near N. ditch		2.88	-	-	-	-
Hedstrom Paddy 109	0	2	2.32	0.35	3.6	0.28	0.13
	plus Si	2	2.70	0.41	3.9	0.30	0.15
Hedstrom Paddy 108 at Harvest	10 T Si slag	1	3.45	0.28	2.8	0.30	0.12
	0	1	2.22	0.27	2.5	0.33	0.17
University Paddy	Near driveway	1	3.70	0.39	3.9	0.29	0.12
	Center	1	1.37	0.25	2.5	0.39	0.14

Yields of the Gully farm site were lower than at the Shetka and Imle sites (Table 1). Unlike the Hedstrom site, the lower yield was not associated with high levels of brown spot. The plant content of Si was moderately high, 2.64%, but the plant Zn was lower than at the other sites (15 ppm). A value of 15 ppm is suggested as sufficient for white rice, but good values for judging sufficiency are not available for wild rice.

Because the paddy was drained too early at the Godward site, yields were not taken. The plants at this site, however, were much lower in K compared to the other sites. The literature for white rice suggests, however, that the plant contents might be more than sufficient for good plant growth.

At the University paddies near Aitkin, plants taller and greener than in the remainder of the paddy were noticed in a corner of a paddy near a driveway where the thinning clippings were blown by the wind. The plants in this area were much higher in Si and K than for plants well away from the edge where the growth was poorer and browns spot incidence was greater. The high Si is probably due to the addition of mineral soil while the high K may have been contributed by the thinnings.

Table 3. Wild Rice Plant Contents of Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), and Sodium (Na) in the 1988 Silica Slag Trials. Sampled at early heading (7 and 8 July). All values reported as ppm.

Cooperator	Treatment	Number of Replicates	Fe	Mn	Zn	Cu	B	Na
Shetka	0	3	153	137	35	2.1	9.7	560
	4 T of Si slag	4	165	155	30	1.7	9.0	720
	8 T of Si slag	3	152	152	34	2.3	9.1	780
Imle	0 T of Si slag	3	58	74	34	1.8	6.1	1900
	4 T of Si slag	3	57	65	26	1.8	5.0	2700
	8 T of Si slag	4	52	60	25	1.4	5.1	2500
Gully Farms	4 T of Si slag	2	74	107	15	2.9	7.1	666
Godward	0 T of Si slag	4	57	89	41	1.7	6.3	6900
	4 T of Si slag	4	59	73	30	1.5	5.4	6400
	8 T of Si slag	4	54	90	33	1.4	5.9	6000
Hedstrom	0 T of Si slag	3	73	38	27	2.5	9.0	1400
Paddy 108	10 T of fly ash	1	53	33	30	2.7	8.1	630
	10 T of Si slag	1	54	45	28	2.3	6.8	970
	gypsum	1	68	38	25	2.3	10.0	1800
	gypsum plus lime	1	72	34	22	2.0	9.1	1800
	0, near S. ditch	1	62	91	40	3.7	10.2	424
Hedstrom	0	2	62	38	27	1.9	9.1	1500
Paddy 109	plus Si slag	2	61	37	26	3.0	8.1	990
Hedstrom Paddy 108	10 T of Si slag	1	64	52	32	1.1	5.4	1800
at harvest	0	1	73	102	41	1.7	7.8	1800
University	Near driveway	1	88	66	34	1.6	13.5	700
Paddy	Center	1	157	92	37	1.4	13.9	3400

The response to slag at the Hedstrom site further confirms the results of the 1987 study (also in the Aitkin area) that on low ash organic soils the yield response to slag can be dramatic. In the 1987 study, the whole plant silica, at harvest, was very low in the control plots, 1.7%. In both the 1987 and 1988 trials response to slag was associated with a decrease in incidence of brown spot. The important

factor causing a response to Si may be protection against the effects of brown spot. The pH increase in the slag treatment compared to the control at the 1988 Hedstrom site may have been a factor, but the pH at the 1987 site was 6.5 before the treatments were added and there was no response to lime.

The data on response to Si slag obtained so far suggest that if disease the pressure is low, 2.5% plant Si at early heading (slightly greater at harvest) is more than sufficient for good growth. At high disease pressure more Si may be needed. The contribution of other elements in the slag (Table 4) cannot be ruled out. Iron deficiency has been observed under greenhouse conditions (discussed later in this report) for a soil similar to that in the 1988 Hedstrom trial. The slag may add enough iron to prevent deficiency. Tissue analysis of iron deficiency is usually not very useful.

Table 4. Elemental concentration of Phosphorus (P), Potassium K, Calcium (ca), Magnesium (Mg), Silicon (Si), Iron (Fe), Manganese (Mg), Zinc (Zn), Cooper (Cu), and Sulfur in Silica Slag Used in the 1988 Silica Slag Trials.

P	K	Ca	Mg	Si	Fe	S	Mn	Zn	Cu
- - - - - - - - - - - % - - - - - - - - - - -							- - - - ppm - - - -		
0.5	0.1	33	0.2	22	0.5	0.3	190	12	15
- - - - - - Quantity Applied with 8 ton/ac Application, lb/ac - - - - - -									
80	16	5280	32	3520	80	48	3	0.2	0.2

We will continue to observe the slag trial sites to see how long the slag treatment is effective and to look for responses under various conditions of weather and disease pressure.

Table 5. Barley Plant Contents of (Si), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg) in the 1988 Silica Trials. Sampled 8 July. All values reported in percent.

Cooperator	Treatment Si Slag, Tons/acre	Number of Replicates	Si	P	K	Ca	Mg
Imle	0	3	1.47	0.25	2.1	0.46	0.17
(variety,	4	3	1.69	0.26	2.0	0.43	0.17
Robust)	8	3	2.20	0.23	2.2	0.46	0.15
Gully	0	1	1.42	0.25	1.5	0.67	0.34
Farms	8	2	1.52	0.29	1.1	0.66	0.36
	16	2	1.63	0.23	1.1	0.64	0.36

Silica Slag Trials on Barley

Silica trials similar to the wild rice trials were conducted at two sites in the Gully area. No yield data were obtained, but observations suggest that there was no yield response to Si. The plant Si did increase with slag treatment at the Imle site (Table 5).

At the Gully farm site, however, there was no difference between any of the treatments, but there was some confusion about the layout and the sampling pattern may have been incorrect. Elements other than Si did not vary with treatment at either site (Table 6). The K content, however, at the Gully site was quite low.

I am very thankful for all of the effort of the cooperators in making this trial a success. Thanks is also due to Progress Fertilizer for supplying the slag.

Table 6. Barley Plant Contents of Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B) and Sodium (Na) in the 1988 Silica Slag Trials.

Cooperator	Treatment Si Slag, tons/acre	Number of Replicates	Fe	Mn	Zn	Cu	B	Na
Imle	0	3	74	22	30	2.0	4.2	330
	4	3	77	21	31	2.1	4.5	320
	8	3	68	22	29	1.6	4.1	330
Gully Farms	0	1	74	50	48	1.8	4.9	8700
	8	2	66	47	59	2.4	5.7	9200
	16	2	61	40	57	2.4	5.0	9200

Greenhouse Evaluation of Wild Rice Response to Silica, Sulfur and Copper (and Also Iron)

A greenhouse study of plant responses to calcium silicate, sulfate sulfur and copper were conducted using a soil similar to that found at the Hedstrom site for the silicate trials. The study was designed as a minus element study with a completely fertilized control amended with silica, copper, sulfate-sulfur, zinc, molybdenum, boron, N, P and K. A minus control containing only N was included. Two minus silica treatments were included; one contained lime equal to the liming effect of calcium silicate, the other did not. Large pots (5 gal plastic pails) were used to simulate the rooting volume of plants in the field.

Unfortunately, early growth of the wild rice seedlings was hampered by severe chlorosis (yellowing) of many of the plants. The condition, which occurred across treatments, was first thought to be sulfur deficiency and sulfate sulfur was added to all treatments. By the time true iron deficiency was identified as the cause of the chlorosis, many plants had leaves that were almost white. Spraying with an iron chelate along with soil application resulted in greening of the plants. The iron treatment resulted in a rapid recovery from the chlorotic condition and most of the chlorotic plants recovered to grow quite well.

Measurement of yields and plant characteristics showed no differences between any of the treatments. Because of the problems during early plant growth, variability within the treatments was very high thus only very dramatic differences between the treatments would have been observed. It is possible, however, to conclude that we didn't have the dramatic response to silica that we saw in the field. In this study, however, we used pure calcium silicate and not the silicate slag.

The problem of iron deficiency of the severity observed in this experiment has not been observed under field conditions and previous laboratory studies suggest that iron deficiency should not be a problem on the soil used. Iron deficiency in wild rice is common in greenhouse studies using air dried mineral soil, but the peat used in this experiment was not air dried. The experimental soil was, however, stored for 4 months in a pile outdoors. Further field observations and sampling of early plant growth is needed to see if iron deficiency may be occur at some sites under field conditions. Our existing plant analysis data were obtained too late in the season to be useful as an indicatior of low plant iron.

Soil Variability Associate with Crop Response Variability at the University Paddies near Aitkin

Aerial photo observations made on July 13, 1988 clearly showed bands of greener wild rice, especially in paddies 2, 3 and 4 (see the article by E. Oelke in this publication). The greener rice appeared to be later maturing and taller.

After draining and harvesting, we sampled soils in these paddies along north to south transects. The depth to subsoil was measured and samples of the surface peat were taken for pH and ash content analysis. In paddy 2, samples of subsoil were also taken at four sites.

The results (Table 7) show that the peat is quite high in ash and pH. The ash contents were all 38% or greater and the pH values ranged from 6.5-7.5. The samples near the center of the green bands (paddy 2, 65 and 415 ft.; paddy 3, 65, 115, and 465 ft.; and paddy 4, 265 ft.) were all from areas of deeper peat (30 to 36" deep). These samples were a bit lower in ash content and lower in pH compared to areas of shallower peat in paddies 2 and 3, but there was no difference between the deep and shallow samples in paddy 4. Most areas away from the deep peat in paddies 3 and 4 had peat depths ranging from 12 to 15 inches. In the center of paddy 2, however, the peat was only 6 inches deep. This very shallow peat had a very high ash content, 82%, and a high pH, 7.4.

Table 7. Soil Depth, Ash Content and pH of Soil Samples in North to South Transects of the University Paddies at Aitkin.

