Minnesota Wild Rice Research 1983

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CONTENTS

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

The wild rice team wishes to acknowledge the assistance provided by many people. The cooperation of Dr. Rust, Superintendent of the North Central Experiment Station, Grand Rapids, and Dr. Wilcox, Superintendent of the Rosemount Experiment Station, was greatly appreciated. The use of facilities at the Horticultural Research Center at Excelsior was appreciated. 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 and laborers at Grand Rapids by Henry Schumer, Research Plot Coordinator was very valuable. We are also extremely grateful to the growers and processors for providing seed, land area and facilities for research. We appreciate the continued support of the Agricultural Experiment Station for wild rice research.

RESEARCH IN SOIL FERTILITY AND CHEMISTRY OF SOIL AND WATER - 1983

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Research during 1983 focused on nitrogen loss mechanisms in paddy soil and water, factors associated with crop failure, and possible causes for growth differences observed along the ditches. The research was conducted on University land in Grand Rapids and in growers' fields near Aitkin and Gully. A growth chamber and 4 x 4 ft. boxes at St. Paul were also utilized for some of the work.

A. WEATHER CONDITIONS

Average air temperatures recorded at four U. S. weather stations were below normal during April and May, followed by nearly normal June, and above normal during July and August (Table 1).

Several growers in the Aitkin area had commented that the wild rice yield in some paddies fell below expectations. General browning and early dying of plants was observed, apparently not caused by disease. The possible cause was the high air temperature between flowering and maturity which resulted in moisture stress. Weather data recorded at the Pine River Dam U. S. Weather Station (northwest of Aitkin) showed 12 days during July and 8 days during August with the maximum air temperature of 90° F or above. In contrast, during 1982, such high temperatures were recorded only on 4 days in July and on 2 days in August.

Soil, water and air temperatures were measured at Grand Rapids within the experimental paddy No. 1 East, and on the St. Paul Campus within an area where experiments in 4 x 4 ft. boxes were conducted (Fig. 1 and 2).

B. YIELD VARIABILITY ON A MINERAL SOIL

A stand of Netum wild rice was established in paddy No. 1 East at the North Central Experiment Station, Grand Rapids. The soil is classified as an Indus clay loam (very fine, montmorillonitic, frigid Typic Ochraqualf). Soil tests (Table 2) indicated a very high level of Bray-1 extractable phosphorus (85 lb/A) and a medium level of exchangeable potassium (202 lb/A).

Wild rice seed was broadcast by hand on May 5 at a rate of 45 lb/A. Individual plots occupied a 14 x 16 ft. area and were separated from adjoining plots by 5 ft. wide alleys. Since the objective was to establish a stand for future studies, no fertilizer treatments were made. Water level was maintained at 8 to 12 inches. A 16 sq. ft. area from each plot was hand-harvested on August 22nd.

Netum grain yield (7% moisture) of individual plots ranged from 512 to 1027 pounds per acre. The overall mean yield was 778 lb/A with a standard deviation of 158, and a coefficient of variability of 20%. These data illustrate the variability of grain yield frequently observed in first year wild rice stands.

C. DIURNAL CHANGES IN THE pH OF PADDY FLOODWATER

Nitrification-denitrification was traditionally thought to be the major mechanism of nitrogen loss from flooded soils. Recently researchers with white rice have suggested that ammonia volatilization may be more important, especially in soils such as peat in which ammonium ions are not held strongly by the soil cation-exchange complex. High floodwater pH and high NH_4-N concentration in the floodwater result in high nitrogen losses. Urea hydrolysis and algal CO_2 consumption are known to raise the pH of paddy water above 9 under the afternoon sun.

Floodwater samples were collected from six wild rice paddies during June and July. The water samples were collected in 250 ml polyethylene bottles by submerging the bottle 2.5 cm below the surface. The pH was determined immediately after sample collection using a combination electrode and portable pH meter. Duplicate water samples were collected and stored in 250 polyethylene bottles, with a preservative added. Chemical analyses were made by the Research Analytical Laboratory. Chemical composition of the water is given in Table 3.

Floodwater pH showed considerable variation during a 24-hour period. The strongest alkalinity (high pH) and greatest variation of the floodwater pH were observed in paddies having shallow water depth

(15 cm) (see Fig. 3 and 4). The floodwater pH at Gully, Polk County, during afternoon hours on a sunny day was above 9.0, reached a maximum of 9.5 (water temperature 29°C) and then steadily declined to a minimum of 7.9, measured at 7:00 a.m. (water temp. 17°C). This paddy had considerable growth of waterplantain, other weeds and some algae. In the paddies with relatively deep water (35 cm), the floodwater pH showed similar but less pronounced variation than that observed in shallow water, and the maximum pH values did not exceed 8.5. The wild rice was in the tillering stage.

At Grand Rapids on a mineral soil, at 15 cm water depth, the maximum floodwater pH of 9.6 was recorded at 2:30 p.m. (water temp. 28°C), declined to 7.0 at 7:00 a.m. (water temp. 23°C) and by noon reached 9.0 (water temp. 29°C). Various rooted water plants and some algae were observed at this sampling site. In 35 cm deep water, the floodwater pH showed less pronounced diurnal change.

In a Kosbau Bros. paddy, Aitkin County, floodwater samples were collected from an area with relatively deep water level (45 cm). No weeds or algae were present. The floodwater pH on this acidic peat remained constant near 6.5 during a 24-hour period. The water temperature fluctuated from a maximum of 27° to 23° C.

Theoretically, 12.5% of ammonium (NH_4) present in the water at pH 8.4 is in the ammonia (NH_3) form, which can volatilize. At higher pH values a larger fraction of the ammonium nitrogen is in the NH_3 form while at low pH less is in the volatile form. Ammonia volatilization should not occur in paddies similar to that investigated in Aitkin County where the floodwater was slightly acid. Nitrogen losses through NH_3 volatilization may be significant, however, at shallow water depth particularly in paddies of the Clearwater River area because of extremely high floodwater pH. Maintenance of proper depth of water in the paddy until the plant canopy closes appears to be important to minimize possible nitrogen losses through NH_3 volatilization.

D. STUDIES IN 4 x 4 FT. BOXES

A nitrogen source and placement experiment was conducted in 4 x 4 ft. wooden boxes on the St. Paul Campus. A 30 cm thick layer of hemic peat was placed into the boxes. Dolomitic aglime was added to the peat to increase its pH from 4.1 to 6.0 and the corresponding base saturation from 15 to 50 percent. Seven fertilizer treatments were replicated four times. Nitrogen fertilizers were applied at a 90 kg/ha (80 lb/A) rate; all boxes received 67 kg/ha of P_2O_5 and 135 kg/ha of K_2O. Nitrogen fertilizer was either deep placed at a 10 cm depth or applied on the soil surface. Phosphorus, potassium and deep placed nitrogen were applied pre-plant; surface nitrogen was applied after seeding. Seed of K2 wild rice variety was placed in rows on May 27. Two extra boxes (51 and 52) without plants were set up, No. 51 with deep placed urea and No. 52 as Control. Boxes were filled with 15 cm of water. On June 1 gas development in several boxes caused foaming and scum accumulation on the surface of water. By June 6 all boxes had gone through the first cycle of foaming and had developed a floating peat condition. The gas was mainly CO_2 with traces of CH_4. A small amount of "Triton" wetting agent was sprayed on the surface to break up the scum (and later the algae) so that it could be skimmed off. Wild rice developed slowly and very few plants survived. So, the experiment was used mainly for monitoring inorganic nitrogen, pH and temperature of the water and soil.

Samples of the floodwater were collected in 250 ml polyethylene bottles 2.5 cm below the surface. Diurnal sampling was conducted to measure the changes in pH and inorganic nitrogen from day to night so as to determine the potential for ammonia volatilization.

Soilwater was collected in ceramic cups placed in selected boxes at depths of 5 cm and 30 cm below the soil surface, i.e., shallow and deep, respectively. The cups and the connecting 91 cm long (6.25 cm diameter) plastic tubes were purged of air with three volumes of argon and sealed to prevent oxygen from entering the anaerobic peat. Samples were extracted by means of a small hand-held vacuum pump. The pH was determined immediately and samples for N analyses were treated with 1 ml of 20% H_2SO_4/100 ml and refrigerated at 4° C. Nitrogen was analyzed by distillation. On August 4 ceramic cups were removed from boxes No. 24 and 44 because of extremely poor rice stand and placed in boxes No. 33, 42 and 43.

The temperature and dissolved oxygen (DO) profiles of floodwater were established in two boxes (No. 24 GU, surface; 44 GU, 10 cm) to determine if stratification in 23-30 cm of water was possible. Both DO and temperature were measured with a YSI DO meter.

The pH values of the diurnal study of floodwater in selected boxes on 6/23 are reported in Table 4. Most of the boxes, except No. 35, showed significant changes in pH from daytime highs of 9-10 and nighttime lows of 5.5-6.5. There was a potential for NH_3 volatilization at these high pH values.

The pH may not have changed much in box No. 35 (GU, surface) because of a lack of a high algal (phytoplankton) population. The dominant algae in the boxes appeared to be Cyanophyta (blue-greens).

The concentrations of ammonium and nitrate in the floodwater on 6/23 from the diurnal study are given in Table 5. Lowest amounts of NH_4-N and NO_3-N were found in boxes receiving no nitrogen fertilizer (Control). It is difficult to determine which placement of urea contributed the greatest amount of N to the floodwater. Gas production within the peat caused a very significant disruption of the soil stability and convectively carried N into the floodwater. There appeared to be very little change in inorganic N from day to night. It is expected, however, that as the pH decreased from 9-10 to 5-7 most of the ammonia was changed to ammonium.

Only trace amounts of inorganic N in floodwater was found on 7/19. The algal growth was very heavy, suggesting that any ammonium or nitrate N would be quickly taken up by algae.

Before the collection of soilwater samples, the water in the ceramic cups was discarded and fresh soilwater was allowed to enter the cups. Liming had achieved the desired pH levels as indicated by soilwater pH (Table 6). The inorganic N levels of soilwater on 7/1/83 are shown in Table 7.

An attempt was made to determine if NH_4-N would be higher in box No. 52 (Control, no plants) compared to box No. 34 (Control, with plants). But the plant growth in all boxes was so poor that there appeared to be no reduction in the NH_4-N level due to an uptake by plants. The soilwater in Control boxes had about one-half of the NH_4-N as the fertilized boxes. The nitrate values of boxes No. 24 and 44, with cups placed 30 cm deep, indicate that argon may have escaped and oxygen was causing nitrification in the cups. It is unlikely that the nitrate came from the floodwater because it contained less than 2 ppm of NO_3-N on 6/23. Later on improvements were made to seal the argon in the cups and very little NO_3-N was detected in the soilwater on subsequent samplings. Ceramic cups were removed from boxes No. 24 and 35 and placed in boxes No. 33, 42 and 43.

The concentrations of NH_4-N in soilwater samples collected on 8/15 and 9/16 are reported in Tables 8 and 9. No NO_3-N was detected in the soilwater on these two dates. Soilwater pH ranged from 5.7 to 6.2 on 8/15.

Dissolved oxygen and temperature profiles were determined in boxes No. 24 and 44 on 6/30 at 9:00 a.m. (Fig. 5). There was a substantial profile development of DO indicating that the floodwater was not mixing from top to bottom. The graphs show that the water near the surface was highly enriched with oxygen and the DO level decreased with depth and approached zero near the surface of peat.

There was very little wind on 6/30. Open areas of paddies with very little plant growth would probably have thoroughly mixed floodwater. As plants develop and buffer the effects of wind energy, stratification could occur. The reason for the stratification is the temperature gradient from the top to the bottom of the floodwater. At 9:00 a.m. a 2°C temperature difference existed in the profile. As the day progressed the topmost layers of water probably became warmer, imparting an even stronger density stratification to inhibit mixing.

Discussion- Wild rice developed slowly and grew poorly in the boxes because of heavy algal growth which caused low light penetration into the floodwater. This could have inhibited vigorous growth by starving the plants of an energy source. Early planting that would permit the plants to develop before the algae would help this situation. The algae may also have given off toxins detrimental to wild rice. The blue-green algae (Mycrocystis) is notorious for toxin production that can badly blister the udders of cattle wading into farm ponds.

Mechanical disruption of the seedbed by CO_2 evolution prevented many plants from establishing a solid footing in the peat.

Generally, inorganic N concentration was higher in flood- and soilwater in boxes receiving nitrogen fertilizer compared to the Control. Nitrogen concentration in floodwater decreased with increased algal growth while nitrogen in the soilwater tended to increase due to mineralization. The analytical results may be somewhat suspect because of the disruption in the boxes by CO_2 evolution. But NH_4-N levels in Control boxes increased from about 5-10 ppm to 10-15 ppm with the fertilized boxes having 20-30 ppm. The attempt to observe a decrease in NH_4-N through plant uptake did not materialize because of poor plant growth.

E. EFFECTS OF THE ADDITIONS OF HIGH LEVELS OF STRAW AND SULFATE

The effect of straw, nitrogen and gypsum (calcium sulfate) on wild rice growth was investigated in one-gallon plastic containers in an environmental growth chamber. Each container was filled to a depth of 15 cm with either an acidic peat from the Kosbau Bros. paddies, Aitkin County, or a neutral peat from the Clearwater Rice, Inc., Clearwater County. The soil was amended with the above mentioned materials, flooded with 5-7.5 cm of demineralized water and planted with K2 variety of wild rice. The young plants ranged from 5 to 10 cm in length. Growth conditions were: 16 hrs. of light at 18-19°C, 8 hrs. of dark at 15-16°C, and a humidity of approximately 90-95%. Wild rice tops were harvested after 50 days, dry weight and chemical composition of plant tissue were determined.

Results of the growth chamber experiment are reported in Table 10. The plants in containers No. 2, 6 and 8 did not grow well and developed no panicles. The plants in containers No. 1, 4, 7 and 9 grew relatively well and developed panicles. Percentage of N in the plant ranged from 1.19 to 1.52% and varied very little while the dry weight of tops varied from zero to 3.73 g per container.

Measurements of the redox potential, Eh, of the soil were in the negative range indicating strongly reduced conditions.

The two containers with Kosbau peat (No. 1 and 2) had drastically different plant growth after 50 days. Containers No. 3 and 9 with the Clearwater peat and various amendments had quite different levels of plant production. The combination of gypsum and 3X rate (24,900 kg/ha) of wheat straw killed all wild rice seedlings even with repeated replanting. The addition of ammonium to 3X rate of straw (container No. 4) increased plant weight nearly five times over 3X straw only (container No. 6), but it did not help the survival of plants in container No. 5 (3X straw + gypsum + N).

The application of a low rate of straw (8,300 kg/ha) produced about 5.5 times more dry matter than the 3X rate of straw. Gypsum alone had a detrimental effect on wild rice and reduced the yield even more than 1X rate of straw. The highest dry weight of wild rice was produced with the application of nitrogen (container No. 9), but the vegetative growth was stimulated by N to such extent that the plants had difficulty remaining upright.

The environmental growth chamber study with various treatments of straw, ammonium and gypsum was designed to establish extreme conditions in an organic soil and to observe wild rice growth under such conditions. Nutrient elements such as N, P, K, Ca, Zn did not seem to be the factors in the growth problems observed. This experiment may provide a clue to the problems observed in the nitrogen source and placement study, i.e., various interrelationships of phytotoxins originating either in the soil or in the root or both. This is an area that needs further investigation.

F. INVESTIGATIONS RELATING TO THE "DITCH EFFECT"

Growers and others have observed strips along ditches where the wild rice appears to be greener and taller (and presumably yield more grain) than the plants in the rest of the field. Thus, the term "ditch effect".

Manomin

On July 26, color differences were observed from a distance in several paddies of the Manomin Wild Rice Company, Aitkin County. On August 22, soil samples were collected and wild rice was hand-harvested from several 4 x 4 ft. areas. The yield and stand density of wild rice, percent of ash, pH and chemical composition of peat determined either by soil tests or ICP analysis of acid digest are given in Table 11.

Wild rice near ditches produced from 50 to 238 pounds of grain per acre more than harvested in the field. In two paddies the number of stems per 16 square feet was greater near the ditch compared to the field. The ash content of the organic soils (0-6 inch depth) near the ditch was 2 to 4 percent higher than the peat further in the paddy. Such a slightly higher ash content of the peat may reflect higher proportion of mineral matter apparently deposited near the ditches during the digging and dredging operations. The content of aluminum (Al) and iron (Fe) found in the soil from the two different areas show trends similar to those observed in ash content, and again, may indicate a peat with more mineral matter along the ditch than the organic soil in the main part of a paddy. The soil of both areas in the field had similar content of other macro- and micronutrients.

Diebold Farm

Similar striking differences in height of wild rice had been observed prior to harvest in several paddies of Diebold Farms, Aitkin County. Soil samples were collected from two paddies near the ditch and in the field. The main difference in soil characteristics (Table 12) is the higher ash content in samples collected along the ditches compared to the soil in the field. In paddy No. 11, the soil along the ditch actually is a mineral soil, containing 89% ash and a high content of exchangeable potassium, deposited there during the ditch cleaning operation the previous year. No yield data were obtained on the Diebold Farm.

No definite conclusions as to the cause of the so-called "ditch effect" can be drawn because of preliminary nature of these investigations. The growth differences in wild rice observed along the ditches and in the main field may be due to three factors: 1) More mineral matter in the peat along the ditches. Differences in the ash content observed in Aitkin County would support this. 2) Plant density differences. There was some evidence of greater number of stems along the ditches.
3) There may be some differences in water depth (not measured in this study) that may affect the growth and nutrition of the plant.

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

Station Year	Month April	May	June	July	August	5 Month Average	GDD T_b=40
	-------------	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
1980	48.9	61.3M[3]	68.5	71.0	64.6	62.9	3466
1981	44.4	55.3	60.8	68.1	65.7	58.8	2898
1982	37.0	55.1	55.5	66.8	63.0	55.5	2477
1983	37.7	50.5[4]	63.7[4]	69.0	68.5	57.9	2819
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
1980	46.1	59.9	64.0	69.0	66.4	61.1	3237
1981	43.9	54.8	62.0	68.0	67.0	59.1	2941
1982	38.6	57.7	58.5	68.0	64.4	57.6	2753
1983	39.0	49.7	62.5	71.1	70.1	58.5	2873
Aitkin							
1974	42.9	49.8	63.1	71.1	63.3	58.0	2770
1975	39.0M	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	50.6	62.0	68.1M	63.4	56.4	2585
1980	53.9	58.3	64.0	68.5	66.0	62.1	3394
1981	45.1M	53.8	62.1M	67.5	66.0	58.9	2902
1982	38.3	57.4	57.6	68.6	64.8	57.3	2723
1983	39.6M	49.3M	60.3M	72.1M	71.9M	58.6	2881
St. Paul, U of M							
1982	43.4	61.3	62.4	73.9	67.3	61.6	3332
1983	42.1	55.2	68.7	76.4	76.0	63.7	3640

1/ Source: Climatological Data, Minnesota, Vol. 80-89 (1974-83), U.S. Dept. of Commerce.
2/ Normals for the period 1931-1960.
3/ M = less than 10 days record missing.
4/ Northwest Divisional Data.

