Minnesota Wild Rice Research 1979

Agricultural Experiment Station
University of Minnesota
St. Paul, Minnesota 55108
January 17, 1980

CONTENTS

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

The wild rice team wishes to acknowledge the assistance provided by many people. The cooperation of Dr. Rust, Superintendent of the North Central Experiment Station, Grand Rapids, was greatly appreciated. The cooperation of Dr. Wilcox, Superintendent of the Rosemount Experiment Station was also greatly appreciated as was the help of John Lange, Coordinator of the Horticultural Research Center at Excelsior. Also, the help of Drs. Rabas and Boedicker at the North Central Experiment Station, Grand Rapids was highly appreciated. The daily supervision of the research plots at Grand Rapids by Henry Schumer, Research Plot Supervisor, was very valuable and deeply appreciated. We are also extremely grateful to the growers and processors for providing seed, land area and facilities for research. We thank the growers for the funds provided in 1979 to the Agricultural Engineering Department.

WILD RICE FERTILIZATION RESEARCH - 1979

A PROGRESS REPORT
December 27, 1979

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Research was continued during 1979 on fertilization, nutrient requirement and water quality. Soil, water and air temperatures, and quality of paddy water were monitored during the growing season to obtain information on the environment in which wild rice grows. A nitrogen rate study was conducted on a mineral soil at Grand Rapids with the Netum variety in first production year. Three fertilization experiments were conducted with a second year stand of K2 variety on peat in Aitkin County to study N, P, K rates, and the effectiveness of foliar fertilization. Tissue samples were collected for plant analysis to learn more about nutrient uptake by the plant.

A. WEATHER AND PLANT DEVELOPMENT

The average air temperature (Table 1) was slightly below normal during April, May and August, and nearly normal during June and July. Generally, weather conditions during the 1979 growing season were more "normal" than those of 1976 and 1977 seasons which were exceptionally early and warm.

Soil, water and air temperatures were measured at three locations by 3-point automatic sensing and recording thermographs (see Fig. 1, 2, 3). Instrument malfunctions caused interruptions in temperature measurements.

The air and water temperatures fluctuated much more than the soil temperatures. The mineral soil at Grand Rapids also showed greater temperature fluctuations than the two organic soils. The temperature of both organic soils was in the low 40's during the plant emergence in early May. The temperature of organic soils measured about 50°F by mid-May, gradually increased to 65°F by mid-July and then gradually decreased towards harvest time.

Plants emerged on May 8 in Aitkin County and on May 11 at Grand Rapids (Fig. 4, 5). The jointing stage was reached by Netum at Grand Rapids on July 6, 55 days after emergence, and by K2 in Aitkin County on July 9. Netum was harvested on August 27, 108 days after emergence. The K2 wild rice was harvested on August 28, 112 days after emergence.

Table 1. Average air temperature as measured at three U.S. weather stations.[1]

Station Year	April	May	June	July	August	5 Month Average	GDD T_b=40
	Month						
	average air temperature, °F						
Fosston, Polk Co.							
Normal[2]	41.0	54.6	63.6	69.4	67.5	59.2	2955
1974	41.0	50.5	63.4	71.6	62.8	57.9	2744
1975	34.8	55.7	61.9	70.5	64.6	57.5	2852
1976	46.6	54.9	66.8	68.8	70.9	61.6	3315
1977	49.1	66.4	64.6	70.3	60.6	62.2	3446
1978	41.7	59.2	63.4	67.8	67.7	60.0	3060
1979	36.0	48.7	63.6	69.6	63.6	56.3	2627
Grand Rapids, N.C. School							
Normal	39.9	52.7	62.0	67.4	65.1	57.4	2681
1974	41.6	49.4	62.7	70.7	62.8	57.4	2670
1975	34.7	57.0	62.2	71.5	65.2	58.1	2951
1976	47.1	54.4	66.1	68.2	67.4	60.6	3166
1977	48.2	63.8	64.0	69.2	60.2	61.1	3284
1978	41.3	57.9	62.8	66.5	66.0	58.9	2892
1979	37.1	49.5	61.5	68.1	62.6	55.8	2511
Aitkin							
1974	42.9	49.8	63.1	71.1	63.3	58.0	2770
1975	39.0M[3]	59.4M	64.4M	72.1	66.2M	60.2	3141
1976	47.5	54.8	66.8	69.3M	68.1	61.3	3267
1977	48.3M	64.4M	65.4M	70.3M	61.0	61.9	3446
1978	40.7M	57.5M	64.1M	67.0M	66.9	59.2	2938
1979	37.7	50.6M	62.0	68.1M	63.4	56.4	2585.1

1/ Source: Climatological Data, Minnesota, Vol. 80, 81, 82, 83, 84, 85 (1974-79), U.S. Dept. of Commerce.

2/ Normals for the period 1931-60.

3/ M = less than 10 days record missing.