Distance from the North Ditch ft.	Paddy 2			Paddy 3			Paddy 4		
	Soil Depth in	Ash Content* %	pH**	Soil Depth in	Ash Content %	pH	Soil Depth in	Ash Content %	pH
15	16	53	6.9	19	41	6.7	15	52	6.8
65	32	42	6.5	32	45	6.7	15	42	6.7
115	21	56	6.8	32	43	6.6	15	46	6.8
165	14	61	7.2	15	56	6.9	12	46	6.9
215	6	81	7.5	11	52	6.9	14	38	6.9
265	7	82	7.4	12	50	7.0	30	45	6.7
315	12	73	7.5	12	49	7.1	22	45	6.6
365	21	55	6.9	12	46	6.9	14	43	6.7
415	34	45	6.4	26	44	6.7	15	41	6.6
465	15	60	6.9	36	41	6.4	21	44	6.7

* Determined at 450°C

** 1:5 H_2O

Observations at 25, 200, and 425 ft. in paddy 5 suggest that the peat in this paddy has depths varies from 20 to 30". Observations at 50, 150 and 250 ft. in paddy 6 suggest that in this paddy the peat depth varies from 15 to 22". No samples were obtained for ash and pH in these paddies. In these paddies the aerial photos showed the crop to be fairly uniformly green.

Observations of the subsoil in paddy 2 showed it to consist of a thin clayey horizon over a loamy sand, except at the north end of the paddy which had a medium sand subsoil. The pH was high (7.4-7.9) but the samples were free of carbonates. Random observations in the other paddies suggested that clay over a loamy sand is most common, but sand was found in the center of paddy 3 and at the south end of paddy 6 (medium sand). The sand in paddy 6 may account for the problems with keeping water on this paddy.

The better growth in the deeper peats seems to be associated with better plant nutrition. In the deeper peats the plant rooting depth is greater. No roots were observed in the mineral soil. The greater rooting depth means that the plants were exploiting a greater soil volume. The greater volume of organic matter exploited by the roots in the deep peat could be supplying more native N to the plants. Other nutrients, however, may also be responsible for the observed differences. Analysis of the plant tissue samples may help aid in the understanding of the problems in these paddies.

Factors Associated with Very Poor Growth on Exposed Subsoils in the Aitkin Area

Very poor growth of wild rice has been observed on subsoils exposed by land leveling on some of the farms in the Aitkin area. In newly leveled fields, plants on the exposed subsoil often will die before the booting stage.

A soil sample was obtained on the Godward farm for chemical analysis. The soil contained calcium carbonate and was low in organic matter (0.32% organic carbon). A DTPA micronutrient test gave the values listed in Table 8. The test suggests sufficient iron, manganese, and copper, but low Zn. Usually 0.8 ppm is needed to be considered sufficient. Zinc deficiency in rice on soils containing calcium carbonate is very common all over the world. Addition of 50 lb. of zinc sulfate or 25 lb. of zinc oxide per acre may help correct the problem. Some test strips should be tried.

Table 8. DTPA Soil Test Values for Exposed Subsoil from a Paddy in the Goodward Farm.

Iron	Manganese	Zinc	Cu
- - - - -	ppm - - - - - - -		
42	5.4	0.27	2.5

WILD RICE BREEDING

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The wild rice breeding project had research plots at the Horticultural Research Center, Excelsior, MN; the Rosemount Agricultural Experiment Station, Rosemount, MN; the North Central Experiment Station, Grand Rapids, MN; and at Aitkin, MN on research paddies built with State funds on the Vomela Farm. In addition, greenhouse facilities at St. Paul and Grand Rapids were used during fall, winter, and spring months. Dr. Raymond Porter joined our research program July 11 as a postdoctoral associate and plant breeder at Grand Rapids.

The high temperatures of the 1988 growing season were particularly damaging to our mid-May plantings. One paddy at Excelsior was a complete failure--none of the planting emerged. The paddies at Grand Rapids suffered significant stand loss after apparently good germination in two paddies and variable germination and survival in another paddy. In all cases, the 1988 data were recorded under stress conditions and should be considered with caution.

1988 Yield Trials

We planted yield trials at Grand Rapids, Aitkin, and Excelsior. The Aitkin trial was fall-planted and had good emergence and early growth conditions. Yields were disappointing--apparently due to heat stress, but some disease developed near harvest time and the disease build-up occurred rapidly on some entries. The Excelsior trial did not emerge. The Grand Rapids trial had variable emergence; some plots had excellent stands and others had only a few plants. Rather than attempt adjustments for stand differences, we have presented unadjusted data in our tables.

The Aitkin Variety Trial (Table 1) had seven forms of Meter, two sources of Voyager and two sources of K2. The primary focus of the trial centered around the three selected populations of Meter from the 1987 Meter selection nursery at Vomela Wild Rice. The Meter plants were tagged to characterize them as early, medium, and late flowering before selection for shattering resistance within the maturity categories. For the early groups, plants which had some seed remaining well after normal

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[1/] Professor, Postdoctoral Associate, Junior Scientist, Field Plot Coordinator, and Research Assistants, respectively. Dr. Porter and Mr. Schumer are located at the North Central Experiment Station.

Table 1. 1988 Wild Rice Yield Trial Results--Aitkin, MN (fall planted).

Entry-Source	Yield[1/]	Percent Dry Weight	Stem Number	Plant Number	Harvest Date	Plant Height
	(lb/A)		-- per plot --			(inches)
Meter						
- Harrell	395	76	112	42	July 28	57
- Imle	414	75	120	50	July 28	56
- Rennemo	502	75	140	50	July 28	59
- Selected (Early)[2/]	333	78	102	43	July 28	54
- Selected (Medium)[2/]	430	76	115	49	July 28	55
- Selected (Late)[2/]	449	76	123	49	July 28	58
- Shetka	345	75	87	27	July 30	56
Voyager						
- Imle	269	77	131	66	August 8	62
- Rennemo	296	77	126	50	August 8	63
K2						
- Shetka	456	73	117	43	August 8	72
- Selected[2/]	345	75	129	50	August 8	68
M1						
- Manomin	380	72	121	57	August 6	72
LSD (.05)	117	2.0	32	10	2 days	5

[1/] Dry weight of unprocessed grain.
[2/] Mass selected for seed retention (nonshattering).

harvest maturity were chosen. In most cases, all the seed had shattered from the plant's mainstems and first tillers. For the medium and later maturity groups, plants were chosen which appeared to have superior seed retention on the mainstems, based on a subjective evaluation--stripping the panicle with a light to medium finger pressure. In all cases, a selection intensity of about 10% was used in a grid blocking system (see Wild Rice Breeding Report, pages 53-54, in Minnesota Wild Rice Research, 1987, Mis. Pub. 54-1988, University of Minnesota).

The remaining four entries of Meter (Table 1) came from four wild rice growers. The K2 entries compare a grower source, and a population selected for shattering resistance; in this case, the selection was done at Grand Rapids in 1987--see previously cited report, page 54.

The results presented in Table 1 were discouraging in view of the low grain yields (dry grain in pounds per acre). In 1987, Meter yielded approximately 700 pounds per acre at the same site. The selection for shattering resistance did not appear to be effective. The yield differences shown in Table 1, are more likely to be due to maturity differences than due to progress from selection for resistance to shattering.

K2 and M1 yields were discouragingly low. The disease build-up was very rapid and that, plus the heat stress, had a major influence on the performance of the test. At a grower field day at Aitkin on July 26, the difference in appearance between K2 and selected K2 was obvious. The selected version had better color and looked more vigorous than K2 itself. Of course, this could have been due to a source difference (K2-Shetka was harvested from the farm in 1987 and the K2 select was grown and selected at Grand Rapids). Never-the-less, by harvest time, the selected version of K2 looked poorer than the check K2. Disease losses probably caused the decline in the selected population.

We measured seed retention on the Aitkin variety trial using the tensile strength meter to record grams of force required to break a kernel from the panicle using a gentle straight-line pull:

Entry	Tensile strength (g)	Entry	Tensile strength (g)
Meter-Harrell	150	Meter-Shetka	125
Meter-sel.-med.	145	Meter-Sel. Early	121
M1-Manomin	134	K2-selected	111
Meter Rennemo	133	Meter Imle	102
Voyager-Imle	127	K2-Shetka	94
Meter-sel.-late	126	Voyager-Rennemo	88

[LSD (0.05) = 47g]

The tensile readings were obtained from 5 plants in each of three replicates. The differences among entries were not significant (α = .24).

Because of the stress problems, we have not drawn conclusions from these data. The experience did remind us, however, of the tedious nature of the tensile strength measurements and the importance of recording the measurements at a uniform state of maturity. Entries harvested on Aug. 6 or Aug. 8 were past the optimum stage of maturity for harvest and probably also for measuring seed retention.

Results of the Grand Rapids yield trial are presented in Table 2. Except for the three experimental entries, all other data were from some very poor stands. Experimental BB is the population of wild rice selected by K. Petrowske of Waskish, MN. Under many circumstances, the phenotypic appearance of the variety is impressive. It is tall, has excellent vigor, and we have had reports of excellent yields in growers' fields. The data in Table 2 showed very good yield for BB relative to the other entries, somewhat medium maturity (compared to K2 and M1) and average plant height. Although the quality of the test was poor, the results for BB looked very good. Based on the selection procedure, we expected tall plant height, late maturity, very good vigor, and high yield.

Manomin Silica Trials - Tensile Strength Readings

(Cooperative with Dr. Paul Bloom - Dept. of Soil Science)

As a follow-up of Dr. Paul Bloom's silica research at Aitkin on the Manomin Farm, we sampled ten plants from each of the 12 treatments listed below. We measured the height of each plant and tensile strength of seed retention on 5 kernels of each plant.

Treatment	Plant height (in.)	Tensile strength (g.)
Plants outside of the treatments	57	60
Check - Urea 50-30-60	65	93
Check - Urea 50-30-60	63	97
Check - Urea 35-20-40	57	54
Fly Ash - 5T/A - Urea 50-30-60	63	99
Fly Ash - 10T/A - Urea 50-30-60	65	108
Sulfur - 50 lb/A - Urea 35-20-40	69	102
Ag lime - 2 T/A - Sulfur 50 lb/A - Urea 35-20-40	66	89
Ag lime - 2 T/A - Sulfur 50 lb/A - Urea 50-30-60	73	74
Calcium Silicate - 10 T/A-Urea 50-30-60	81	108
Calcium Silicate - 10 T/A-Urea 50-30-60	78	107
LSD (0.05)	6	40

Table 2. 1988 Wild Rice Yield Trial Results--Grand Rapids, MN (spring planted).