Table 2. Soil test values of experimental paddy No. 1 East, Grand Rapids.[1]

pH	Organic Matter %	Bray-1 P lb/A	Exchangeable K lb/A	Exchangeable Mg lb/A	S ppm	DTPA Extractable Zn ppm	DTPA Extractable Cu ppm	NO_3-N lb/A
5.6	3.4	85	202	446	8	5.6	0.8	30

1/ Samples collected from 0-6 inch depth on 5/5/83.

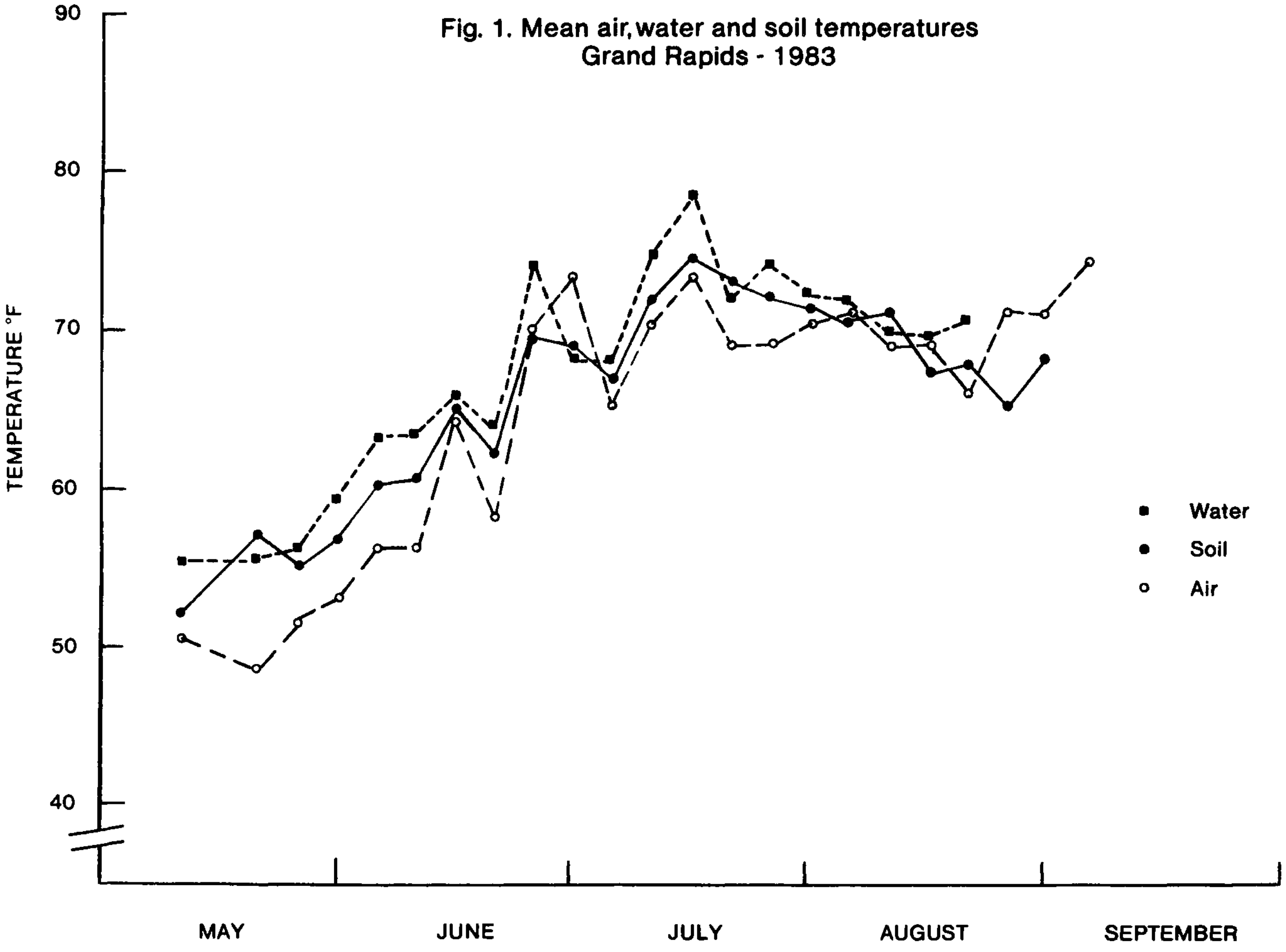

Fig. 1. Mean air, water and soil temperatures
Grand Rapids - 1983

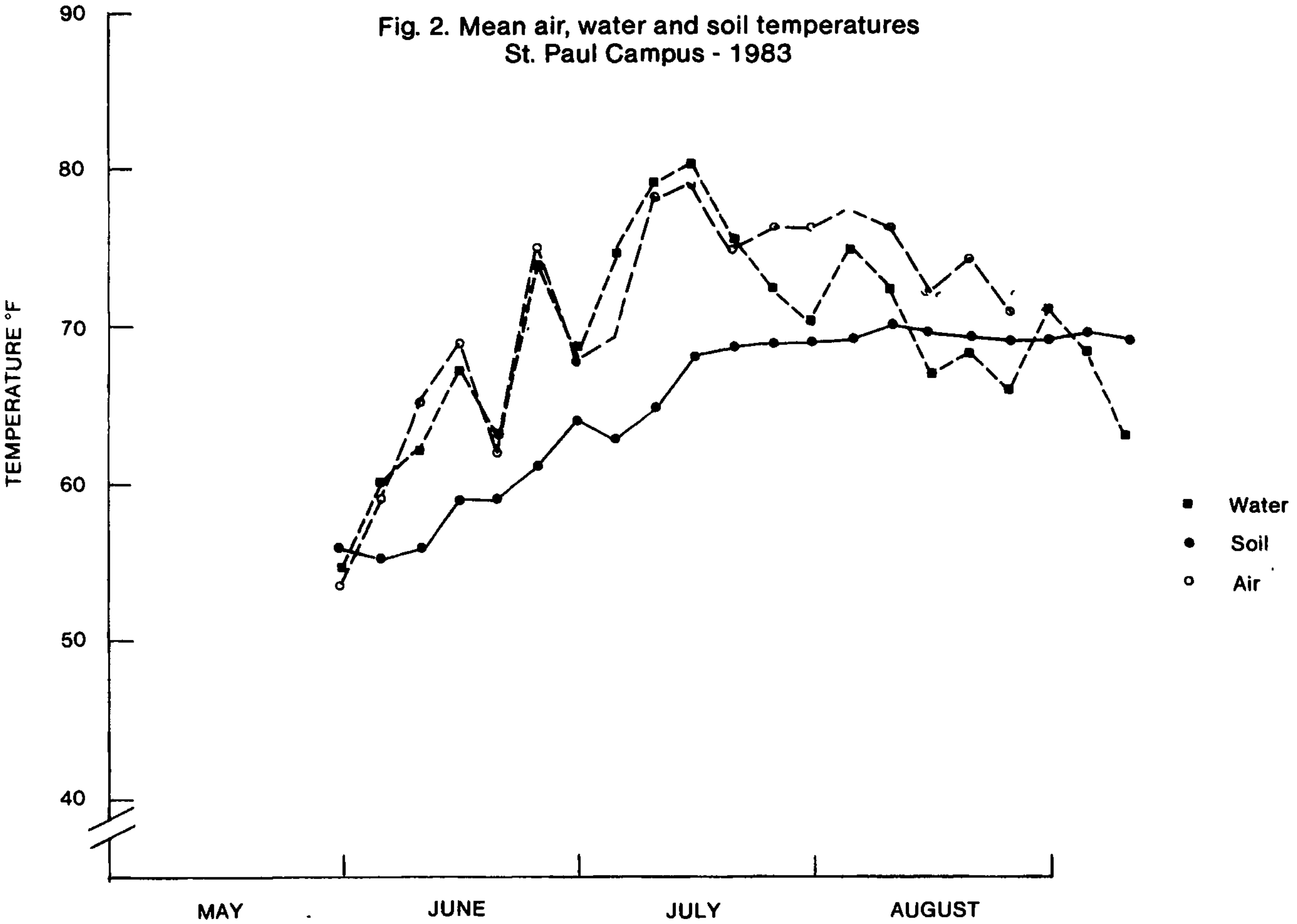

Fig. 2. Mean air, water and soil temperatures
St. Paul Campus - 1983

Table 3. Chemical composition of water collected from wild rice paddies - 1983.

Sample No.	Sampling Date	Location	pH	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Nitrate & Nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm	Na ppm
1	6/28	Gully-E, deep water	7.7	152	279	3.6	<0.05	0.30	0.20	28.5	71.8	23.9	9.3	7.7
6	6/28	Gully-W, shallow water	9.2	167	335	1.2	<0.05	0.40	0.34	45.6	84.5	29.7	2.1	8.8
12	6/28	Gully-W, deep water	8.5	ND[1/]	473	2.2	<0.05	0.52	0.49	ND	122.2	40.2	8.7	9.2
18	7/7	Aitkin, diversion ditch	ND	63	85	1.2	<0.05	0.09	0.02	1.6	22.1	6.7	0.6	2.7
19	7/7	Aitkin, pump	ND	61	85	1.2	<0.05	0.08	0.03	1.4	22.1	6.7	0.6	2.7
20	7/7	Aitkin, paddy	6.6	58	78	1.9	<0.05	1.20	1.09	1.4	18.7	7.2	1.8	4.0
24	7/20	Grand Rapids, paddy 1E, 30-35 cm depth	7.9	68	79	0.9	<0.05	0.08	0.04	1.0	21.2	5.8	1.3	2.8
25	7/20	Grand Rapids, paddy 9A, 15 cm	9.6	67	75	1.5	<0.05	0.11	0.05	0.7	18.7	6.1	2.5	3.4
26	7/20	Grand Rapids, Prairie River	ND	68	79	1.0	<0.05	0.08	0.02	0.9	21.4	5.7	0.9	2.5

[1/] ND = not determined.

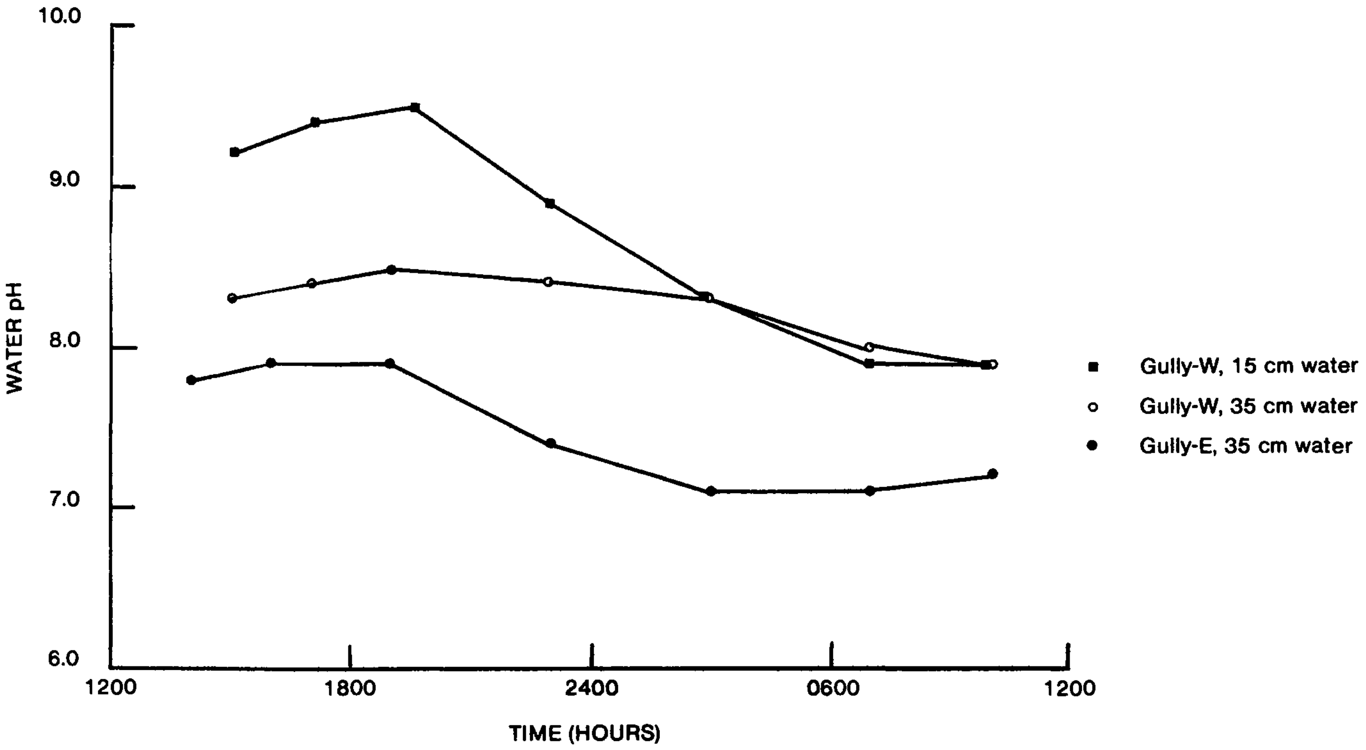

Fig. 3. Changes in the pH of paddy floodwater on peat.

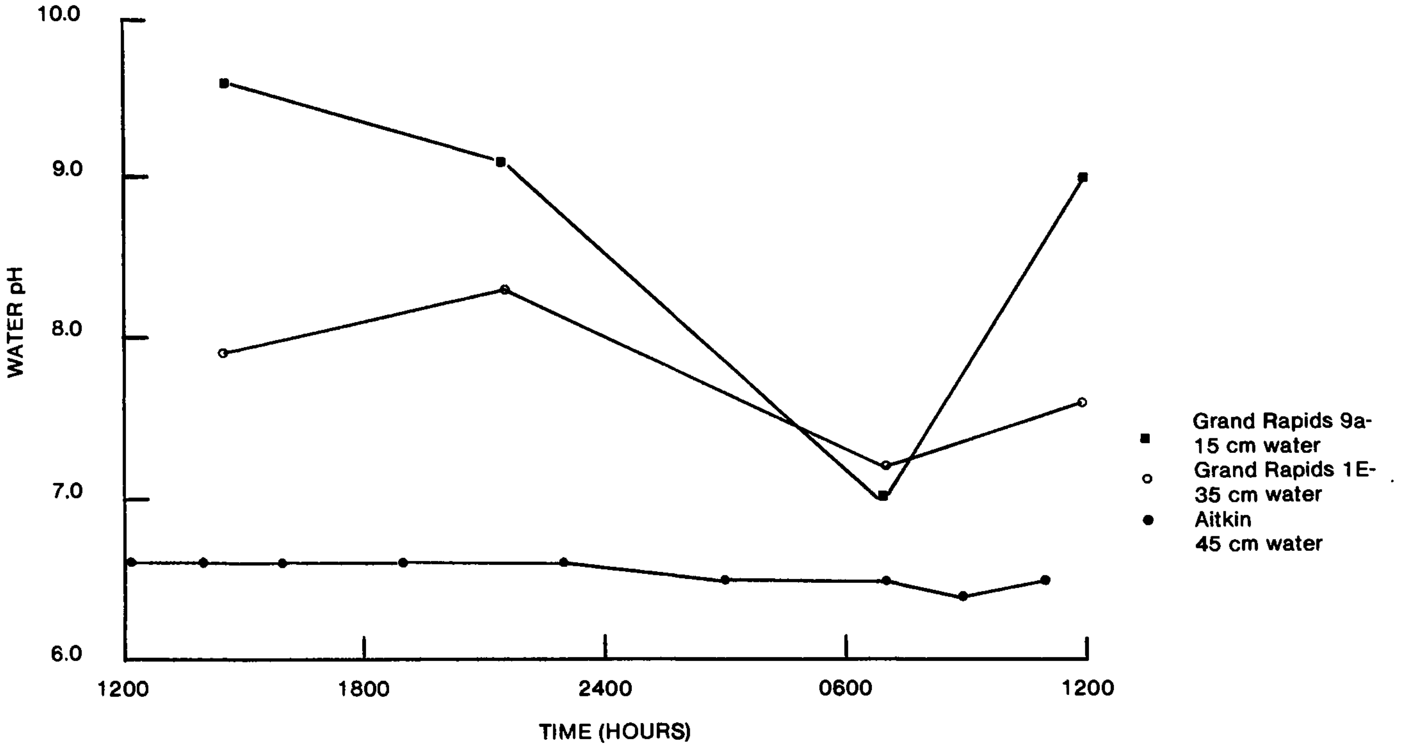

Fig. 4. Changes in the pH of paddy floodwater on mineral and organic soils.

Table 4. Diurnal changes in the pH and temperature of floodwater in 4 x 4 ft. boxes on 6/23-24/83.

Box No.	Fertilizer Treatment	Time (hours)							
		1200	1400	1600	1900	2300	0300	0700	1200
		Floodwater Temperature, °C							
		29.4	32.3	31.8	28.5	24.5	22.4	20.9	20.2
		Floodwater pH							
34	Control	9.6	9.8	10.1	9.7	6.4	5.4	5.6	5.8
42	Control	9.1	9.6	9.8	9.5	7.5	6.6	6.6	6.5
52	Control	10.0	9.8	9.9	9.3	6.4	6.9	6.4	6.3
24	GU, surf. applied	9.0	8.9	9.3	8.6	6.5	6.4	6.2	6.3
35	GU, surf. applied	6.4	6.5	6.6	6.8	6.4	6.1	6.2	6.1
36	GU, 10 cm depth	9.0	9.0	9.0	8.6	6.5	6.3	6.3	6.3
44	GU, 10 cm depth	8.0	8.1	8.1	7.3	6.2	6.0	6.1	5.8
51	GU, 10 cm depth	9.2	7.9	8.8	6.9	6.2	7.6	6.5	6.1

GU = Granular urea, commercial grade.

Table 5. Inorganic N of floodwater in 4 x 4 ft. boxes from diurnal study on 6/23-24/83.

Box No.	Fertilizer Treatment	Time (hours)			Time (hours)		
		1400	2300	0300	1400	2300	0300
		NH_4-N, ppm			NO_3-N, ppm		
34	Control	0.07	**	**	0.0	0.0	0.07
42	Control	0.0	0.28	0.21	0.0	0.0	0.0
52	Control	0.07	0.35	0.0	0.0	0.71	0.0
24	GU, surf. applied	3.12	2.69	2.62	1.28	0.92	0.99
35	GU, surf. applied	2.13	2.20	1.91	2.48	2.48	2.55
36	GU, 10 cm depth	1.13	1.20	1.13	1.42	1.13	1.13
44	GU, 10 cm depth	2.13	2.27	2.41	1.20	0.92	0.92
51	GU, 10 cm depth	1.13	1.84	1.84	0.43	0.35	0.07

** Values were about 3 ppm NH_4-N, but are omitted because the water became turbid from suspended matter.

Table 6. Soilwater pH at different depths in 4 x 4 ft. boxes on 7/1/83.