Fig. 1

MEAN AIR, WATER AND SOIL TEMPERATURES

GRAND RAPIDS – 1979

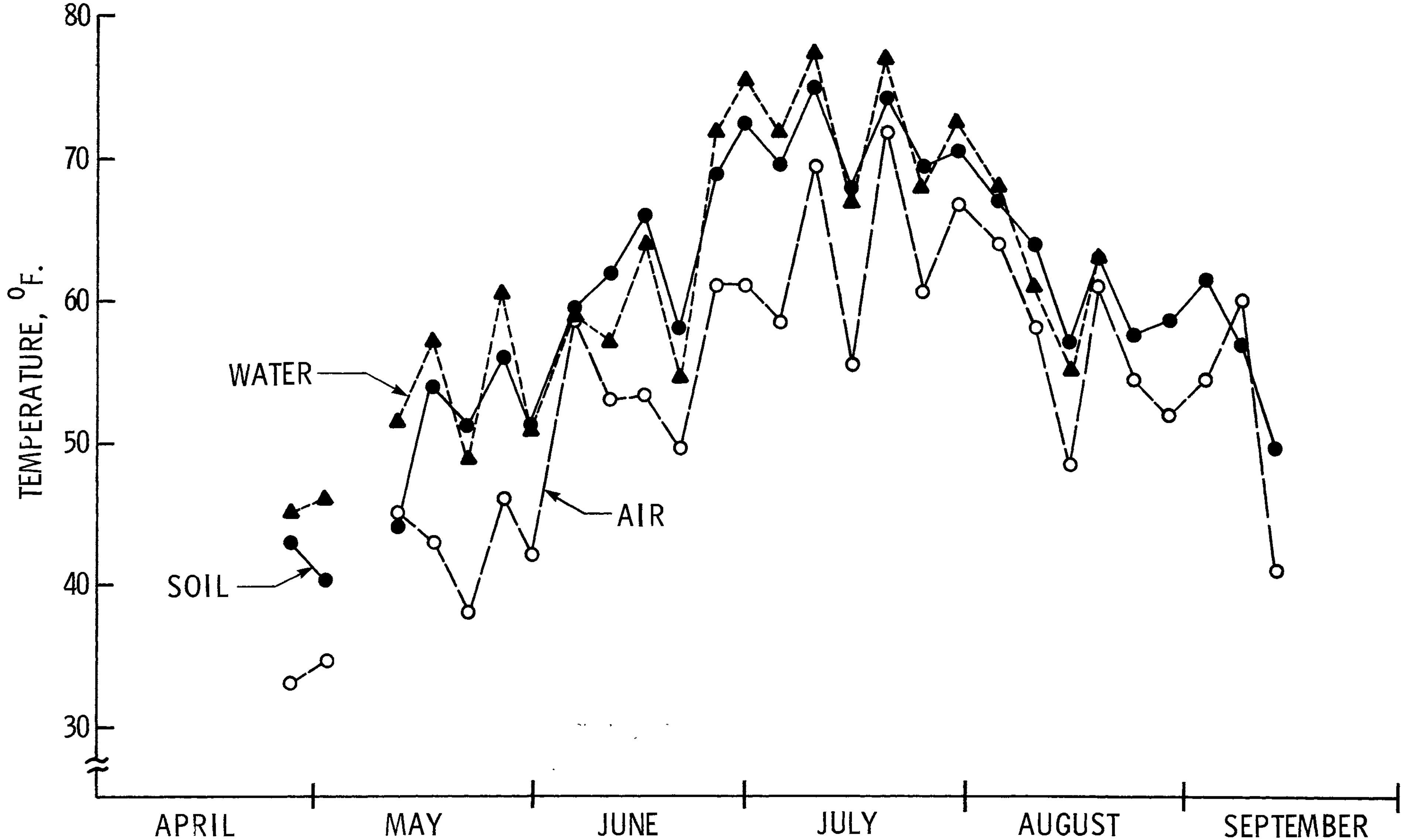

Fig. 2

MEAN AIR, WATER AND SOIL TEMPERATURES

KOSBAU BROS., AITKIN – 1979

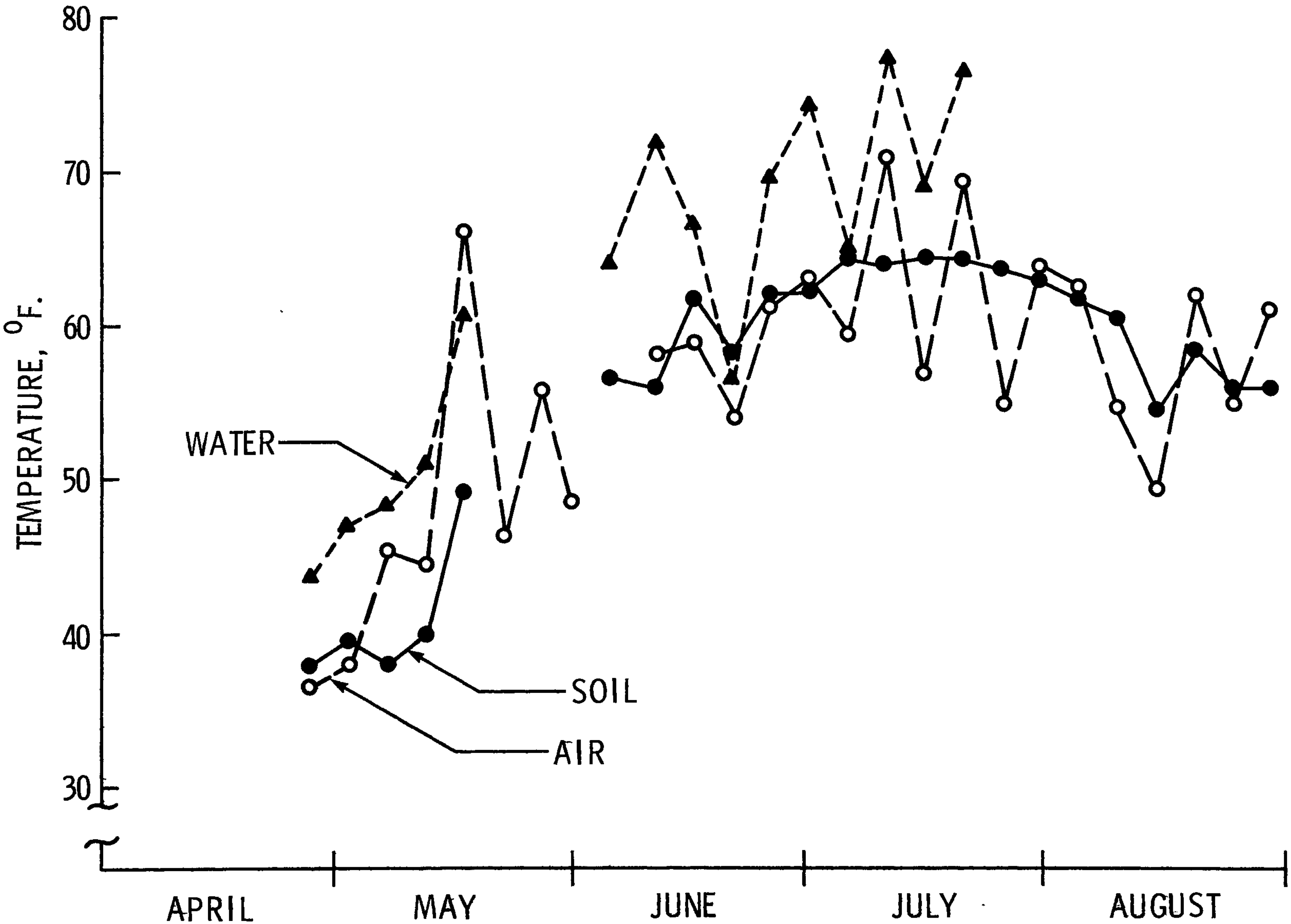

Fig. 3

MEAN AIR, WATER AND SOIL TEMPERATURES

GULLY – 1979

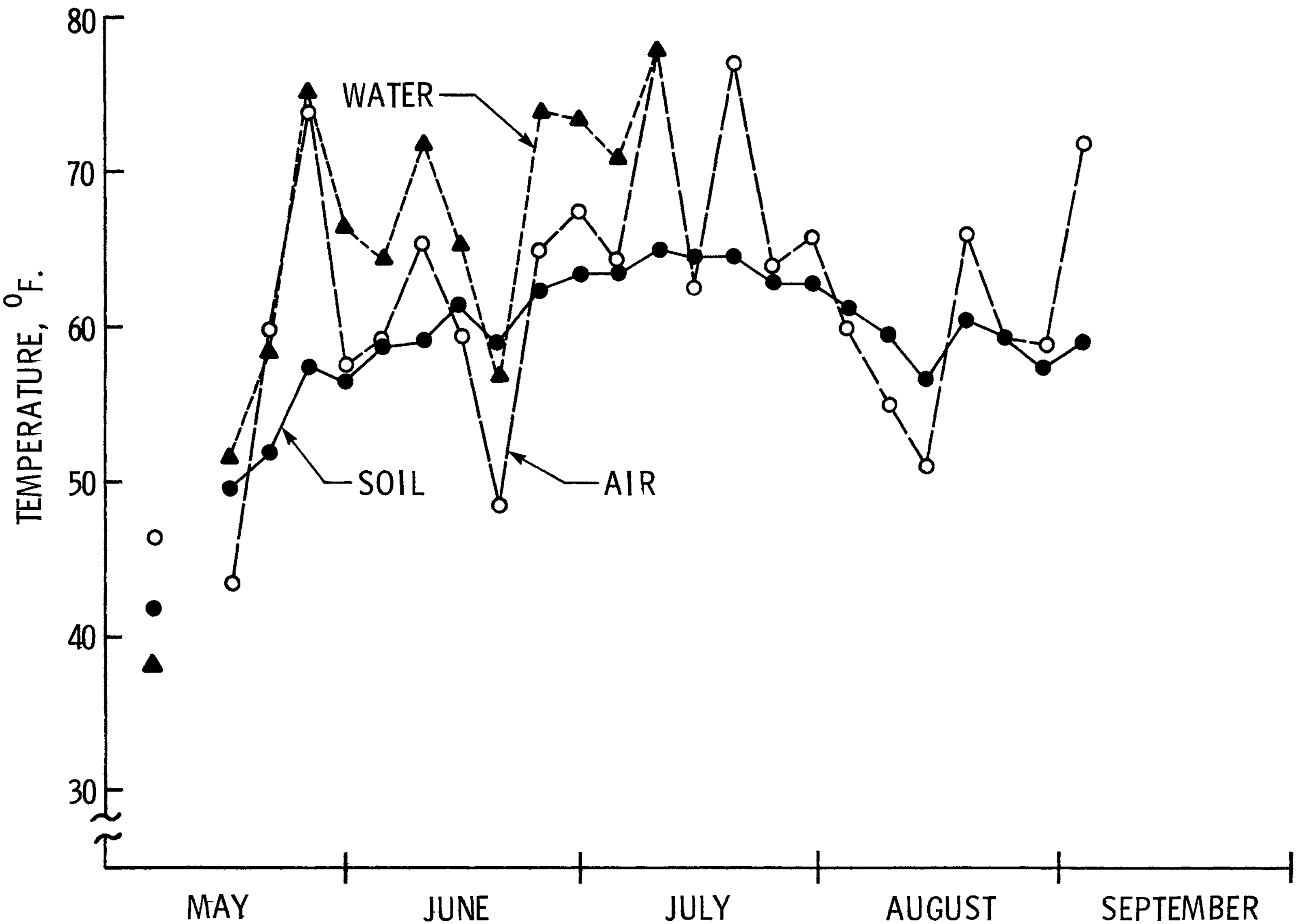

Fig. 4

WILD RICE DEVELOPMENT
NETUM VARIETY, GRAND RAPIDS, 1979

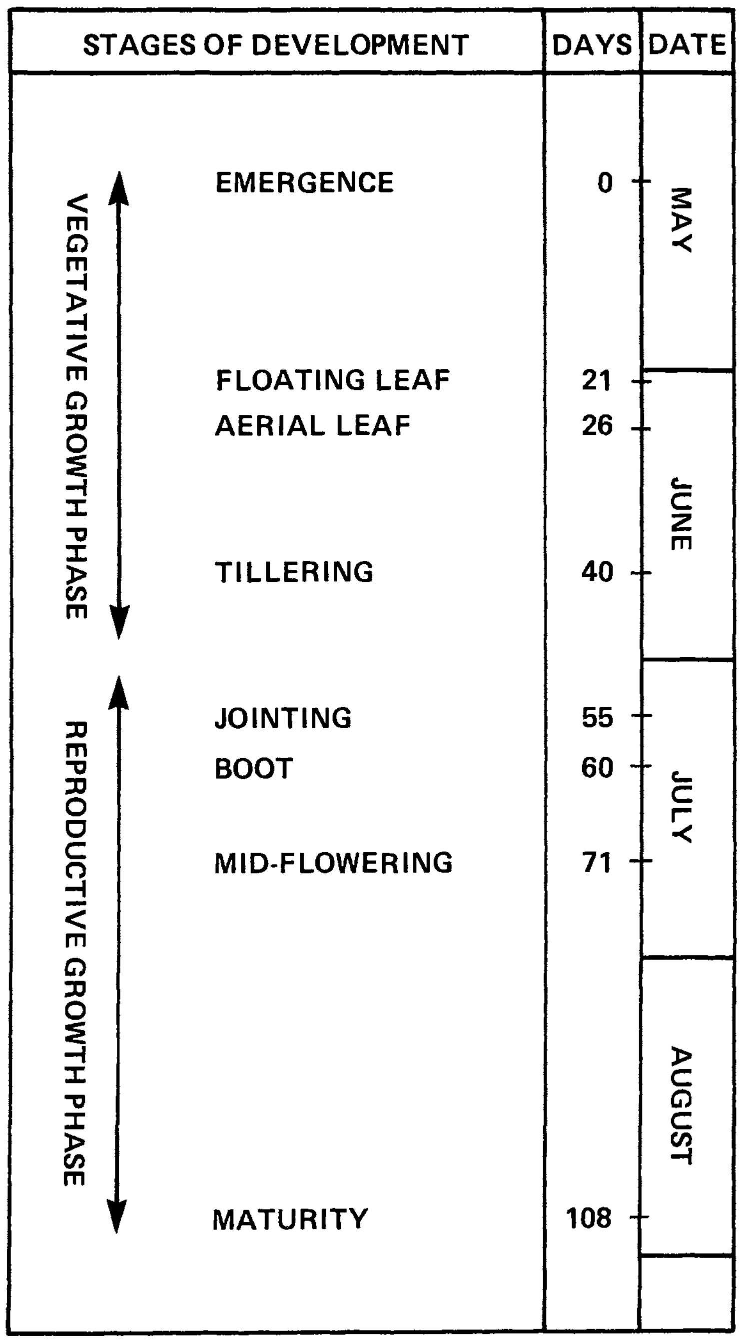

Fig. 5

WILD RICE DEVELOPMENT
K2 VARIETY, KOSBAU BROS., AITKIN CO., 1979

	STAGES OF DEVELOPMENT	DAYS	DATE
VEGETATIVE GROWTH PHASE	EMERGENCE	0	MAY
	FLOATING LEAF	27	JUNE
	AERIAL LEAF	44	
	TILLERING	52	
REPRODUCTIVE GROWTH PHASE	JOINTING	62	JULY
	BOOT	72	
	MID-FLOWERING	84	
	EARLY GRAIN FORMATION	97	AUGUST
	MATURITY	112	

B. CHEMICAL CHARACTERISTICS OF PADDY WATER

The quality of paddy water is of interest to the grower as well as to state and federal agencies. The grower may be concerned, for example, with the concentration of sulfate in the water. Plant response to fertilization may be related to nutrient levels found in the water. Public control agencies may want to know levels of nitrogen and phosphorus present in the water when it is released during draining of paddies.

Water samples were collected from several sites at three different paddy locations during the 1979 growing season. At Washkish, water samples were collected from two sites on May 22 for general reference. At Grand Rapids, samples were collected from an experimental paddy used for a nitrogen rate study on mineral soil. Source of water is the Prairie River. Water was also sampled at two sites in Kosbau Bros. paddies in Aitkin County. Paddies at this site derived water from the Little Willow River via a diversion ditch. One sampling site was located at the beginning of the diversion ditch, just above a bridge; the other site was within a paddy in which three fertilization trials were conducted. The third sampling location was in the Imle and Gunvalson paddies near Gully. These paddies derived water from the Clearwater River.

Water samples were collected and stored in 250 ml polyethylene bottles. After the determination of pH and conductivity, a preservative was added (2 ml mercuric chloride solution, made by dissolving 40 mg $HgCl_2$/L, to 250 ml of sample). Chemical analyses were made by the Research Analytical Laboratory, University of Minnesota. Information on location, sampling dates, and chemical composition data of water are given in Table 2.

The pH of water is the measurement of hydrogen-ion activity. Water samples from the rivers showed some differences. Greatest differences in pH, however, were found in the water from different paddies. There was a certain relationship found between the pH and hardness of the water from different sampling sites. The hardness of water is calculated by multiplying calcium and magnesium concentrations by specific factors, adding up and is expressed as $CaCO_3$, mg/liter. Water from the Clearwater River was very hard (314 mg/L) and strongly alkaline with pH of 8.0 or above. The water from the Prairie River and the Little Willow River is moderately hard, with values of 96 and 89 mg/L, respectively, and had a pH value of 7.3, indicating slight alkalinity. At Gully and Grand Rapids, the levels of hardness and pH of paddy water were nearly the same as those found in the river water. In Aitkin County on peat, however, the paddy water showed 18 to 23% lower calcium and 30 to 43% lower magnesium content than the river water, and 4-fold decrease in hardness. Consequently, the water within the Kosbau paddy was acid (pH 5.0-6.6) and was relatively soft, having a hardness value of 22 mg/liter.

At Grand Rapids, concentrations of total N and P in paddy and river water were nearly the same, and remained relatively constant throughout the growing season. Total concentration in the water ranged from 0.2 to 0.9 ppm N, and 0.04 to 0.2 ppm P. The K concentration of paddy water was only slightly higher than that found in river water, except for the June 21 sampling date when the paddy water had three times more K than river water (17.5 vs. 5.9 ppm K).

At Gully, nutrient concentrations in the river and paddy water were inconsistent and showed considerable variation.

Paddy water at the Aitkin County location had considerably higher concentration of total N, P and K than found in the river water. Total N concentration of paddy water ranged from 1.9 to 4.3 ppm compared to 0.4-0.8 ppm found in samples collected from the diversion ditch. Total P concentration in paddy water ranged from 1.45 to 1.93 as compared to 0.04-0.11 ppm in the water from the diversion ditch. Potassium levels of paddy water ranged from 7 to 11 ppm while the water from the diversion ditch had concentration of less than 1 ppm to 5 ppm K.

The sulfate concentration of water is reported in terms of parts per million of sulfate-sulfur. To convert results to the sulfate form, they would have to be multiplied by 3. For example, 20.5 ppm sulfate-S x 3 = 61.5 ppm sulfate (SO_4) in the water.

The water at Grand Rapids and in Aitkin County did not contain appreciable amounts of sulfate (4-9 ppm SO_4). The sulfate concentration in the water at Gully, however, was relatively high (62-79 ppm SO_4).

Table 2. Chemical composition of water collected from wild rice paddies during 1979 growing season.

Sample No.	Sampling Date	Location	pH	Conductivity millimhos/cm	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Grand Rapids															
5.	5/22	EP	7.5	.12	44.5	63.8	0.3	0	0	0.04	0.03	1.4	17.8	4.4	3.3
6.	5/22	PR	7.3	.16	70.5	96.1	0.2	0	0	0.09	0.05	2.1	27.5	6.3	2.9
10.	6/21	EP	7.6	.12			0.4			0.04			34.5	8.4	17.5
11.	6/21	PR	7.3	.18			0.9			0.05			31.4	7.8	5.9
16.	7/6	EP	7.2	.14			0.6			0.05			18.7	4.3	<0.75
17.	7/6	PR	7.0	.17			0.6			0.04			23.0	5.3	<0.75
20.	7/11	EP		.14			0.7			0.05			17.5	4.3	<0.75
21.	7/11	PR	7.3	.15			0.6			0.06			19.8	4.5	<0.75
22.	7/19	EP	7.7	.13			0.8			0.08			19.7	4.7	<0.75
23.	7/19	PR	7.0	.13			0.6			0.20			19.9	4.4	<0.75
26.	7/31	EP	7.7	.12			0.6			0.08			16.1	6.6	1.27
27.	7/31	PR	7.5	.16			0.5			0.05			19.9	6.1	<0.75

Abbreviations and description of sampling sites at Grand Rapids: EP = Experimental Paddy #1E; PR = Prairie River

Sample No.	Sampling Date	Location	pH	Conductivity millimhos/cm	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Kosbau Bros., Aitkin Co.															
7.	5/15	EP	5.2	.05	3.5	18.9	1.9	0.5	0	1.45	1.33	2.4	3.9	1.6	8.1
8.	5/25	EP	5.0	.07	7.0	22.3	2.4	0.1	0	1.81	1.69	2.9	4.5	1.9	8.1
9.	5/25	DD	7.3	.17	69.0	88.9	0.4	0	0	0.09	0.08	1.7	24.4	6.3	2.1
12.	6/21	EP	6.6	.05			3.3			1.87			6.3	2.6	11.2
13.	6/21	DD	7.3	.18			0.4			0.04			27.8	6.0	5.0
18.	7/6	EP	5.7	.05			4.3			1.93			5.5	2.6	6.5
19.	7/6	DD	7.3	.19			0.8			0.11			26.9	7.1	<0.75
28.	7/31	D	5.1	.10			6.2			3.07			8.5	2.7	3.5

Abbreviations and description of sampling sites at Kosbau Bros.: EP = Experimental Paddy; DD = Diversion ditch at bridge near the Little Willow River; D = Ditch on the south side of experimental paddy.

Table 2. Chemical composition of water collected from wild rice paddies during 1979 growing season (continued).

Sample No.	Sampling Date	Location	pH	Conductivity millimhos/cm	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Imle and Gunvalson, Gully															
1.	5/21	PP	8.1	.48	135.5	262.8	1.1	0	0	0.33	0.24	26.4	71.5	20.3	15.6
2.	5/21	CR	8.0	.51	194.5	314.3	0.5	0	0	0.05	0.05	20.5	85.9	24.0	4.1
14.	6/27	PP	8.3	.62			0.8			0.14			88.4	24.6	7.6
15.	6/27	CR	8.0	.53			2.0			1.15			99.5	26.5	18.3
24.	7/31	D	7.0	.43			0.9			0.11			57.6	17.4	1.4
25.	7/31	CR	7.4	.45			1.7			0.41			56.5	19.9	2.1

Abbreviations and description of sampling sites at Gully: PP = Production Paddy; CR = Clearwater River; D = Ditch on west side of paddy.

Sample No.	Sampling Date	Location	pH	Conductivity millimhos/cm	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Washkish															
3.	5/22	D	7.1	.21	40.5	88.1	1.6	0	0	0.68	0.58	4.1	22.1	7.7	20.7
4.	5/22	TR	6.9	.14	55.5	85.8	0.7	0	0	0.07	0.06	2.6	22.4	7.0	1.6

Abbreviations and description of sampling sites at Washkish: D = Ditch on east side of paddy complex; TR = Tamarac River.

C. NITROGEN RATE STUDY ON MINERAL SOIL

A field experiment was conducted with the Netum variety on a mineral soil at the North Central Experiment Station, Grand Rapids. The experimental paddy, No. 1 East, was in fallow during 1978 and was fumigated with methyl bromide in the fall. Soil tests indicated a very high level of extractable phosphorus, nearly a high level of exchangeable potassium (Table 3). The nitrate-N reading of 42 lb/A in the top 6 inches of soil (main rooting depth of wild rice) indicated that considerable amount of nitrate had been produced under fallow. Four rates of nitrogen were used in this experiment: 0, 20, 40 and 80 pounds per acre. Urea (46-0-0) was applied by hand and incorporated into the soil by rototilling. A randomized block design was used in this experiment. Each nitrogen treatment was replicated five times. Individual plots occupied a 14 x 16 ft. area and were separated from adjoining plots by 5 ft. wide alleys. Seed of Netum variety was broadcast-applied by hand on October 18 and rototilled into the soil. Plant density, at jointing, was about three plants per square foot. Water level was maintained at about 6 to 10 inches. Ten plants were collected at random from each plot at jointing, and five plants at late flowering for weight measurements and plant analysis. The jointing state was reached on July 6 (Fig. 4). Water was drained from the paddy on August 25. A 32 sq. ft. area from each plot was hand-harvested on August 27 for yield determination.

Netum wild rice produced 945 to 1049 pounds of grain per acre (Table 4). The yield, however, was not affected by N fertilization.

The second leaf at jointing contained 4.16 - 4.55% N, considered to be a relatively high concentration (Table 5). Total nitrogen uptake by wild rice at jointing or late flowering was not affected by the nitrogen treatments (Table 6).

Table 3. Soil test values of experimental paddy, No. 1 East, Grand Rapids.

Sampling Depth inches	pH	Extractable P pp2m	Exchangeable K pp2m	NO_3-N lb/A
0 - 6	5.5	84	196	42
6 - 12	5.6	83	197	42

Samples collected on 10/18/78.

Table 4. Effect of nitrogen application on the yield of Netum wild rice, Grand Rapids, 1st year stand, 1979.

N Rate lbs/acre	Grain Yield lbs/acre
0	1037[1)]
20	945
40	1049
80	999
Significance	ns
C.V., %	13

1) 7% moisture, average of 5 replications

Table 5. Effect of nitrogen application on N concentration in 2nd leaf of Netum wild rice at jointing, Grand Rapids, 1979.

N Rate lbs/acre	N % in Dry Matter
0	4.29
20	4.16
40	4.32
80	4.55
Significance	ns
C.V., %	25

Table 6. Effect of nitrogen application on total uptake of N by the wild rice plant at jointing and late flowering. Netum variety, Grand Rapids, 1979.

N Rate	Stage of Development	
lbs/acre	Jointing	Late Flowering
	---N in milligrams per plant---	
0	234	535
20	210	604
40	196	599
80	226	625
Significance	ns	ns
C.V., %	37	23

D. FERTILIZATION STUDIES ON PEAT

Three fertilizer experiments, carried out in a Kosbau Bros. paddy in Aitkin County during 1978, were continued in 1979. A second year stand of the K2 variety was used. Fertilizer was applied by hand to 12 x 12 foot plot areas on October 23, 1978 and incorporated into the soil by rototilling. Wild rice started to emerge on May 8 and by July 9 (62 days after emergence) had reached the jointing stage (Fig. 5). Rice was thinned once by airboat on June 4 when most plants were in the floating leaf stage. Average plant density was three plants per square foot. The stand, however, was spotty and thin in some areas. The paddy was drained on July 26. A 4 x 4 foot area was hand-harvested from each plot for yield measurement on August 28. No color or height differences were observed during growing season and the crop response to fertilization was modest and rather inconsistent. Soil tests, of samples collected on October 23, 1978 prior to fertilizer application, indicated medium to high extractable P levels, medium to high exchangeable K level, and low nitrate-N content (Table 7). The grain yield ranged from 250 to 550 lb/acre.

Table 7. Soil test values of experimental areas, Kosbau Bros., Aitkin Co.