Entry-Source	Yield[1]	Percent Dry Weight	Stem Number	Plant Number	Harvest Date	Plant Height
	(lb/A)		-- per plot --			(inches)
Meter						
- Harrell	280	66	104	11	August 9	57
- Imle	249	69	110	18	August 9	54
- Shetka	244	67	124	24	August 9	55
Experimental						
- BB[2]	1084	64	194	26	August 23	68
Experimental						
- M3 x Net[3]	491	63	240	43	August 9	65
Experimental						
- D x J[3]	518	69	227	39	August 9	65
Voyager						
- Imle	403	65	137	18	August 15	60
- Rennemo	257	66	101	9	August 15	54
K2	370	61	75	4	August 23	55
M1	514	60	127	11	August 23	63
Netum	353	66	153	29	August 9	63
LSD (.05)	241	6	58	14	2 days	6

[1] Dry weight of unprocessed grain.
[2] Variety developed by K. Petrowske, Waskish, MN.
[3] Experiments from breeding program--to be used as parental sources for a 4-way cross in 1989.

The results regarding tensile strength measurements of shattering resistance are inconclusive but intriguing. Our sample size was extremely small and thus prevented detection of significant differences. None the less, the fly ash and calcium silicate treated strips in the paddy produced plants which had higher tensile strength measurements than the control plants.

While the results from these measurements are interesting from a research point of view, Dr. Bloom (personal communication) has had little success in affecting yield at other locations and years, when silica treatments have been applied. Dr. Porter measured tensile strength of seed retention on Bloom's experiments at Imle and Gunvalson's operation in Clearwater County (data not reported). He found no significant differences in his analysis of the data.

Selection for Seed Shattering Resistance in M3 (Tri Hutomo)

In 1987, Tri Hutomo used three different methods of selecting for resistance to seed shattering in the variety M3 at Rosemount, MN. From a series of half-sib families, superior families were identified based on a shattering score (subjective scoring system of gently stripping mainstems to rate plants for seed retention), the best families based on an assessment of the percent of shattering on plant mainstems, and the best plants selected from throughout his paddy. I had selected some superior plants (shattering score) from an M3 early population at Grand Rapids in 1986, seed of which were planted at Grand Rapids in 1987. Gary Linkert selected plants from Tri Hutomo's 1987 experiment at Rosemount in mid-October after almost all seed had fallen from the plants. Tri Hutomo also selected some populations using family selection for tall plants and best shattering score, tall plants, short plants, early flowering, and late flowering. Finally, a random sample of seed was collected for use as a control population. These materials were planted at Rosemount in 1988 to evaluate the efficiency of the selection schemes.

The results of his experiments are being processed. However, some preliminary observations are presented in Table 3. Each of the eleven entries were ranked for performance based on yield, tensile strength, plant height, stand density, stem number and then as a sum of the ranks to come up with the overall ranking of the populations. The low number is desirable. There are some clear messages from the table: 1) progress from selecting for surviving seed very late in the fall was very poor except for increasing plant height; 2) selecting for early flowering plants did not produce desirable results; 3) selecting for tall plants (family basis) and short plants, and for best plant-individual shattering score tended to produce desirable results. A more complete report of the experiment will be written when analyses have been completed.

Table 3. Performance (based on ranks of yield, tensile strength, seed retention, plant height, stand density, and stem number per plot) of M3-derived populations selected based on several morphological and seed-shattering criteria in 1987.

Entry No.	Selection Criteria	Rank by each Trait					Overall Rank
		Yield	Tensile Strength	Plant Height	Stand Density	Stem Number	
1	Bulk, best families, shattering score	8	9	7	1	8	8
2	Bulk, best families, % shattering	6	4	9	6	3	6
3	Bulk, best individual plant shattering score	1	6	5	3	7	3
4	Random sample	5	8	2	4	6	4
5	M3E (G.R.) selection	9	1	11	10	10	9
6	Gary's selection (late M3 from Rosmount)	11	11	3	11	11	11
7	Bulk, best families for tall plant and shattering score	3	5	6	9	4	5
8	Taller plants (family selection)	2	2	1	2	1	1
9	Shorter plants (family selection)	4	3	4	5	5	2
10	Earlier flowering plants (family selection)	10	10	10	7	9	10
11	Later flowering plants (family selection)	7	7	8	8	2	7

K2 Half-Sib Family Selection--Grand Rapids (Porter)

Using seed from individual plants collected in 1987 from Tom Godward's farm near Aitkin, MN, 140 half-sib families were spring-planted in two replications, each plot consisting of one six-foot row. A sets-in-reps design was employed, with each of 7 sets consisting of 20 families not repeated in other sets. At the initiation of flowering, plants were tagged with tape every 3-5 days, color-coded according to the time of the emergence of the lowest staminate branch.

Prior to harvest, the two best mainstems in each row were selected based on the seed retention estimated by gently hand-stripping each tagged panicle. The maturity of each head was taken into account in the selections. Since there was an average of 14 plants in each row, within-family selection intensity was approximately 15%. The heights of four plants within the row (i.e. not an end plant) were also measured prior to harvest. Average maturity for each row was estimated from the number of tags of each color in the row.

At harvest, stem number, plant number, seed green weight, and seed dry weight were determined. These data, along with calculated genetic variances, error variances, heritability and gain from selection are presented in Table 4. Seed dry weight was the most highly heritable trait at 46%. Based on dry weight, the best-yielding 5 of the 20 families in each set were selected for planting next year. Since only the least shattering 15% of each row was saved, this means that selection was between families for yield, and within families for seed retention. A portion of the seed from all 140 families was also saved for future comparisons with the selected families.

Phenotypic correlations between traits were calculated and are presented in Table 5. As often occurs, there was a strong correlation between stems per plot and yield, but tillering was also moderately correlated with yield. Plant height and maturity were poorly correlated with the other traits. There was apparently not much genetic variability for height in this population (Table 4), at least not on a family mean basis. However, maturity appears to be as heritable as yield here, and experience has proven that maturity is quite amenable to change.

Plot yields were quite high. The mean of all families would be equivalent to 1270 lb/A dry wt., while the minimum was 680 lb/A and the maximum was 2205 lb/A dry wt. It is hoped that improvements in harvestable yield can be made by selecting for both high yield and increased seed retention.

Table 4. Means, genetic and error variances, and narrow-sense heritabilities for traits of 140 half-sib families of K2.

TRAIT	MEAN ±	SE	σ^2_G ±	SE	σ^2_E ±	SE	HER ±	SE
Stems	64.1 ±	1.3	29.9 ±	23.2	237.9 ±	29.0	0.20 ±	0.16
Plants	13.9 ±	0.3	0.9 ±	0.8	8.9 ±	1.1	0.17 ±	0.16
Tillers[a]	4.8 ±	0.1	0.3 ±	0.1	1.1 ±	0.1	0.32 ±	0.15
Height[b]	202.6 ±	0.9	10.2 ±	10.4	110.6 ±	13.5	0.16 ±	0.16
Gr. wt.[c]	118.9 ±	2.8	340.6 ±	127.6	1102.7 ±	134.2	0.38 ±	0.14
Dry wt.[c]	99.3 ±	2.0	222.5 ±	67.8	532.9 ±	64.9	0.46 ±	0.14
Mat.[d]	76.9 ±	0.1	0.9 ±	0.3	2.4 ±	0.3	0.44 ±	0.14

[a] per plant

[b] cm

[c] grams per plot

[d] days after May 1

Table 5. Phenotypic correlations among traits for 140 half-sib families.

	Plants	Tillers	Height	Gr. wt.	Dry wt.	Maturity
Stems	0.51	0.50	-0.08	0.76	0.70	-0.14
Plants		-0.45	-0.08	0.34	0.38	-0.27
Tillers			0.02	0.44	0.35	0.08
Height				0.08	0.11	-0.10
Green wt.					0.96	-0.08
Dry wt.						-0.12

Mass Selection for Increased Seed Retention--Grand Rapids

A large proportion of the total plant breeding research in 1988 involved selection for shattering resistance. Since these experiments are still in progress, only brief descriptions are presented.

K2 Populations

Selection was continued on several populations of K2. One population consisted of bulked progeny of plants rated as "1" or "2" on a 1-5 scale. Another was of "best plant" selections (evaluated subjectively). Another came from seed collected very late in the growing season, immediately after the first hard frost. Plants in each population were tagged as the staminate portion of the mainstem panicle emerged. A different tape color was used at each tagging date (approximately 3-5 days apart) to color-code plants in the same maturity group. Populations were subjected to 10% selection intensity based on gently hand-stripping each panicle to determine seed retention at panicle maturity. Selections were made only among plants of similar maturity which were near each other in the field. Selected seed was bulked and saved by maturity group for planting in 1989.

M1 Population

An unselected population of the variety M1 was subjected to 10% selection intensity for seed retention, using the same maturity-coded groupings and selection techniques as used for K2. Seed was bulked and saved by maturity for planting in 1989.

Voyager

An unselected population of Voyager, planted in 6-row blocks for evaluation of the efficacy of various insecticides against riceworm (by D. Noetzel), was subjected to 10% selection intensity for seed retention. As in the previous experiments, plants were tagged for maturity and selections were made by N. Page and W. Majerus only among plants similar in maturity within the same block. Seed was bulked and saved in two maturity groups for planting in 1989.

"Crowsfoot" Panicle Study--Grand Rapids

The "Crowsfoot" panicle characteristic has been observed in many wild rice plantings. It occurs when the branches of the pistillate portion of the head (normally adherent to the central stalk, or rachis, of the panicle) open up in a fashion similar to the staminate branches of a normal plant. Since the trait may have some value in reducing riceworm damage, a study was initiated to better understand its genetics and its stability. At the Manomin Development Company farm, collections were made by G. Linkert, N. Page, and R. Porter of 50 Crowsfoot pistillate heads and 25 non-Crowsfoot pistillate heads from the variety M3, known for its high proportion of pistillate heads. Seed from each type will

be planted adjacent to the other in 1989 for observation and for crossing between and within types. In cooperation with D. Noetzel of Entomology, artificial infestation of each type with riceworm larvae or eggs will be attempted, and on damage in each type will be observed.

Greenhouse Studies of Seed Retention--Grand Rapids

The following experiments were carried out in the greenhouse at the North Central Experiment Station by R. Porter and H. Schumer. The cooperation of R. Zeyen, Plant Pathology Department, University of Minnesota, is acknowledged for aid in the silica research.

Soil Silica Levels and Seed Retention

In October of 1988, 20 half-sib families of Meter, obtained from W. Harrell's farm near Palisades, MN, were planted in 6-inch pots of peat soil obtained from the Manomin Development Company farm near Aitkin. We added 0, 4, 8, 12, 16, or 20 g of sodium silicate per kg of soil, such that each family appeared in each soil treatment. Plants were tagged weekly as the staminate portion of the panicle emerged. Also at panicle emergence, tensile strength of five unpollinated or recently-pollinated florets of each mainstem was measured using a tensile strength meter. Four weeks later, tensile strength was measured on five mature seeds of the same mainstems.