Box No.	Fertilizer Treatment	5 cm Deep			30 cm Deep		
		Ceramic Cup No.			Ceramic Cup No.		
		1	2	3	1	2	3
		Soilwater pH					
34	Control	5.8	6.0	5.9	ND	ND	ND
52	Control	5.9	6.3	6.2	6.0	5.8	ND
24	GU, surf. applied	7.2	6.3	6.1	6.4	5.9	ND
44	GU, 10 cm depth	5.6	5.9	5.9	5.9	5.4	ND
51	GU, 10 cm depth	6.2	6.6	5.7	6.2	5.8	ND

ND = not determined.

Table 7. Soilwater inorganic N at different depths in 4 x 4 ft. boxes on 7/1/83.

Box No.	Fertilizer Treatment	5 cm Deep			30 cm Deep		
		Ceramic Cup No.			Ceramic Cup No.		
		1	2	3	1	2	3
		Soilwater NH_4-N, ppm					
34	Control	8.71	8.3	7.6	-	-	-
52	Control	10.0	7.8	6.1	9.1	7.9	-
24	GU, surf. applied	21.1	16.9	24.3	16.1	14.5	-
44	GU, 10 cm depth	17.0	16.0	21.6	11.3	7.9	-
51	GU, 10 cm depth	22.4	15.2	16.2	12.6	13.4	-
		Soilwater NO_3-N, ppm					
34	Control	0.0	0.0	0.0	-	-	-
52	Control	0.0	0.0	0.0	0.0	0.0	-
24	GU, surf. applied	0.0	0.0	0.3	16.5	21.7	-
44	GU, 10 cm depth	0.0	0.0	-	7.3	0.0	-
51	GU, 10 cm depth	0.2	0.0	-	0.9	0.0	-

- = no ceramic cup available

Table 8. Soilwater inorganic N at different depths in 4 x 4 ft. boxes on 8/15/83.

Box No.	Fertilizer Treatment	5 cm Deep			30 cm Deep		
		Ceramic Cup No.			Ceramic Cup No.		
		1	2	3	1	2	3
		Soilwater NH_4-N, ppm					
34	Control	15.2	12.9	15.9	-	-	-
42	Control	16.2	15.7	-	17.2	-	-
52	Control	7.5	11.4	-	15.9	13.6	-
43	GU, surf. applied	25.6	25.7	-	27.3	-	-
51	GU, 10 cm depth	21.3	17.3	23.5	24.7	-	-
33	SCU, 10 cm depth	38.5	32.2	-	30.7	29.3	-

GU = Granular urea, commercial grade; SCU = Sulfur coated urea; - = no ceramic cup available.

Table 9. Soilwater NH_4-N at different depths in 4 x 4 ft. boxes on 9/16/83.

Box No.	Fertilizer Treatment	5 cm Deep			30 cm Deep		
		Ceramic Cup No.			Ceramic Cup No.		
		1	2	3	1	2	3
34	Control	13.1	5.6	15.4	-	-	-
42	Control	16.4	13.8	-	16.8	-	-
52	Control	10.9	22.8	16.0	6.0	-	-
43	GU, surf. applied	21.0	13.8	-	23.7	-	-
51	GU, 10 cm depth	17.0	15.4	23.4	17.0	15.4	23.4
33	SCU, 10 cm depth	36.8	29.4	-	29.2	30.5	-

GU = Granular urea, commercial grade; SCU = Sulfur coated urea; - = no ceramic cup available.

Table 10. Effect of straw, ammonium and gypsum application on growth of wild rice.

Container No.	Peat	Amendment	pH 6 cm in peat	Eh mv	Dry Wt. of Plant g	N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm	Al ppm	Na ppm
						Concentration in Plant Tops											
1	Kosbau	None	5.2	-105	2.5*	1.26	0.53	2.6	0.39	0.15	81	194	41	16	7	25	764
2	"	3S	5.9	-126	0.1	1.37	-	-	-	-	-	-	-	-	-	-	-
3	Clearwater	3S, G	6.9	-172	-	-	-	-	-	-	-	-	-	-	-	-	-
4	"	3S, N	6.7	-176	1.8*	1.19	0.35	3.1	0.37	0.10	29	238	25	8	3	4	452
5	"	3S, G,N	6.9	-137	-	-	-	-	-	-	-	-	-	-	-	-	-
6	"	3S	7.0	-192	0.4	1.43	0.42	3.2	0.53	0.10	39	245	26	7	4	12	739
7	"	1S	6.8	-214	2.1*	1.25	0.38	3.3	0.43	0.09	42	405	32	8	4	12	629
8	"	G	6.9	-178	0.9	1.52	0.42	2.0	0.11	0.23	65	374	47	16	15	5	972
9	"	N	7.0	-204	3.7*	1.44	0.31	1.1	0.35	0.17	26	118	22	10	6	6	3068

3S = 24,900 kg/ha wheat straw; 1S = 8,300 kg/ha; G = 10,000 kg/ha gypsum; N = ammonium chloride, 150 kg N/ha;
* = plants developed panicles

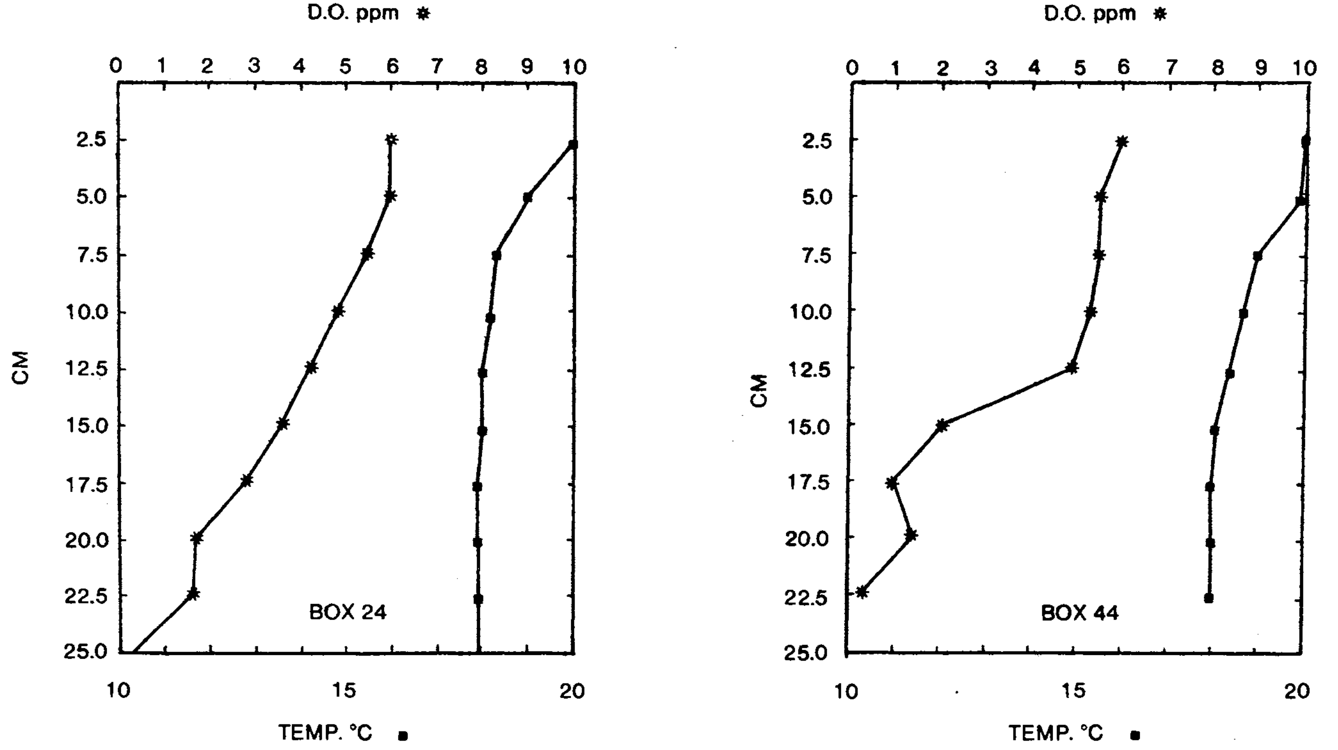

Fig. 5. Dissolved oxygen (DO) and temperature profiles of the floodwater in boxes No. 24 (GU, Surf) and 44 (GU, 10 cm.) on 6/30/83, 9:00 a.m.

Table 11. Yield and density of wild rice, and soil characteristics in different areas of paddies, Manomin Wild Rice Company, Aitkin County - 1983.

Paddy No.	Location	Sampling Depth inches	Grain Yield lb/A	Stems per 16 sq.ft.	Ash %	pH	Extractable P lb/A	Exchangeable K lb/A	Zn ppm	S ppm	Cu ppm	N %	Ca %	Mg %	Al %	Fe %	Mn ppm	B ppm
116	near	0-6	301	57	34	6.2	56	49	13	53	5	2.1	2.7	0.3	0.80	0.92	239	15
	ditch	6-12			27	6.1	37	35	8		3	2.3	2.7	0.2	0.76	0.89	198	12
		12-18			26	6.1	14	44	3		2	ND →						
116	distant	0-6	230	63	31	5.9	51	53	14	49	5	ND →						
	from	6-12			26	5.6	18	68	11		4	ND →						
	ditch	12-18			21	5.4	9	68	3		1	ND →						
117	near	0-6	458	85	35	6.1	57	55	14	92	5	2.4	2.6	0.3	0.89	1.01	233	15
	ditch	6-12			26	5.8	12	48	4		3	3.0	2.5	0.3	0.70	1.18	175	14
		12-18			54	6.0	10	86	2		3	2.0	1.9	0.4	1.60	1.75	161	14
117	distant	0-6	408	56	31	6.0	35	56	16	48	5	2.2	2.5	0.3	0.84	0.86	181	11
	from	6-12			23	5.6	8	35	6		3	2.6	2.7	0.3	0.60	1.03	144	9
	ditch	12-18			24	5.6	9	47	ND		ND	3.1	2.4	0.3	0.62	1.01	144	10
118	near	0-6	498	76	35	6.0	52	51	14	61	4	2.2	2.4	0.3	0.78	1.01	227	10
	ditch	6-12			24	5.8	27	22	8		3	2.7	2.2	0.3	0.53	0.96	166	11
		12-18			22	5.6	9	50	5		3	3.0	1.9	0.3	0.57	1.08	115	9
118	distant	0-6	260	61	33	6.0	39	84	13	40	4	2.4	2.5	0.3	0.73	0.95	198	11
	from	6-12			20	5.7	8	35	5		2	2.9	2.1	0.3	0.51	0.93	137	9
	ditch	12-18			24	5.7	9	58	4		2	2.9	2.0	0.3	0.70	0.97	127	10

ND = not determined

Table 12. Soil characteristics in different areas of paddies, Diebold Farm, Aitkin County - 1983.

Paddy No.	Location	Sampling Depth inches	Ash %	pH	Extractable P lb/A	Exchangeable K lb/A	Zn ppm	S ppm	Cu ppm	B ppm
10	near ditch	0-6	25	5.2	34	95	18	21	1.4	0.3
		6-12	22	5.1	17	73	15	31	1.4	0.3
10	distant	0-6	21	5.3	31	117	19	47	1.1	0.3
	from ditch	6-12	21	5.3	34	135	18	23	1.3	0.3
11	near ditch	0-6	89	5.4	36	303	1	12	1.0	0.1
		6-12	87	5.5	60	260	2	10	1.6	0.2
11	distant	0-6	23	5.5	50	191	23	22	2.2	0.4
	from ditch	6-12	20	5.3	26	137	22	24	2.1	0.2

WILD RICE PRODUCTION RESEARCH - 1983

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Cultural research in 1983 concentrated on weed control, plant population and disease interaction, reducing wild rice plant populations with chemicals, and seed storage. The research was conducted on University plot land in St. Paul and Grand Rapids and in growers' fields near Aitkin and Gully. A glasshouse and growth chamber at St. Paul were also utilized for some of the work. Temperatures during May and June were cool but July and August were very warm resulting in early flowering and maturity.

WEED RESEARCH

Herbicides

The herbicide trials in 1983 continued on the use of MCPA for control of common waterplantain. Trials were conducted using spray and pipewick application methods. The trials were conducted at Grand Rapids and on a grower's field near Aitkin.

Yield, injury, lodging, plant height and stem height of wild rice when MCPA was applied at three stages of growth are given in Table 1. The chemicals were applied with a back-pack sprayer at the rate of 1/4, 1/2, 3/4 and 1 lb/A a.i. (active ingredient) when wild rice was in the early and late tillering stage, and in the boot stage of growth. MCPA at 1/4 lb/A a.i. did not injure wild rice or reduce yield when applied at any of the treatment dates. Higher rates of MCPA injured wild rice and reduced yield, especially when applied at the boot stage of growth. This experiment, as well as ones conducted in previous years, indicates that wild rice is very sensitive to injury from late (boot stage or later) applications of MCPA.

MCPA was applied to a stand of wild rice infested with common waterplantain in a grower's field near Aitkin. Applications were made when common waterplantain had 5 to 6 leaves out of the water or when it was in the flower bud stage. The results from this trial are given in Table 2. Control of common waterplantain was better with the earlier applications compared to the later ones.

During 1983 MCPA received clearance for use in wild rice. The recommendation for use of MCPA in wild rice is to apply 1/4 to 3/8 lb/A when common waterplantain has 3 to 5 leaves out of the water, based on this and previous years data. MCPA should not be applied to wild rice in the elongation stage (first internode begins to elongate) or beyond.

The pipewick applicator was used for a fourth year to apply herbicides to common waterplantain without contacting the leaves of wild rice, thus reducing risk of wild rice injury compared to spray applications. Two chemicals, MCPA and glyphosate, were applied at two dates to common waterplantain in a grower's field near Aitkin. Two gallons of water were mixed with one gallon of MCPA or one gallon of glyphosate and these solutions were put into a 10 ft. hand-held pipewick applicator. Single and double passes were made at each date. Plot size was 10 x 20 ft. for the trial. The results from the 1982 and 1983 trials are given in Table 3.

Table 1. The influence of applying four rates of MCPA onto wild rice at three stages of growth - Grand Rapids - 1983.

Wild rice growth stage and date	MCPA rate	Injury rating	Lodging rating	Plant height	Stem no.	Grain yield*	Yield for each growth stage
	lb/A a.i.	-	-	cm	$1\ ft^2$	----------lb/A----------	
Early tillering (6/23)	1/4	0	0	210	7.4	791	608
	1/2	2	0	182	8.4	648	
	3/4	4	0	174	6.1	563	
	1	5	1	167	5.2	431	
Late tillering (6/28)	1/4	0	0	205	7.8	624	610
	1/2	1	0	195	7.2	707	
	3/4	2	0	184	8.2	663	
	1	3	1	182	6.6	447	
Boot (7/8)	1/4	0	0	194	7.1	891	459
	1/2	6	4	167	5.0	319	
	3/4	7	7	156	4.7	389	
	1	7	7	151	2.8	237	
Untreated check		0	0	188	7.4	775	
LSD .05		-	-	-	-	197	

* 40% moisture.

Table 2. The influence of applying MCPA at two dates onto a stand of wild rice infested with common waterplantain - Aitkin - 1983.

Common waterplantain growth stage and date	MCPA date	Common waterplantain control*	Wild rice injury
	lb/A a.i.	%	rating
5-6 aerial leaves (6/6)**	1/4	50	0
	1/2	63	0
	3/4	77	1
	1	90	0
Flower bud developing (6/23)**	1/4	33	0
	1/2	28	0
	3/4	20	0
	1	20	0

* Ratings taken on 7/5; injury on wild rice, 0 = no injury, 10 = all dead.

** Wild rice on 6/6 had 2 to 3 aerial leaves and on 6/23 it was in the mid to late tillering stage.

Table 3. Applications of MCPA and glyphosate with pipewick applicator onto common waterplantain - Aitkin - 1982, 1983.

Date and chemical (1983)	Rate*	Injury rating** Common waterplantain		Injury rating** Wild rice		Wild rice yield*** lb/A
June 6		1982	1983	1982	1983	1982
MCPA	Single	10	8	0	0	765
Glyphosate	Single	10	9	0	0	635
MCPA	Double	10	9	0	0	735
Glyphosate	Double	9	8	0	2	785
June 12						
MCPA	Single	10	5	0	0	605
Glyphosate	Single	8	5	0	2	645
MCPA	Double	10	7	0	0	445
Glyphosate	Double	9	6	0	4	590
Hand weeded		10	10	0	0	805
Not weeded		0	0	0	0	545
	LSD .05	--	--	--	--	155

* Single = 1 pass with applicator; double = 2 passes over same area with applicator.
** 0 = no injury; 10 = dead; taken 4 weeks after treatment.
*** 40% moisture.

As in 1982 the first application was made when common waterplantain had 2 to 4 leaves out of the water (3 to 6 inches) and wild rice had mostly floating leaves. The second application was made when common waterplantain had 4 to 6 leaves out of the water and 15 to 25% of the wild rice plants had aerial leaves. Good control of common waterplantain was obtained by both MCPA and glyphosate at both rates in 1982, however wild rice yields were reduced in 1982 when the compounds were applied at the later date. In 1983, the best control was obtained at the first date. Some injury to wild rice in 1983 was obtained with the double application of glyphosate at the first date and with both rates at the second date. MCPA appears to be better for use in a pipewick applicator for controlling common waterplantain than glyphosate since more injury to wild rice was obtained with glyphosate when wild rice plants with upright leaves at application time come in contract with the applicator.

Using the information we have obtained during the last four years with the pipewick applicator, MCPA was cleared for use in wild rice. One gallon (4 lb. gal. a.i.) of MCPA should be mixed with two gallons of water for use in a pipewick. Most common waterplantain plants should have 3 to 4 leaves out of the water before MCPA is applied. The wicks in the pipewick must come in direct contact with the leaves of the weed.

A research program for the cultural and chemical control of burreed (*Sparganium eurycarpum* Engelm.) was initiated in 1983. Sharon Clay, graduate student on the project, is conducting this research. A survey of wild rice fields was conducted this spring and burreed was found to be present in 90% of the acreage ranging from slight to heavy infestations. It was found to be a severe weed in some fields. Preliminary observations on the growth habit of burreed indicates that it is a perennial. It spreads by rhizomes which develop corms at the base of new plants. The upright leaves of burreed emerge from the water before wild rice.

A competition study was planted at Grand Rapids to obtain some estimate of wild rice yield losses that can be expected from burreed interference. Burreed corms and buds from rhizomes were planted at different densities and allowed to compete with wild rice throughout the growing season. The results are given in Table 4.

Table 4. Yield of wild rice as influenced by different plant populations of burreed - Grand Rapids - 1983.