Area		pH	Extractable P pp2m	Exchangeable K pp2m	NO_3-N lb/A
NK trial,	K0	4.3	18	124	0.5
	K60	4.3	20	154	
	K200	4.3	25	217	
NP trial,	P0	4.3	22	205	0.8
	P80	4.2	25	197	
Foliar Fertilization (check plots)		4.4	20	178	1.5

Samples collected on 10/23/78. Results are for 0-6 inch depth.

NK Rate Trial

Potassium treatments, made in the fall of 1977, had resulted in a gradual increase of K test levels. Exchangeable K test levels of 124, 154 and 217 pp2m corresponded with the potassium treatments of 0, 60, 200 lbs. K_2O per acre, respectively (Table 7). Nitrogen treatments consisted of the following rates: 0, 30, 90 pounds per acre. Potassium was applied at rates of 0, 60 and 200 pounds of K_2O per acre. All plots received phosphorus at 40 pounds P_2O_5 per acre. Fertilizer treatments, arranged in a randomized block design, were replicated six times. Urea, muriate of potash and concentrated superphosphate were applied by hand during the fall of 1978 and incorporated into the soil by rototilling.

The yield of wild rice ranged from 258 to 405 pounds per acre (Table 8). Neither nitrogen nor potassium treatments had any effect on the yield.

Table 8. Effect of nitrogen and potassium application on grain yield of wild rice, Kosbau Bros., 1979.

K Rate K_2O lb/acre	N Rate, lb/acre 0	30	90	Average (K Rate)
	Grain Yield, lb/acre			
0	265	280	405	317
60	333	269	291	298
200	258	367	309	311
Average (N Rate)	285	305	335	
Significance	ns			
C.V., %	35			

7% moisture, average of 6 replications.

NP Rate Trial

Average extractable phosphorus in the experimental area measured 22 and 25 pp2m, indicating high relative level (Table 7). Nitrogen was applied at rates of 0, 30, 60 lb/acre, and phosphorus treatments included 0, 40, 80 pounds of P_2O_5 per acre. All plots received potassium at 60 lbs/acre of K_2O. Fertilizer treatments were replicated six times. Urea, concentrated superphosphate and muriate of potash were applied by hand in the fall and incorporated into the soil by rototilling.

Grain yields ranged from 251 to 366 pounds per acre (Table 9). Although some yield differences were detected at the 10% level, crop response was inconsistent and not related to nitrogen and phosphorus treatments.

Table 9. Effect of nitrogen and phosphorus application on grain yield of wild rice, Kosbau Bros., 1979.

P Rate P_2O_5 lb/acre	N Rate, lb/acre 0	30	60	Average (P Rate)
	Grain Yield, lb/acre			
0	277	340	313	310
40	251	291	300	281
80	366	298	262	309
Average (N Rate)	298	310	292	
Significance	+			
BLSD (0.10)	79			
C.V., %	21			

7% moisture, average of 6 replications.

Foliar Fertilization Trial

Interest in foliar application of fertilizer was aroused in 1975-76 by publicity generated by spectacular soybean yield increases obtained in Iowa. Numerous field trials were initiated with soybeans and other crops and a full-scale sales program was launched by at least one major fertilizer company. Research in Minnesota and other states, mainly with soybeans, has not shown any substantial benefits from foliar fertilization.

Some wild rice growers also showed interest in foliar fertilization. Field trials were initiated in 1976, and continued in 1977, in Aitkin County to provide information on the effectiveness of foliar fertilization of wild rice.

In the fall of 1977, a new experiment was established on a new seeding of K2 variety in an area adjoining NK and NP trials. The experiment was continued in 1979. Soil tests indicated medium phosphorus and potassium availability, and the nitrate-N content of top 6 inches was relatively low (Table 7).

Soil application of fertilizer (30+40+60) was made during the fall of 1978 and incorporated into the soil. Fertilizer solution was sprayed on 12 x 12 foot plot areas with a backpack sprayer at a rate of 26.4 gallons per acre or 250 pounds per acre. Spraying pressure was maintained at 30 psi by using a carbon dioxide cylinder. The formulation, materials used and costs were reported, in detail, in the 1976 Wild Rice Research Report. At 1976 prices, the total cost of three foliar applications would be $48.15 per acre, consisting of $19.35 for fertilizer materials and $28.80 for aerial application. Currently the cost of such applications should be well over $50.00 per acre. Soil application of 30+40+60 pounds per acre of plant nutrients, at present prices, would cost about $22.00 per acre, including application costs.

In 1979, foliar fertilizer applications were made on the following dates:

1st spraying, 7/11 - jointing to early boot stage,
2nd spraying, 7/31 - mid-flowering,
3rd spraying, 8/14 - early grain formation.

No "leaf burn" damage to wild rice was observed in this trial.

The grain yield in this experiment ranged from 380 to 565 pounds per acre (Table 10). The yield of wild rice was increased significantly (at 10% level) by about 150 lb/acre over the control either by soil applied fertilizer or three foliar applications. There was no advantage, however, of combining these two types of fertilizer application. It must be pointed out that similar yield increases from fertilization were obtained at (a) $22.00 for soil application, and (b) over $50 per acre for three foliar applications. Consequently, foliar fertilization of wild rice is not recommended, at the present time, neither as a substitute of nor as a supplement to soil application. Topdressing of solid nitrogen fertilizers, urea and ammonium nitrate, at jointing (basically a soil application) is not included in this recommendation.

Table 10. Effect of foliar and soil application of fertilizer on grain yield of wild rice, Kosbau Bros., 1979.

Number	Foliar Application: Total Plant Nutrients Applied, lbs/acre				Soil Application		Average (Foliar)
	N	P_2O_5	K_2O	S	None	30+40+60	
					----Grain Yield, lbs/acre-----		
None	None				380a	523b	452
1x	15 +	6 +	9 +	1.3		427ab	427
2x	30 +	12 +	18 +	2.6		514ab	514
3x	45 +	18 +	27 +	3.9	565b	441ab	503
Average (soil)					473	476	
Significance					+		
BLSD (0.10)					142		
C.V., %					25		

7% moisture, average of 6 replications.

Values followed by different letters are significantly different (10% level).

ACKNOWLEDGMENTS

Grateful acknowledgments are made to the following cooperators and University personnel for their valuable assistance during 1979 in obtaining the information reported here: Messrs. Franklin and Harold Kosbau, Aitkin County; Messrs. Paul Imle and John Gunvalson, East Polk County; the Staff of the North Central Experiment Station; Dr. E. A. Oelke; Messrs. Joe Zachmann, Robert Stassen, Loren Nickelson, and Henry Schumer, University of Minnesota.

WILD RICE PRODUCTION AND SEED RESEARCH - 1979

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Research was continued on weed control, elimination of volunteer wild rice plants, time of harvest, seed survival, and seed storage. The work was conducted on University plot land in St. Paul and Grand Rapids and in growers' fields near Aitkin and Clearbrook. Volunteer wild rice plants in the plots at Grand Rapids resulted in abandonment of some research at this location. The temperatures during the 1979 growing season were lower than normal, causing a delay in maturity. However, freezing temperatures did not occur until after the harvest season. Yields in 1979 were about average or slightly above.

WEED RESEARCH

Herbicides

The herbicide trials in 1979 concentrated on the use of 2,4-D amine in wild rice for control of water plantain. The trials were conducted at Grand Rapids and Aitkin.

One trial was conducted at Grand Rapids to see if one variety was more susceptible to injury from 2,4-D amine than another. Four varieties, M1, K2, Netum, and Johnson were treated with 3 rates of 2,4-D amine at the late aerial leaf, mid-tillering and elongation stages of growth. No water plantain was present in these plots. Table 1 gives the yields of the 4 varieties treated with 2,4-D amine.

From this one year's data, there does not appear to be any difference among varieties in their response to 2,4-D amine since there was no interaction for varieties and rate of 2,4-D amine. However, yields of the Johnson and Netum varieties were reduced more than for the other 2 varieties at the highest rate of 2,4-D amine when applied at the late aerial leaf stage of growth. This was not evident at the other 2 application dates. When 2,4-D amine was applied at these 2 dates, little yield reduction for any of the varieties was obtained even with 3/4 lb/A, a.i. The recommended application time for 2,4-D amine is at the late tillering stage of growth and only at 1/4 lb/A a.i. since higher rates have given considerable wild rice injury in other trials and years.

Table 1. Yield response of 4 varieties to 2,4-D amine applied at 3 rates on 3 different dates - Grand Rapids - 1979.

Date	Rate of 2,4-D amine lb/A, a.i.	Variety				
		Netum	K2	M1	Johnson	Average of all varieties
		-----------Grain yield, lb/A-----------				
6-27	0	1050	1142	862	1050	1026
(late aerial leaf)	1/4	766	829	762	1162	880
	1/2	891	1038	594	829	838
	3/4	693	888	699	752	758
7-6	0	822	928	966	826	886
(mid-tillering)	1/4	923	944	704	982	888
	1/2	872	974	811	883	885
	3/4	760	1192	1016	861	957
7-11	0	827	1126	1208	474	908
(elongation)	1/4	834	949	1091	542	854
	1/2	758	978	912	562	802
	3/4	733	992	822	670	804

Even though the yield for all varieties was reduced when 2,4-D amine was applied at the late aerial leaf stage of growth, no visible injury to wild rice was observed. This experiment will be repeated in 1980.

The total volume of liquid applied per acre with an herbicide can influence the amount of weed control and also the amount of injury to the crop. Thus, an experiment was initiated using 6 different total water volumes with 2 rates of 2,4-D amine. The treatments were made when the Johnson variety was in the late-tillering stage of growth. The yields for this experiment are shown in Table 2.

Table 2. Grain yield response of wild rice to 2,4-D amine applied at 2 rates and 6 total spray volumes - Grand Rapids - 1979.

Total spray volume gal/A	Rate of 2,4-D amine - lb/A, a.i. 0	1/4	1/2
	------------Yield - lb/A------------		
2	832*	660	826
5	832	750	656
10	848	728	726
15	730	709	836
30	627	660	845
35	813	653	718
Average	780	693	768

* No significant differences among yields; 40% moisture

No significant differences in yield were observed among the various total spray volumes used, indicating that in this experiment, there was no influence on wild rice injury by the total spray volume per acre used. No visible injury to wild rice was evident for any of the treatments. This experiment will be repeated in 1980.

Three rates of 2,4-D amine were applied at different times to water plantain which developed from rootstocks to determine at which stage of plant development water plantain can be the most readily controlled. Table 3 shows the control ratings taken at 3 different dates after application of 2,4-D amine.

Table 3. Control of water plantain by 2,4-D amine when applied at different growth stages - Grand Rapids - 1979.

Growth stage of water plantain	Rate of 2,4-D amine	Date of water plantain control ratings 7/25	8/8	8/22
	lb/A, a.i.	--water plantain control rating*------		
3-4 leaf stage (7/5)	1/4	1.7	1.0	0.7
	1/2	2.7	2.7	2.0
	3/4	3.7	3.3	3.0
7-8 leaf stage (7/12)	1/4	2.0	0.3	1.0
	1/2	2.3	2.7	6.3
	3/4	6.0	8.0	9.0
Beginning of flowering (7/18)	1/4	0.7	0.3	0.3
	1/2	0.7	2.7	3.3
	3/4	1.0	4.0	4.3
Control	0	0	0	0

* 0 = no control; 10 = complete control

The best water plantain control was obtained when the plants were in the 7-8 aerial leaf stage of growth (Table 3). This was in contrast to last year when the best control was obtained when water plantain was beginning to flower (bud stage). However, in both years, 3/4 lb/A, a.i. was needed for good control of water plantain. In both years, 1/2 lb/A, a.i. gave fair control, while 1/4 lb/A, a.i. gave only some control. A better chemical than 2,4-D amine is needed to chemically control water plantain since wild rice in many cases will not tolerate 3/4 lb/A, a.i. of 2,4-D amine.

Some other chemicals were tried this year for their effectiveness in controlling water plantain. These were acifluorfen, nitrofen, and granular hydrothol 191. Acifluorfen was tried at 1/4, 1/2, 1, and 2 lb/A, a.i. on water plantain as a spray application. No control of water plantain was obtained with any of these rates. Thus, acifluorfen will not be tested further. Granular hydrothol 191 was tried primarily for control of water plantain seedlings before they emerged from the water. It was applied at 1.5, 3.0, 4.5, and 6 lb/A, a.i. Water plantain control was erratic and further testing will be necessary with this compound.

Nitrofen was also tried primarily for controlling seedling water plantain. It was applied into the water at 1, 3, 5, and 10 lb/A, a.i. when seedling water plantain was still submerged. The applications were made 4 weeks after flooding. Good control of seedling water plantain which had germinated was obtained even with the 1 lb/A, a.i. rate. However, the water plantain which germinated 3-4 weeks after treatment was not controlled. Very little wild rice was present in the treated rings, so no information was obtained on wild rice tolerance to nitrofen. We will test this compound more in 1980.

A new herbicide application technique was tried this year for the control of rootstock water plantain. A 5 foot long, rope-wick applicator was constructed and used to apply MCPA and glyphosate to rootstock water plantain which had 4-6 aerial leaves. The construction of the applicator is shown in Figure 1.

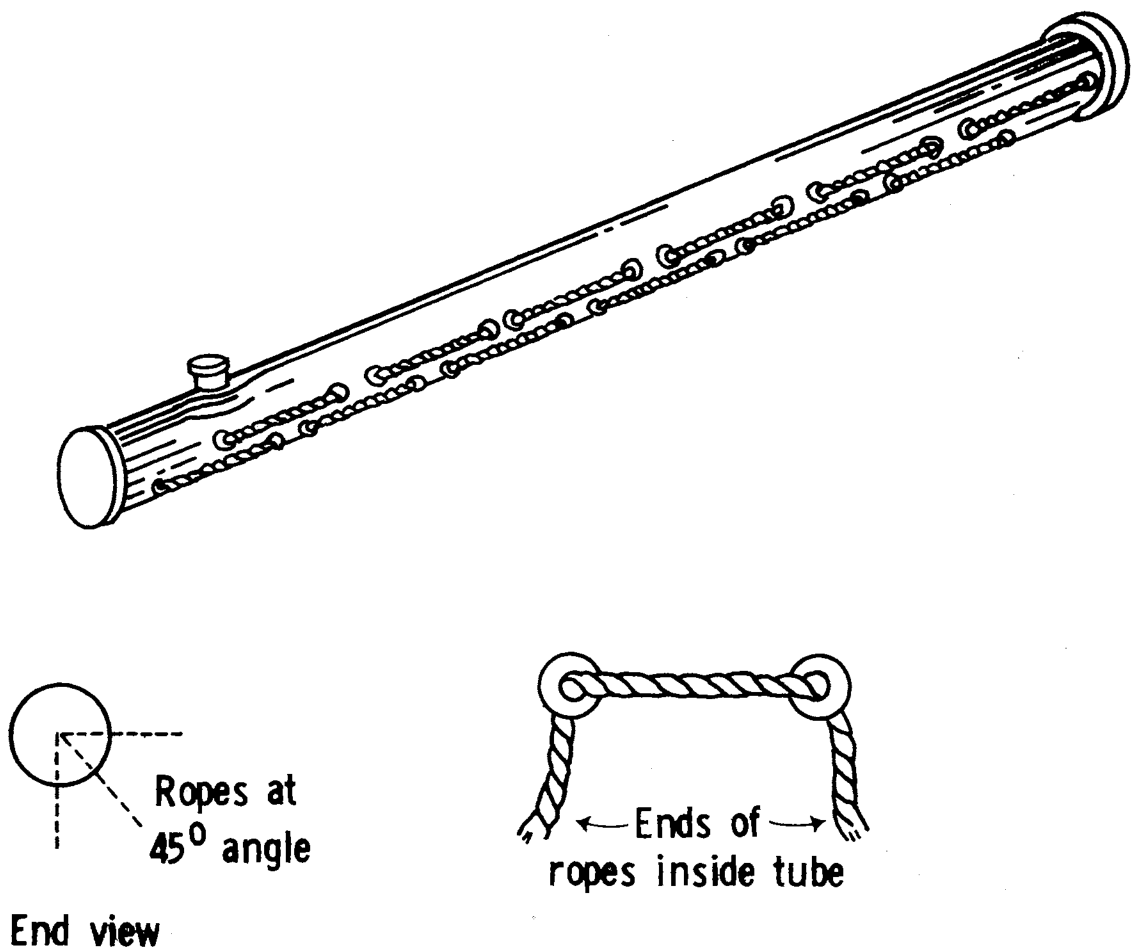

Figure 1. Outside view of rope-wick applicator showing the placement of ropes which act as the wicks. The tube was 3-inch PVC piping capped on the ends. The ropes were soft braided nylon marine rope. The holes in the tube for the ropes were 5/8 in. in diameter and spaced alternately 8 and 2 in. apart. The applicator was constructed as outlined by J. E. Dale, Plant Physiologist, Southern Weed Science Laboratory, USDA, AR-SEA, Stoneville, Mississippi.