Results have not yet been analyzed, but tensile strength of immature florets appeared to show a trend toward higher tensile strength with increasing silica. However, any benefits due to improved silica nutrition may have been negated at the highest treatment levels due to sodium toxicity from the sodium silicate. Early measurements of tensile strength did not appear to correspond well to measurements at maturity. Plants with the highest mature seed tensile strength did not have the lowest immature tensile strength. This suggests that plants with low floret tensile strength can probably be eliminated from the population at anthesis.

Also, the variation in immature tensile strength from plant to plant seemed greater than variation among treatments, indicating that genetics may have a greater role than silica nutrition in determining tensile strength, at least under these conditions. Nevertheless, firm conclusions cannot be drawn yet; sodium toxicity occurred in some of the plants.

Mass Selection for Seed Retention and Reduced Dormancy

In October, four varieties were planted in pots (two plants per pot) with mineral soil. The seed had been collected from farmer's fields in August: M1 and M3 from the Manomin farm, Voyager from the Imle/Gunvalson farm near Gully, MN, and K2 from the Kosbau farm near Aitkin, MN. Seed had only been stored approximately 60 days, but that which germinated was considered to have a reduced dormancy period and was transplanted into the pots. During the seed maturation period, plants which were obviously more shattering were rogued out until 20-25% of each population was left. After harvesting, seed will be stored approximately 45 days and only germinating seed will be transplanted to the field for another cycle of selection.

Selection for Fungal Brown Spot Resistance--St. Paul

In a cooperative project between Wild Rice Pathology (J. Percich) and Wild Rice Breeding (R. Porter and G. Linkert), screening for resistance to fungal brown spot (Bipolaris oryzae) was initiated. The initial stages have involved successful culture of a number of isolates of the causal organism. However, efforts to produce infection in a greenhouse mist chamber are still ongoing. Continuing efforts will involve mass screening in the greenhouse and in the field to identify potentially resistant genotypes. Plans are being made to utilize a field misting system developed by J. Percich and J. Boedicker (North Central Experiment Station), for the field screening portion of the collaborative effort in 1989.

Performance of Wild Rice Populations Developed by Three Different Half-Sib Mating Designs - Majerus, Ph.D. Thesis

We are interested in trying to ascertain why some of our experimental populations appear to have lost productivity during the time (3 to 4 years) we grow them in small paddies (0.1 to 1.0 acres). The results of this experiment may also help explain some of the changes in productivity which occur in grower paddies over the several years the paddies are in production.

The objective of this study is to determine if any differences exist between the following mating schemes in wild rice: half-sib family rows, polycross of half-sibs, and half-sib family blocks. Inferences will be based on the following assumptions: 1) wind-dispersed pollen travels short distances (3 to 6 feet) from the point of dehiscence, 2) plants within the same half-sib family may inter-pollinate, 3) tillers of plants within a half-sib family may pollinate subsequent tillers of the same plant resulting in self-pollination and 4) therefore, any decline in performance may be the consequence of inbreeding by nonrandom mating within half-sib families.

MATERIALS AND METHODS

In summer 1988, a series of bulk populations were generated from 200 randomly selected half-sib families, 100 from each M1 and K2 wild rice cultivars. Seed of the 100 half-sibs from each cultivar were planted to facilitate three different mating schemes: open-pollination in half-sib family blocks, random mating in a polycross of half-sibs, and open-pollination of half-sib family rows. From each mating arrangement, panicles from 3 stem types (main stem, first tiller, and remaining tiller) were harvested separately, and later combined, resulting in nine bulks per cultivar. These eighteen bulk populations, nine bulks from M1 and nine bulks from K2, should represent a range of possible variation among and within plant matings from the three schemes and three stem type combinations (Table 6).

The 100 K2 half-sib families were planted, as described below, in a paddy at the North Central Experiment Station at Grand Rapids, Minnesota. The 100 M1 half-sib family selections were planted at the Horticultural Research Center at Excelsior, Minnesota.

To induce some level of inbreeding, a form of plot-inbreeding (Macaulay, 1928) was used. One hundred plants per family were planted in five by five foot blocks with three feet between blocks. Twenty-five to thirty seeds per panicle from five random main stems, first tillers, and remaining tillers were harvested from the center two square feet of each five square foot block per family. From these seed sources, three bulks per cultivar were made: main stem bulk (SIBMMS, SIBKMS), first tiller bulk (SIBMFT, SIBKFT), and remaining tiller bulk (SIBMRT, SIBKRT).

The 100 half-sib families were grown as entries of a polycross mating design, replicated 15 times in a hill plot planting arrangement. Three seeds of each family were planted in each replicate on 15 inch centers. At the tillering stage, each hill was thinned to one plant. Replicates of the main stems, first tillers, and remaining tillers were harvested, per cultivar, with twenty-five to thirty seeds per head bulked to make the following: main stem bulk (POLYMMS, POLYKMS), first tiller bulk (POLYMFT, POLYKFT), and remaining tiller bulk (POLYMRT, POLYKRT).

The open-pollinated half-sib family row mating scheme consisted of three replicates of the 100 randomly selected families planted in a blocks-within-replicates design. Family rows, five feet long and one foot apart, were planted and subsequently thinned to fifteen plants per row. Three plants within each half-sib row (three replicates and 100 families) were harvested by main stem, first tiller, and remaining tillers. From these M2 and K2 seed sources, twenty-five to thirty seeds per head were bulked as follows: main stem bulk (OPMMS, OPKMS), first tiller bulk (OPMFT, OPKFT), and remaining tiller bulk (OPMRT. OPKRT).

The eighteen bulks (Table 6) will be tested in 1989 in a randomized complete block design with a split plot arrangement in paddies at the North Central Experiment Station and Horticultural Research Center. Each treatment will be planted in two, 20-foot long rows spaced 15 inches apart and thinned to 60 plants per row. Traits measured will include: grain yield, plant height, flowering date, vigor score, and seed retention score, all of which will be evaluated on a plot basis. Grain yield related traits will include dry weight, green weight, percent dry matter, and dry weight per stem. Plant height will be measured in centimeters from the base of the plant to the top of the highest pistillate florets. Flowering date will be recorded as number of days accumulated between planting and the date when 50% of the plants per plot arrive at 100% staminate floret branch emergence. Plot vigor will be scored on the plant appearance at the second aerial leaf stage. A one to five scale will be used; one for most vigorous and five for least vigorous. Seed retention score based on hand stripping of panicles will be used to quantify shattering resistance (Stucker and Hutomo, 1987).

Table 6. The nine bulks of M1 and K2 varieties from 100 random half-sib families to be tested in 1989, for evaluating performance between three different half-sib mating schemes and panicle head type combinations.

M1 bulks	
Open-pollinated half-sib row family	Abbreviations
main stem bulk	OPMMS
first tiller bulk	OPMFT
remaining tiller bulk	OPMRT
Polycross half-sib family	
main stem bulk	POLYMMS
first tiller bulk	POLYMFT
remaining tiller bulk	POLYMRT
Sibmated family	
main stem bulk	SIBMMS
first tiller bulk	SIBMFT
remaining tiller bulk	SIBMRT
K2 bulks	
Open-pollinated half-sib row family	
main stem bulk	OPKMS
first tiller bulk	OPKFT
remaining tiller bulk	OPKRT
Polycross half-sib family	
main stem bulk	POLYKMS
first tiller bulk	POLYKFT
remaining tiller bulk	POLYKRT
Sibmated family	
main stem bulk	SIBKMS
first tiller bulk	SIBKFT
remaining tiller bulk	SIBKRT

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Proposed Germplasm Release--Pistillate M3.

Schumer and Stucker

The wild rice plant is normally monoecious, with both pistillate and staminate flowers on a panicle--pistillate flowers superior to staminate. However, wild rice growers and researchers have long been aware of an all pistillate panicle type. A population segregating for the trait is a mixture of normal monoecious plants and plants that are all female. In effect, the pistillate plants are male sterile. As such, they can be useful (just as are genetic male sterile plants in other species) for making population crosses in wild rice. Henry Schumer, wild rice coordinator at Grand Rapids, has been working with a pistillate population selected from the variety M3, known to segregate for pistillate plant type. The breeder of M3 included the pistillate type deliberately and the variety still segregates nicely for the trait--although its frequency is low. The pistillate families developed by Schumer segregate approximately 1 to 1 as would be expected for a trait controlled by a single locus and expressed when a plant is homozygous for the recessive allele.

The trait is very attractive because of the increased yield potential (all florets are pistillate). However, the pistillate plant types do not set seed on all florets. Because we believe there is value to using the trait as a male sterile source--and because others may be interested in a source of pistillate plant type which has high frequencies of pistillate plant types, we propose to bulk the six families of the material and release the bulk as a germplasm source. The attached tables will demonstrate a good likelihood that the trait is segregating 1 to 1 (Tables 7 and 8), has some increased yield potential (Tables 7 and 9), and causes little change in plant height (Table 9). Table 10 describes the panicle characteristics.

The evidence supports a recessive single gene control, but some more documentation would be necessary to confirm this. All evidence shows a very attractive potential for increased yield if all the florets would bear seed.

We believe the population should be released as a germplasm source. Release date should be fall of 1989 at which time we should have sufficient seed for a limited distribution. Seed source would likely be maintained by Schumer at the North Central Experiment Station.

Attached is an earlier report that was prepared by Schumer. It will explain some background of the selection procedure. Since the trait is controlled by a homozygous recessive locus, a mixed population (a pollen source) is required to maintain the trait. This is well known to plant breeders working with genetic male steriles. Further, the population requires roguing of all fertile plants when the breeder's objective is to use the population for crossing with other populations. This is a limiting factor but not prohibitively difficult with wild rice.

Table 7. Field evaluation of a population segregating for pistillate panicle type: 5 plots of 2 20-foot rows at Grand Rapids in 1985.

	Number of Plants	
Plot	Normal	Pistillate
1	62	61
2	49	46
3	45	42
4	44	40
5	60	71
Total	260	260

Fifty to 100 heads of each panicle type were harvested from each plot.

Type	Green Weight (g/head)	Dry Weight (g/head)	Percent Dry Weight
Normal	2.6	1.48	56.8
Pistillate	5.0	2.74	54.8

Table 8. Field grow-outs of 6 populations segregating for pistillate plant type. Each family was grown in 5 plots, 5 feet in length at Grand Rapids in 1988.

	Number of Plants	
Family	Normal	Pistillate
A	47	49
B	41	37
C	31	27
D	44	38
E	37	45
F	47	42
Total	247	238

Table 9. Comparison of normal and pistillate panicles from segregating families grown in 5-foot rows spaced 15" apart at Grand Rapids in 1988.