Type of plant structure planted	Number planted	Burreed		Wild rice		
		Plants	Dry weight	Panicles	Plants	Grain yield*
	/2 ft^2	/16 ft^2	lb/A	/16 ft^2	/16 ft^2	lb/A
Rhizome	8	14	680	164	127	810bc
	32	7	551	185	95	1117a
	48	7	430	174	104	1040ab
Corm	2	7	393	192	106	1115a
	8	25	1278	144	89	767c
	16	40	1964	155	96	773c
Control	0	0	0	188	106	1080a

* 40% moisture; numbers followed by the same letter are not significantly different according to Duncans multiple Range Test at the 5% level.

The number of plants established from rhizomes did not correspond with the number of rhizome buds planted. The corms produced an average of 2.8 plants per corm. One half burreed plant/ft^2 did not reduce wild rice yield, 1-2.5 plant/ft^2 reduced yield approximately 25%. It appears that burreed is competitive but not as competitive as common waterplantain since the upright burreed leaves do not shade the wild rice plants as much as common waterplantain leaves.

Table 5. Effectiveness of several herbicides on burreed - Gully - 1983.

Chemical	Rate	Burreed plants	Dry weight of burreed	Wild rice panicles	Grain yield*
	lb/A a.i.	/16 ft^2	lb/A	/16 ft^2	lb/A
Propanil	1	20	544	75	428
	2	19	459	79	367
	4	16	418	67	383
Triclopyr	1	18	280	49	295
	2	16	295	34	178
	4	4	67	18	60
2,4-D amine	1	6	156	66	298
	2	4	42	63	272
	4	3	39	32	168
2,4-D amine + crop oil	1	5	120	55	297
	2	5	133	40	192
	4	5	69	22	125
Bentazon	1	4	48	85	477
	2	1	5	75	465
	4	2	9	36	220
Bentazon + crop oil	1	3	32	57	293
	2	3	57	53	377
	4	1	12	30	185
Control		25	729	67	216
LSD .05		9	265	26	156

* 40% moisture.

A number of herbicides were tried for contol of burreed. Table 5 gives the results of herbicides applied to burreed in a field of wild rice near Gully. The most promising herbicide appears to be bentazon. It gave good control of burreed; reducing the number of burreed plants from 25 to 1 per 16 ft^2 and more than doubled wild rice yield at the 1 and 2 lb/A rate. Injury to wild rice did occur at these rates but wild rice recovered from the injury (data not shown).

Cultural Weed Control

We reported in 1981 and 1982 that fall flooding may significantly reduce the viability of common waterplantain corms the following spring. The 1981 experiment was conducted outdoors in large fiberglass containers placed on the soil surface while the 1982 experiment was conducted in a freezer. In 1983, the 1981 experiment was repeated using the large fiberglass containers. In addition, corms were placed in pits lined with plastic, thus allowing these corms to overwinter at soil level instead of above ground as was the case in the fiberglass containers. Table 6 summarizes the results from this experiment.

Table 6. Common waterplantain corm survival as influenced by depth of burial and time of flooding - St. Paul - 1983.

Depth in soil	Spring flooded		Fall flooded	
	Boxes	Pits	Boxes	Pits
In.	% survival			
0	20	100	0	28
3	16	50	0	22
6	37	44	0	31
12	0	0	0	0

As in 1981, the corms that were planted in the fiberglass containers above ground and the containers that were flooded in the fall did not survive the winter at any of the burial depths. Some of the corms did survive in the containers when they were spring flooded but not when the corms were buried 12 inches deep. Fall flooding was not as detrimental to corm survival in the plastic lined pits, however the survival percentage was greater in the spring flooded pits. As was true for the boxes, any corms buried 12 inches deep did not survive whether the soil was fall or spring flooded.

Two years of experiments outdoors and one experiment in a freezer indicate that flooding which is not accompanied by ice formation or sub-freezing temperatures without sufficient water to allow ice formation will not significantly influence corm viability. In addition, a minimum of 8 weeks of ice-encasement is required before mortality of the corms will occur. Thus, growers could reduce the infestation of common waterplantain by fall flooding but care must be taken to maintain enough water before freeze-up so the corms become encased in ice. Burying corms more than 6 inches deep by tillage will also help reduce the population of common waterplantain.

An experiment was initiated at Grand Rapids in 1983 on the influence of water depth on the growth of burreed. Burreed corms and rhizomes were planted in a sloping paddy with water depth ranging from 0 to 20 inches deep. The number of burreed plants and their dry weight which developed from 5 corms or 20 rhizomes planted in a 20 ft^2 area at 0, 5, 10, 14 and 20 inch water depths is presented in Table 7. Burreed plant height was not influenced by water depth (data not shown). The number of plants that developed from corms was reduced at water depths of 14 and 20 inches. Plant number and dry weight of plants grown from corms were decreased by 90% from 5 to 20 inches. Water depth had a significant influence on the growth of burreed and growers may reduce the number of burreed plants by keeping the water 14 to 20 inches deep. However, wild rice growth and yield are also reduced by these depths, thus it appears that some other cultural control or chemical control will be necessary to control burreed.

Table 7. The effect of water depth on growth of burreed - Grand Rapids - 1983.

Water depth	Plant structure planted	Burreed plants at harvest	Burreed dry weight
in.		/20 ft^2	lb/A
0	Corm	32.3	706
	Rhizome	3.0	53
5	Corm	40.0	1300
	Rhizome	10.0	154
10	Corm	31.0	979
	Rhizome	4.3	120
14	Corm	21.0	893
	Rhizome	1.0	14
20	Corm	4.0	110
	Rhizome	1.5	48
	LSD .05	10.8	95

PLANT POPULATION

Reducing Plant Population with Chemicals

A pipewick was modified by leaving alternate six inch spaces on the pipewick without rope wicks. An experiment was initiated at Grand Rapids to reduce high wild rice plant populations with the modified pipewick using MCPA or glyphosate in the pipewick. Small areas were seeded at a high rate and thinned with MCPA or glyphosate using the modified pipewick applicator. Plant populations were reduced when wild rice was in the late tillering or boot stage of growth. MCPA solution consisted of 1 gallon of MCPA (4 lb/gal a.i.) mixed with 1 gallon of water. The glyphosate solution also consisted of 1 gallon of glyphosate mixed with 1 gallon of water. Table 8 gives the results from this experiment.

Table 8. Reducing wild rice plant population with use of a modified pipewick applicator - Grand Rapids - 1983.

Chemical	Date, growth stage	Rate*	Plant height	Stem number	Plant number	Grain yield
			cm	$/ft^2$	$/ft^2$	lb/A
Glyphosate	6/28	Single	182	8.0	6.9	985
	tillering	Double	152	7.9	5.6	580
MCPA	6/28	Single	188	8.8	6.4	1170
	tillering	Double	182	8.4	5.1	1110
Glyphosate	7/7 boot	Single	158	8.7	7.8	690
MCPA	7/7	Single	202	8.8	6.7	1417
	boot	Double	168	7.9	5.6	1400
	Control	-	238	10.1	7.9	1658

* Single = one application; double = two applications over the same area.

Both MCPA and glyphosate reduced the plant population by 10 to 20%. Glyphosate injured some of the remaining plants indicating that these plants came in contact with the wicks. The yield was considerably reduced in all glyphosate treated plots. The MCPA treated plots had less injury. Yields were reduced but not as much as with glyphosate. It may be that chemical thinning with a pipewick will have to be done earlier than the tillering stage before the leaves of the remaining plants spread into the rows that are to be left. It may also be necessary to leave wider untreated rows of plants. The pipewick will be modified and the experiment conducted again in 1984.

PLANT POPULATION AND BROWN SPOT DISEASE

In cooperation with Dr. Percich, the 1982 trial at Grand Rapids to investigate the relationship of wild rice plant population and incidence of brown spot disease was repeated in 1983. Wild rice (K2) was solid seeded at 4 rates. Higher seeding rates were used in 1983 to obtain higher plant populations than we had in 1982. An overhead sprinkler system was used to keep the leaf canopy of some plots moist during the day. The sprinkler system intermittently moistened the leaf canopy for 3 minutes every 30 minutes. One set of plots which included all of the plant populations was misted, a second set was misted and artifically inoculated with brown spot, a third set was treated with Dithane M-45 and a fourth set was left untreated. The results for the experiments in 1982 and 1983 are given in Table 9.

A higher plant population was achieved in 1983 compared to 1982. The highest plant population achieved was 11 plants per ft^2 in 1983 and 4 in 1982. This resulted in severe lodging in some plots in 1983 while no lodging occurred in 1982. Also severity of infection of the upper leaves was more related to plant population in 1983 compared to 1982. This was particularly true for the plants which were inoculated and moistened and for the untreated plants.

It was very evident again in 1983 that keeping the leaf canopy moist during the day and inoculating the leaves had a significant influence on the amount of disease (Table 9). The percent of the leaf covered with lesions was the highest for this treatment in both years. The size of the lesions was also the greatest with this treatment. The average yield from these plots was the lowest in both years. The considerable yield reduction (40%) compared to the Dithane treated plots in 1983 was due partly to the severe lodging which occurred at the higher plant populations. No yield was obtained from 3 out of th 4 replications at the high plan popu- lation. In both years the Dithane treated plots yielded the highest when averaged over all plant populations.

The conclusions that can be drawn from the 2 years of work on plant population and disease are that moisture on the leaf canopy during the day enhances infection and the infection is more severe at higher plant populations. Also brown spot disease enhances lodging particularly at high plant populations.

Table 9. Wild rice yield as influenced by plant population, intermittent moistening of the leaf canopy, inoculation for brown spot or treating with a fungicide - Grand Rapids - 1982, 1983.

Treatment of leaf canopy	1982****						1983****						
	Plant no.	Stem no.	Grain moisture	Leaf area infected*	Lesion size	Grain** yield	Plant no.	Stem no.	Grain moisture	Leaf area infected*	Lesion size*	Lodging rating***	Grain** yield
	/ft^2	/ft^2	%	%	mm	lb/A	/ft^2	/ft^2	%	%	mm	no.	lb/A
Moistened	1.1	4.0	35	7	4.5	682	5.1	3.9	45	26	3.2	0	390
	2.0	5.1	44	22	4.2	762	8.4	4.6	42	1	2.2	2.5	429
	3.1	5.4	30	5	4.5	822	5.8	5.2	43	19	2.1	2.5	408
	3.8	7.2	38	10	4.0	880	4.7	4.7	42	24	2.5	5.0	362
	3.8	8.6	38	15	4.2	1007	6.0	4.6	43	17	2.5	2.5	397
	2.8	6.1	37	12	4.3	831							
Moistened and inoculated	1.7	5.4	54	28	4.5	595	4.1	3.9	37	10	2.8	0	368
	2.0	5.6	41	26	4.5	660	8.3	5.1	35	39	2.4	2.5	408
	1.7	5.2	39	28	4.5	892	8.4	5.4	54	42	3.2	2.5	176
	4.2	6.5	39	28	4.8	882	9.9	8.7	72	68	4.0	8.0	48
	3.3	8.2	36	25	4.5	832	7.6	5.8	50	40	3.1	3.5	250
	2.6	6.2	40	27	4.6	772							
Treated with Dithane M-45	1.5	5.1	39	3	3.0	818	4.8	3.7	45	2	1.2	2.0	285
	2.0	6.1	33	1	3.0	870	6.8	6.1	44	7	1.8	1.0	501
	1.9	5.9	36	2	3.2	1118	6.4	4.8	43	3	2.1	6.5	511
	3.7	7.2	37	1	3.8	1128	8.7	5.8	43	2	1.8	5.0	363
	3.0	8.1	37	1	4.0	1232	6.7	5.1	44	4	1.7	3.6	415
	2.4	6.5	36	2	3.4	1033							
Untreated	1.7	5.6	39	1	4.2	815	2.6	4.9	46	4	1.5	0.5	418
	1.5	5.4	30	2	4.0	888	7.7	6.6	46	6	2.4	0.5	368
	2.4	6.1	37	2	2.8	828	11.1	7.8	44	26	1.0	6.5	304
	2.1	5.8	30	4	3.8	1035	8.2	5.6	44	39	1.1	6.0	322
	2.6	6.2	37	3	3.5	1028	7.4	6.2	45	19	1.5	3.4	353
	2.1	5.8	35	2	3.7	918							
LSD .05	1.6	2.1	--	13.5	1.0	266	--	--	--	--	--	--	--

* Upper third of leaf canopy. ** 40% moisture. *** 0 = no lodging; 10 = complete lodging. **** For each treatment of leaf canopy, the values are listed in order of increasing seeding rates. Five seeding rates were used in 1982 and four in 1983.

SEED STORAGE

Wild rice seeds, variety Johnson, were mixed with peat soil and the mixture placed into plastic bags which were closed and tied. Some of the bags were placed in a cooler at +2°C and some in a freezer at -2°C. Bags containing the seed and peat soil were removed after 6, 9 and 12 months for germinination testing. The seeds removed from the -2°C cooler had germination percentages of 72, 46 and 20 after 6, 9 and 12 months of storage, respectively. The seeds removed from the -2°C freezer had germination percentages of 11, 3 and 13 after 6, 9 and 12 months of storage, respectively. Germination steadily declined during the 12 month period when seeds were stored in peat at -2°C. At -2°C storage, it appeared that germination percentage was increasing again after 12 months compared to 9 months of storage. We plan to continue this experiment using longer storage at -2°C to see if germination of the seeds stored longer than 12 months will continue to show an increase in germination percentage.

ACKNOWLEDGEMENT

We wish to thank Henry Schumer, plot coordinator at Grand Rapids, for his continued enthusiastic support of our research. His daily supervision was extremely helpful. The help of Drs. Rust, Boedicker and Rabas at Grand Rapids was greatly appreciated. A number of growers, Franklin and Harold Kosbau, Art Hedstrom and George Landreth, provided land or seed for our research. Their support is much appreciated.

PHYSIOLOGICAL MATURITY OF GRAIN

J. Kurle, R.K. Crookston and E.A. Oelke

Introduction

Physiological maturity (PM) of grains occurs when maximum kernel dry weight is achieved. Growers need to be aware when grains have reached their maximum weight so as not to harvest before the majority of grains are at their maximum weight. A visual indicator of PM could be helpful to growers in determining when to harvest. The occurrence of the indicator must be easily recognizable and closely coincident with the occurrence of PM as determined by kernel dry weight accumulation. In barley and wheat, developmental changes occur in the vascular bundle of the caryopsis at PM to produce a dark pigment strand which is a useful PM indicator on an individual kernel basis.

The objective of this study was to determine if developmental changes occurring in the vascular bundle (strand, vein) might be a useable indicator of physiological maturity in wild rice. The vascular bundle can be seen as a ridge going the length of the kernel opposite the side where the embryo is located. The two characteristics of the vascular bundle which were evaluated as a PM indicator were: 1) Shrinkage and collapse of the vascular bundle and 2) color change of the vascular bundle.

Materials and Methods

Wild rice, variety Netum, was grown in 54 ft^3 fiberglass boxes (dimensions 3 ft x 3 ft x 6 ft) filled with a greenhouse soil mix (6 parts field soil, 6 parts sand, 5 parts peat, 2 parts manure). Germinated seedlings were transplanted into the boxes when a floating leaf, 1 to 1.5 inches long, was present. Seedlings were spaced approximately 8" apart to obtain a planting density of 40 plants/box or 97,000 plants/acre. Water depth throughout the study was maintained at 4 to 6 inches. Fertilizer (20-20-20) was applied at a rate of 100 gm/box twice prior to flowering. All panicles were bagged in nylon mesh bags to prevent shattering losses.

Flowering was recorded and tagging began when the panicle first emerged from the leaf sheath. After six days, developing caryopses, one half to three quarters of the length of the lemma and palea, were marked with acrylic paints. Two days later those remaining caryopses which had reached the proper length were marked. Sampling began 12 days after flowering and continued at two-day intervals for twenty days. At each sample, 4 panicles were harvested and up to ten kernels were removed from each panicle. The color and condition of the dorsal vascular strand was noted and the kernels were weighed. The kernels were then dried for forty-eight hours at 36°C and reweighed to determine moisture percentage.

The date of physiological maturity was calculated by two methods. The first method defined PM as the point after which there was no significant increase in kernel weight as determined by Duncan's Multiple Range Test at the 5% level. The second method described grain weight accumulation as a curvilinear relationship using a cubic polynomial equation. PM was defined as the point of maximum dry weight accumulation. This point coincided with the point of zero slope when the first derivative of the equation was taken. The PM date obtained by differentiation, or the date when maximum kernel weight was achieved, normally followed the date determined by Duncan's Multiple Range Test beyond which there was no significant increase in kernel weight.

Results and Discussion

The date PM occurred according to Duncan's Multiple Range Test was 19 days after flowering (DAF) (Figure 1). The date maximum kernel weight was reached occurred 26.6 days after flowering.

The date "brown vein" (brown coloring of vascular strand) occurred in 100% of the kernels was 23 DAF and the date 100% of the kernels first showed collapse of the vein was 26 DAF (Table 1). Brown vein occurred 4 days after the Duncan's Multiple Range Test PM date and preceded the differentiated PM date by 3.6 days. The date 100% of the kernels showed collapse of the vascular bundle followed the Duncan's Multiple Range Test PM date by 7 days and preceded the differentiated PM date by .6 days.

Moisture values were 26% on the Duncan's Multiple Range Test PM date and 21% on the differentiated PM date, the decrease in kernel moisture to a final value of 15% within two days after PM is identical to the moisture decrease occurring in other grains at PM (Table 1). The moisture decrease and attainment of maximum kernel weight followed by collapse of the vascular bundle indicate that collapse of the vascular bundle follows closely after PM. On the other hand the appearance of brown vein in 100% of the kernels at 26% moisture anticipates the occurrence of PM.

The indicator of harvest maturity which is presently used is the presence of dark color in 35% of the kernels from a random sample of panicles from a field. In our study this occurred between 19 and 21 days after flowering for a panicle. Wild rice is also harvested when a bulk sample reaches 35% moisture. This type of sample was not taken in our study. Because our study evaluated grain development on an individual kernel basis, the relationship of these results to production practices requires further evaluation. In each panicle the number of kernels sampled was a small portion of the total number present. This number was determined by the number of florets pollinated prior to fixed marking dates and was dependent on environmental factors. In addition the individual kernels sampled were prevented from shattering even after an abscission layer had formed. Moisture values as low as those achieved in this study might not occur under field conditions.