With the rope-wick applicator, a concentrated formulation of the herbicide can be applied onto water plantain, if it is taller than wild rice, without getting any of the herbicide onto wild rice or into the water. In most years, water plantain from rootstocks emerges from the water before wild rice and has 3-6 upright leaves before wild rice is in the aerial leaf stage. MCPA and glyphosate were both applied to rootstock water plantain which had 5 to 6 upright leaves. MCPA gave good control of water plantain and glyphosate gave only fair control. Both of these compounds were also applied to bur-reed using the rope-wick applicator in a growers field. Bur-reed was 12 inches above the water with a few plants beginning to flower. One application of glyphosate controlled bur-reed while 2 applications of MCPA were needed for good control. More trials will be conducted in 1980 with the rope-wick applicator for weed control.

Competition of Water Plantain in Wild Rice

In order to investigate the competitive effect of water plantain on wild rice, 4 densities of rootstocks and 3 densities of seedling water plantain were established in wild rice sown at a rate of 4 seeds/sq. ft. The results of the study are given in Table 4.

Table 4. Effect of water plantain density on yield and yield components of wild rice - Grand Rapids - 1979.

Water plantain plants/ft^2	plants/ ft^2	Panicles/ plant	Seeds/ panicle	Wt/100 seeds	Grain wt*	Processed wt
				gm	lb/A	lb/A
Control	3.42	1.97	54.2	2.13	1241	447
5 Seedlings	3.43	1.77	57.1	1.93	1106	407
10 Seedlings	3.28	1.98	60.1	2.02	1180	432
20 Seedlings	3.51	1.98	68.3	1.90	1382	510
1/2 Rootstock	3.24	1.52	62.5	1.95	966	347
1 Rootstock	3.48	1.22	48.6	1.98	661	237
2 Rootstocks	2.90	1.20	35.4	1.81	517	184
4 Rootstocks	2.36	.80	24.2	1.68	145	42
LSD .05	.66	.38	13.2	.20	202	74

* As harvested, wet weight

Water plantain established from seed does not significantly affect yield or yield components even at the highest density (20 seeds/ft^2). When established from rootstocks, however, all densities planted significantly reduced yield, with the highest density (4/ft^2) reducing yield by 90%. The number of panicles per plant decreased with an increase in weed numbers. Moreover, it was the only component of yield that was affected at the two lowest densities (0.5 and 1/ft^2). The number of seeds/panicle and the weight per 100 seeds was reduced significantly by the two highest densities (2 and 4 rootstocks/ft^2). In addition, at the highest density, the number of wild rice plants/ft^2 was reduced by 35%.

Even though water plantain grown from seed apparently does not compete with wild rice, great care should be taken to avoid the dissemination of the seed as higher seedling population will mean a higher probability for rootstocks the following year. As indicated in this experiment, very few rootstocks are needed to significantly reduce yield.

Length of Competition of Water Plantain in Wild Rice

Water plantain established from rootstocks was removed by hand after 2, 4, 6 and 8 weeks of growth to investigate when it exerts competition on wild rice. A weed-free check and an all-season treatment were also included. The results are summarized in Table 5.

Table 5. Effect of length of competition on yield and yield components of wild rice, Grand Rapids-1979.

Length of competition	Wild rice: Grain wt*	Processed grain wt	Panicles per plant	Wt per 100 seeds
	lb/A	lb/A	----	gm
Weed free	1290	447	2.1	2.3
2 weeks	1375	485	2.1	2.2
4 weeks	1209	381	2.1	2.2
6 weeks	1210	434	2.0	2.2
8 weeks	696	256	1.7	2.3
All season	521	166	1.3	1.9
LSD .05	232	93	0.4	0.2

* As harvested, wet wt.

From this research it appears that yield will not be reduced if the weeds are removed or controlled before 6 weeks of growth. At six weeks, the wild rice plant was aerial and was just beginning to tiller. However, after 8 weeks of competition, there was a 43% yield reduction. The only yield component significantly affected after eight weeks was the number of panicles per plant. The all season treatment resulted in a 63% yield reduction. Panicles per plant and weight per 100 seeds were both decreased significantly.

The Effect of Shade on Growth of Water Plantain

To investigate the effect of shade on the growth and development of water plantain, seeds and rootstocks of water plantain were grown in plastic lined boxes. Different amounts of shade (0, 30, 47, and 79% shade) were applied with the aid of plastic netting after 3 weeks of growth. On June 25th, a severe hailstorm defoliated the check plots of the rootstocks and partially damaged the seedlings. However, all plants readily re-established. The results of this experiment are summarized in tables 5 and 6.

Table 6. The effect of shade on water plantain growing from rootstocks - St. Paul-1979.

Percent shade	Flower stalks per plant	Gm seeds per plant	Dry weight per plant (gm)
0	1.8	9.9	20.9
30	1.5	10.0	22.6
47	1.8	11.2	26.1
79	1.5	5.6	14.6
LSD .05	N.S.	1.5	3.1

Table 7. The effect of shade on water plantain growing from seeds - St. Paul-1979.

Percent shade	Weight of seeds per plant	Plants with seed stalks	Plants per square ft.	Dry weight per plant
	mg	%	-----	gm
0	553	76	46	1.2
30	676	60	29	1.7
47	584	53	39	1.2
79	333	18	25	0.8
LSD .05	N.S.	34	N.S.	0.4

At harvest time the 0% and 30% shade treatments had already started to senesce and decompose which may account for the slightly lower dry weight in the rootstock experiment. The growth and production of seeds in water plantain were not significantly affected until there was at least 79% shade. Seed production in both seedlings and rootstocks was reduced by nearly 40% under 79% shade. The size of the plant was similarly affected.

An attempt was made to measure the percent shade in a wild rice canopy, but we lacked equipment to do it accurately. It might be, however, that in a good stand of wild rice (4 plants per square foot) the amount of shading could be greater than 79% by early July.

These data may indicate that a good stand of wild rice could help limit the establishment of water plantain, particularly that which grows from seed.

Length of Germination Period of Water Plantain Seeds

Another study was conducted to investigate how long during the growing season seeds from water plantain are able to germinate and emerge. Four steel rings were placed on the edge of a research paddy which was seriously infested with water plantain. Seedlings were counted and removed every three weeks beginning on June 27, when the first group was large enough to pull. On June 27, 91 seedlings per square meter were removed while 70 were removed on July 18 and 12 on August 8. No more germination and emergence occurred after August 8.

It appears that it is environmentally favorable for seedlings to germinate and establish throughout the summer. The absence of seedlings on the last date may be due to the depletion of the soil of viable seeds.

Effect of Light Intensity on Wild Rice Growth

This study was conducted to investigate what portion of competition exerted by water plantain is competition for light. No research to date has dealt with the effect of light quantity on wild rice growth.

To imitate the shading effects from water plantain, shade clothes were applied after 3 weeks of growth and removed when the plants were taller than 55 cm, which is the height of a water plantain canopy. The shade treatments were 0, 30, 47, and 79% shade. The shading material was removed July 13, July 16, and July 21 for 30, 47, and 79% shade, respectively.

Information on the growth of wild rice was obtained at weekly intervals. The data for July 20, August 3, and September 7, which was the last date of harvest, are summarized in Tables 8 and 9.

Table 8. The influence of shade on wild rice growth - St. Paul- 1979.

Percent shading	Measurement date: 7/20 Plant height	7/20 Tillers per plant	8/3 Plant height	8/3 Tillers per plant
	cm	----	cm	----
0	77.8	4.6	132.9	4.5
30	80.1	2.8	135.5	2.9
47	76.9	2.1	125.0	2.6
79	60.0	0.6	95.4	2.6
LSD .05	8.2	0.6	17.7	0.5

Table 9. Final (9/7) plant measurements and yield of wild rice as influenced by shading - St. Paul - 1979.

Percent shading	Measurements: Plant height	Tillers per plant	Dry weight per plant	Weight per panicle	Grain yield per box *
	cm	----	gm	gm	gm
0	154	3.4	14.9	1.33	217
30	155	2.2	10.1	1.50	216
47	151	2.0	9.5	1.43	205
79	127	2.4	8.9	1.20	172
LSD .05	17	0.5	3.2	0.16	31

* 16 square feet; 2% moisture

On July 20, the date nearest the time of shade removal for all treatments, tillers per plant decreased linearly with an increase in shade. However, after only one week without shade, all treatments aside from the control were virtually equal in tiller number. Height was only significantly affected under the 79% shading at both dates.

At harvest the trends observed on August 8 were maintained for both height and tiller number. Yield was significantly reduced only under the 79% shade. The reduction in panicle size can partially explain this yield decrease. In addition, all shade treatments significantly reduced the dry weight produced per plant.

Although it is difficult to relate these shade treatments to the shade produced by water plantain, it appears that wild rice is significantly influenced by the light intensity it receives early in the growing season.

The Relative Rate of Establishment of Water Plantain and Wild Rice at Two Temperatures

Competition between crops and weeds can be greatly influenced by the rate at which they establish in relation to one another. Since wild rice is flooded before water temperatures are optimum for germination and growth, this study was conducted to measure the relative rate of establishment of water plantain rootstocks and wild rice at two temperatures. This experiment was conducted in modified milk coolers where the temperature of the water could be maintained at a desired level. Wild rice and water plantain were grown in 59° F (15° C) and 68° F (20° C) water and leaf area measurements were obtained at 5 day intervals. Figure 2 shows the response of water plantain and wild rice to the two temperatures.

Water plantain established much faster than wild rice at both temperatures. This is quite similar to the relative rates observed in the field. In order to see if temperature and plant species interacted, an analysis of variance was performed for day 20 and day 30. There was a significant interaction between plant species and temperature at both dates. Figure 3 shows how temperature interacts with plant type.

Both interactions are similar in that at 68° F the growth of water plantain is much greater in relation to wild rice than it is at 59° F. This means that at cooler temperatures wild rice establishes better in relation to water plantain than at high temperatures.

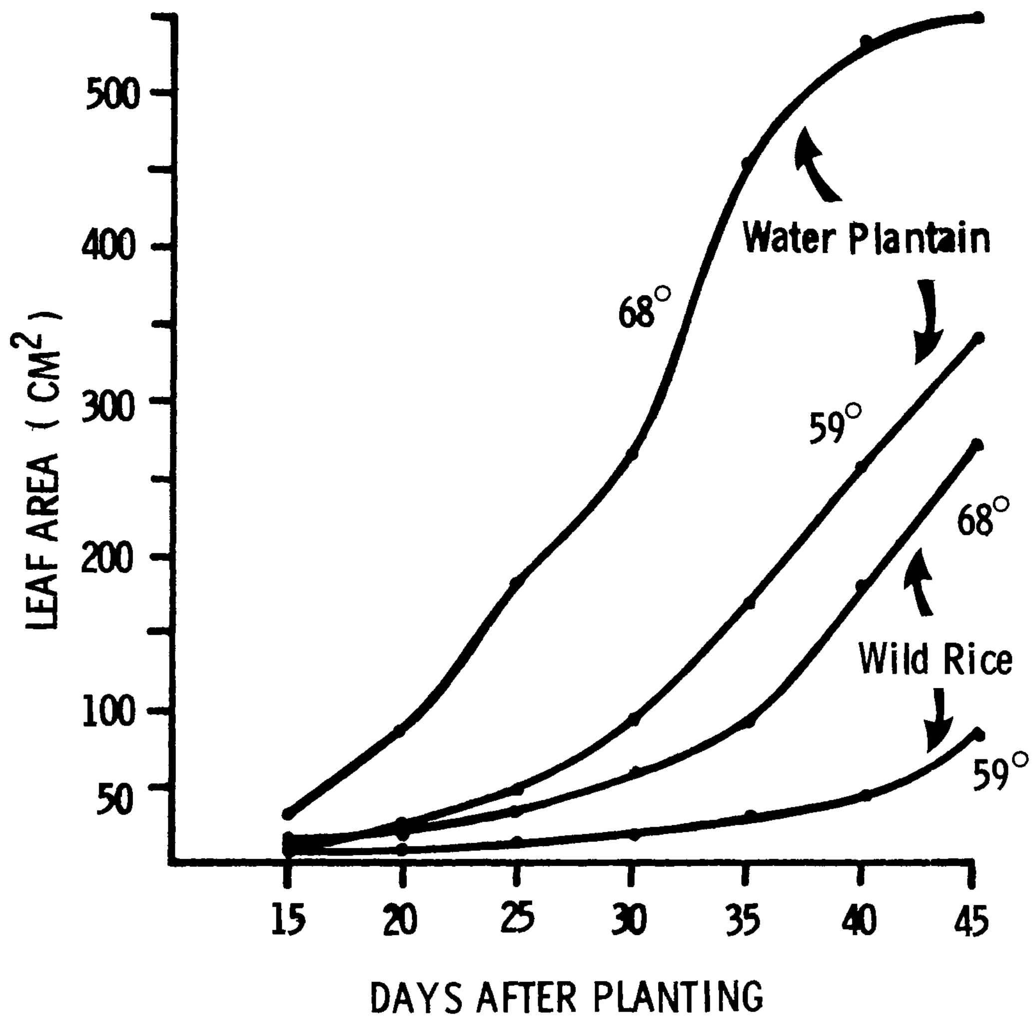

Figure 2. The leaf area production rate of water plantain and wild rice grown with flood water temperatures of 59 or 68 °F.

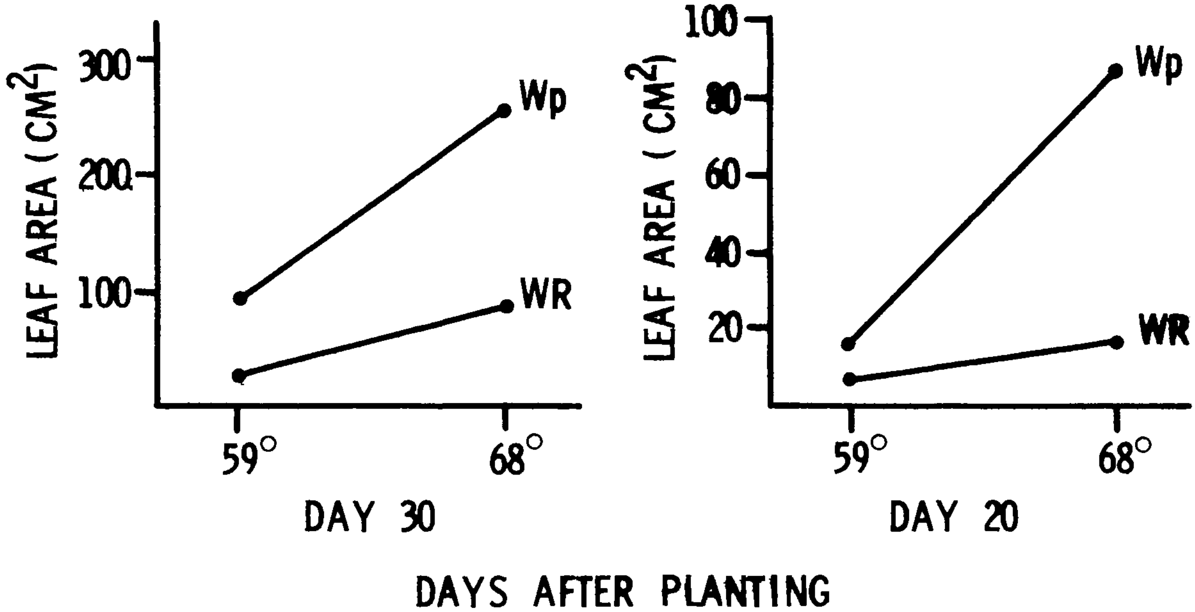

Figure 3. The amount of leaf area produced by water plantain (Wp) and wild rice (WR) after 20 and 30 days of growth in flood water temperatures of 59 and 68 °F.