Family	Number of Panicles		Green Weight (g/head)		Dry Weight (g/head)		Plant Height (cm)	
	Normal	Pistillate	Normal	Pist.	Normal	Pist.	Normal	Pist.
A	311	345	1.95	2.74	1.18	1.58	---	---
B	78	122	2.10	2.89	1.32	1.69	165	154
C	81	99	1.97	2.38	1.17	1.36	170	176
D	109	84	2.30	2.67	1.43	1.61	172	177
E	118	103	1.99	3.04	1.25	1.82	172	161
F	322	288	1.87	2.35	1.19	1.45	---	---
TOTAL	1019	1041	-	-	-	-	-	-
Mean	-	-	2.03	2.68	1.26	1.58	170	167
Percent increase over normal				32%		25%		

Table 10. Comparison of normal and pistillate panicles for length, number of branches and number of florets, Grand Rapids, 1988 (25 panicles of each type).

	Normal	Pistillate
Total panicle length (cm)	40.8	43.8
Pistillate length (cm)	20.6	43.8
Number of male branches	16.6	0
Number of female branches	17.2	32.4
Number of female florets	137.2	381.9

NOTE: The Minnesota Agricultural Experiment Station Crop Variety Review Committee approved release of this population for germplasm purposes. An official release statement and name will be forthcoming (RES).

OBSERVATIONS ON TWO CYCLES OF SELECTION FOR THE PISTILLATE CHARACTERISTIC

Henry J. Schumer
March 1985

INTRODUCTION

The existence of the pistillate characteristic in wild rice has been known and observed for at least 13 years. The 1972 Progress Report of Wild Rice Research stated "Observations are being made on male sterility . . . that may be useful in the future." In Extension Bulletin 464, Wild Rice Production in Minnesota, the variety M_3 is described as follows: ". . . has a mixture of all female and female-male panicles. It was developed by Manomin Development Co. in 1974." One of the objectives stated in the 1973 Progress Report of Wild Rice Research was: "Determine the inheritance of plants having only pistillate (female) flower." It was with this goal in mind that I was asked by Dr. Robert Stucker, the wild rice breeding project director, to conduct winter greenhouse experiments which would give insight into the pistillate characteristics and establish a gene source that could be used as a future breeding tool. The following is a report on three years, two cycles of selection, for the pistillate (male sterile) characteristic.

PROCEDURE

In the fall of 1982 a seed sample of the variety M_3 was obtained from the Manomin Development Co. and used as the source of pistillate plants for the experiments. All greenhouse planting for this and the two consecutive years followed a standard procedure.

The seeds were pregerminated and one transplant placed in a 6-in pot, giving a plant density of 4 plants per sq ft. The pots were contained in a 4 ft by 6 ft tank flooded to the 3-in level over the containers. Sixteen-hour daylengths were maintained by a 4 ft by 6 ft lightbank containing 6 fluorescent tubes with 160 watts each. Planting occurred in October and November with harvest dates the following February and March.

OBSERVATIONS

The 1982-83 growing season produced 8 pistillate plants out of 421 plants. This is a 1.9% expression for the characteristic. These 8 plants were treated as separate lines and the seed was kept segregated. During the first growing season individual crosses were made by selfing the normal monoecious panicle and fertilizing a pistillate type head with the same pollen. Seed set under the head bags was very poor and only three crosses were brought forward to represent the F_1 population in the next growing season.

For the 1983-84 season 100 identified pistillate-to-normal plants and 85 identified normal selfs were planted. Concurrently, 675 plants representing 7 of the original pistillate plants were planted and allowed to intermate. The observed results were as follows:

	Pistillate ♀ x Normal			Normal selfed		
Entry	Bp-1	Bp-2	Bp-3	1X	2X	3X
# P type	0	0	0	0	0	0

Progeny of Pistillate Plants

Lines

	Bp	Cp	Dp	Ep	Fp	Gp	Hp	Total
# P type	1	6	20	2	39	29	19	116
Plant total	44	79	52	28	225	86	70	584
% P type	2.3	7.6	38.5	7.1	17.3	33.7	27.1	19.8

Individual crosses within the F_1 pistillate-to-normal population were continued along with additional pistillate-to-normal crosses within the line populations. The line populations were also subjected to the second cycle of selection, only the pistillate plants were harvested and again the individual lines were kept separate.

During the summer of 1984 a cooler malfunction caused massive losses of stored seed materials, no F_2 individual pistillate-to-normal entries and only one F_1 individual line cross remained viable. There was enough seed to plant the 6 population lines. The seed reserves were planted and the following observations recorded:

	Pistillate to Normal	Normal selfed
Entry	EP1	E1 X
# P type	5	1
Plant total	12	6
% P type	41.6	16.6

	Lines						
	Cp	Dp	Ep	Fp	Gp	Hp	Total
# P type	27	65	25	33	77	54	281
Plant total	68	124	59	70	152	102	575
% P type	39.7	52.4	42.3	47.1	50.6	52.9	48.8

Unlike the previous year the line populations were not allowed to intermate between lines; each population was kept isolated by a plastic barrier. There were no individual crosses made in the 1984-85 growing season and once again the pistillate plants were harvested separately from normal types.

A chronological review of the data, by discarding the line designations and using only total figures, will illustrate the population shift to a 50% pistillate 50% normal ratio. The parent population had only 1.9% pistillate plants (msms) with a high proportion of homozygous dominant (MsMs) normal plants, possibly 80% because there was a 20% expression in the F_1 (1983-84) pistillate parent population, and none of the crosses or normal selfs expressed for the characteristic. Random mating took place in the F_1 population but all pollen sources were heterozygous (Msms), which caused a 50% expression in the F_2 (1984-85) pistillate parent population and the one individual cross made in the F_1 to a pistillate expressed 50% (X^2 = 50% - 70%) with a 25% expression in the selfed (X^2 = 10% - 20%).

The chi-square test on the F_2 data null hypothesis that 50% of population will be pistillate and 50% will be normal, resulted in a 50 to 70% probability for acceptance well out of the significant area.

SUMMARY

We now have a male sterile population in our inventory that will reduce the need for emasculation and allow varietal crosses on a larger scale, although it will still be necessary to rogue out the normal types from the pistillate rows. Future work with the present seed source should include field trials to add supporting data to what has already been collected and the initiation of a selection program which will incorporate desired characteristics (ex. plant height, seed size) into pistillate lines.

WILD RICE WORM CONTROL, 1988

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Wild rice was planted at the North Central Experiment Station in Grand Rapids, MN on 12 May. Treatments were arranged in a randomized complete block design using plots with acceptable stands. Insecticides were applied on 29 July using a hand held CO_2 sprayer. Approximately 20 gal of total material was applied per acre at a pressure of 40 psi. Counts of damaged heads were made on Aug 30. Two independent comparisons are included.

The planting date for these trials was rather late and the season the warmest in history. Both stands and insect numbers were less than normal. However I felt since these are the first comparisons of a label compound (malathion) and pyrethroids they are worth reporting.

Table 1.

Insecticide * & formulation	Dosage in lb (AI)/acre	Avg no. heads damaged/20 heads
Bacillus thuringiensis	6 pts	11.3 a
Untreated	---	9.8 ab
Sevin XLR 4F	1.0	9.8 ab
methoxychlor 4E	1.0	6.8 a-c
Ambush 2E	0.04	3.3 bc
Capture 2E	0.02	2.3 c
malathion 5E	1.0	2.3 c
Karate 1E	0.02	2.0 c
Asana 1.9E	0.02	1.8 c

Numbers with the same letter are not different at (P=0.05) using DNMRT.

*Only malathion is labeled for use on wild rice.

Table 2.

Insecticide * & formulation	Dosage in lb (AI)/acre	Avg no. heads damaged/20 heads
Untreated	---	7.8 a
methoxychlor 4E	1.5	4.8 ab
malathion 5E	1.0	4.3 b
methoxychlor 4E	0.75	3.3 bc
Karate 2E	0.01	2.0 bc
methoxychlor 4E	1.0	1.8 bc
Ambush 2E	0.1	0.8 c
Ambush 2E	0.05	0.8 c
Ambush 2E	0.025	0.5 c
Scout xtra .9E	0.025	0.5 c
Asana 1.9E	0.4	0.3 c
Scout xtra .9E	0.05	0.3 c
Asana 1.9 E	0.02	0.3 c
Scout xtra .9E	0.0125	0.0 c

Numbers with the same letter are not different at (P=0.05) using DNMRT.

*Only malathion is labeled on wild rice.

DETECTION OF OPHIOBOLIN AND POSSIBLE USE IN *IN VITRO* SCREENING OF WILD RICE GERMPLASM FOR RESISTANCE TO FUNGAL BROWN SPOT

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Introduction

Bipolaris oryzae, the causal organism of fungal brown spot (FBS), produces ophiobolin, a non-specific phytotoxin, during infection and in culture (Orsenigo, 1957; Nakamura and Ishibashi, 1958). During FBS infection of rice (*Oryza sativa*), the toxin first kills host cells surrounding the infection, then the fungal mycelium colonizes the dead cells (Chattopadhyay and Samaddar, 1976). At the cellular level, the actions of the toxin result in disruption of the host plasmalemma, as evidenced by leakage of ions and solutes from affected tissues, and a rapid and irreversible depolarization of the membrane (Chattopadhyay and Samaddar, 1976; Gianani et al., 1980). At the molecular level, ophiobolin binds to the calcium-regulating protein calmodulin (CaM), inhibiting numerous calcium-dependent cellular processes (Leung, et al., 1984; Nejidat, 1987).

The use of phytotoxins for *in vitro* screening has become a useful tool in germplasm enhancement. Various toxins produced by *Bipolaris* species have been used to identify disease resistance in seedlings (Luke and Wallace, 1969) and tissue cultures (Gengenbach et al, 1977; Ling et al., 1985; Gengenbach and Rines, 1986) of various cereal crops. The use of ophiobolin for *in vitro* screening of wild rice seedlings and tissue cultures is currently under investigation on our laboratory.

The purpose of this study was to develop a rapid detection method for ophiobolin, to determine if ophiobolin was present in isolates of *B. oryzae* from wild rice, and to evaluate the reaction of wild rice seedlings to various concentrations of ophiobolin.

Detection Methods

Introduction

Thin layer chromatography (TLC) is a simple but efficient method for separation and identification of compounds in a mixture. Detection depends on resolution of the compounds on the chromatogram and reaction with color reagents. Different compounds can be distinguished by their R_f value (the distance the compound traveled on the plate relative to the solvent front) and by their reaction to color reagents.