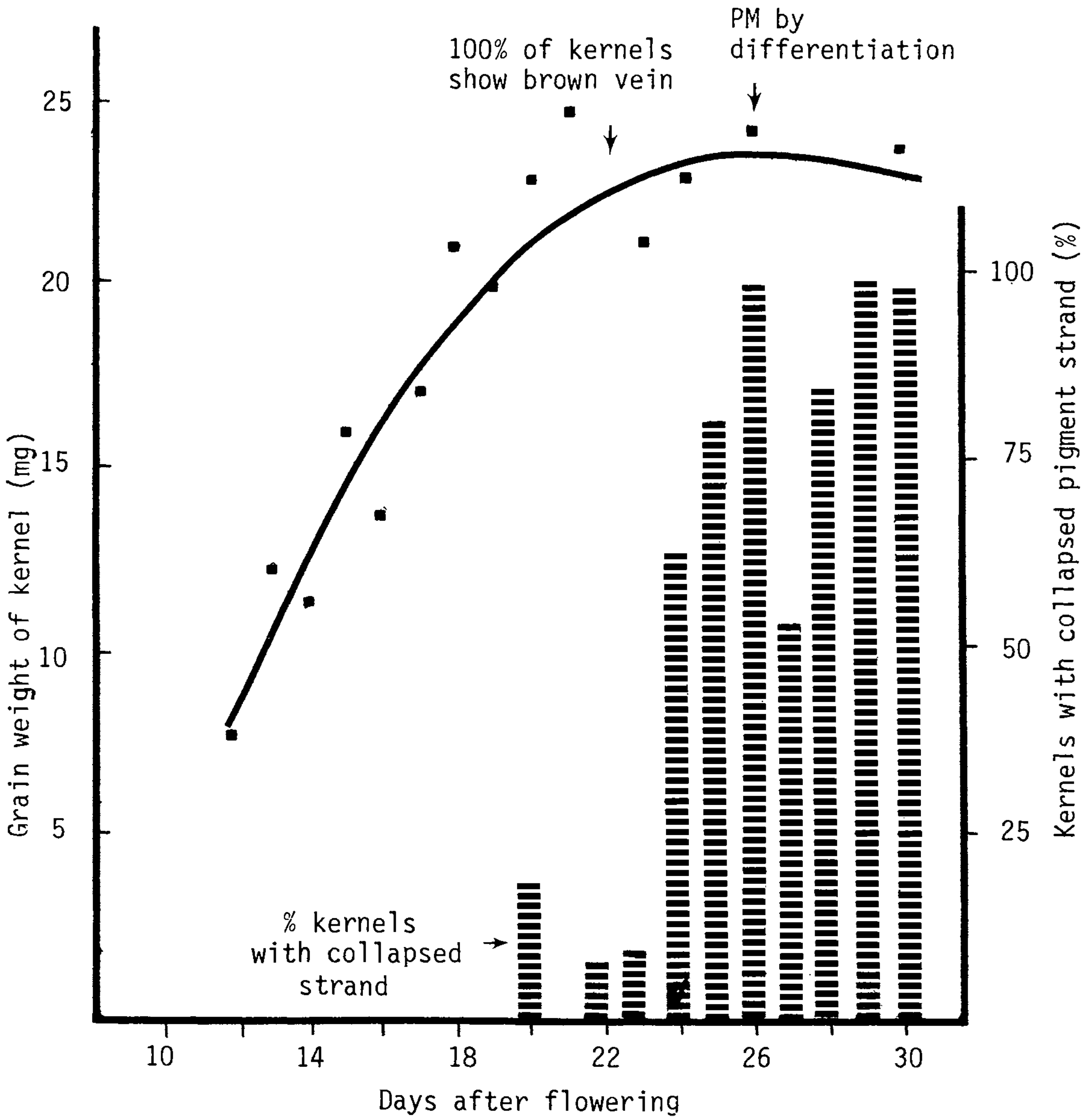

Figure 1. The dry weight accumulation of wild rice kernel and percent of kernels with a collapsed pigment strand during grain filling in wild rice. The solid curve represents the predicted curve for dry weight accumulation. Physiological maturity (PM) calculated by differentiation method was at 26.6 days after flowering.

Table 1. Kernel weight, presence of brown vein, presence of collapsed vein and percent grain moisture during maturation of the grain.

				Percent grain moisture	
Days after flowering	Kernel weight (milligrams)	Brown vein as % of sample	Collapsed vein % of sample	Actual % H_2O	Predicted % H_2O
12	7.9	0	0	56.9	45.6
13	12.4	0	0	29.4	41.2
14	11.4	0	0	37.5	37.5
15	16.2	0	0	28.9	34.5
16	13.9	0	0	23.5	32.2
17	17.1	0	0	41.3	30.0
18	21.0	0	0	34.3	28.9
19	20.0	0	0	25.5	27.7
20	22.8	17	17	28.9	26.9
21	24.7	80	0	30.5	26.2
22	18.0	100	8	19.6	25.5
23	21.8	36	9	31.1	24.8
24	22.7	90	64	22.0	24.1
25	21.3	85	83	19.7	23.1
26	24.3	100	100	20.7	21.8
PM					
27	26.3	92	54	15.7	20.2
28	24.4	96	86	21.7	18.2
29	20.5	100	100	15.1	15.5
30	23.3	100	100	13.9	12.3
Final 50 kernel wt	24.2				

WILD RICE BREEDING - 1983

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Success with experiments planned for 1983 was varied. In general, experiments conducted at Grand Rapids, Rosemount and Waskish resulted in data of satisfactory to good quality. Experiments conducted at Excelsior failed to produce usable data with the exception of the advanced yield trial and those were of poor quality. The quality of the growing season was likely responsible for part of our problems. In 1982, we measured ranges of up to 10 days difference in flowering and 13 days in harvest date between Voyager and Johnson. In 1983, those ranges dropped to 5 and 8 days for flowering and harvest dates, respectively, in our northern environments. At Excelsior, the high temperatures and/or disease resulted in plot failure in most cases. Going into seed filling stage, many of the Excelsior plots appeared to have outstanding potential. At harvest, the data had to be discarded.

Some of the results presented here-in are preliminary and analyses may not be complete. Experiments and subjects are presented in the following order:

1) 1983 advanced yield trial results
2) Progress report on experimental population Dwarf
3) Half-sib selection studies (Report on Ph.D. thesis research by W.E. Palm)
4) Inter-genotypic competition study (Report on Ph.D. thesis research by J. Hernandez)
5) Grain dry weight accumulation in Voyager and K2
6) Discussion of selections and experiments in planning phases

1) 1983 Advanced Yield Trials

Trials were fall planted at Waskish and Grand Rapids and spring planted at Grand Rapids and Excelsior in randomized complete block arrangements, six replicates per site. We used four-row plots, ten feet in length with rows spaced 1 foot apart and a skip row between plots. Ranges of plots were separated by 5-foot alleys. Plots were hand-planted. Plots at Grand Rapids were fertilized with urea (30 lb/A of N) at planting. At harvest, the upper 2 to 3 feet of plant material was cut with a hand-scythe, the stems and plants were counted, and the material was threshed with a Vogel thresher. Data were recorded for flowering date and harvest date (in days after June 1), green weight and dry weight of grain, and plant height based on 10 plants per plot. Stems per plant and % dry weight were computed for each plot. We like to harvest when grain is approximately 65% dry weight; the decision to harvest a plot is based on panicle appearance of tillers and amount of shattering on the main stem.

The Waskish trial was planted on a new paddy at Pete Olsons. Because of travel restrictions, we did not record flowering date on the Waskish plots and some compromises were made on harvest date; some plots were harvested somewhat earlier or later than optimum. At the other locations, each plot was harvested at its optimum stage based on our subjective criteria.

The entries in the AYT tests consisted of Voyager (an early version of K2 described in the 1982 progress report), K2, Netum, Johnson, M1 or M3 depending on the trial, and four experimental populations. Voyager B.B. is the designation we used for a population developed by bulking plants from Voyager which had the "bottle brush" phenotype. The staminate flower branches do not open out as in normal plants; the plants are probably pollen sterile; and the flowers tend to be purple in color at anthesis. Bottle brush plants in our opinion look impressive at harvest; they look like they will be high yielding. M3 x Netum is the result of a cross between Netum and early flowering plants of M3; it has been maintained by random mating in isolation and has had pistillate plants, bottle brush plants and shattering type plants removed by selection in 1981 and 1982. Dwarf x Jns is the result of a cross of Dwarf plants and Johnson plants made several years ago. The population has been increased by random mating without selection. Dwarf has been described in previous reports and will be discussed separately in the next section of the report.

Results of the individual AYT trials are given in Tables 1-4 and the means over trials are presented in Table 5. The fall-planted sites (Grand Rapids, Table 1 and Waskish, Table 3) indicate a problem we have with stand establishment. Voyager, Voyager B.B., and M3 x Netum have very low stands (number of plants per plot) compared to the other varieties. Seed from all three entries were threshed (in 1982) with our Vogel thresher. I conclude that significant damage to the seed occurred in the threshing process. We can test germination for our spring trials (Table 2 and 4) and the result is obvious in the plants per plot column of the tables. We hand-thinned the plots at Grand Rapids (Table 2), at the first aerial leaf stage, and were well-pleased with the uniformity of the stands across entries.

Our first interest in the results of the AYT's involves comparison of Voyager and K2. Compared to last year's results, the advantage in earlier flowering and earlier harvest date of Voyager has greatly diminished. The average over trials (Table 5) shows a 2-day earlier flowering and a 2-day earlier harvest of Voyager over K2. I suspect that the environment may have had some effect on the reduced maturity differences. However, compared to Netum, Voyager was earlier in flowering and harvest in 1983 than it was in 1982. In addition, K2 was earlier than Netum. I would not be surprised if seed source in 1982 has had a profound effect on the relative performance of Voyager, K2 and Netum. We normally purchased K2 seed from Kosbau's. In the fall of 1982, Kosbau did not have seed (we got there late) but we were able to purchase K2 seed from Gully Farms. For several years now, Sandlunds have given Netum seed to us for research purposes. In 1982, they had finished harvest before we requested seed. George Landreth gave us some Netum seed which he had remaining from a clean-up operation.

In both cases, genetic shifts could easily have accounted for the 1983 results. Erickson's (Gully Farm) version of K2 may be earlier than Kosbau's K2 source. Very likely, the late harvest of Netum from wet areas in Landreth's paddies resulted in selection of later plants of Netum (and perhaps taller plants) since we seem to be developing evidence that early plants tend to be shorter than late plants. Both cases would

Table 1. Advanced yield trial results -- Grand Rapids fall planting, 1982.

Entry	Plants per plot	Stems per plant	Height	% Dry weight	Dry weight yield[1]	Harvest date	Flowering date
			(in.)		(lb/Acre)	(days after June 1)	
Voyager	30	5.2	70	63.2	1057	77.0	40
K2	70	2.8	73	63.4	930	78.2	42
Netum	86	2.6	79	63.8	1119	79.8	42
Jns	72	2.6	77	64.4	766	81.8	45
M1	74	2.5	79	64.3	1046	81.3	44
Voyager B.B.	22	6.9	66	62.8	1048	77.0	40
Dwarf x Jns	51	4.1	75	67.0	998	77.5	42
M3 x Netum	23	6.9	71	62.9	1070	77.3	40
Dwarf	58	4.5	57	66.8	509	59.0	31
LSD (.05)[2]	10	.7	5.6	2.7	133	4.6	2.5

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[1] Yield of grain and hulls.

[2] Two means which differ by more than the LSD are significant. Means are based on six replicates.

Table 2. Advanced yield trial results -- Grand Rapids, spring planting, 1983.

Entry	Plants per plot	Stems per plant	Height	% Dry weight	Dry weight[1] yield	Harvest date	Flowering date
			(in.)		(lb/Acre)	(days after June 1)	
Voyager	78	2.4	73	67.6	1054	78.0	40
K2	92	2.0	80	65.1	847	78.5	42
Netum	90	1.9	84	65.0	868	78.5	42
Jns	78	1.9	85	65.0	624	86.0	43
M3	79	2.1	86	64.0	952	83.5	45
Voyager B.B.	80	2.3	75	66.8	1104	78.0	40
Dwarf x Jns	89	2.1	82	66.2	962	78.0	39
M3 x Netum	84	2.4	78	68.3	1138	78.0	38
Dwarf	102	2.8	53	70.0	848	59.0	32
LSD (.05)[2]	11	.3	4.4	1.2	146	.5	1.8

---

[1] Yield of grain and hulls.

[2] LSD based on 6 replicates.

Table 3. Advanced yield trial results -- Waskish fall planting, 1982.

Entry	Plants per plot	Stems per plant	Height	% Dry weight	Dry weight[1] yield	Harvest date
			(in.)		(lb/Acre)	(days after June 1)
Voyager	24	6.2	70	64.7	1197	84.0
K2	48	3.5	79	63.4	1028	86.3
Netum	44	3.3	83	63.5	964	87.5
Jns	45	2.6	84	64.3	866	91.0
M1	41	2.8	81	64.4	841	91.0
Voyager B.B.	13	8.3	70	65.6	1031	84.0
Dwarf x Jns	33	4.9	78	64.9	1110	85.2
M3 x Netum	15	8.2	74	65.8	1010	84.0
Dwarf	33	5.3	54	59.5	620	64.0
LSD (.05)[2]	8	1.3	4.6	2.1	211	2.5

---

[1] Yield of grain and hulls

[2] LSD based on six replicates.

Table 4. Advanced yield trial results -- Excelsior spring planted, 1983.

Entry	Plants per plot	Stems per plant	Height	% Dry weight	Dry weight[1] yield	Harvest date	Flowering date
			(in.)		(lb/Acre)	(days after June 1)	
Voyager	96	2.3	48	61.9	614	75.8	44
K2	94	2.4	53	70.9	451	81.2	46
Netum	79	2.8	58	71.1	527	82.5	46
Jns	67	2.0	59	71.2	274	87.2	48
M3	89	2.2	56	71.5	601	84.7	48
Voyager B.B.	52	3.1	50	65.8	574	75.3	44
Dwarf x Jns	69	2.7	58	69.1	483	80.0	44
M3 x Netum	41	3.7	51	74.4	481	81.8	43
LSD (.05)[2]	31	.6	3.6	6.5	133	3.7	1.2

[1] Yield of grain and hulls.

[2] LSD (.05) based on six replicates.

Table 5. Results of 1983 advanced yield trials averaged over 2 planting dates at Grand Rapids, a fall planting at Waskish and a spring planting at Excelsior.

Entry	Plants per plot	Stems per plant	Height	% Dry weight	Dry weight[1] yield	Harvest date	Flowering[3] date
			(in.)		(lb/Acre)	(days after June 1)	
Voyager	57	4.0	65	64.4	980	79	44
K2	76	2.7	71	65.7	814	81	46
Netum	74	2.6	76	65.9	870	82	46
Jns	65	2.8	76	66.2	632	86	48
Voyager B.B.	42	5.2	65	65.2	939	79	44
Dwarf x Jns	60	3.5	73	66.8	888	80	44
M3 x Netum	41	5.3	69	67.8	925	80	43
LSD (.05)[2]	19	1.5	3.0	3.3 NS	103	2	--

---

[1] Yield of grain and hulls.

[2] Two means which differ by more than the LSD are significant. Means are based on a total of 24 replicates.

[3] Flowering data not recorded at Waskish.

make Voyager closer to the possibly early K2 from Gully Farms, and Netum would appear to be later.

The answers (and explanations) to the decreased differences in maturity of Voyager compared to K2 will have to wait another year. Study of the tables will show that Voyager is earlier than K2, generally 5 to 6 inches shorter, and, in both 1982 and 1983, generally yields more than K2. The large differences in stems per plant of Voyager compared to K2 in Tables 1 and 3 are a function of the decreased number of plants in the Voyager plots.

A high number of stems per plant was demonstrated for all three entries which had low stands per plot. The remarkable result is the competitive to high yield of M3 x Net, Voyager, and Voyager-bottle-brush at Waskish and Grand Rapids, fall planting. This result was suggested by the competition studies conducted in 1981 and 1982. You don't need a lot of plants per unit area for a good yield. In the Waskish and Grand Rapids fall plantings, the range in plants per square foot over all entries was from .65 to 4.30. However, there was no association between number of plants per square foot and dry weight yield of the entries ($r = -.22$, 16 df).

From statistical analysis of the AYT tests, we can compute components of variance estimates to use in making decisions about extent of testing necessary to distinguish differences among varieties. Also, we can evaluate the necessity of having variety tests throughout the growing region compared to conducting tests in only one or two locations and years. The data presented in Table 6 are from 1983. More extensive analyses on 1982 and 1983 data will be computed and results prepared for publication later this year. Two items are worth noting. Height data show that differences between heights of two entries are relatively constant regardless of where the tests are conducted, because genotype x environment interaction for height was not significant. GE interaction for height was not significant in 1982, either. Harvest date and green weight yield also showed non-significant GE interaction. However, I believe these will require closer inspection because they were significant in 1982.

The heritability estimates presented in Table 6 provide a measure of genetic control of expression of a trait relative to control by environmental effects. All traits had ratios that would be considered large (and good news) by plant breeders, with the exception of % dry weight. In these tests, % dry weight provides a measure of our ability to harvest wild rice plots at a uniform stage of maturity. The heritability estimate of close to zero merely indicates that we are doing a relatively good job in this respect.

2) Progress Report on Experimental Population Dwarf.

Dwarf has been described in previous reports (1982) and many growers have seen the population in our AYT (Advanced Yield Trial) plots at field days or at Pete Olson's paddies in 1982. Table 7 provides a summary of data on Dwarf compared to Netum and dry weight yield of Johnson. Description of the 1981 test and 1982 trials can be found in those progress reports. The 1983 data came from the 1983 AYT's and may be found in Tables 1-3.

Table 6. Components of variance estimates and heritability ratios for traits evaluated in advanced yield trials at 4 environments in 1983.

Component[1]	Harvest date[2]	Plants	Stem Number	Green weight	Dry weight	Stems per plant	% Dry weight	Height
				—— gm/plot	———			(inches)
$\hat{\sigma}^2_E$	8.58 ± 1.11	223.47 ± 28.86	729.86 ± 94.22	2184.9 ± 282.07	830.63 ± 107.23	.48 ± .06	11.04 ± 1.42	103.03 ± 13.30
$\hat{\sigma}^2_{GE}$[3]	.64 ± .72	141.21 ± 59.68	294.70 ± 139.66	178.64 ± 186.94	95.32 ± 79.94	1.12 ± .40	3.85 ± 1.91	-2.00 ± 5.52
$\hat{\sigma}^2_G$	6.76 ± 4.21	157.54 ± 117.66	176.36 ± 165.60	1225.81 ± 787.37	517.54 ± 333.11	1.20 ± .87	-.17 ± .86	136.96 ± 81.27
Heritability	.93	.78	.63	.90	.90	.80	-.13	.97

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[1] Degrees of freedom for error, genotype by environment interaction, and the component of variance among populations are 120, 18, and 6, respectively.

[2] Harvest date is expressed as days after June 1.

[3] GE interaction was significant for all traits except harvest date, green weight, and height.

Table 7.
Harvest date, plant height and dry weight yield of experimental population "Dwarf" compared to Netum (1981-1983) and to dry weight yield of Johnson.