DATE OF HARVEST OF DIFFERENT VARIETIES

A variety and date of harvest trial was conducted on the Truman Sandland farm near Clearbrook in cooperation with Dr. Stucker, plant breeder, and Robert Tervola, Clearwater County Extension Director. Four varieties, M1, K2, Johnson and Netum, were harvested at 3 dates. The results are shown in Table 10.

Table 10. Yield, moisture percent at harvest and plant population of four varieties planted in the fall of 1978 on Sandland farm north of Clearbrook.

Harvest date	Variety: Netum	M1	Johnson	K2	LSD .05*
	- - - - - - Lb/A grain at 40% moisture - - - -				
8-28	817	531	501	678	235
9-4	1326	1351	1490	1614	NS
9-11	1252	1358	1537	1429	NS
	- - - - - - - - - - Moisture % - - - - - - - - - -				
8-28	54.7	60.5	61.6	58.6	1.8
9-4	44.3	49.1	48.3	46.5	NS
9-11	40.6	43.0	42.1	45.2	NS
	- - - - - - - - - - Plants/ft^2 - - - - - - - - - -				
Ave. for last 2 dates	2.0	1.4	1.6	1.7	NS

* Values can be used to statistically compare the four varieties at one date; NS = not statistically different.

The first harvest date was on August 28. Netum yielded the most on this date with K2 the second highest, M1 next, and Johnson the least. Netum was also the most mature on this date followed by K2, M1, and Johnson as evidenced by the grain moisture. On the latter 2 harvest dates (September 4 and 11), there was no significant difference in yield among the 4 varieties. Peak yields were obtained at the second harvest date for the 2 early varieties, Netum and K2, and at the third harvest date for the 2 later maturing varieties, M1 and Johnson.

VOLUNTEER CONTROL

Plowing

A grower's field which was plowed 20 inches deep with a large single bottom plow and then rotovated (shallow) after harvest in the fall of 1978 was observed for volunteer wild rice plants in 1979. The peat in the field was 1 to 3 feet in depth. Some areas of the field had no volunteer wild rice plants but much of the field had 1/4 to 3 wild rice plants per square foot. This indicates that the wild rice seed was not buried deep enough in all areas of the field or that rotovating brought some seeds to the surface. The field was rotovated to reduce the ridging effect of the plow. Perhaps a better way to reduce ridging would be to pack the area with a roller after plowing. Plowing at a higher speed than we were able to with a crawler tractor may also reduce ridging. More fields were deep plowed in the fall of 1979 and these will be observed again for volunteer wild rice plants.

An area in a field was plowed to a depth of 10 in. with a slatted moldboard plow in the fall of 1978. This spring there were 2-3 volunteer plants per square foot in the plowed area compared to 8-10 in the unplowed area. The volunteer plants were removed before seed set and combines were not allowed to pass over the area during harvest. The area was rotovated after harvest. In the spring of 1980 the plowed and cleared area will be observed for volunteer wild rice plants.

Chemicals

In the fall (9/25), in a grower's field near Aitkin, three rates (25, 50 and 100 gal/A) of vapam were applied to the bottom of a plow furrow with a vapam applicator mounted on a 5-bottom plow. Dormant wild rice seeds were placed in mesh bags and the bags buried at the bottom of the plow layer right after plowing. Three weeks (10/16) after application the bags were retrieved, put into a cold room (35° F) and germinated in beakers of water on 12/4 for germination. About 30% of the seeds germinated regardless of the vapam treatment. Either the soil needs to be sealed and packed after vapam application or vapam is not effective on dormant seed. More tests will have to be conducted on the use of vapam for controlling residual seed in the soil.

SEED SURVIVAL

Seed Survival in the Soil

Seed samples were removed on October 21 from the seed survival experiment started 3 years ago in Grand Rapids to determine the length of time wild rice seed remains viable when buried at 3 different depths in peat and mineral soil under 3 different flooding regimes. Nylon mesh bags containing 550 seeds each were retrieved from each burial depth and flooding regime. Table 11 gives the germination of the seeds which had been buried in the soil for 3 years.

Table 11. The influence of burial depth, soil type, and flooding regimes on seed germination after 3 years in the soil - Grand Rapids-1979.

Burial depth	Flooding regime and soil type: Continuous flood, Mineral	Continuous flood, Peat	Continuous fallow, Mineral	Continuous fallow, Peat	Winter fallow-summer flood, Mineral	Winter fallow-summer flood, Peat
	Germination percent*					
0 in.	0	0	0	0	0	0
2 in.	8.9	4.7	0	0	3.2	1.6
10 in.	7.0	5.8	0.1	0.7	5.1	2.6

* Seeds removed 10/21/79; very little germination occurred unless pericarp was removed from above the embryo.

Very little germination occurred without removing the pericarp from above the embryo. No seeds remained viable after 3 years when they were left on the soil surface regardless of the flooding treatment. Also no seeds remained viable after 3 years when buried 2 inches deep in mineral and peat soil which was continuously fallowed during this time. However, 2 to 9% of the seeds were still viable when buried at 2 inches in the continuous flood and winter fallow-summer flood treatments. At the 10 inch depth, some seed remained viable for all the treatments. The least, however, remained viable in the continuous fallow treatment indicating that keeping a field dry for 3 years will kill nearly all of the wild rice seeds. However, it is difficult to dry out many low lying peat fields and 3 years of fallow may not achieve the same results as we did in our experiment. Probably the best way for a grower to reduce the number of viable seeds in a field in the shortest period of time would be to not work a field after harvest in the fall, then flood in the spring, drain after 6 weeks and eliminate the plants which grew by cultivation. This procedure could be followed for 2 years and probably would eliminate most of the viable seeds so a new variety could be planted in the fall of the second year. We will be checking a field in which a grower is using this procedure.

WILD RICE PLANT DEVELOPMENT

Temperature and Daylength Response

Three nonshattering varieties, Netum, K2 and Johnson, and a shattering type from Canada were planted in two growth chambers. One chamber had a temperature regime of 78° F during the day and 65° F at night. The other chamber had a daytime temperature of 68° F and night temperature of 55° F. Both chambers had full light intensity for 14 hours and both were divided by black plastic so one side of each chamber could be given 1/2 hr of low light intensity after 6 hr of darkness to simulate an 18 hr day. Results of this study are summarized in Tables 12, 13, and 14.

The number of days from planting to floral initiation, tillering, flowering, appearance of first dark seed and last dark seed for the four varieties are shown in Table 12. There was very little difference in plant response to the 14 hr daylength compared to the simulated 18 hr daylength in each chamber. This is in contrast to some of our earlier work when we obtained earlier flowering when the night was interrupted. However, we did obtain a difference in the number of florets produced as is indicated later. All varieties required a significantly longer time to mature in the cold compared to the warm chamber. For days to floral initiation and tillering there was about a 2 week lag in the cold chamber and for days to flowering and seed fill, a 4-5 week delay. This indicates that flowering and grain filling is delayed more than early plant growth by cool temperatures.

The number of growing degree days required for each stage of growth are given in Table 13. Growing degree days were calculated by averaging the maximum and minimum temperatures and subtracting 50 from the average. The resulting value for each day was added together to obtain total growing degree days. Even though it took longer for the plants to develop in the cold chamber, the total growing degree days required for the plants to develop to maturity was less in the cold chamber compared to the warm chamber. The Netum variety and the Canadian shattering type required fewer growing degree days to mature than the K2 and Johnson varieties.

Table 14 shows the measurements made on the 4 varieties for 4 plant characteristics. The plants in the cool chamber tended to be taller, had more leaves on the main stem, and had more tillers compared to those in the warm chamber. They also had more florets on the main stem compared to the warm chamber. In the warm chamber the number of florets on the main stem of the plants in the uninterrupted night side (short day) were significantly lower (50% or more) than on the main stem of the plants in the interrupted night (long day) side. This was not nearly as evident in the cool chamber. This indicates that wild rice probably would yield less under short days especially when the temperatures are warm compared to cooler, long day conditions. More temperature and daylength studies are planned in the future.

Table 12. Temperature and daylength influence on plant development for 4 wild rice varieties, St. Paul-1977.

		Day-night temperature, ° F			
		78-65		68-55	
Variety	Growth stage	Interrupted night*	Uninterrupted night**	Interrupted night*	Uninterrupted night**
		Days from planting			
Netum	Floral initiation	31	31	44	42
	Tillering	42	42	56	58
	Flowering	54	48	84	76
	First dark seed	72	68	110	107
	Last dark seed	77	73	124	114
K2	Floral initiation	34	32	46	44
	Tillering	50	45	64	66
	Flowering	62	52	86	88
	First dark seed	79	73	106	114
	Last dark seed	84	78	126	125
Canadian shattering	Floral initiation	28	28	42	41
	Tillering	38	44	57	62
	Flowering	50	45	80	76
	First dark seed	63	68	104	104
	Last dark seed	67	72	124	115
Johnson	Floral initiation	36	30	51	45
	Tillering	48	48	60	61
	Flowering	64	53	90	79
	First dark seed	78	72	120	117
	Last dark seed	82	76	130	129

* Daylength was 14 hr with the 10 hr night period interrupted for 1/2 hr with low light intensity to simulate an 18 hr day.

** Daylength was 14 hr with no interruption of the night with light.

Table 13. Number of growing degree days required for development of 4 wild rice varieties when grown at 2 different temperature regimes, St. Paul-1977.

Variety	Growth stage	Day-night temperature, ° F 78-65 Interrupted night*	78-65 Uninterrupted night**	68-55 Interrupted night*	68-55 Uninterrupted night**
		- - - - - - - - - Growing degree days***	- - - - - - - -		
Netum	Floral initiation	666	666	506	483
	Tillering	903	903	644	667
	Flowering	1161	1032	966	874
	First dark seed	1548	1462	1265	1231
	Last dark seed	1656	1570	1426	1311
K2	Floral initiation	731	688	529	506
	Tillering	1075	968	736	759
	Flowering	1333	1118	989	1012
	First dark seed	1699	1570	1219	1311
	Last dark seed	1806	1677	1449	1438
Canadian shattering	Floral initiation	602	602	483	472
	Tillering	817	946	656	713
	Flowering	1075	968	920	874
	First dark seed	1354	1462	1196	1196
	Last dark seed	1440	1548	1426	1323
Johnson	Floral initiation	774	645	587	518
	Tillering	1032	1032	690	702
	Flowering	1376	1140	1035	908
	First dark seed	1677	1548	1380	1346
	Last dark seed	1763	1634	1495	1484

* Daylength was 14 hr with the 10 hr night period interrupted for 1/2 hr with low light intensity to simulate an 18 hr day.

** Daylength was 14 hr with no interruption of the night with light.

*** Growing degree days calculated by: $\frac{\text{Max + Min Temp}}{2} - 50$. Warm chamber had 21.5 growing degree days per day and cool chamber had 11.5 growing degree days per day.

Table 14. Plant growth measurements made on 4 wild rice varieties grown at 2 different temperature regimes, St. Paul-1977.

Variety	Plant characteristic	Day-night temperature, ° F			
		78-65		68-55	
		Interrupted night*	Uninterrupted night**	Interrupted night*	Uninterrupted night**
Netum	Plant height (cm)	91	86	98	105
	Leaf no.***	3.2	2.8	3.2	3.1
	Tiller no.***	1.1	1.0	2.2	0.8
	Floret no.***	40	18	47	40
K2	Plant height (cm)	77	76	85	94
	Leaf no.	3.0	3.0	3.2	3.8
	Tiller no.	1.4	1.1	1.4	1.7
	Floret no.	34	22	40	42
Canadian shattering	Plant height (cm)	101	70	100	108
	Leaf no.	2.3	2.6	3.0	3.0
	Tiller no.	0.8	0.7	1.6	1.3
	Floret no.	30	12	30	29
Johnson	Plant height (cm)	92	86	106	100
	Leaf no.	2.9	2.6	3.3	3.3
	Tiller no.	1.0	0.8	1.5	1.5
	Floret no.	30	17	42	30

* Daylength was 14 hr with 10 hr night interrupted for 1/2 hr with low light intensity to simulate 18 hr day.

** Daylength was 14 hr with no interruption with light.

*** Leaf, tiller and floret no. for all varieties was counted on the main stem at maturity.

ACKNOWLEDGEMENT

The help during the year of Mike McClellan, plot technician, and Joel Ransom, graduate student, was greatly appreciated. The work at Grand Rapids would not have been possible without the help of Henry Schumer. Greatly appreciated was the cooperation of growers Franklin and Harold Kosbau, Ray Skoe, Truman, Dale, and John Sandland, Warren Bardwell, and Art Hedstrom. Experiments were conducted in their fields and some of them donated seed for research purposes which was very helpful and appreciated.

WILD RICE DISEASE RESEARCH - 1979

A PROGRESS REPORT

January 25, 1980

Dr. James Angelo Percich, Project Leader
Mr. Loren L. Nickelson, Research Specialist
Mr. Robert Bowden and Mr. M. Kosim Kardin, Graduate Assistants

In 1979 the plant pathology wild rice research team continued to focus on the development of biological and cost efficient means of chemical plant disease control procedures. Also, more complete studies of the biology of several fungal and bacterial pathogens affecting wild rice were initiated. Major areas of investigation centered on the following:

1. The field testing of various fungicides in combination with different stickers and spreaders to improve the effectiveness of controlling brown spot caused by *Helminthosporium oryzae* (*Bipolaris oryzae*) and *Helminthosporium sativum* (*Bipolaris sorokiniana*).

2. A defoliation study to determine the amount of leaf loss overtime a wild rice plant could sustane before it had an affect upon yield.

3. An investigation into the possible acquired resistance of *Bipolaris oryzae* and *Bipolaris sorokiniana* to Dithane M-45 and other fungicides.

4. The continuation of a preliminary study of stalk not caused by *Helminthosporium sigmoidium* focusing on disease development and control procedures.

5. The study of the identity and biology of the bacterial organisms causing bacterial leaf streak on wild rice.

6. Continued screening of plant introduction for brown spot resistance.

MATERIALS AND METHODS

CHEMICAL CONTROL STUDIES

The wild rice research paddies at the North Central Experiment Station at Grand Rapids, Minnesota were planted in the spring of 1979 with the cultivated wild rice "variety"designated as K-2 at a rate of 35 lb. per acre. Emergence occurred on June 12, 1979. The paddies were then divided into 8 x 8 ft. test plots, thinned to a plant density of 2-3 plants per sq. ft., and then sprayed with various fungicides and sticker-spreader materials. Fungicide applications were made utilizing a backback CO_2 pressurized sprayer system delivering 300 ml of material at 25 psi, which is equivalent to a rate of 35 gallons of spray material per acre.

The following chemicals and rates of application were utilized at the suggested label rates for the control of brown spot on wild rice and other related grass species.

Chemical	Rate
Benlate 50-WP	1 lb actual per acre
Bravo-6F (59%AI)	10 lb. actual per acre
Dithane M-45 (80% AI)	2 lb. actual per acre

The first spray application was initiated on July 24, 1979 during the late boot stage of plant development. The 2nd, 3rd, and 4th sprays were applied on July 31, and August 8 and 15, respectively.

The test plots were inoculated with mixed isolates of *Bipolaris oryzae* and *B. sorokiniana* on July 24 and August 9, 1979. All plots were hand harvested, green weight determined, and then dried for 14 days at 95F, and weighed. All yield data was then converted to pounds per acre.

The test plots were replicated 7 times in a completely randomized design. The check plots were inoculated with water alone.