When separating ophiobolin from a biological matrix, such as plant or fungal material, it is best to select a developing solvent which will minimize interference from substances that might co-migrate with the

toxin. Since each biological matrix is different, a single developing solvent cannot be used for all cases. Knowledge of the R_f values for ophiobolin in different developing solvents is required to select the solvent which will maximize resolution from the components of the matrix. The R_f values are also necessary if recovery of the toxin from the plate is desired.

Color reagents are sprayed onto developed chromatograms and react with the compounds on the plate to produce characteristic color reactions. The colors may distinguish between compounds, and they provide the means for detection of compounds which are not colored or fluorescent. Numerous color reagents exist, but most are not suitable for detection of ophiobolin.

Materials and Methods

Thin Layer Chromatography Purified ophiobolin was dissolved in methanol (1 ug/ul) and spotted on 5 X 20 cm pre-coated silica gel-glass TLC plates (Keiselgel 60 F_{254}, Merck). Chromatograms were developed in a solvent-saturated tank until the solvent front reached ca 0.5 cm from the top of the plate.

R_f Values The R_f values for ophiobolin (the distance the compound traveled on the plate relative to the solvent front) were recorded in various developing solvents. The limits of detection in each solvent was determined by spraying developed chromatograms with p-anisaldehyde and observing the smallest amount detected by the color reagent.

Color Reagents Six spray reagents were tested to determine their ability to detect ophiobolin on TLC plates. The formulas for the reagents are given in Table 1. Chromatograms were sprayed with color reagents using a glass chromatography sprayer (Sigma) and compressed nitrogen in a laboratory fume hood. The color reactions with each reagent were recorded and limits of detection with various indicator reagents and developing solvents were determined.

Table 1. Formulas of Color Reagents for Detection of Ophiobolin on Thin Layer Chromatograms.

Reagent	Formula
2,4 Dinitrophenyl-hydrazine	0.32% in 2N HCl
Phenylhydrazine	1% in 2N HCl
Para-anisaldehyde	1% 4-Methoxybenzaldehyde 21% H_2SO_4, 5% CH_3COOH (glacial), in methanol
Phosphomolybdic acid	10% 20 MoO_3-2 H_3PO_4-48 H_2O in methanol
Sulfuric acid	25% H_2SO_4 in water
Kato's Reagents	
I	3% 4(p-nitrobenzyl pyridine) in 2:3 chloroform:carbon tetrachloride
II	10% Tetraethlene pentamine in 2:3 chloroform:carbon tetrachloride

Results and Discussion

R_f values A range of R_f values was obtained for ophiobolin by using six different developing solvents. The limits of detection were determined for each solvent (Table 2).

Table 2. R_f values and Limits of Detection for Ophiobolin using Thin Layer Chromatography and Six Different Developing Solvents

Developing Solvent	R_f Value	limit of detection (ug)
Methylene chloride-acetone 9:1	.34	0.1
Toluene-ethyl acetate-formic acid 6:3:1	.45	0.05
Chloroform-methanol 5:1	.63	0.5
Chloroform-acetone-ethanol 13:5:2	.66	0.1
Chloroform-ethanol 3:1	1.00	*
Carbon tetrachloride-ethanol 3:1	.90	0.1

*Sample diffused along solvent front

Color Reagents Four of six reagents tested were suitable as chromatographic indicators for ophiobolin, judging by their color reactions and relatively low limits of detection (Table 3). Sulfuric acid and Kato's reagents were not satisfactory indicators for ophiobolin. Detection techniques were developed and compared using purified ophiobolin. Knowledge of the characteristic R_f values and color reactions of purified ophiobolin facilitates its detection and recovery from crude samples.

Table 3. Color Reactions and Limits of Detection for Ophiobolin on Thin Layer Chromatography Plates Treated with Color Reagents.

Reagent	Color	Limit of Detection (ug)
2, 4 Dinitrophenyl-hydrazine	yellow	2
Phenylhydrazine	pink	2
Para-anisaldehyde	purple	0.05
Phosphomolybdic acid	blue	0.1
Sulfuric acid	tan	5
Kato's Reagents I+II	no reaction	NA

Detection of Ophiobolin in Samples

Introduction

Before ophiobolin is used in an extensive screening program, its presence in isolates of B. oryzae infecting wild rice should be verified. Ophiobolins have been detected in cultures of B. oryzae infecting Oryza spp. (Oresnigo, 1957), but they have not been proven to occur in isolates from wild rice.

Materials and Methods

Culture. Bipolaris oryzae was cultured from infected wild rice leaves on Potato Dextrose Agar (PDA) (Difco Laboratories). Pathogenicity was verified by inoculation of wild rice seedlings in the laboratory (Johnson and Percich, 1988) and re-isolating from infected leaves. Liquid cultures of B. oryzae were established by inoculating 100 ml potato dextrose broth (PDB) (Difco Laboratories) in 125 ml erlenmeyer flasks with plugs (0.25 cm) of infected agar from the margins of pathogenic cultures. The liquid cultures were incubated at 24-26 C with 12 h light/dark for 12 days, then stored in a refrigerator at 2 C.

Extraction. Ophiobolin was extracted from liquid cultures of B. oryzae. The liquid was filtered through a double layer of cheesecloth and then through filter paper (Whatman #1) to remove fungal mycelium and suspended particles. The liquid from five cultures (500 ml) was shaken with 500 ml chloroform for 24 hours. The chloroform and aqueous fractions were separated in a separatory funnel and the chloroform fraction was evaporated to near dryness in a rotary evaporator. The extract was left overnight in a fume hood for crystallization. Usually 10-15 mg of crude solid extract was obtained from 500 ml of culture filtrate. The extract was dissolved in methanol (10 ml) and stored in the dark at 2 C.

TLC Methods. Extracts of B. oryzae liquid culture filtrates and purified ophiobolin (as a standard) were analyzed by TLC on 5 X 20 cm silica gel-glass plates (Keiselgel 60 F_{254}, Merck) 80 X 40 mm silica gel-plastics plates (Polygram Sil G/UV_{254}, Macherey-Nagel) using the methods described previously. Regions corresponding to the R_f value for ophiobolin were scraped and washed through a filter. The filtrate was analyzed by two-dimensional TLC (2-D TLC) on 20 X 20 cm silica gel-glass plates (Keiselgel 60 F_{254}, Merck). Plates were developed in 9:1 chloroform:methanol followed by toluene:ethyl acetate:formic acid 6:3:1 in a solvent-satorated tank. Chromatograms were sprayed with color reagents using a glass chromatography sprayer (Sigma) in a laboratory fume hood.

Results and Discussion

Ophiobolin was detected in culture filtrates of B. oryzae pathogenic to wild rice. Resolution of ophiobolin was better on 5 X 20 cm plates than on 40 X 80 mm plates. Positive reactions with p-anisaldehyde and phosphomolybdic acid were observed on both types of plates. Putative

ophiobolin from culture extracts co-migrated with purified ophiobolin standards in 2-D TLC and reacted positively with p-anisaldehyde and phosphomolybdic acid.

This is the first report of ophiobolin in culture filtrates of B. oryzae from wild rice. The presence of this phytotoxin suggests that it may play a role in pathogenesis.

Effects of Ophiobolin on Wild Rice Seedlings

Introduction

Although ophiobolin is non-specific toxin (it produces symptoms on plants which are not hosts of B. oryzae), its effects on wild rice have not been determined. Bioassays with toxins produced by other Bipolaris species have been used to both screen seedlings of potential germplasm lines and to identify and quantify toxins (Pringle and Braun, 1957; Luke and Wheeler, 1955).

Materials and Methods

Toxin Ophiobolin solutions of 10^{-4}, 10^{-5}, 10^{-6}, and 10^{-7} M were prepared by adding purified ophiobolin dissolved in methanol to sterile distilled water. Sterile distilled water was used as a control.

Procedure. Glass test tubes (1.5 X 15 cm) were filled with 5 ml of the test solutions, and five wild rice seeds (cv Meter) were placed in each tube. Five tubes of each solution were prepared. The tubes were capped and incubated at 24-26 C and 12 h light/dark. After 10 days, the seedlings were removed and measurements were taken of primary roots. The experiment was replicated three times.

Results and Discussion

Significant inhibition of primary root growth occurred in seedlings incubated in ophiobolin concentrations as low as 10^{-6} M (Table 4). Seedlings grown in 10^{-4} M did not survive for the duration of the experiment. Some seedlings grown in the 10^{-5} M solution and all seedlings in lower concentrations or SDW survived. The effects of ophiobolin on wild rice seedlings further suggest that the phytotoxin has a role in pathogenesis. The survival of some treated seedlings despite significant root inhibition indicates that in vitro screening of seedlings and tissue cultures with ophiobolin may be a practical method of screening germplasm for FBS resistance.

Table 4. Average Length of Primary Roots of Meter Wild Rice Seedlings Grown in Different Concentrations of Ophiobolin or Sterile Distilled Water.

Ophiobolin Molar Concentration	Primary Root Length (cm)
10^{-4}	0.1a
10^{-5}	0.6b
10^{-6}	2.2c
10^{-7}	2.4d
SDW	2.5d

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

Conclusions

A rapid and efficient TLC method has been developed for analysis of ophiobolin. Ophiobolin has been shown to occur in culture filtrates of B. oryzae pathogenic to wild rice. Ophiobolin concentrations as low as 10^{-6} M have been shown to significantly affect root elongation of wild rice seedlings. These data suggest that in vitro selection of wild rice seedlings and tissue cultures with ophiobolin is a good method of screening for FBS resistance.

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ASSESSING KERNEL SIZE DISTRIBUTION IN WILD RICE BY MECHANICAL AND COMPUTER IMAGING METHODS AND PERCENT RECOVERY BY MECHANICAL METHODS

James J. Boedicker, Cletus E. Schertz and Michael C. Lueders

Introduction

Research conducted by the wild rice harvest project in 1988 was directed to investigating alternative procedures for size grading wild rice grain. The work dealt primarily with green (as harvested) wild rice; however, much of the work on kernel size evaluation has direct application to processed wild rice grain. The research on grading was an outgrowth of previous research on development of quick methods for determining percent recovery and grain size distribution of green wild rice. These factors are influenced by combine adjustment and affect profitability.

Specific objectives of the research conducted in 1988 were:

1) To determine kernel size distribution and percent recovery of green wild rice by two procedures:

   a) test method as proposed by USDA in spring 1988

   b) mechanical method developed by the U of M

2) To compare results of tests from those two methods:

3) To investigate computerized image analysis for measuring the size of individual kernels and for analyzing the kernel size distribution in wild rice grain.