Environment	Harvest Date[1]		Plant Height (inches)		Dry Weight Yield (lb/A)		
	Dwarf	Netum	Dwarf	Netum	Dwarf	Netum	Johnson
1981							
Grand Rapids	58	81	43	72	566	1160	---
1982							
Grand Rapids (Fall planted)	57	73	43	67	804	724	539
Grand Rapids (Spring planted)	57	77	46	70	761	719	610
Waskish (Fall planted)	64	87	52	71	743	1142	751
1983							
Grand Rapids (Fall planted)	59	79	57	78	509	1118	766
Grand Rapids (Spring planted)	59	79	53	84	848	868	624
Waskish (Fall planted)	64	87	54	83	620	964	866
LSD (.05)		2		8		162	
Mean over environments	60	80	50	75	693	956	693

[1] Days after June 1.

Dwarf is characterized by 3 striking attributes compared to Netum: a) it is about 3 weeks earlier in harvest date; b) it is some 25 inches shorter; and c) it is considerably poorer in yield on the average. The results (Table 7) indicate that on several occasions Dwarf has yielded equal to Netum and out-yielded Johnson. Dwarf would be at least a month earlier in harvest than Jns.

Table 8 presents information on seed size of Dwarf, compared to Netum, Voyager and K2, based on data from the Grand Rapids AYT in 1983 and several AYT's in 1982. We chose to express seed size as a function of weight of 100 hulled seeds. Based on results in both years, Dwarf has significantly larger seed (about 17% by weight) than the other 3 varieties. A pound of dry hulled seed of Dwarf would contain approximately 15,300 seed compared to about 17,900 in the other varieties.

We believe that Dwarf should be released. However, results from an increase paddy constructed by George Landreth at Landreth Farms provided evidence of two problems: a very low yield of seed (approximately 150 lbs green weight from one acre) which pretty much prevented an increase for release in 1984, and an obvious difference in types of plants. There were very short early plants and intermediate height, medium maturity plants. The segregation of plant types was equally obvious in the plots of Dwarf at Olsons. At this stage, I'm not sure whether to proceed with a release of very heterogeneous materials or make another selection to stablize the heterogeneity of plant type. We have fall planted a .75 acre increase paddy at Grand Rapids which will permit the selection for more uniform plant type if it is necessary. However, part of the paddy was planted with a source of Dwarf which appeared uniform in 1983. If it remains uniform we may not have a problem. If it is all heterogeneous for maturity and height, something must be done. The two types mature at different times and very low yield must result for growers unless the problem is resolved by selecting for only one type.

3) Half-Sib Family Selection Studies (W.E. Palm)

The purpose of this study was to evaluate half-sib family selection for yield, flowering date, and plant height. This selection scheme has been used previously in wild rice to select for greater seed retention (Everett and Stucker, 1983. Crop Science 23:956-960).

The studies' purposes were multiple. The evaluation of half-sib families (the progeny of the seed of a single plant) in an appropriate experimental design allows us to obtain estimates of genetic and environmental variances which can be used to assess the heritability of the traits and to predict the amount of genetic gain from selection. New populations were developed and tested to assess whether the realized (actual) gain from selection was comparable to predicted gain from selection. Phenotypic correlations were calculated from both phases of the study to evaluate the relationship among the traits measured in the experiment.

One hundred fourteen randomly chosen half-sib families of K2 were evaluated for flowering date, plant height, and yield in 1982 at Grand Rapids, in replicated, single row, six-foot, unbordered plots. A blocks-in-replicates experimental design with two blocks of 57 families each

Table 8. Comparison of seed size differences (as measured by weight of 100 seeds) among Dwarf, K2, Netum and Voyager in 1982 and 1983.

Population	Weight in grams of 100 seeds	
	1982	1983[1]
Dwarf	2.94	2.99**
K2	2.50	2.53
Netum	2.58	2.55
Voyager	2.58	2.50
LSD (.05)	Not available	.22

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[1] 1983 data from 3 samples in each of 6 replicates of the Grand Rapids spring planted AYT. Seed were hulled and dry.

** Dwarf seed weighed significantly more than seed of the other varieties in 1983.

was used. Data were taken on flowering date (days after 1 June when 50% of the plants in the plot had pistillate florets showing), plant height (in centimeters), and yield of grain per plot (both wet and dry weights in grams).

Family means were calculated and divergent selection for the three characters was conducted based on the family means. The selection intensity was 10.5% for all characters except high yield where the selection intensity was 8.8%. Populations for the evaluation of gain from selection were formed using two methods based on seed source. Remnant seed of all families was stored in the cold room at planting and a sample of viable open-pollinated seed from every family was saved at the time of harvest. Remnant seed of families selected for high and low yield was germinated, and the two populations were grown in separate greenhouses to develop seed of the new populations. The resultant seed from the high and low yield families was termed the high and low yield intermated populations, respectively.

The second method of population formation involved the use of random samples of open-pollinated seed saved from all families at the time of harvest. A balanced composite of seed from selected families was bulked to form the "open-pollinated" populations. Open-pollinated populations were formed from selections for high and low yield, early and late flowering date, and short and tall plant height. A small sample of open-pollinated seed from every family was bulked to form an unselected check population (called K2 Random) for comparison with the selected populations.

In 1983 two experiments were conducted. The first was to evaluate another set of randomly chosen half-sib families. The second was to evaluate the populations formed from the families selected in 1982. These are the Half-Sib Family Evaluation Experiment and the Evaluation of Gain From Selection Experiment, respectively.

The 1983 Half-Sib Family Evaluation Experiment consisted of 240 Voyager half-sib families evaluated in replicated, single row, six-foot, unbordered plots. Of these families, 144 were randomly chosen disregarding the phenotype of the maternal plant. The other 96 were chosen because the maternal plant exhibited the "bottle-brush" phenotype. Because there was not a substantial difference between the types of families, the analyses were combined. A blocks-in-replicates design was used with 10 blocks of 24 families each. The block size was reduced in comparison to 1982 in an attempt to remove additional environmental variance from phenotypic variance. The same characters were measured in this experiment as in 1982 with the addition of a visual plot rating and counts of number of plants per plot. From this latter value yield of dry grain per plant can be calculated.

The Evaluation of Gain From Selection Experiment included the previously described selected intermated and open-pollinated populations, and the check populations, K2 Random, K2, Voyager, and Voyager "Bottle-Brush". The latter population is a composite of plants selected on the basis of the "bottle-brush" phenotype.

This experiment was grown in a randomized complete block design at two locations, Grand Rapids and Excelsior, MN in 1983, in single row, ten-foot plots. There were six replicates at each location. In three replicates per location the entry row was unbordered; the other three replicates had entry rows bordered by K2 rows on both sides. The experiment was designed in this manner to assess whether there would be a genotype by competition level interaction effect. Growing the experiment at two locations allowed an assessment of genotype by environment interaction effects.

Results:

Half-Sib Family Evaluation Experiments

The heritabilities for the primary traits of interest measured both years are shown in Table 9. The heritabilities for all traits both years were high. This would indicate that substantial progress could be made for any of these traits through selection of superior families. The similarity of heritabilities from year to year is interesting. Voyager (1983) was selected from K2 (1982) on the basis of earlier flowering but there was an accompanying correlated response for reduced plant height. The amount of genetic variance for these two characters might have been reduced in Voyager because of the selection process, yet the heritability estimates indicate that this did not take place and that gain from selection within Voyager for even earlier flowering and shorter plant height should be possible.

In most crop species, flowering date and plant height have been shown to be rather highly heritable traits and wild rice appears to be no exception. However in most crop species grain yield is considered a low heritability trait. The rather high estimates of heritability for grain yield (Table 9) in these two experiments were surprising. The magnitude of the estimates is probably best explained by the fact that wild rice is relatively unselected for grain yield; therefore there is abundant genetic variation for yield and good opportunity for improvement in grain yield through selection.

Expected gain from selection is a potentially more useful measure of the useable genetic variance in a population. This quantity is a function of the amounts of additive genetic variance, phenotypic variance, parental control in population formation, and the selection intensity or the proportion of families selected. The expected gain from selection among K2 half-sib families evaluated in 1982 is shown in Table 10 (in terms of percent change from the population mean). The differences between low and high wet and dry weight yield expected gains are due to the difference in selection intensity between these two populations. Only the expectations for populations derived by bulking samples of open-pollinated seed are shown in Table 10. The expectations of gain for populations derived by intermating remnant seed of selected families are not shown in Table 10 but would be twice the values shown.

The shape of the distribution of family means with respect to a given trait was of tangential interest in these experiments. The distribution of the family means for yield (Fig. 1) approximates a normal

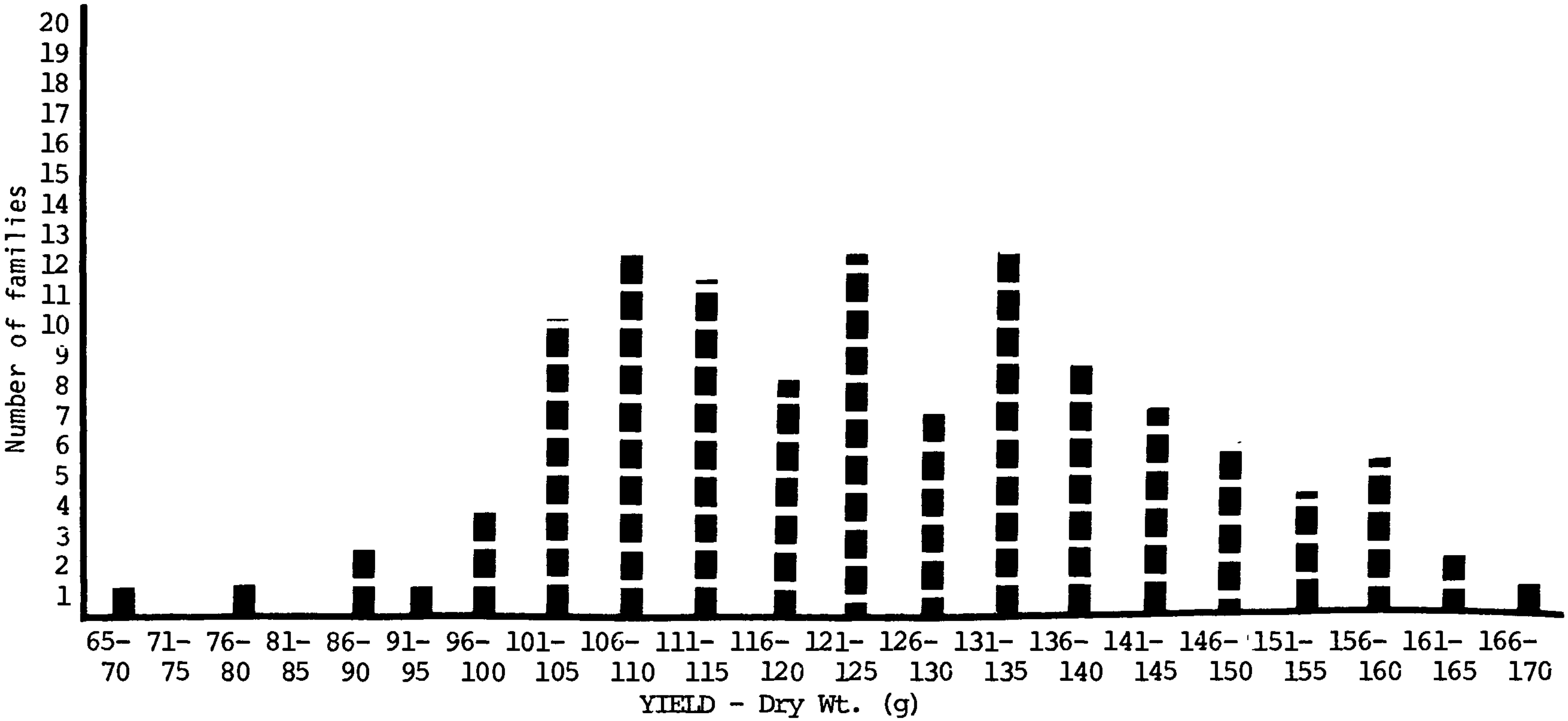
Table 9. Heritabilities from the Half-Sib Family Evaluation Experiments (1982 and 1983).

Trait	Family Source	
	(K2-1982)	(Voyager-1983)
Flowering date (days post 1 June)	88.5 ± 18.4	87.7 ± 13.1
Plant height (cm)	80.3 ± 22.5	83.1 ± 9.9
Wet weight yield (cm)	83.2 ± 21.1	79.3 ± 16.1
Dry weight yield (g)	82.6 ± 21.4	78.4 ± 16.4

Table 10. Expected and realized gains from selection (in percent of population mean) and realized heritabilities from the half-sib experiments (1982, 1983).

Trait	Expected gain	Realized gain	Realized heritabilities
	(%)	(%)	
Flowering date (days post 1 June)	17.53	Early 7.39	81.2
		Late 2.02	22.0
Plant height (cm)	2.25	Short 4.12	46.9
		Tall 0.49	5.5
Wet weight yield	Low 7.48	Low -7.98	
	High 7.83	High 9.91	
Dry weight yield	Low 7.31	Low -10.77	-26.6
	High 7.64	High 13.94	35.8

Figure 1. Frequency distribution of half-sib family mean yields from the variety K2 in 1982.



distribution as would be anticipated for a quantitative trait and which is quite important for the assumptions underlying quantitative genetics theory. The distribution of family means also provides visual evidence that yield of K2 could be improved if we could identify the best families and discard the poor yielding families.

The phenotypic correlations among characters measured in the 1983 Half-Sib Evaluation Experiment are shown above the diagonal in Table 11. The correlation of visual plot rating scores with plants per plot (r = 0.76) indicates that visual plot ratings do, in part assess the stand density of the plot. The fact that visual plot ratings are only moderately correlated with yield of dry grain per plot (r = 0.52) suggests that there is variation in yield per plot which is not accounted for by plot appearance, perhaps attesting to there being inherent yield differences among families. This same conclusion is born out by the moderate correlation of plants per plot and yield of dry grain per plot (r = 0.59). The ability of wild rice plants to compensate for decreased stand with increased yield per plant is indicated by the negative relationship between plants per plot and yield per plant (r = -0.70). The extremely close correlation between green (wet) weight yield per plot and dry weight yield per plot (r = 0.99) is very encouraging in that selections of superior families can be made on the basis of green weight at harvest without spending the time required for drying and reweighing samples prior to analysis of data and/or selection. The lack of close association between flowering date and harvest date with yield of dry grain per plot (r = 0.04 and 0.14, respectively) indicates no apparent yield disadvantage associated with earlier maturity. Likewise a moderate association between plant height and yield of dry grain per plot (r = 0.53) indicates that shorter plant stature (within the range observed in this experiment) should not hinder selection for yield.

Evaluation of Gain From Selection Experiment.

The entry means for combined locations for the characters of interest are shown in Table 12. K2 Random Bulk is the most appropriate check population to use in comparing selected populations. K2 itself should have been an appropriate check population but we believe the K2 seed source obtained from Gully Farms in 1982 was not representative of the typical behavior of this variety (seed usually obtained from Kosbau Brothers).

Compared to K2 Random Bulk, the open-pollinated population selected for early flowering was significantly earlier than the check (Table 12) but the late open-pollinated population was not significantly later. Selection for early flowering appeared to be more effective than selection for late flowering.

Compared to K2 Random Bulk, the short open-pollinated population was significantly shorter (Table 12) but the tall population was not significantly taller than the check population. Selection for shorter plant stature appeared to be more effective than selection for tall plant stature.

There were no significant differences among entries for yield. Both the low and high yield open-pollinated populations yielded more

Table 11. Phenotypic correlation coefficients among characters measured in the Half-Sib Family Evaluation Experiment (above diagonal, n = 240) and the Evaluation of Gain From Selection Experiment (below diagonal, n = 144) (1983).

	Plot rating	Flowering date	Plant height	Plants/ plot	Harvest date	Wet weight	Dry weight	Yield/ plant
Plot rating		-.27	.26	.76	-.29	.53	.52	-.57
Flowering date	-.37		.02	-.19	.37	-.03	-.04	.28
Plant height	.44	-.79		.19	.11	.52	.53	.16
Plants/ plot	.73	-.06	.09		-.30	.61	.59	-.70
Harvest date	-.35	.83	-.75	-.08		.07	.14	.51
Wet weight	.54	-.59	.69	.29	-.45		.99	-.03
Dry weight	.54	-.59	.67	.31	-.44	.99		.06
Yield/ plant	-.06	-.40	.45	-.32	.25	.65	.64	

Note: Correlation coefficients of approximately ± 0.70 or greater are considered large enough to be of importance.

Table 12. Entry means for flowering date, plant height, and yield of dry grain per plot from the Evaluation of Gain From Selection experiment (1983).

Entry	Flowering date	Plant height	Yield
	(days post 1 June)	(cm)	(g)
High yield open-pollinated	48.3	180.8	89.9
Low yield open-pollinated	49.4	183.4	87.4
Early open-pollinated	45.9*	181.8	93.3
Late open-pollinated	50.6^{N}	181.3	94.3
Short open-pollinated	48.5	176.8**	85.3
Tall open-pollinated	50.0	185.3^{N}	83.8
K2 Random Bulk	49.6	184.4	78.9
Voyager "Bottle-brush"	45.3	157.3	59.3
Voyager	45.8	159.9	100.1
K2	48.2	179.4	78.1
LSD (.05)	1.6	7.9	NS

**Shorter than K2 random bulk.

^{N} Not significantly different from K2 random bulk.

* Earlier than K2 random bulk.

than the K2 Random Bulk and the variety K2, but both the early and the late open-pollinated populations yielded more than the high and low yield selected populations. Voyager yielded the most at both locations and across locations.

The high and low yield intermated populations were not included in this analysis. They performed very poorly at Grand Rapids, probably due to the seed remaining dormant for a period of time after planting, and they subsequently suffered from competition from adjacent plots or border rows. At Excelsior the "intermated" populations functioned quite well however, probably due to a three week delay in planting which enhanced breaking of dormancy. The extreme change in rank of these entries between the two locations was in part responsible for the lack of significant differences among entries for yield; the majority of the variation for yield in the experiment could be ascribed to the intermated population by environment interaction component of variance.

The results of selection can be assessed by comparing expected and realized gain from selection and by comparing heritabilities obtained from variances among the half-sib families and realized heritabilities obtained from selection. The expected and realized gains from selection in terms of percent of the population mean can be compared directly in Table 10. Whenever the realized gain is similar in amount to expected gain, selection may be considered effective. Negative realized gains (as in low yield, wet and dry weight) indicate that response was in the opposite direction from expected. Comparison of the realized gains for divergent selection (early vs. late, short vs. tall) indicated that selection for early flowering was more effective than for late flowering and selection for short stature was more effective than for tall stature.

It is apparent from inspection of heritabilities obtained from the half-sib families (1982, Table 9) and realized heritabilities (Table 10) that in no case was the realized heritability as large as the predicted heritability estimates. K2 Random Bulk was used as the reference population for the realized heritabilities. Therefore negative estimates of realized heritability, such as for low dry weight yield, mean that this population yielded more than K2 Random Bulk when it should have yielded less. Comparison of the realized heritabilities calculated for divergently selected populations gives an indication, as did realized gains, in which direction selection was more effective.