Various sticker-spreader compounds were also used in the three fungicides tested. The number of replication, inoculation times, and spray procedures were the same as above. The various sticker-spreaders investigated and the amounts used are as follows:

Sticker-Spreader	Rate
Triton CS-7	1.0 pint per 100 gallons
Triton B-1956	0.5 pint per 100 gallons
Acrylocoat	1.0 pint per 100 gallons
Rhoplex	1.0 pint per 100 gallons

DEFOLIATION STUDY

Wild rice plants, variety K-2 were thinned to 60 plants per 3 x 20 ft. plot areas on July 3, 1979 during the 2nd or 3rd aerial leaf stage of development. A defoliation of both the flag and the adjacent leaves was performed on both the primary and secondary tillering stems at the following times and stages of development:

Defoliation	Date	Stage of Development
1st	August 2, 1979	Late flowering
2nd	August 16, 1979	Early Grain Formation
3rd	August 30, 1979	Grain Filling-Maturity

Each defoliation was replicated in 6 test plots. The control plots were not defoliated and allowed to grow and mature normally. All plots were sprayed 4 times with Dithane M-45 plus Triton CS-7 at a rate of 2 lb per acre. The harvesting occurred on September 6, 1979 when the control plants contained approximately 30% dark seed. Green weights were determined.

RESULTS

CHEMICAL CONTROL OF BROWN SPOT

When Dithane M-45 was used in combination with either Triton CS-7, Triton B-1956, Acrylocoat, or Rhoplex on plants that were then inoculated with mixed cultures of B. oryzae and B. sorokiniana all combinations produced significant (at the 5% level) levels of control and subsequent yields (Tables 1-5).

Three and four applications of Dithane M-45 plus Triton B-1956 produced a 19 and 73%, respectively increase over the non-treated inoculated plants (Table 1).

Dithane M-45 in combination with acrylocoat at 2, 3, and 4 applications resulted in 64, 49 and 39% increases over the control, respectively (Table 2). All of these increases were significantly greater than the yields of the non-chemically treated plots.

When Dithane M-45 was used in combination with Rhoplex B-85 for the control of brown spot increases of 28, 24, and 50% with 2, 3 and 4 applications resulted, respectively over the non-treated plots (Table 3).

The effectiveness of 3 applications of Dithane M-45 plus Triton CS-7 was compared with the various sticker-spreader materials tested (Table 4). Dithane M-45 plus Triton CS-7 resulted in a 40% increase in yield when compared to the control. When Dithane M-45 plus Triton B-1956 was compared to Dithane M-45 plus Triton CS-7, only a non-significant 5% increase resulted. However, Dithane M-45 plus Acrylocoat or Rhoplex B-85 resulted in significant 14 and 25% increases, respectively over Dithand M-45 plus Triton CS-7 (Table 3).

The effect of 3 applications of Dithane M-45 plus Triton CS-7, Dithane M-45 plus Triton B-1956, Benlate 50-WP plus Triton CS-7, and flowable Bravo-6F were compared in their ability to control brown spot (Table 4). All chemicals tested resulted in significant levels of control when compared to the unsprayed checks. Again, Dithane M-45 with either Triton B-1956 or Triton CS-7 did not differ significantly from each other. Benlate 50-WP was significantly better than all the other chemicals tested and was, as in 1978 (34% increase over the check with 3 applications), the most effective compound tested. However, Bravo in 1979 resulted in only a 19% increase over the control as opposed to a 59% increase in control (Table 5), during the 1978 field trials.

DEFOLIATION STUDY

Wild rice plants that were not defoliated and allowed to develop normally yielded 1210 lbs. green weight on a per acre basis (Table 6). However, plants which had both their flags and the leaves adjacent to the flag removed during the late flower period of plant development yielded 1103 lbs per acre, which was a 107 lbs per acre decrease over the untreated plants. If the defoliation occurred during early grain formation or during grain filling, yields of 1148 and 1177 per acre, respectively, were demonstrated. These yields are 5 and 3% less than the non-defoliated control.

Grain diameters as they relate to time of defoliation were also compared (Table 7). Grain diameters of 4/64 inches or larger (>) are those which had the highest quality and potential economic value. Defoliation during the late flowering or early grain formation of plant development resulted in only 26 and 29%, respectively, of the total grain having a size of > 4/64 in, vehicle 37% of the control grain was of this size or larger.

Acquired Resistance of Bipolaris Oryzae and Bipolaris Sorokiniana, the Causal Organisms of Brown Spot of Wild Rice, to Dithane M-45 and Other Fungicides.

Dithane M-45 is the only fungicide that has been recommended to control brown spot disease of wild rice in Minnesota. In some commercial paddies the chemical has been used for at least four continuous years.

It has been known that the effectiveness of a fungicide in controlling a disease often decline after its continuous use over a period of time. Its failure to control the disease has been attributed to the development of resistant strains of the pathogen to the fungicide. In this study, the possibilities of the development of resistant strains of Bipolaris oryzae and Bipolaris sorokiniana to Dithane M-45, Bravo 6F, and Sisthane will be elucidated.

Eight isolates of B. oryzae and five isolates of B. sorokiniana were used in the experiments with Dithane M-45, while only five isolates of each species were used in the experiments with other fungicides. These isolates of fungi were cultured on PDA Difco media for 10 days. Then mycelial discs taken from these cultures were transferred onto a series of media containing 0, 1, 10, 100 and 1000 ug/ml of a fungicide. The highest tolerable concentration of the fungicide on which the fungi still grow was observed after three weeks. The colonies of the fungi that still grew at this concentration were transferred to the same fungicide concentration, and to a series of media containing higher concentration, and to a series of media containing higher concentrations of the fungicide. This procedure was repeated several times at three week intervals.

In the first transfer, all five isolates of B. sorokiniana grew at 100 ug/ml of Dithane M45, while only six out of eight isolates of B. oryzae could grow at this concentration. There was no isolate of B. oryzae and B. sorokiniana that could grow at 1000 ug/ml of Dithane M-45. However, after 7 - 8 passages through media mixed with Dithane M 45, we could obtain some colonies of B. oryzae and B. sorokiniana that could grow at 6000 ug/ml of Dithane M45. One colonies of B. sorokiniana could even grow at 8000 ug/ml of Dithane M45.

All isolates of B. oryzae and B. sorokiniana could grow at 1000 ug/ml of Bravo 6F in the first transfer. And after the third transfer, we succeeded to culture all isolates of both species on media containing 100 000 ug/ml Bravo 6 F.

All isolates of B. sorokiniana could only grow on media containing 10 ug/ml of Sisthane. And no one of these isolates grew at 100 ug/ml of Sisthane. However, very poor growth of isolates of B. oryzae were still observed at this concentration. In the see cond transfer, mycelial discs taken from one isolate of B. oryzae grown on media containing 10 ug/ml of Sisthane (Ho T 92-S-10 V) produced colonies that grew rapidly even at 100 ug/ml of Sisthane. This isolate only grew well at concentration as high as 100 ug/ml of Sisthane, but failed to grow at higher concentration even after six passages through media mixed with Sisthane, or if it grew, the colong would not survive in the subsequent transfer. After six sub cultures on media mixed with Sisthane, isolate Ho T 92 that poorly grew at 100 ug/ml of Sisthane in the first transfer, and other isolates of B. oryzae could be cultured at least at 200 ug/ml of Sisthane. Some isolates produced colonies that could even grow at 400 ug/ml of Sisthane, even the growth was very limited. After six passages through Sisthane containing media, only four isolates of B.

sorokiniana could grow at 100 ug/ml of Sisthane, while isolate Hs 36 GG-2b could only grow at 80 ug/ml of Sisthane.

The data suggested that after several passages through media mixed with Dithane or Sisthane, isolates of B. oryzae and B. sorokiniana could tolerate and grew at higher concentration of these fungicides. The increase in tolerance of isolates of B. oryzae and B. sorokiniana to Brovo 6 F was not clear, as in every transfer the fungi always succeeded to grow at the highest concentration of the fungicide tested.

BACTERIAL LEAF STREAK

Bacterial leaf streak (BLS) is a disease of wild rice characterized by narrow, dark green, water-soaked streaks which expand length-wise along the leaf blade and may also advance laterally across the leaf vains. Water-soaked tissues eventually turn brown or black giving leaves a striped appearance.

The causal agent of BLS has not been well established so in 1979, isolations were made from infected field material to recover pathogenic bacteria. Isolations consistently yielded a white, Gram-negative bacterium which has been proved to be the causal agent by numerous pathogenicity tests. This bacterium has been identified as Pseudomonas sp.

A field survey was conducted in 1979 to determine the incidence and severity of BLS in Minnesota. Nine of twelve growers surveyed were found to have BLS present in their fields. Seven native lake and river stands were also surveyed for the presence of BLS, but none was found. In commercial paddies in 1979, an average of less than 1% of the plants were infected and of these, an average of less than 1% of the leaf area was affected. The severity of BLS can be expected to vary with weather conditions and may be a problem in some years. The survey will be repeated in 1980.

ANTHRACNOSE FOUR SPECIES

Anthracnose was discovered in commercial paddies and natural stands for the first time in 1979. It is caused by Colletotrichum sp. and produces light tan to brown, diamond-shaped leaf lesions which usually contain very small black or pink dots at their centers. These small dots are fungal structures which produce spores to initiate new infections. The importance of anthracnose on wild rice has not been established, and further investigation is planned in 1980.

STEM ROT OF WILD RICE

Studies involving the biology and chemical control of the fungal pathogen Helminosporium sigmoidium, the causal agent of "stalk rot" was conducted in the Aikin, Minnesota area during 1979. Helicopter applications of DuTer and Dithane M-45 were compared for their ability to control stalk rot of wild rice.

The treated plant received either 2 sprays of DuTer at 1 lb per acre (at a cost of $9.00 per pound) or four sprays of Dithane M-45 plus Triton CS-7 at the recommended rates. A third treatment received both fungicides at the above rates. The check plots were not sprayed with either compound.

Analysis of the yield data indicated that those plots receiving DuTer only resulted in a 4% increase in dry weight over the control. While Dithane M-45 plus CS-7 at the recommended rates showed a 5% increase in dry weight over the control. Those plots sprayed with both Dithane M-45 and DuTer resulted in a 2% increase in yield when compared to the untreated plots.

In all cases no phytotoxicity to wild rice was observed due to Du-Ter alone or in combination with Dithane M-45.

The over wintering (survival) of sclerotia of H. sigmoidium was 50% less in the plots treated with Du Ter than in those treated with Dithane M-45.

Research efforts during 1980 will attempt to gain a better understanding of the following:

1. The biology of Helminthosporium sigmodium.

2. The control of H. sigmoidium through cultural and/or chemical means.

3. Assessing potential crop loss resulting from H. sigmoidium infection.

DEVELOPMENT OF DISEASE RESISTANT LINES IN COOPERATION WITH DR. R. E. STUCKER: DEPT. AGRONOMY AND PLANT GENETICS

Throughout the summer of 1979, the plant pathology staff screened wild rice introductions for possible disease resistance to Brown Spot Disease. Plants were inoculated on two difference occasions with isolates of B. oryzae and B. sorokiniana collected throughout the State of Minnesota. The resulting infection was monitored and individual plant reactions were observed and recorded. Disease readings were based on lesion size on a scale of 0 (healthy) to 5 (complete leaf and stem infection) four times during the growing season.

Due to poor environmental conditions, optimal disease development did not occur. The disease which was present and its subsequent severity did not allow for clear-cut possible plant resistance to manifest itself. This inability to create epidemics, with a degree of consistency, has created problems at the Grand Rapids North Central Experiment Station during the past two years.

Therefore, new approaches are being explored for 1980. Some of these include:

1. The development of a sprinkler irrigated disease paddy at Rosemount Plant Pathology Farm in Rosemount, Minnesota. Environmental conditions characterized by hot days (80-90F) and warm nights (64 F and above); couple with control of plant wettness and canapy humidity too, hopefull, will provide an ideal environment for disease development.

2. The use of a quanitative inoculator and a detached leaf bioassay procedure to help screen plants for disease resistance.

3. A seedling bioassay procedure to test intact young plants in the greenhouse.

Items 2 and 3 above are being presently investigated in a joint research effort involving plant pathology and breeding under the direction of Drs. Jim Percich and Bob Stucker, respectively.

CONCLUSIONS AND SUMMARY OF WORK COMPLETED IN 1979

1. Chemical Control

   a. In field testing during 1978 and 1979 it was demonstrated that Triton B-1956 performed better than or as well as Triton CS-7. Therefore, it is recommended that either Triton B-1956 (0.5 pint per 100 gal) may be safely and effectively used with Dithane M-45 for the control of brown spot of wild rice.

   b. Good disease control was obtained at Grand Rapids, Minnesota with only 3 applications of Dithane M-45. However, since only a low level of disease developed, a true test could not be determined. Therefore, recommendation for large scale airplane application in 1980 is four applications of Dithane M-45 at a rate of 2 lb per acre in 5 gal. of water plus either 1.6 oz of Triton CS-7 or 0.8 of Triton B-1956. In all cases applications should be made at 7 to 10 day intervals with the last application being at least 26 days before harvest to comply with State of Minnesota and EPA regulations.

   c. Continuation of a study involving the control of *H. sigmoidium*, the causal organism of "stalk rot" of wild rice.

2. Defoliation Study

   a. In this preliminary study it was demonstrated that the loss of the flag and an adjacent leaf on the tillers of a wild rice plant reduced the quality and quantity of the yield significantly. Therefore, protection of these leaves against loss, for example from foliar fungal pathogens by the use of Dithane M-45, is of considerable importance.

   b. Assessing how much foliar loss a wild rice plant can sustain and during what periods of development will be studied extensively during 1980. Such information may lead to new recommendations concerning when and how much a grower must spray to protect his crop.

3. Pathogen Studies

   a. The relationship between the fungi that cause brown spot and the continuous use of Dithane M-45 regarding its affects on the growth, development, pathogenicity, etc. of these pathogens have potentially far reaching implications. Such research is vital if we are to assure, and hopefully prevent, such pathogen resistance from not developing.

   b. The identification and study of the organisms causing bacterial leaf streak on wild rice. How and if these bacteria affect wild rice production is still unknown.

c. The study of Helminthosporium sigmoidium, the causal organism of stalk rot of wild rice is now just beginning to get underway. The seriousness of this widespread and common pathogen has yet to be determined.

RESEARCH GOALS FOR 1980

1. Biological Studies

   a. Study of the presently identified fungal and bacterial pathogens of wild rice.

   b. Continued search and awareness of any other biotic or abiotic agents which may affect the health of wild rice.

   c. Continued work on the identification and possible control of seed-borne pathogens.

   d. Crop loss assessment.

   e. Environmental monitoring

   f. Development and improvement of techniques utilized for finding resistance to brown spot in wild rice.

2. Chemical Studies

   a. Development of reliable field chemical control paddy facilities which help insure the development of severe disease epidemics.

   b. Further testing of Dithane M-45 and various sticker spreader materials.

ACKNOWLEDGMENT

We gratefully acknowledge and appreciate the cooperation of the following individuals: Henry Schumer and his staff at the North Central School and Experiment Station, Grand Rapids, Minnesota and Franklin and Harold Kosbau and other cooperating Minnesota Wild Rice Growers for their continued interest and support of the Plant Pathology Wild Rice Project in 1979.

TABLE 1. EFFECT OF DITHANE M-45 PLUS B-1956 ON BROWN SPOT DISEASE CONTROL AT GRAND RAPIDS, MINNESOTA IN 1978

APPLICATIONS	WEIGHT	TREATMENT WT. OVER CHECK	% INCREASE OVER OVER CHECK
2	515		-
3	614	25	19
4	899	99	73

CHECK = 518 LB/A

TABLE 2. EFFECT OF DITHANE M-45 PLUS ACRYLOCOAT ON BROWN SPOT DISEASE CONTROL AT GRAND RAPIDS, MINNESOTA IN 1979

Applications	Weight	Treatment Wt. over check	% Increase over check
2	849	86	64
3	772	66	49
4	718	52	39

Check = 518 lb/A

TABLE 3. EFFECT OF DITHANE M-45 PLUS RHOPLEX B-85 ON BROWN SPOT DISEASE CONTROL AT GRAND RAPIDS, MINNESOTA IN 1979

Applications	Weight	Treatment Wt. over check	% Increase over check
2	664	38	28
3	641	32	24
4	776	67	50

CHECK = 518 LB/A

TABLE 4. EFFECT OF THREE APPLICATIONS OF DITHANE M-45 WITH VARIOUS STICKER-SPREADERS FOR THE CONTROL OF BROWN SPOT ON WILD RICE AT GRAND RAPIDS, MINNESOTA DURING 1979

Treatment	Treatment Wt.	Treatment Wt. Over Dithane M-45 + Triton CS-7	%Increase Over Dithane M-45 + Triton CS-7
Dithane M-45 Plus			
1. Triton CS-7	680		
2. Triton B-1956	714	34	5*
3. Acrylocoat	772	92	14*
4. Rhoplex B-85	849	169	25

Control 518 lb/A

*Not significant at the 5% level.