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Determining Kernel Size Distribution and Percent Recovery

Test Method Proposed by USDA

In April, 1988, the USDA at the Western Regional Research Center, Albany, California distributed a proposed test method for grading green wild rice grain. This method consists of four major steps:

1) Dockage separation with the use of a Carter Dockage Tester,

2) Partial drying, removing and separating hulls,

3) Sorting into four kernel size categories using a Carter Dockage Tester:

   I) over # 2 riddle
   II) through # 2 riddle and over # 22 sieve
   III) through # 22 sieve and over # 11 sieve
   IV) through # 11 sieve,

4) Final oven drying.

The size of the openings in the # 2 riddle in Step 3 is not specified. The purpose of the riddle is to sort according to kernel length. The sieves have slot openings and sort according to kernel width. The slot dimensions are:

# 22 sieve:	3.875/64	X	15/32 inch
# 11 sieve:	3.200/64	X	15/32 inch

To evaluate the USDA proposed method, freshly harvested wild rice samples were obtained. Four samples of green wild rice (labeled A, B, C and D) were collected from a combine. Selected adjustments were made on the combine to cause a difference in "quality" of the green wild rice in each sample. Subsamples, from samples A,B,C and D, were analyzed utilizing the test method proposed by USDA. Most of the equipment specified in the proposed method was available from U of M inventory or borrowed from the Minnesota State Grain Testing Lab and the Carter Day Co. A substitution was made to use the U of M laboratory huller and fanner instead of the Satake sheller which wasn't available. The substitution was considered nonconsequential to the outcome of the investigation.

The results of this test method provide information on the percent of hulled grain in each of the four size categories, described in Step 3, as well as the percent recovery. Percent recovery is the ratio of total mass of hulled grain in the four size categories to the mass of the initial green sample. This ratio is expressed as a percentage.

Results for the USDA method are shown in Tables 1 and 2. Table 1 shows results that were available within two hours from the start of the test. All percentages in this table are calculated using the mass of the partially dried, hulled grain at the time of sorting. The actual grain moisture content at the time of sorting is given in the right column of

Table 1. Table 2 provides similar information but on the basis of grain mass after final oven drying.

Test results for each sample can be represented by a numeric code of five numbers; eg., 59-17-13-11 : 50. The first 4 numbers of the code indicate the percentage of total grain mass in each of the respective size categories obtained from the Carter Dockage Tester. The number after the colon indicates the percent recovery. The numeric codes, shown in the tables, are the averaged values for each set of four replications.

Mechanical Method Developed by U of M

Over recent years, researchers at the U of M have developed a mechanical method for evaluating quality of green wild rice as an indication of combine performance. This method has three major steps:

1) Partial drying, removing and separating hulls,

2) Sorting by size on pocket plates into four kernel length categories:

   I) over 20/64" pocket plate
   II) retained in 20/64" pockets and over 12/64" pocket plate
   III) retained in 12/64" pockets and over 6/64" pocket plate
   IV) retained in 6/64" pockets

3) Final oven drying.

The dimensions in Step 2 are the diameters of round, flat-bottomed holes in the respective pocket plates. The holes have sufficient depth to retain a single layer of kernels.

As with the USDA proposed test method, four subsamples from each sample (A, B, C & D) of green wild rice were analyzed by the U of M method. This method provides information on percent of hulled grain in four kernel length categories and the percent recovery. Results of the replicated samples are given in Tables 3 and 4. Table 3 shows information available within two hours of the start of the test. In this Table, percentages of grain mass in the respective pocket plate categories, as well as percent recovery, are based on mass of hulled grain at the time of sorting. The right column in Table 3 shows actual moisture content of the grain at the time of sorting. Table 4 shows similar information but on the basis of grain mass after final oven drying.

Results, from the U of M method, can also be represented by a numeric code of five numbers; eg., 74-21-4-1 : 49. The first four numbers of the code indicate the percentage of total grain mass in each of the respective length categories obtained from the pocket plates. The number after the colon indicates the percent recovery. The codes, as shown in the tables, are the average value for each length category and percent recovery of four replications.

Comparison of the USDA and U of M Methods

Observations of the results are:

1) The percent recovery by the two methods are nearly equal for the respective samples.
2) Final oven drying reduces the calculated percent recovery by 2 to 4 percentage points.
3) The percentage of grain mass over the 20/64" pocket plate in the U of M method was 10 to 22 percentage points higher than that over the # 2 riddle in the USDA method.
4) The other three size categories are not directly comparable since the USDA sizing for these categories was based on kernel width whereas grading was by length in the U of M method.

Recently USDA distributed a revised set of "Wild Rice Grading Standards" that specifies a "U.S. Sizing Device" for length classification instead of the Carter Dockage Tester with riddle. Based on directions given in the standards on use of this device, it apparently is similar to the pocket plates used in the U of M procedure.

Computerized Image Analysis for Kernel Size Distribution

Research was initiated to investigate computerized image analysis as an approach for evaluating kernel size distribution in hulled wild rice. This method appears to have potential as a procedure for rapidly and accurately determining the percentages of grain mass in selected kernel size categories. Equipment includes a horizontal viewing table, a video camera mounted above the table and a computer. The kernels are placed in a single layer on the viewing table. The dimensions are established by the computer counting the pixels covered by the kernel image. The magnification is adjustable to provide measurements at selected degrees of resolution. The real length is calibrated by viewing an object of known length.

The image analysis procedure provides a variety of dimensional information about each kernel viewed; eg., coordinate positions of the kernel on the viewing surface, viewed area of the kernel, perimeter, breadth and length. Other values can also be computed.

The difficult kernel property to evaluate by image analysis is mass. Information about the mass of each kernel is needed so that the computer can tabulate the information and calculate the percentages of grain mass in each size category. A method was developed for correlating kernel mass with dimensional data calculated by the computer.

Kernels tend to lie on the broadside so that the largest kernel width is observed by the camera. This is a problem in that the width dimension observed is the largest. However, this is an advantage because this tendency causes the kernels to consistently lie in a similar orientation.

Another problem is when two kernels touch, they are viewed as a single kernel. There are two possible solutions to this problem. One is to have the computer discount these kernels which would exceed set thresholds for selected dimensions. Another solution is to develop a technique for placing the kernels on the viewing table so that kernels do not touch.

Results from image analysis of selected wild rice kernels are shown in Figures 1 and 2. Figure 1 shows the relationship of kernel length, as measured by image analysis, to kernel length, measured with a micrometer. Figure 2 shows a relationship of kernel volume to kernel mass. The volume computations by image analysis use an effective average kernel width for determining the kernel cross sectional area. This area is multiplied by the kernel length to calculate volume. The actual kernel mass was determined with an analytical balance. Measurements show that the mass of a kernel is proportional to the volume of the kernel.

Results from this study show:

1) computerized image analysis provides an accurate measurement of the kernel length and
2) calculation of kernel volume and its relationship to mass is sufficiently accurate for use in determining percentages of grain mass within selected kernel length categories.

Computerized image analysis can be valuable for determining kernel size mass distribution of wild rice samples. An additional sample of wild rice (approximately 100 individual kernels) has been submitted to an outside firm for image analysis. Individual mass and dimensional data have been manually measured for comparison with the image analysis values. Results from this sample will be analyzed for accuracy with which computerized image analysis can categorize and provide kernel size distribution information.

Table 1. Kernel size distribution and recovery by USDA's proposed method, determined two hours after start of test.

Sample ID	Carter Dockage Tester Output (Partially dried kernels, hulls removed) CDT I[1] %	CDT II[2] %	CDT III[3] %	CDT IV[4] %	Recovery[5] % R	Moisture[7] %Mwb
A-1[8]	63.4	16.4	11.0	9.3	NA	13.6
A-2[8]	61.5	16.7	12.9	8.9	NA	12.7
A-3	56.2	18.2	13.2	12.4	50.1	8.3
A-4	54.3	16.6	15.5	13.5	48.8	NA
Avg.	58.8	17.0	13.1	11.0	49.5	11.6
Std Dev	4.3	.8	1.9	2.3	.9	2.8
C	7.2	4.9	14.1	20.6	1.8	24.5
	Numeric Code[6] : 59-17-13-11 : 50					
B-1	57.6	17.7	14.2	10.5	53.7	7.3
B-2	55.2	22.8	13.1	8.9	54.2	6.4
B-3	54.6	22.6	12.6	10.2	53.5	5.8
B-4	55.1	21.7	13.2	10.1	54.2	NA
Avg.	55.6	21.2	13.3	9.9	53.9	6.5
Std.Dev.	1.4	2.4	.6	.7	.3	.7
C	2.4	11.1	4.9	7.2	.6	11.3
	Numeric Code[6] : 56-21-13-10 : 54					
C-1	67.0	9.5	8.6	14.9	39.8	6.3
C-2	68.0	8.9	7.3	15.8	42.3	8.0
C-3	66.2	8.3	9.0	16.5	39.9	8.4
C-4	67.8	7.9	9.0	15.3	39.7	NA
Avg	67.3	8.6	8.5	15.6	40.4	7.6
Std Dev	.8	.7	.8	.7	1.3	1.1
C	1.2	8.3	9.6	4.3	3.1	14.3
	Numeric Code[6] : 67-9-8-16 : 40					
D-1	68.3	8.4	9.1	14.2	44.1	8.1
D-2	65.6	8.3	9.5	16.6	41.2	7.2
D-3	67.5	9.4	9.4	13.7	42.7	6.5
D-4	61.6	14.3	10.2	13.8	44.3	NA
Avg	65.7	10.1	9.5	14.6	43.1	7.3
Std Dev	3.0	2.9	.5	1.4	1.4	.8
C	4.5	28.1	5.0	9.3	3.4	11.1
	Numeric Code[6] : 68-10-10-15 : 43					

1. Over # 2 riddle.

2. Through # 2 riddle and over # 22 sieve.

3. Through # 22 sieve and over # 11 sieve.

4. Through # 11 sieve.

5. Ratio of mass of partially dried hulled kernels to mass of original sample, expressed as a percent.

6. Results in code form: first four numbers indicate the average percentage of kernel mass in respective Carter Dockage Tester output categories; last number indicates the percent recovery.

7. Moisture at time of sorting, by subsequent oven drying, 48 hrs at 103 °C.

8. Dried for 30 minutes instead of 45 minutes as for the other samples.

Table 2. Kernel size distribution and recovery by USDA's proposed method, determined after oven drying for 48 hours.