The effects of having plots bordered versus unbordered was investigated. Of the characters discussed, only yield (both wet and dry weight) was significantly affected by the bordering treatment. Border rows significantly decreased the yield of the entry rows. This decrease can probably be ascribed to three main factors; first, interplant competition, second, shattering of the entry row caused during removal of the border rows, and third, the increased stand density (per unit land area) due to the presence of border rows increased the amount of disease (primarily *H. oryzae*) in the bordered entry rows. The entry by bordering treatment interaction effect was not significant for any of the traits discussed here.

The phenotypic correlations among characters measured in the Evaluation of Gain From Selection Experiment are given below the diagonal in

Table 11. The relatively strong correlation (r = 0.73) between visual plot ratings and plants per plot indicate that plot ratings are partial predictors of final stand. The strong negative correlation between plant height and flowering date (r = -0.79) I believe is somewhat spurious, being caused primarily by the intermated populations which, particularly at Grand Rapids remained very short and were late flowering at both locations. A positive relationship (i.e. tall and late flowering) has been observed in most other situations. The same spurious relationship appears to exist between plant height and harvest date (r = -0.75), most likely for the same reasons. Flowering date and harvest date were highly correlated (r = 0.83) as expected. The relationship between plant height and grain yield (r = 0.69 for wet weight) is not encouraging. The strong correlation between wet weight and dry weight yields per plot (r = 0.99) is very encouraging and suggests that unless percent dry matter or percent recovery is desired, decisions about yield among entries can be made without drying samples. The phenotypic correlations among traits as estimated from the half-sib family experiments were generally similar (Table 11) to those computed in the gain test.

In summary, the results from the two years of Half-Sib Family Evaluation experiments indicate sufficient genetic variance in populations of wild rice to permit gain from selection. The heritabilities for yield and agronomic characters are high and substantial progress appears likely from selecting within existing varieties. No strong phenotypic correlations were evident which would hinder the breeder in development of earlier, shorter, higher yielding cultivars.

The results from the Evaluation of Gain From Selection experiment were not as encouraging, particularly with respect to selection for yield. Some modifications in procedures will need to be implemented before the selection scheme will be effective.

4) Intergenotypic Competition Study (J. Hernandez)

In production wild rice is grown in paddies as a single variety. In our yield trials, we grow several varieties very close to each other. In all other agronomic crops, experiments have been conducted to determine if varieties can be yield tested without border rows. The answer depends on whether one variety is adversely (or favorably affected) by a neighboring variety when border rows (and skip rows in wild rice) are not used. We have designed this study to evaluate intergenotypic competition in wild rice using four varieties (Netum, M3, K2 and Voyager) to be evaluated over a two-year period. Each variety is planted as a single row and on either side of the row at a 1-foot spacing is a row of either the same variety, or different varieties. For example, Voyager is grown surrounded by itself, two rows of Netum, two rows of K2, two rows of M3 or combinations of the three other varieties. We used plots 12 feet in length and end-trimmed them to 10 feet at harvest. The treatment combinations were planted in a randomized complete block design with six replicates at Grand Rapids (spring-planted) and Excelsior. The plots at Grand Rapids provided usable data but land leveling demonstrations at the 1982 field day caused obvious variation in three of the six replicates. The plots at Excelsior were destroyed by disease and/or heat damage.

Table 13. Analysis of variance of characters measured in the one-row intergenotypic competition experiment; Grand Rapids, spring planted, 1983.

Source of Variation	Pf	Mean Squares					
		Grain Dry Weight	Plants per Plot	Stems per Plot	Plant Height[1/] A	Plant Height[1/] B	% Dry Weight
Replications	5	1494.01	1078.17	457.07	1563.74	2594.96	13.41
Treatments	(27)	(743.70)	(217.25)	(576.68)	(578.20)	(557.35)	(11.30)
Within K2	6	249.00†	28.19	85.04	427.65	151.75	1.63
Within Voyager	6	265.54†	51.36	249.78†	170.65	156.27	1.63
Within M3	6	66.66	7.16	62.32	402.43	223.93	1.09
Within Netum	6	324.05*	37.60	372.16**	360.44	255.27	1.30
Among Pop'ns	3	4882.80**	1706.63**	3651.52**	2481.46**	3441.71**	90.40**
Error	135	128.52	57.52	119.90	265.44	270.50	1.63

[1/] A and B plant height measured on opposing ends of the plots.

†,*,** Mean squares significant at .90, .95 and .99 probabilities, respectively.

Table 14. Effects of intergenotypic competition in single-row plots of wild rice.

Tested variety	Competing variety	Stems per plot	Grain dry weight	Height	Competition rating[1]	Mean competition rating
			(gm/plot)	(cm)	(dry wt.)	
K2	K2	75.5	76.0	190	1	1.50
"	Voyager	75.3	64.5	194	3	--
"	M3	83.5	75.4	194	2	--
"	Netum	72.2	62.1	182	4	--
Voyager	K2	100.2	80.6	180	2	--
"	Voyager	98.3	82.0	174	1	1.75
"	M3	89.0	70.4	184	3	--
"	Netum	91.2	64.7	176	4	--
M3	K2	92.8	99.2	200	1	--
"	Voyager	91.0	93.2	202	2	--
"	M3	92.0	89.2	199	4	3.25
"	Netum	88.0	91.3	197	3	--
Netum	K2	105.7	90.2	191	2	--
"	Voyager	98.2	94.0	196	1	--
"	M3	88.7	78.8	200	4	--
"	Netum	97.3	85.3	205	3	3.50
LSD (.0.5)		10.5	10.9	16 cm		

[1] Rating of 1 indicates a weak competitor and 4 is a strong competitor.

Date were recorded at Grand Rapids on plant height, stand count, stem count, and yield of grain (threshed with the Vogel thresher). Results of analysis of variance of the data are presented in Table 13. There are a total of 28 treatments (combinations of test rows and competing rows). Differences among treatments were significant for grain weight, plants per plot, stems per plot and two measures of plant height. However, most of the difference was due to the comparison among populations and not due to competition.

There were seven test rows of each variety, surrounded by various competing varieties. If competition was significnat, the sources of variation listed as Within K2, Within Voyager, etc. will be statistically significant in Table 13. Netum showed significant competition effects as measured by dry weight yield and stems per plot. Voyager and K2 showed some differences at a lower level of probability (P = .90). Plants per plot, and height were not affected by competition and % dry weight computations indicated that maturity was not affected either.

The effects of intergenotypic competition are illustrated in Table 14. The tested variety is given in the first column. The competing variety is given in the next column. Results for stems per plot, yield and height are given. For an example, see that Netum was tested with Netum as the competing (border) rows and yielded 85.3 grams per plot. When Voyager was the competing variety, Netum yielded more than when it bordered itself (94.5). This is an indication that Netum is a stronger competitor than Voyager. The confirming evidence can be seen when Voyager was tested against itself and yielded 82 grams per plot. When Netum was the competing variety, the Voyager test row yielded 64.7 grams per plot. Netum was much taller and later than Voyager and thus has an advantage in competing for light and possibly some other environmental factors.

We have attempted to classify the varieties using a competition rating for the competing variety in the presence of the four tested varieties (Table 14) and the mean competition rating. The highest yielding plot shows the "least" competition within each test series. Many of the differences are not statistically significant. The experiment will be repeated in 1984 and more conclusive results are expected. We are confident that we will show significant competition. We are not sure that the competition effects will require that we use border rows.

5) Grain Dry Weight Accumulation in Voyager and K2

The objective of this experiment was to develop information on the rate of accumulation of grain dry weight in wild rice and to determine if the rate of accumulation differed between the variety K2 and the variety Voyager, an early maturing version of K2 (Voyager's development was described in the 1982 Minnesota Wild Rice Research Progress Report). I was specifically interested in the stage of maturity prior to harvest and tried to sample the span of time from approximately 55% dry weight to maximum (after the normal harvest date).

The experiment was spring-planted in 1983 at Grand Rapids in a randomized complete block design with six replicates. A split-plot restriction was used; the two varieties were used as whole-plot treatments and dates of sampling of yield (green weight, dry weight) formed the sub-plot treatments. Twenty 10-foot long rows spaced 1-foot apart were planted for each variety in each replicate. Starting at approximately 50% dry matter in the grain, two row-plots were harvested at 2 to 3 day intervals for eight sampling dates or until plots were no longer usable. Grain dry weight and % dry weight were the characters for which analyses were computed. Results are presented in Figures 2 and 3.

Voyager was first sampled on August 11 and K2 on August 15. We started at our desired moisture level with K2 (see Figure 3 but Voyager was slightly above 60% dry weight at the onset. The rate of dry weight increase can be seen in Figure 2. Notice that Voyager had higher dry weight grain yield than K2 from the outset until day 86 (Aug. 25). Points on the graph are averages from the 6 replicates at each harvest date. A severe wind storm badly damaged nets and poles at the research station. The decline in yield is obvious starting at this point. By Aug. 31, Voyager was yielding slightly less than K2, and Figure 3 shows that % dry weight for Voyager was about 70% compared to about 66% for K2.

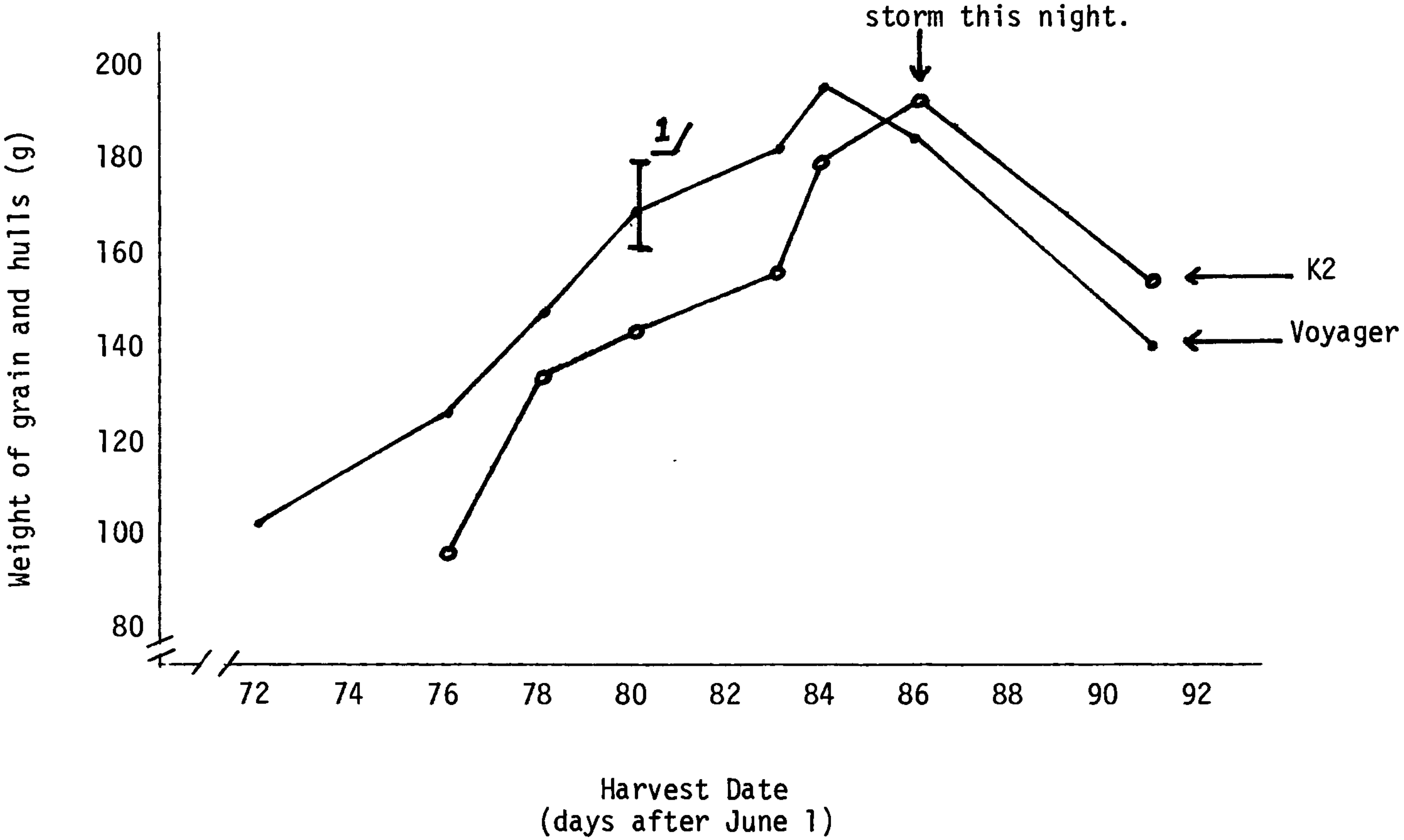
The figures illustrate two points: a) Voyager was clearly earlier and higher yielding that K2 when the two varieties were harvested on the same date, until Voyager reached maturity and probably started to shatter; b) the rate of dry weight accumulation in the two varieties was practically identical. Ignoring the last sample date (after the storm) the varieties were accumulating dry weight yield at about 36 lbs per acre of dry grain (and hulls) per day and were gaining % dry weight at the rate of .5 of a percentage point per day. The experiment will be repeated next year.

6) Discussion of Selections and Experiments in Progress.

Experimental populations M3 x Netum, Voyager bottle brush, and Dwarf x Johnson were included in the 1983 advanced yield trials (Tables 1-5). M3 x Netum has been tested for 3 years now and continues to look good but does not offer any advantage over Voyager. We will plant half-sib families from M3 x Netum and attempt to improve its yield capacity by half-sib selection procedures evaluated by Wally Palm. His results were not as promising as we had hoped but the method used may still permit us to improve the yield of M3 x Netum by selection.

Dwarf x Jns was developed by crossing Dwarf plants with Johnson. It has been random mated 3 generations. We selected plants of three types from the maintenance nursery last year. The types were a) early, short plants, b) early, medium height plants, and c) medium maturity, medium height plants. The families from the three types will be evaluated for yield and bulk populations of each type will be tested. We would like to select a medium maturity medium plant height variety which would fall somewhere between Dwarf and Voyager in earliness and height, but which would have much better yield than the present Dwarf population. Mr. Tri Hutomo will be investigating the populations as part of his Master of Science research.

Figure 2. Change in grain dry weight of Voyager and K2 as a function of harvest dates.



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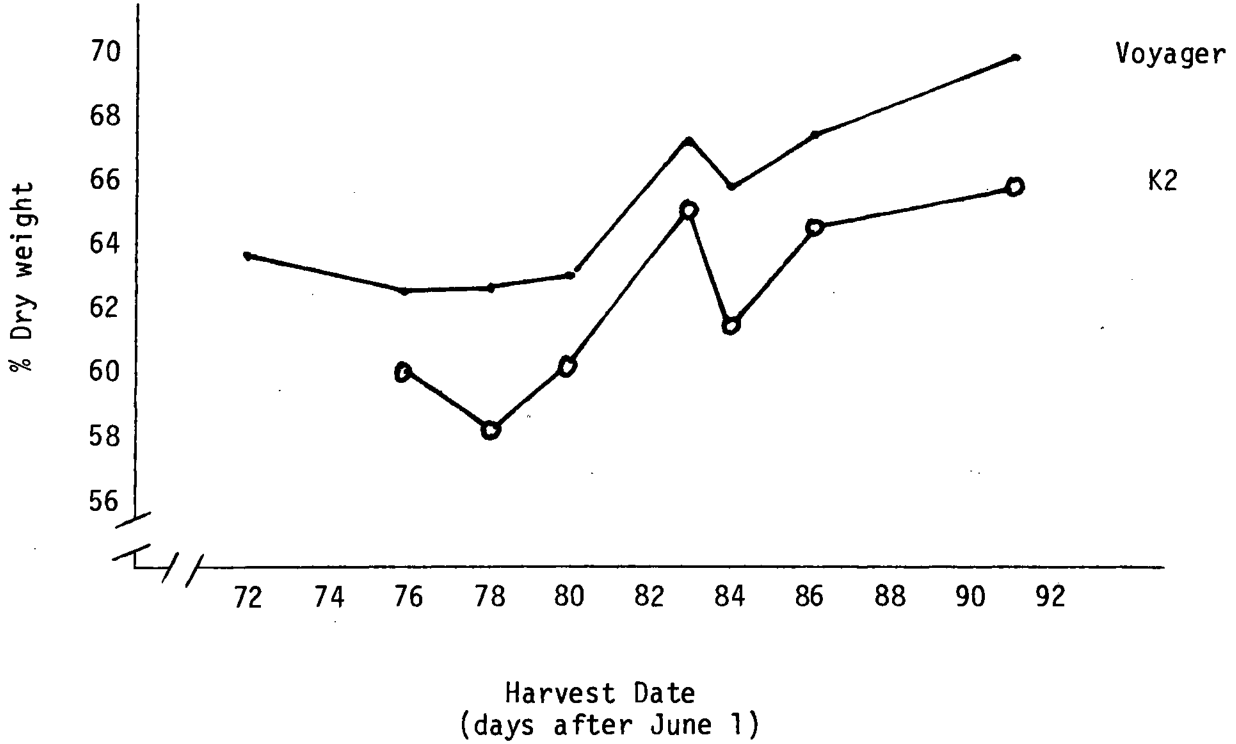
[1] LSD (.05) between any two means.

Figure 3. Change in percent dry weight (grain) of Voyager and K2 as a function of harvest date.



The Voyager bottle brush population will be used in genetic studies to test the association between the panicle type and its apparent male sterility. We also will pursue possible ways to use the male sterility in population crosses, and we would like to develop information on the pollen sterility system itself.

We have initiated a selection experiment within the Voyager variety. We selected plants which appeared to have several tillers which matured more uniformly than normal plants. (We call this selection for tiller synchrony of maturity). If we can decrease the difference in time of maturity of the main-stem and the first 2 or 3 tillers, we believe we can significantly reduce shattering losses in cultivated wild rice. Mr. Patrick Hayes will be conducting this research for his Ph.D. thesis.

Acknowledgements:

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WILD RICE DISEASE RESEARCH

A PROGRESS REPORT

January 26, 1984

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INTRODUCTION

The areas of investigation during 1983 centered on the following:

1) Laboratory and greenhouse evaluation of several egosterol-inhibiting systemic fungicides (Imazalil, Nuarimol, RH-5781, and RH-5787) for their efficiacy in controlling *Bipolaris oryzae*, causal organism of fungal brown spot.

2) Field testing of the systemic fungicide halacrinate (Tilt^R) and chlorothanil (Bravo) for control of foliar fungal pathogens and the initiation of registration (Sec. 18) for their use on cultivated wild rice in Minnesota.

3) Completion and publication of studies involving fungicide resistance and adaptation by *B. oryzae* to finapanil and Dithane M-45^R, respectively.