TABLE 5. EFFECT OF THREE APPLICATIONS OF VARIOUS FUNGICIDES ON THE CONTROL OF BROWN SPOT AT GRAND RAPIDS, MINNESOTA DURING 1979

Treatment	Treatment Wt.	Treatment Wt. Over control	% Increase over control
Benlate 50-LOP- plus Triton CS-7	787	269	52
Bravo-6F plus Triton CS-7	618	100	19
Dithane M-45 plus Triton B-1956	714	196	38
Dithane M-45 plus Triton CS-7	680	162	31

Control 518 lb/A

TABLE 6. THE EFFECT OF DEFOLIATION OF WILD RICE AT THREE DIFFERENT STAGES OF PLANT DEVELOPMENT

Treatment	Treatment weight	Weight Loss compared to control	% Weight Loss compared to control
1. Control (no defoliation)	1210		
2. First defoliation (late flowering)	1103	107	9
3. Second defoliation (early grain formation)	1148*	62	5
4. Third defoliation (grain filling)	1177*	33	3

* Not significant at 5% level.

TABLE 7. RELATIONSHIP BETWEEN THE GRAIN SIZE (DIAMETER) TO AGE OF PLANT AT THE TIME OF DEFOLIATION

Treatment	Percent Grain Diameters in Inches		
	< [A] 2/64	3/64	> [B] 4/64
1. Late flowering	12	38	26
2. early grain formation	16	55	29
3. grain filling-maturity	11	55	34
4. control (no defoliation)	10	53	37

A) LESS THAN

B) GREATER THAN

Wild-rice Breeding Research - 1979

R.E. Stucker, Gary Linkert,
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Agronomy and Plant Genetics

Breeding project activities in 1979 will be presented in the following categories.

1. Yield tests of varieties
2. Preliminary yield trials
3. Within variety selection for earliness
4. Promising populations

Advanced yield test results

We compared the varieties M1, M3, Johnson, K2 and Netum in tests at Grand Rapids and Excelsior. The Grand Rapids test was fall planted in Oct., 1978 in six replications of 4-row plots ten feet in length. The Excelsior test was spring planted, May 21, 1979, in 12 replications. Both tests were netted and suffered little, if any, bird damage. The Excelsior plots were sprayed three times with Malathion to control wild rice worm but we still had obvious damage. The center 2 rows of each plot were harvested when they reached maturity (40% dark kernels). Results are shown in Tables 1 and 2. Yields are presented as green weight of grain adjusted to 40% moisture content. The Grand Rapids yields averaged 1899 lb/A and Excelsior yields averaged 1320 lb/A. The difference in average yields could be due to rice worm damage, to the difference between spring versus fall planting or to some possible detrimental effects of higher temperatures at Excelsior. However, we had an average of 2.8 plants per square foot at Grand Rapids compared to 1.5 plants per square foot at Excelsior. The difference in stand could have been due to germination losses from stored seed. We attempted to use the same seeding rate at both locations.

The differences in yield of the varieties at Grand Rapids were not statistically significant. Netum was harvested 4 days earlier than K2 and eleven days earlier than the others. K2, M1, M3 and Johnson were very similar. At Excelsior, Netum was significantly lower than M1, M3, and Johnson, but likely not significantly lower than K2. Netum flowered 8 days before K2 and was harvested 2 days earlier.

We had a yield test, cooperative with Dr. Ervin Oelke's project, on one of the Sandland paddies north of Clearbrook (refer to Oelke's report, Table 10 for details). For the September 4 harvest date, relative yields of the varieties Netum, M1, Johnson and K2, were similar to our advanced yield trial results except that K2 was highest in yield. Table 3 presents yield results from tests in 1978 and 1979. Netum is the lowest yielding variety. However, it is earlier than the others. When the season is cut short, Netum is very likely to be the superior variety with K2 a good second. At the early harvest at Sandland's paddy - Aug. 28 harvest, the yields were 817, 678, 531 and 501 lbs green weight per acre for Netum, K2, M1 and Johnson. M3 was not included in the test. We still believe that Netum will mature from 2 days up to a week earlier than K2. It was 8 days earlier heading at Excelsior, 5 days earlier at Grand Rapids, but only a day or two earlier at Clearbrook.

Preliminary yield trials

We had 2 preliminary yield trials at Grand Rapids, 1979. The plots were fall-planted in 1978 in 3 replications in 2-row plots, seven feet in length. Plots were hand-harvested as they matured so shattering losses were minimal as was bird damage and insect losses. The entries in the two trials were selected for earliness. One test with 55 entries traced to the original population from which Netum was selected. The strains were selected for earliness for 3 cycles, however. Another test with 18 entries consisted of early strains from diverse sources in the breeding program. Two things were very impressive in the preliminary yield trials. The materials were very early compared to the advanced yield trial varieties, including Netum. The other was that the average yield of the strains was slightly larger than the mean of the advanced yield trial. Results are presented in Table 4.

The yields are very poorly measured - 2 or 3 reps and only small plots (14 ft^2). Nevertheless, I expected much lower yields based on the earliness of the strains. The preliminary yield trials were on a better part of the paddy than was the advanced yield trial. Thus, I don't expect selections from the preliminary yield trial to be superior to the varieties in yield. They were surprisingly good in my opinion, though. We intend to plant out the earliest half of the preliminary yield trial strains. These will have flowered around July 9 or 10. The materials will be selected mildly for flowering date and agronomic uniformity and allowed to intermate in isolation. The resulting population will then be tested for possible release as an early variety. Of course, we need a couple of years of testing before any decisions about release can be made.

Within variety selection for earliness

We designed experiments to increase earliness of K2 and M3. We planted K2 and M3 at Excelsior and intended to have about 10,000 plants from which we would select the earliest 100 plants. The M3 stands were poor so selections were taken from a first-year stand of M3 on the Manomin paddies in the Blind Lake area. The selected plants were transplanted to waste paper baskets and moved to isolation areas at Excelsior for intermating within each variety. We harvested several thousand seed of each variety, which will be planted in 1980 for comparison to the parent varieties. We will have to see how much increase in earliness was accomplished before we decide whether another cycle of selection will be required. Our objective is to develop early versions of each variety.

In line with this objective, we harvested 200 random plants from each of the varieties K2, Netum and M3 last fall. Netum plants were taken from the Sandland paddies at Clearbrook; K2 plants were taken from the Kosbau paddies at Aitkin; and M3 plants were taken from the Manomin paddies at their Blind Lake area. These plants will be evaluated as families at Grand Rapids (planted Fall, '79) and Excelsior (planting to be done Spring, '80). By evaluating maturity of these families, we should be able to predict how much flowering date can be changed in each variety. Some other agronomic traits will also be evaluated if time and techniques exist. We would like to take measurements on shattering resistance but may not be able to handle all of the families. This information would permit us to decide if within variety selection for shattering resistance is worth-while.

Leslie Everett, graduate student assistant will be evaluating some techniques for breeding for shattering resistance within Netum. His techniques will differ from those used by W.A. Elliott and Gary Linkert in the population discussed below.

Promising populations

Project work continues on several populations. There are two of primary interest to us in the near future. The materials from which Netum was derived have been carried on in a cyclic selection program for shattering resistance. We planted 200 seeds from plants which had the best tensile strength when measured with the tensile strength meter. About 100 plants reached flowering and were allowed to intermate in isolation at Grand Rapids. We harvested about 2900 seeds. These will be planted in isolation in 1980 to start build-up of a potential variety which we hope will have increased resistance to shattering. We will start evaluation in 1981.

The other population of immediate interest involves selection for short plant height. The population, started several years ago, from diverse sources of short plants, was grown in isolation at Rosemount last year. We harvested seed from plants that were 100 cm (39 inches) or shorter. We will continue selection for short plant height and start testing the population for maturity and yield potential in 1980.

We had very low incidence of disease in our paddies in 1979 except for one experiment at Excelsior. The disease plots at Excelsior were not inoculated for disease but still had considerable infection. We plan to grow a larger disease nursery at Excelsior in 1980 and a somewhat smaller test at Grand Rapids. Dr.Percich's project will be cooperating.

General comments

Except for low disease incidence in our disease nurseries, 1979 appeared to be a good year for the breeding project. Our primary disappointment was that we were not able to fall plant at Excelsior. Plans for building two new paddies at Rosemount are complete and the contractor will start as soon as possible this spring. We hope they will be constructed in time for planting. The new irrigation well is completed but has not been tested.

We wish to acknowledge the help of Henry Schumer at Grand Rapids. He has the wild-rice greenhouse section at Grand Rapids partially operational and will be making some crosses of Netum times plants from the germplasm pool this winter. Also, we appreciate the cooperation of Franklin and Harold Kosbau of Aitkin; Hugo Watson and Art Hedstrom of Manomin; and Truman, Dale, and John Sandland, and Warren Bardwell of Clearbrook; and Bob Tervola, Clearwater County Extension Director, who helped plant and took notes on the yield trial at Sandlands' farm. John Lang, coordinator of the University fruit farm and arboretum, has been very helpful in our work at Excelsior.

Table 1. 1979 Wild-rice advanced yield trial results - Excelsior, MN (12reps)

Entry	Heading date	Harvest date	% Moisture	Adjusted [1] Yield(lb/A)	Plants per ft^2	Panicles per ft^2
Netum	7-16	8-21	34	1162	1.6	7.1
K2	7-24	8-23	38	1253	1.6	7.3
M1	7-25	8-28	36	1422	1.3	7.0
M3	7-25	8-27	36	1404	1.6	7.2
Johnson	7-27	8-28	39	1359	1.4	7.0
LSD(.05)[2]	1 day	1 day	ns[3]	176	.2	ns[3]

[1] Adjusted yield is computed as green weight in pounds per acre at 40% moisture.

[2] If the difference between two variety means exceeds the LSD value, the difference may be considered real rather than due to chance variation.

[3] The varieties do not differ for these traits.

Table 2. 1979 Wild-rice advanced yield trial results - Grand Rapids, MN (6 reps)

Entry	Heading date	Harvest date	% Moisture	Adjusted Yield(lb/A)	Plants per ft^2	Panicles per ft^2
Netum	7-17	8-25	37.5	1740	3.4	9.6
K2	7-22	8-29	40.2	1895	2.8	9.0
M1	7-25	9-5	—	1830	2.3	7.4
M3	7-23	9-5	—	1957	3.1	9.5
Johnson	7-24	9-5	—	2072	2.6	8.1
LSD(.05)	1 day	—	—	ns	.4	.7

Table 3. Summary of yield test results for 1978 and 1979. Yield is expressed as green weight pounds per acre at 40% moisture.

Variety	Test					
	GR-'78	Excel.-'78	GR-'79	Excel.-'79	Sandland-'79 (Sept.4)	Average[1]
Netum	1457	1055	1740	1162	1326	1348
K2	1822	1485	1895	1253	1614	1614
M1	—	—	1830	1422	1351	1534
M3	1811	1828	1957	1404	—	1750
Johnson	1197	1305	2072	1359	1490	1485
Test average	1572	1418	1899	1320	1445	—

[1] The average yields are probably not significantly different when variability of the testing procedures is considered. In a growing season when the later varieties can mature, Netum is likely to be significantly lower in yield. When growing season is cut short by frost or harvest losses due to storms, Netum is very likely to be the best yielding variety.

Table 4. Comparison of mean flowering date, harvest date and yield of preliminary yield trial strains with advanced yield trial at Grand Rapids.

Test	Mean of the tests		
	Flowering date	Harvest date	Yield[1]
Advanced yield trial	July 22	Sept. 2	1899
Preliminary yield trial (Exp. 3 selections)	July 11	Aug. 21	2083
Preliminary yield trial (Excelsior selections)	July 13	Aug. 19	1912
Netum	July 17	Aug. 25	1740

[1]Yield in pounds per acre at 40% moisture.

WILD RICE HARVEST STUDIES

Cletus Schertz and James Boedicker

The harvest studies were concentrated in two areas, those of: 1) developing a combine discharge sample collector with an objective being to incur minimum interference to the combining operation from which the sample is being collected, and 2) developing a combine discharge sample processing system with an objective being to accomplish the sample processing within a few hours after the time of collecting a sample. This year's objectives were directed to the development of the collection and processing equipment and did not stress the collection and processing of a significant number of discharge samples.

Combine Discharge Sample Collector

A combine discharge sample collector was developed utilizing the concept of collector bags (diapers) being inserted beneath the combine discharge for a prescribed distance. For each sampling two bags were used, one for the sieve discharge material and one for the walker discharge material. The collector bags were supported on a frame which was carried on the rear of an all-terrain vehicle (ATV). This combine discharge sample collector is shown in Figure 1. During the sampling procedure the ATV was towed by a rigid hitch to the combine with the rigid hitch hinged freely at its two ends. When not hitched to a combine, the collector frame was supported by a chain to the ATV. When hitched to the combine the power of the ATV was used only to overcome the pushing of the soil in front of the tracks and to maintain proper alignment of the collecting bags beneath the combine discharge. Insertion and retraction of the collection bags was accomplished manually by a rope control.

Figure 1. Combine discharge sample collector. During the actual time of sampling, the collector bags (diapers) are open to collect the discharge material.

After collection of the samples into the collector bags, the hitch was disconnected from the combine and the collector frame was supported on the ATV for carrying of the samples to the edge of the field.

Experimental sampling with this combine discharge sample collector made use of thirty feet of field travel. In some runs the walker discharge from this distance filled the collector bag to overflowing. The actuation and retraction of the collector bags was difficult if the one pulling the manual rope control was not strong enough. This made for errors in start and stop positions. The ATV had no difficulty supporting the loaded collector bags. In some situations the straw became wrapped around the wheels between the tires and the track. This wrapping of straw on the wheels is a severe problem.

Combine Discharge Sample Processing

The desire to process the samples in a relatively short period of time necessitated taking the processing equipment to the field. Before processing the combine discharge samples by mechanical means, they were hand sorted to remove the wild rice heads that had kernels attached. These kernels attached to the heads were classified as threshing loss.

If the heads are not removed, that grain on the heads would show up inappropriately in the discharge loss sample. This field processing of the combine discharge samples was attempted by feeding the discharge samples directly to the cylinder of a parked combine equipped with a catch tray beneath the concave grate, transition grate and straw walkers. (The combine used this past season was the one used in previous years to study the separation characteristics within the combine.) The intent this year was to feed the samples to the combine without drying of the samples. The material passing to the catch-tray was subsequently processed in a Carter-Day dockage tester and a Carter-Day aspirator. The material passing over the straw walkers was retained for subsequent drying and meticulous separation of the missed grain from the straw.

Table 1 shows some of the results from processing with the in-field processing equipment (parked combine, dockage tester and aspirator) with the green weight shown. Table 2 shows the results from subsequent processing of the samples of grain discharge losses to the condition of being dehulled, dried and weight calculated as equivalent to that at 7% Mwb.

The parked combine for processing the samples separated 82 to 99 percent of the grain in the samples (Table 2). However, excessive chaff and straw pieces were also present. These straw pieces were carried through in excessive amounts in some of the fractions coming from the aspirator. This wide range in percent separated with the combine is partially explained from the variations in treatment of the samples. Two of the samples were allowed to open-air dry over a weekend. They had the highest percent separation. Two of the samples were given less than optimum treatment in an attempt to reduce the extent of chaff and straw pieces in the grain sample. These two had the lowest percentage separation.

The aspirator was effective in separating the grain of the sample. The samples were reasonably free of straw pieces. The dockage tester was only partially effective in the separation of the grain.

TABLE 1. Discharge losses as determined in the field without dehulling. Total green weight of grain collected in 1st, 2nd and 3rd aspiration outlets. lb/ac.