Sample ID	Carter Dockage Tester Output (Dried kernels, hulls removed) CDT I[1] %	CDT II[2] %	CDT III[3] %	CDT IV[4] %	Recovery[5] % R
A-1	63.2	16.5	10.7	9.6	45.6
A-2	61.2	16.7	13.0	9.1	47.4
A-3	56.1	18.1	13.2	12.6	45.9
A-4	NA	NA	NA	NA	NA
Avg.	60.2	17.1	12.3	10.4	46.3
Std.Dev.	3.7	.9	1.4	1.9	1.0
Co Var	6.1	5.2	11.3	18.2	2.1
Numeric Code[6] :	60-17-12-10 : 46				
B-1	57.5	17.7	14.2	10.7	49.8
B-2	55.1	22.7	13.2	9.0	50.7
B-3	54.5	22.6	12.6	10.3	50.4
B-4	NA	NA	NA	NA	NA
Avg.	55.7	21.0	13.3	10.0	50.3
Std.Dev.	1.6	2.9	.8	.9	.5
C	2.8	13.7	6.0	8.7	.9
Numeric Code[6] :	56-21-13-10 : 50				
C-1	67.0	9.5	8.4	15.1	37.3
C-2	68.2	8.7	7.3	15.8	38.9
C-3	66.0	8.2	9.0	16.7	36.6
C-4	NA	NA	NA	NA	NA
Avg	67.1	8.8	8.2	15.9	37.6
Std Dev	1.1	.6	.9	.8	1.2
C	1.6	7.2	10.6	5.1	3.2
Numeric Code[6] :	67-9-8-16 : 38				
D-1	68.0	8.4	9.1	14.5	40.5
D-2	65.4	8.3	9.5	16.9	38.2
D-3	67.2	9.4	9.4	14.0	40.0
D-4	NA	NA	NA	NA	NA
Avg	66.9	8.7	9.3	15.1	39.6
Std Dev	1.4	.6	.2	1.5	1.2
C	2.0	6.9	2.4	10.2	3.0
Numeric Code[6] :	67-8-9-15 : 40				

1. Over # 2 riddle.

2. Through # 2 riddle and over # 22 sieve.

3. Through # 22 sieve and over # 11 sieve.

4. Through # 11 sieve.

5. Ratio of mass of partially dried hulled kernels to mass of original sample, expressed as a percent.

6. Results in code form: first four numbers indicate the average percentage of kernel mass in respective Carter Dockage Tester output categories; last number indicates the percent recovery.

Table 3. Kernel size distribution and recovery by U of M procedure, determined two hours after start of test.

Sample ID	Pocket Plate Output (Partially dried kernels, hulls removed) PP I[1] %	PP II[2] %	PP III[3] %	PP IV[4] %	Recovery[5] % R	Moisture[7] %Mwb
A-1	75.6	19.1	4.4	.9	49.3	6.0
A-2	72.5	22.1	4.5	.9	48.8	5.3
A-3	73.8	21.5	3.8	.9	48.8	5.5
A-4	73.6	21.5	4.0	.9	48.5	5.1
Avg.	73.9	21.1	4.2	.9	48.8	5.5
Std Dev	1.3	1.3	.3	.0	.4	.4
Co Var	1.8	6.4	8.1	2.1	.7	7.3
	Numeric Code[6] : 74-21-4-1 : 49					
B-1	77.4	18.5	3.4	.7	53.9	5.6
B-2	78.3	17.3	3.6	.8	53.6	6.0
B-3	77.0	18.7	3.5	.7	53.9	5.4
B-4	76.3	18.6	4.4	.8	53.6	5.6
Avg.	77.3	18.3	3.7	.8	53.7	5.6
Std Dev	.9	.7	.4	.1	.2	.3
C	1.1	3.6	11.7	7.7	.3	4.6
	Numeric Code[6] : 77-18-4-1 : 54					
C-1	79.0	16.1	3.9	1.0	39.9	6.0
C-2	80.5	14.9	3.6	1.0	41.4	5.8
C-3	79.0	15.9	3.9	1.2	42.3	5.8
C-4	78.6	15.9	4.3	1.1	39.5	5.6
Avg	79.3	15.7	3.9	1.1	40.8	5.8
Std Dev	.8	.5	.3	.1	1.3	.2
C	1.0	3.5	7.6	8.3	3.1	3.4
	Numeric Code[6] : 79-16-4-1 : 41					
D-1	80.7	14.1	4.2	.9	43.9	7.2
D-2	77.2	16.5	5.1	1.2	41.8	5.5
D-3	76.8	16.6	5.4	1.2	42.0	5.0
D-4	75.3	17.8	5.9	1.0	43.0	5.5
Avg	77.5	16.3	5.2	1.1	42.7	5.8
Std Dev	2.3	1.5	.7	.1	1.0	1.0
C	3.0	9.4	13.4	13.7	2.3	17.0
	Numeric Code[6] : 78-16-5-1 : 43					

1. Over 20/64 inch pocket plate

2. Retained in 20/64 inch pocket and over 12/64 inch pocket plate

3. Retained in 12/64 inch pocket and over 6/64 inch pocket plate

4. Retained in 6/64 inch pocket plate

5. Ratio of mass of partially dried hulled kernels to mass of original sample, expressed as a percent.

6. Results in code form: first four numbers indicate the average percentage of kernel mass in respective Carter Dockage Tester output categories; last number indicates the percent recovery.

7. Moisture at time of sorting, by subsequent oven drying, 48 hrs at 103 $^{\circ}$ C.

Table 4. Kernel size distribution and recovery by U of M procedure, determined after oven drying for 48 hours.

Sample ID	Pocket Plate Output (Dried kernels, hulls removed) PP I[1] %	PP II[2] %	PP III[3] %	PP IV[4] %	Recovery[5] % R
A-1	75.6	19.1	4.4	.9	46.4
A-2	72.4	22.1	4.5	.9	46.2
A-3	73.9	21.5	3.8	.8	46.1
A-4	73.5	21.6	4.0	.9	46.0
Avg	73.9	21.1	4.2	.9	46.2
Std Dev	1.3	1.3	.4	.0	.2
C	1.8	6.3	8.4	2.9	.3
	Numeric Code[6] : 74-21-4-1 : 46				
B-1	77.3	18.5	3.4	.7	50.9
B-2	78.3	17.3	3.6	.8	50.4
B-3	77.0	18.7	3.5	.7	50.9
B-4	76.3	18.6	4.3	.8	50.6
Avg	77.2	18.3	3.7	.7	50.7
Std Dev	.8	.7	.4	.0	.3
C	1.1	3.6	11.3	6.0	.6
	Numeric Code[6] : 77-18-4-1 : 51				
C-1	79.1	16.2	3.8	.9	37.5
C-2	80.5	15.0	3.6	1.0	39.0
C-3	78.9	16.0	3.9	1.2	39.8
C-4	78.5	16.0	4.4	1.1	37.3
Avg	79.2	15.8	3.9	1.1	38.4
StdDev	.9	.6	.3	.1	1.2
C	1.1	3.5	8.6	10.4	3.1
	Numeric Code[6] : 79-16-4-1 : 38				
D-1	80.5	14.2	4.3	.9	40.7
D-2	77.1	16.6	5.2	1.2	39.5
D-3	76.7	16.7	5.4	1.2	39.9
D-4	75.5	17.6	5.9	1.0	40.6
Avg	77.4	16.3	5.2	1.1	40.2
Std Dev	2.2	1.4	.7	.2	.6
C	2.8	8.7	12.9	14.0	1.5
	Numeric Code[6] : 77-16-5-1 : 40				

1. Over 20/64 inch pocket plate

2. Retained in 20/64 inch pocket and over 12/64 inch pocket plate

3. Retained in 12/64 inch pocket and over 6/64 inch pocket plate

4. Retained in 6/64 inch pocket plate

5. Ratio of mass of partially dried hulled kernels to mass of original sample, expressed as a percent.

6. Results in code form: first four numbers indicate the average percentage of kernel mass in respective Carter Dockage Tester output categories; last number indicates the percent recovery.

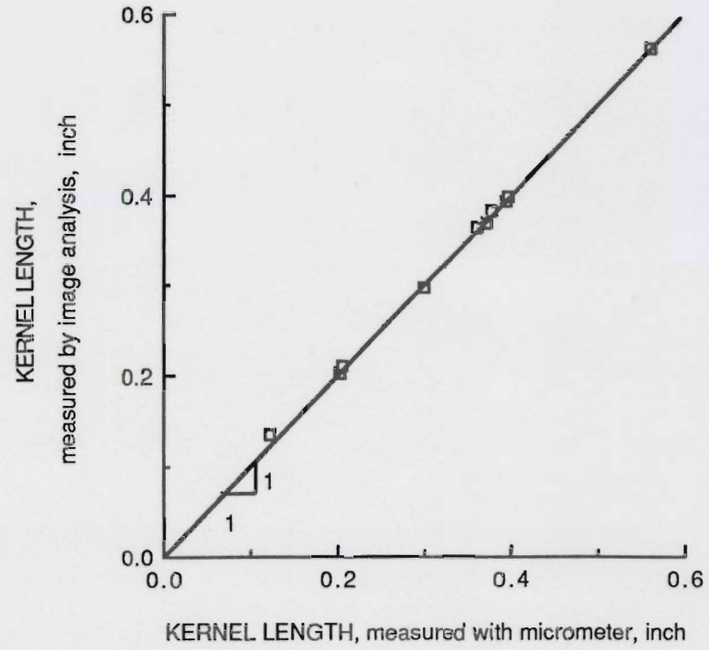

Figure 1. Relationship of kernel length by image analysis to kernel length measured with a micrometer.

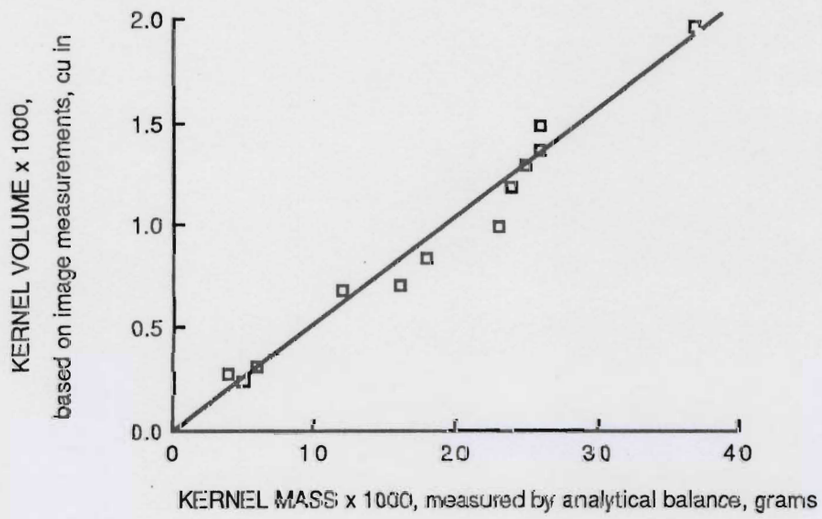

Figure 2. Relationship of kernel volume to kernel mass.