Run No.	Straw Walker	Sieve	Total
79101*	9.6	17.6	27.2
79102*	22.5	20.7	43.2
79201**	16.4	38.7	55.1
79202**	30.6	63.2	93.8
79301***			
79302	8.7	20.0	28.7
79401***			
79402	14.1	33.1	47.2

* Areas of 79101 and 79102 were on opposite ends of the same field.

** Areas 79201 and 79202 were next to each other in adjacent rounds of the combine.

*** Samples from run nos. 79301 and 79401 are being held in cold storage for off-season experimental processing.

TABLE 2. Summary of combine discharge losses.

	Losses, dehulled grain, lb @ 7% Mwb/ac				Percent Separated in parked combine	
		Discharge Losses			Sample from	
Run No.	Threshing Loss	Straw Walker	Sieve	Total	Straw Walker	Sieve
79101*		5.3	9.2	14.5	99.3	99.4
79102*		15.0	14.3	29.3	98.4	98.5
79201**		8.3	16.0	24.3	96.2	97.8
79202**		15.3	25.9	41.2	94.7	96.5
79301***						
79302		3.3	6.9	10.1	83.2	93.4
79401***						
79402		6.8	14.3	21.1	82.0	94.4

* Areas of 79101 and 79102 were on opposite ends of the same field.

** Areas 79201 and 79202 were next to each other in adjacent rounds of the combine.

*** Samples from run nos. 79301 and 79401 are being held in cold storage for off-season experimental processing.

PROCESSING RESEARCH - 1979

John Strait, Stephen Schenk, J.J. Boedicker

Wild rice processing research during the 1979 season was mainly concerned with studying the influence of variables related to parching upon the quality and processing characteristics of the parched rice. The primary purpose of this research was to establish design and operating parameters upon which to base the development of an improved parching system. Research for an M.S. thesis was completed on the separation of unhulled kernels from finished wild rice by electrostatic means. Two laboratory-scale parchers using heated air have been designed and the construction of one has been completed.

Delayed Hulling

A series of experiments were conducted in which wild rice hulled immediately upon removal from the parcher was compared with rice which was allowed to cool to varying degrees before it was hulled. Preliminary trials last year indicated that allowing the rice to cool before hulling would influence development of stress cracks, the occurrence of broken kernels and kernel strength. In one experiment, six lots of wild rice parched in the laboratory rotary drum parcher to a grain temperature of 285° F. Voltage to the heaters was varied so that the time required for parching varied from 50 to 240 minutes. The rice was divided upon removal from the parcher into two lots. One lot was hulled immediately while the other was allowed to stand in upon containers for about 24 hours before hulling. The results are shown in Table 1.

Table 1. Influence of drying time and hulling hot or cold on wild rice parched in laboratory rotary drum parcher with open front to a grain temperature of 285° F.

Test Run	Hulling Temperature	Parching Time, Minutes	Moisture Content, % W.B.	Unhulled Rice, %	Broken Kernels, %	Sound Whole Kernels %	Kernel Strength
H-1	Hot	50	7.2	6.6	3.7	9.3	2.9
	Cold	50	6.3	5.6	18.1	19.5	6.7
H-2	Hot	85	7.0	4.3	18.1	9.3	3.5
	Cold	85	5.8	5.2	37.8	16.1	7.5
H-3	Hot	120	5.0	3.1	4.3	31.9	5.4
	Cold	120	4.9	4.3	10.4	15.3	6.8
H-4	Hot	162	4.0	1.9	6.9	44.1	7.1
	Cold	162	4.7	3.3	16.9	39.2	7.3
H-6	Hot	285	2.9	2.3	6.5	65.1	3.9
	Cold	285	3.7	2.1	9.7	63.8	4.2
H-5	Hot	356	1.9	1.4	9.2	66.4	13.1
	Cold	356	2.3	1.9	10.5	58.9	14.7

The most noticeable difference between the two treatments was the increased quantity of broken kernels in the lots hulled cold. The percentage of sound whole kernels--meaning whole kernels free of stress cracks--was generally equal or greater in the cold-hulled samples as was overall kernel strength. We found more large diameter kernels free of stress cracks in the cold-hulled lots. We thought that perhaps this was due to the greater rate of temperature change experienced by the kernels hulled hot so a second experiment was run.

In the second experiment a batch of wild rice parched in the laboratory parcher was divided into five samples and four were placed in separate insulated containers to be hulled later, while the fifth sample was hulled immediately. Table 2 shows the results of this experiment.

Table 2. Effect of cooling time in insulated containers upon the quality and processing characteristics of wild rice parched to 285° F grain temperature in the laboratory rotary drum parcher.

Test Run	Moisture Content, % W.B.	Nominal Cooling Time, Min.	Grain Temperature at Hulling, °F	Unhulled Rice, %	Broken Kernels, %	Sound Whole Kernels %	Kernel Strength
I-0	5.1	0	240	2.0	3.3	19.3	6.9
I-30	5.5	30	147	3.7	4.7	26.1	6.8
I-60	5.2	60	129	2.6	6.6	20.4	7.6
I-120	5.3	120	97	3.2	7.9	19.9	8.8
I-240	5.2	240	81	3.1	9.1	24.3	12.0

Samples were hulled after 30, 60, 120, and 240 minutes of nominal cooling time as indicated. Also shown is the temperature of the rice when hulled. Hulling efficiency and the percentage of sound whole kernels was about the same for all treatments. The percentage of broken kernels increased with increased cooling time as did kernel strength. From these two experiments and related observations, it appears best to hull the rice immediately after parching since such a procedure results in a minimum of broken kernels.

Stress Cracks

It seems reasonable that stress cracks formed in wild rice kernels due to both temperature and moisture gradients would predispose the kernels with stress cracks to breakage during hulling and subsequent processing. In fact, microscopic examination of broken kernels showed that in most of the kernel fragments, stress cracks were present. It is, therefore, believed that the kernel originally broke at a stress crack. Stress cracks almost always form perpendicular to the longitudinal axis of the kernel and occur at random along its length. Reduction of stress cracks seems important in the development of an improved parching system.

Slow Drying

Experiments were conducted in which wild rice was dried in a shallow layer in room air and also by moving room air through a thin layer of grain with a fan. Stress cracks were substantially eliminated when the rice was dried in still air and were infrequent when the rice was dried in moving air from an ordinary office fan. Of course, under these drying conditions gelatinization of the starch would not occur. Also, the less mature kernels retained their green color.

An experiment was run where wild rice was placed in a large round aluminum pan to a depth of about two inches, covered tightly with heavy aluminum foil and placed in the laboratory oven set at 275° F. Drying was completed after about 20 hours after which the rice was hulled and examined. Breakage upon hulling was about 4%, but none of the whole kernels examined had stress cracks present. The color of the rice was brown in all sizes and kernel strength was high. Gelatinization of the starch would be expected to have been nearly complete. These tests showed that the quality factors desirable in a parching system can be achieved even though drying in this manner would be commercially impractical.

Closed Parcher Experiments

The rotary drum laboratory parcher was fitted with a cover to close the front opening in an effort to improve its performance in light of results obtained with the covered pan. Experiments were conducted to study the influence of several operating variables upon the characteristics of the finished rice and to compare results obtained with prior open front operation of the parcher.

Parching time

A series of runs were made with unseparated wild rice parched to a final grain temperature of 285° F. The voltage to the heating coils was varied to give parching times varying from 75 to 240 minutes. The rice was hulled immediately upon removal from the parcher. The results are shown in Table 3. The percentage of broken kernels was uniformly low for all runs. The percentage of sound whole kernels and kernel strength generally increased with increased parching time. A comparison of the results of these tests with similar ones with open front operation and for equal parching times shows improved results with closed front operation with respect to breakage, kernel strength and percentages of whole kernels free of stress cracks. Hulling efficiency, however, was lower than for open front operation.

Final grain temperature

Four experimental runs were completed where the wild rice was removed from the parcher when the grain temperature reached 285, 280, 275, and 270° F. As shown in Table 4, hulling efficiency for the remaining three runs were lower than when rice was parched to 285° F. The percentages of broken kernels were low for all runs. The percentage of sound whole kernels tended to increase and kernel strength tended to decrease as the final grain temperature decreased.

Table 3. Influence of parching time on unseparated wild rice parched in laboratory rotary drum parcher with closed front to a grain temperature of 285° F. Rice was hulled immediately upon removal from parcher.

Test Run	Parching Time, Min.	Moisture Content, % W.B.	Unhulled Rice %	Broken Kernels, %	Sound Whole Kernels, %	Kernel Strength
K-1	75	6.5	6.5	2.6	46.9	10.8
K-4	105	6.1	9.1	2.0	64.5	12.9
K-12	105		4.8	2.6	62.2	10.9
K-11	115	4.9	11.2	3.0	73.1	14.6
K-6	150	6.2	11.2	2.7	61.5	14.9
K-13	185	7.6	11.4	2.5	88.6	18.7
K-5	210	5.2	9.7	2.8	58.8	19.1
K-7	240	4.9	12.4	4.1	75.6	17.9

Table 4. Influence of final grain temperature upon unseparated wild rice parched in the laboratory rotary drum parcher with closed front. Rice was hulled immediately upon removal from the parcher.

Test Run	Final Grain Temp, °F	Parching Time, Minutes	Moisture Content % W.B.	Unhulled Rice %	Broken Kernels, %	Sound Whole Kernels,%	Kernel Strength
K-6	285	150	6.2	11.2	2.7	61.5	14.9
K-8	280	142	5.7	14.0	2.4	68.5	11.3
K-9	275	145	5.9	14.1	2.6	74.8	10.0
K-10	270	136	6.8	14.1	2.4	70.9	11.0

Parching in stages

A series of five test runs was completed where the wild rice was removed from the parcher at temperatures lower than 285° F, allowed to stand in buckets for 24 hours, and then returned to the parcher to complete parching to a grain temperature of 285° F. Both stages were done with the front of the parcher closed. The results are shown in Table 5. Only hulling efficiency was improved by parching in two stages. Excellent hulling efficiencies were obtained as compared to a single-stage process. Kernel breakage was very high for the L-2 run where the first stage temperature was 275° F and decreased as the first stage temperature decreased with L-5 approaching but not as good as the single-stage run. The percentage of sound whole kernels followed about the same pattern with respect to the single stage run as described for breakage.

Table 5. Characteristics of finished wild rice parched in two stages to 285° F grain temperature in the laboratory parcher with front opening closed. Approximately 24 hours between stages.

Test No.	Grain Temperature 1st Stage, °F	Moisture Content, %W.B. First Stage	Moisture Content, %W.B. Second Stage	Unhulled Rice %	Broken Kernels,	Sound Whole Kernels, %	Kernel Strength
L-1*	285	5.7	5.7	10.7	2.8	63.9	11.8
L-2	275	6.5	3.7	2.8	16.1	33.4	9.3
L-3	265	6.9	4.4	1.9	12.6	42.8	10.6
L-4	255	8.5	4.9	2.6	8.2	59.6	12.3
L-5	245	11.7	4.8	3.3	4.4	52.4	14.2

*Control, parched in one stage to 285° F.

Early removal of front cover

Tests were conducted to study the influence of removing the parcher cover before parching was completed. Table 6 shows the results of these tests. Excellent hulling efficiencies were obtained where the cover was removed at grain temperatures lower than 285° F. The percentage of broken kernels was highest for the run where the cover was removed at 270° F grain temperature and decreased as the temperature at which the cover was removed increased. The percentage of sound whole kernels was highest where the parcher remained closed.

Table 6. Influence on the characteristics of finished rice of removing the the parcher cover at a grain temperature below the final grain temperature of 285° F.

Run No.	Grain Temperature, °F Cover Removed at	Grain Temperature, °F Final Grain	Final Moisture Content, %	Unhulled Rice, %	Broken Rice, %	Sound Whole Kernels, %
M-2	270	285	4.4	2.4	6.2	50.6
M-3	275	285	5.0	2.9	4.9	42.2
M-4	280	285	4.9	1.8	3.4	44.7
M-1	285	285	5.8	5.5	2.7	67.0

Elevated final grain temperature

Table 7 shows the results of three test runs made to determine if parching to grain temperatures above 285° F would be advantageous in a closed parcher. Reasonably good hulling efficiencies were obtained while performance measured in terms of broken kernels may have deteriorated somewhat.

Table 7. Influence of final grain temperature upon the characteristics of finished rice parched in laboratory rotary drum parcher with closed front.

Run No.	Final Grain Temp. °F	Final M.C. % W.B.	Unhulled Rice, %	Broken Kernels %	Sound Whole Kernels,%
N-1	290	7.18	4.3	8.8	51.3
N-2	295	6.82	4.7	3.5	62.3
N-3	300	6.41	5.1	6.7	67.0

Summary

To summarize the results of experiments with the rotary drum parcher and related studies, the following conclusions are presented:

1. It appears to be advantageous to hull wild rice as soon as possible after removal from the parcher.

2. Stress cracks can be eliminated by very slow drying procedures.

3. Except for hulling efficiency, operation of the rotary drum parcher in the laboratory with the front opening closed produced clearly better results than operation with the front open.

   a. The percentage of broken kernels was much lower.

   b. The percentage of sound whole kernels was increased.

   c. Good performance can be achieved with moderately fast parching rates.

   d. Two-step parching gives good hulling efficiency but more broken kernels.

   e. Removing the cover shortly before parching is completed gives good hulling efficiency but breakage may increase somewhat.

Parching With Heated Air

A laboratory-scale parcher has been constructed which uses heated air to parch the wild rice. The parcher is equipped with a rotating drum, covered with 12x12 mesh woven wire, which rotates at about 20 revolutions per minute. A supply duct with electric heating elements receives air from a fan for passage over the drum. A return duct from the drum chamber to the fan inlet provides for continuous recirculation of the air. A damper in the return duct can be used to adjust the rate of air flow. A thermostat in the heater circuit regulates the temperature of the air to a preset value. The parcher drum can be charged with up to five pounds of green wild rice.

Table 8 shows results obtained from five test runs made with the heated air parcher. Parching times were relatively short. Hulling efficiencies were excellent. The percentage of broken kernels for all runs was slightly higher than in test runs with the surface heated rotary drum parcher when the front was closed. Steaming the wild rice for a period of 20 minutes prior to parching resulted in a considerable reduction in the percentage of kernels with stress cracks.

Table 8. Characteristics of wild rice parched in the hot air laboratory-scale parcher.

Run No.	Parching Time Min.	Air Temperature, °F	Moisture Content % W.B.	Whole Kernels, %	Broken Kernels, %	Unhulled Rice, %	Sound Whole Kernels, %
X 6(1)(2)	50	275	--	92.7	5.1	2.3	48.2
X 9(1)(3)	41	275	6.0	94.9	3.1	2.0	44.4
X 13(4)	43	275	7.3	94.0	4.3	1.7	18.3
X 14(3)	38	295	6.1	94.9	3.9	1.1	23.8
X 10(3)	46	275	5.8	94.2	4.2	1.6	15.8

(1) Sample was steamed 20 minutes before parching.

(2) 1976 unseparated rice = 36%.

(3) 1979 unseparated rice, m.c. = 43%.

(4) .45 lb. water added to 3.8 lb. rice before parching m.c. = 48.8%.

The overall performance of the hot air parcher without preparching treatment of the rice appears to be approximately equal to that of the rotary drum parcher with open front. Where the rice was steamed prior to parching, its overall performance appears to be generally better than the rotary drum parcher with open front but not as good as the rotary drum parcher operated with its front closed.

There is some evidence from the tests conducted to date that increasing the air temperature may be advantageous in reducing breakage and stress cracks. A series of tests will be conducted with steam being introduced into the return air duct. Increasing the moisture content of the air in the parcher could possibly give results equal to or approaching those obtained with the closed front rotating drum parcher or eliminate the need for a separate steaming operation.

Continuous Flow Parcher

A laboratory-scale parcher is under construction which will employ a recirculating hot air system along with wire mesh conveyor belts to move the rice through the parcher. A parcher of this type would allow a continuous flow of wild rice into and out of the parcher.

Separation of Unhulled Kernels

Stephen Schenk is completing an M.S. thesis on the spearation of unhulled kernels from finished wild rice by electrostatic means. The results of his research indicate that separation by electrostatic means is well below a level of precision suitable for commercial use.