4) Initiation of host-parasite studies (early infection events) of *B. oryzae* on various cultivars on wild rice.

5) Continuation of epidemiological and crop-loss research of fungal brown spot.

6) Continued investigation of the interaction between soil fertilization, plant nutrition and fungal brown spot severity.

7) Influence of stand density and the severity of fungal brown spot.

MATERIALS AND METHODS

I. Chemical Control.

A. *Laboratory fungicide screening*. The fungicides Hacrinate, (1-bromo-5 chloro-quinolin-8 yl. acrylate). Tilt. CIBA-GEIGY Corp., RH-5787 and RH-3756 (Experimental chemicals), Rohm & Haas Co., and Triphenyltin hydroxide. Supertin, Griffin Corp. were each separately amended into flasks containing 100 ml. Potato Dextrose Broth (PDB) at 0, 0.1, 1.0, 5.0, 10.0 and 100 ug/ml. active ingredient. Each flask was inoculated with a mycelial disc (20 mm.) of *Bipolaris oryzae* (Breda de Haas) Shoemaker, causal organism of fungal brown spot of wild rice (*Zizania aquatica* L.). The flasks were incubated for 5, 10, and 15 days on a reciprocating shaker (80 cycles/min.) at 24 C. The resulting mycelial mat was removed using a funnel containing filter paper (Whatman No. 1) attached to a suction flask. The mycelia was dried at 55 C. for 24 hrs. and immediately weighed. Each treatment was replicated six times. The experiments were repeated twice.

B. Influence of stand density on the incidence and severity of fungal brown spot (In cooperation with Dr. E. Oelke). Refer to Dr. Oelke's report in Minnesota Wild Rice Research - 1983.

C. Effect of various "carrier" materials on the germination and emergence of wild rice seed. (In cooperation with M. McDlellen). Poor seedling stands have been a re-occurring problem in both greenhouse and field experimental plots. Oats have been generally used in the past as a "carrier" material with wild rice seed to help ensure even and controlled sowing. However, seedling stands have, at times, been less than expected on the basis of seed lots germination studies. Therefore, preliminary work was begun in 1983 to determine if wild rice seedling emergence could be affected by the use of various types and amounts of "carrier" materials.

The following treatments were utilized:

Carrier	Amount (cc.)
1. Barley	250, 500 and 700
2. Oats	250, 500 and 700
3. Perlite	500
4. Sphagnum	500
5. Vermiculite	500
6. Wild rice seed, alone	250

In treatments 1 through 5, above, 250 cc. of wild rice seed was incorporated into the various carrier materials. The mixtures were then separately sown onto the surface of a non-pasteurized greenhouse soil mix sand, loam and peat (1:1:1), topped with approximately 1.25 cm. of silica sand and then flooded. Greenhouse temperature was maintained at 24 2 C. with an 18-hour photoperiod.

Results: Initial results indicate that regardless of the volume of barley or oats used, the number and percent of germinated seed and resulting seedlings were less than sowing with wild rice alone (Table 8). Perlite, sphagnum and vermiculite resulted in 63, 69 and 99% emergence when compared to the control. Therefore, it appears that the use of a non-nutrient, inert and inorganic carrier, such as vermiculite may greatly enhance seed germination and seedling emergence.

Limited soil plating for the determination of the kind and numbers of soil-borne fungi (Plant Pathological Methods, by Tuite) utilizing PDA amended with 200 ug/ml. of both streptomycin-sulfate and penicillin-G indicated high numbers (1 x 10^5/gm dry soil) of *Alternaria, Fusarium, Aspergillus* and *Geotrichum* spp. However, soil from the areas surrounding wild rice seed planted with either perlite sphagnum or vermiculite had fewer numbers of the above fungi (1 x 10^2 - 1 x 10^3/gm. dry soil) and less population diversity with Aspergillus spp. being most absorbent. This work must be repeated

(Continued on page 65-71)

Rate of q ai/ha)	Nos.	Applications - Treatments
280	2[a]	1[b]
	A	B
420	C	D
560	E	F
0		
Inoculated	G	--
Uninoculated	H	--

a Boot (7/12/83) and flowering (7/28/83)

b Boot (7/12/83)

Each treatment consisted of six replications.

Inoculation of plants. Wild rice plants, cultivar K-2 were inoculated with three different single spored isolates of *B. oryzae* (Bo 64, Bo 11GU and Bo67). The fungus was maintained on Difco potato dextrose agar (PDA) slants at 5 C. and increased on PDA petri dished at 24 C. under 12 hours of near ultraviolet light for seven days. Spore suspensions were inoculated into pre-moistened mixture of oats, barley and wheat (5:5:1) in stainless steel trays (16 x 57 x 70 cm.). Aqueous inoculum suspensions containing approximately 1×10^6 macro- and micro- conidia per ml. were sprayed on plants with the sprayer previously described. Fungal inoculations occurred on 8 and 16 July 1982. Secondary infection from artificial and naturally occurring inocula did occur.

Plant evaluation. All plots were hand harvested on August 18, 1983, eighteen days after the last fungicide application. The grain from each plot was dried at 55 C. for 72 hours, dehulled and weighted. An average disease index scale of increasing severity from 1 (no leaf lesions) to 5 (50% leaf area covered) was determined at late flowering and harvest for each test plot. Frozen stem, leaf and seed materials (Bravo study) from the treatment consisting of three applications at 2.34 l/ha (2 pt/a) were sent to Dr. S. Miyazaki, Pesticide Research Center at Michigan State University in East Lansing, Michigan, for residue analysis.

Mean data in all tests were compared with Duncan's multiple range test at the 5% level of significance.

D. Evaluation of triphanyltin hydroxide to control Sclerotium oryzae (Formally, Helminthosporium sigmoideum), causal organism of wild rice stalk rot. Triphenyltin hydroxide (Super-Tin) was amended to 100 ml.

PDB at either 0, 1, 5, 10 and 100 ug/ml. Each flask was inoculated with 20 mm. disc from the outer edge of a 15-day-old mycelial mat of *S. oryzae* growing on Potato Dextrose Agar (PDA). The inoculated flasks were incubated on a reciprocating shaker at 24 C. for 5, 10, and 15 days. The resulting mycelial mats were removed, dried, and weighted as previously described under the "Laboratory Fungicide Screening Section" of this report. Each treatment consisted of six replications.

Greenhouse studies involving the fungicide Super-Tin were initiated to determine if the chemical was phototoxic to wild rice and to examine its ability to control stalk rot. The following treatments were utilized:

Super-Tin l/ha (oz./A)		Inoculated	Uninoculated
0	(0)	A	B
0.4	(5)	C	D
0.8	(10)	E	F
1.6	(20)	G	H
3.2	(40)	I	J

Plants of the variety Netum were inoculated with *S. oryzae* during the tillering stage of plant development (main stem only) by securing a piece of naturally infected wild rice stem sections 0.6 cm. (1/4 in.) with parafilm plastic to the main stem at the stem-water surface. Plants were sprayed with the fungicide at the water listed above. The plants were incubated for two months at 24 2 C. and evaluated for foliar symptoms of chemical phototoxicity and disease control.

Stalk rot disease severity was determined using the following disease index:

1 = Healthy - no visible symptoms
2 = Light - infection on leaf sheaths only
3 = Medium - infection on outer culm surface
4 = Moderate - infection penetrating to inner culm surface
5 = Culm shriveled, mycelial growth and/or sclerotia present

II. Pathogen(s) Studies

A. *Role of Fusarium moniliforme as a possible foliar pathogen of Wild rice - preliminary investigation*. Five single conidial isolates from seed of the variety Netum were cultured on PDA under near UV light at 24 C. for 30 days. Conidia were removed from the culture by washing with sterile distilled water. The resulting conidial suspension (1×10^4 conidia/ml.0) was sprayed on plants of the variety Netum (jointing stage) to run-off. The plants were immediately placed in a misting chamber with 100% RH at 24 + 2 C. for three days under an 18-hour photoperiod. Plants were evaluated for disease 14 days after inoculation. Twenty plants were inoculated while an equal number served as uninoculated controls.

(Continued on page 72-81)

B. Control of seed-borne fungi. To determine if storage wild rice seed in fungicide prior to planting would reduce seed and embryo-borne fungi and thus improve seed germination and subsequent seedling vigor. The systemic fungicides carboxin (5, 6-Dihydro-2 methyl-1, 4 oxythiin-3-carboxanilide), Vitavax and oxycarboxin (5,5-Dihiydro-2 methyl-1, 4 oxathiin-3-carboxaniclide-4, 4-dioxide) both produced by Uniroyal Chemical Corp. were incorporated into lots of cultivar K-2 at 0.31, 1.25 and 2.45 g/45.4 kg. (2,8, and 16 oz./100 lbs.). Each experiment and unit consisted of approximately 1,000 seeds in one liter of deionized water and was replicated four times. The seeds were incubated at 4 C (39 F.) and treated with the particular fungicide and dosage 10, 20, and 30 days prior to planting. After each given incubation period, the seeds were washed in distilled water for 5 min., soaked in sterile distilled water 5% sodium hypochlorate bleach (80:20) for 10 min., rinsed with sterile water, dried with sterilized filter paper and then, placed on 5% Water Agar (WA) each containing 10 seeds/plate. Plates were incubated at 24 C. in the dark for five days. Each treatment plate consisted of ten replicates.

C. Field evaluation of chlorothalonil (Bravo) and halacrinate (Tilt). A section of a research paddy at the University of Minnesota North Central Experiment Station at Grand Rapids, Minnesota, was planted with the cultivar K-2 wild rice (*Zizania palustris*) utilizing a randomized block design. Sixteen 9 m^2 (100 ft.^{2}) blocks, each containing 3-4 plants/m^2 (blocks sown on 4/28/83). The fungicide was applied with a backpack CO$_2$ pressurized sprayer system delivering 300 ml. of material at 40 psi. per plot, which is equivalent to a rate 331 l/ha (35 gal/A. Chlorothalonil was first applied at 2.34 l/ha (2 pt./A.) at late -boot to early flowering on 7 July 1983. The 2nd and 3rd sprays were made at 10-day intervals following the first application. The plots were inoculated with three mixed isolates of *Bipolaris oryzae*, 24 hours, preceding the first fungicide application. An overhead misting system was utilized for 72 hours following chemical application at 3 min/ 15 min. intervals to help insure infection and cycling of the pathogen. The controls consisted of inoculated plots sprayed with water only. All treatments were replicated six times.

The halacrinate evaluation trial consisted of six 9 x 9 (30 x 30 ft.) blocks, each consisting of eight rows approximately 1 m. apart. Each row contained 120 cultivar K-2 wild rice plants at 10 cm. (4 in.) intervals (thinned 6/14/83). The fungicide was applied at 280, 420 and 560 q ai/ha (4, 6 and 8 of ai/A) utilizing the following schedule:

(Continued on page 62-63)

and statistically analyzed using varied soils before definitive conclusions and recommendations can be made.

D. Host parasite studies of *Bipolaris oryzae* on wild rice. The pre-infection events of *Bipolaris oryzae* on the wild rice cultivars K-2, Johnson and the nonhost *Asplenum nidus* were investigated. The number of germ tubes per conidium, germ tube length, presence of swollen hyphal tips, stomatol or direct penetration, and presence of discolored host cells was noted at 8, 12, 18, 24 and 48 hours after inoculation. A significant difference in percent conidial germination and found between the two wild rice cultivars and the nonhost at 8 hours after inoculation. Preliminary findings suggest that the behavior of the conidia on the leaf surfaces is varied. Nonetheless, six major events were identified: germination, germ tube elongation, development of hyphal branches, penetration of the host tissue, hyphal growth within host cells and emergence of hyphae from host tissue. Three means of penetration were observed: directly through the epidermis with appressoria formation, through stomata and cell junctures without appressoria formation. Penetration of nonhost was not observed. After infection, hyphae can emerge from stomatol openings or cell junctures. Hyphal adhere to the leaf surfaces with the help of a mucilaginous sheath. Further analysis of the data will determine whether there are significant differences between the behaviors of conidia on K-2 and Johnson.

III. Crop Loss and Epidemiology of Fungal Brown Spot.

A. Yield reduction experiments. During the summer of 1983, a study was conducted at the Rosemount Experiment Station to determine the effect of varied levels of fungal brown spot on wild rice yields.

A randomized complete block design with five blocks and six replications per treatment was employed for this study. Treatments consisted of four levels of disease and a nondiseased control. The cultivar K-2 was planted in 7 x 10 foot experimental plots to a final density or approximately two plants per square foot and three tillers per plant. Fungal brown spot was initiated in the plots at the boot stage of plant development by inoculation with *Bipolaris oryzae*. As the season progressed, fungicide applications were applied to the bot-to-1/2-elongation treatment and the boot-to-milk treatment starting at 1/2 grain elongation and medium milk growth stages respectively. The treatments designated as Light and Heavy were diseases from the boot stage until harvest. Disease severity was lower on the Light treatment than on the Heavy treatment. Control plots were kept free of disease throughout the season by timely application of the protective fungicide, Mancorzeb (Dithane M-45, flowable).

Figure 1. indicates the fungicide application and spore inocula-

tion schedules used in this experiment. At harvest the inner 4 x 7 foot area of each plot was picked by hand, dried (140 F.), dehulled, graded and weighed. Kernels of grade three and above were used in determining yields. Yield reduction is expressed as a comparison to control yields. A second experiment was performed at the Rosemount Experiment Station to assess the effect of cultivar on disease-related yield reductions. Four cultivars of wild rice, K-2, Johnson, Netum and M3, were used in the experiment. A split block design incorporated four replications of a randomized planting of each of the four cultivars in each whole plot. Four, fourteen-foot-long rows, one foot apart, designated as subplots, were planted to each cultivar in each whole plot. One half of each block (a whole plot) was designated as a control; the remaining half was the diseased treatment. Controls were kept free of disease by the timely use of mancozeb (Dithane M-45, flowable) at the rate of 2 pints per acre. Diseased whole plots were inoculated once in the boot stage of plant development. Disease severity ratings were taken on each of the upper three leaves on each cultivar subplot individually. At harvest, the center 10 feet of the inner two rows were collected by hand, dried, the panicles counted, threshed, graded and weighted. Yield reduction of each cultivar is expressed as the percent loss due to disease compared to the yields from the control plots of the same cultivar.

An experiment was conducted at the Grand Rapids Experiment Station to determine the effect of varied levels of Nitrogen on the rate of fungal brown spot disease increase in the field and to quantify the degree of disease associated yield reduction with nitrogen levels. Four levels of nitrogen, 0, 30, 60 and 90 pounds per acre, were applied prior to spring planting. Within each level of nitrogen four plots, 8 ft. x 10 ft., were designated as controls. Four similar plots were designated as disease plots. Control plots were sprayed with the protective fungicide mancozeb (Dithane M-45) in an attempt to keep them disease free. Disease plots were twice inoculated with a mixture of *Bipolaris oryzae* isolates to induce disease. At harvest the inner 4 ft. x 8 ft. area was harvested by hand, panicle counted, threshed, dried, hulled graded and weighted. Finished rice of grades greater than three were pooled for final yield determination, expressed on a dry weight basis. Yield reduction of disease treatments are expressed as a comparison to control yields at the same level of nitrogen.

Five commercial fields, equipped with hygrothermographs for the recording of air tempaerature and humidity, were surveyed during the growing season. Five additional fields, not containing weather instruments were also surveyed for disease. Generally fungal brown spot disease was very light in the early spring on floating leaves. In fields receiving regular applications of mancozeb (Dithane M-45) the disease severity stayed lower than most years. The data gathered is being used in development of a model to provide short-term forecasting of wild rice bown spot dissease epidemics.

Results: The first experiment described above, the fungal brown spot yield reduction study involving four epidemics and a control treatment, showed that yield reductions were not affected by decreased disease due to fungicide applications during or after the milk stage of plant development. The fungicide application applied at the 1/4 grain elongation stage of plant development did affect disease-related yield reduction in a positive manner. Figure 2. shows the boot-to-1/4-elongation treatment had a 39 percent yield reduction, while the boot-to-milk treatment had a 74 percent yield reduction. The analysis of variance test indicated that the treatments were highly significant in reducing yields, with the F test equal to 0.0000000003. The disease severity readings taken are shown in Figure 3.

The results of the second experiment described above, involving four cultivars of wild rice, are shown in Figures 4. and 5. The experiment indicates that cultivars vary in their yield reduction response to disease. The analysis of variance test shown in Figure 5. shows the factor cultivar is very significant. Under the disease conditions of this experiment, Johnson and K-2 cultivars gave yield reductions of 90 percent, when compared with the control. Netum and M3 cultivars gave yield reductions of 76 and 71 percent respectively when subjected to the same inoculum pressure.

A comparison of the yield reduction associated with an epidemic of fungal brown spot and varied levels of nitrogen shows decreasing yield reductions with increasing amounts of nitrogen applied. Figure 6. shows a range of yield reductions from 32 percent on the zero pounds nitrogen plots to 15.5 percent on the 90 pounds nitrogen per acre plots. Regression analysis of the percent yield reduction against the rate of nitrogen fertilization shows nitrogen levels signifcantly affect yield reduction. The regression equation, percent yield reduction = 32.3 - 0.184 x nitrogen (pounds/acre), was derived from this data. The correlation coefficient, a measure of the strength of the relationship between the two factors, was very high 0.998. Nitrogen appears to lessen the impact of disease on yield reduction, although the data indicates control yields are not improved at nitrogen rates of more than 30 pounds per acre.

Figure 1. 1983 Fungicide and Inoculation Schedule for Fungal Brown Spot Yield Reduction Study.

Month	Day	Boot	Heading	Light	Heavy	Control
7	22					D
7	24	1	1	1	1	
7	30					D
8	3	D				D
8	12	D	D			D
8	13			1	1	

Figure 2. Comparison of Wild Rice Yields Associated with Four Epidemics Initiated at the Boot Stage of Wild Rice Growth and Curtailed at Later Stages.

	TREATMENTS				
Infection Boot to -	1/4 Elong.	Milk	Ripe Light	Ripe Heavy	Control
Yield (lb. D.W./Acre)	303	131	154	127	499
% reduction of control	39±14	74±24	69±13	74±27	0±8

Figure 3. Average Percent Leaf Area with Brown Spot for Each Treatment in the Fungal Brown Spot Yield Reduction Study.

Date		Plant Stage	Disease Progress Boot to -------				
Mo.	Day		1/2 Elong.	Milk	Ripe (Light)	Ripe (Heavy)	Control
7	24	Boot	0%	0%	0%	0%	Trace
8	5	1/2 Elong.	2/5/60a	2/5/60	2/5/60	2/5/60	Trace
8	13	50% mid Milk					
		50% late Milk	2/7/60	6/16/97	4/13/95	5/18/100	Trace

a = top leaf/second leaf/third leaf

Figure 4. Comparison of Average Yields and Yield Reductions for Four Cultivars of Wild Rice Subjected to Equal Disease Pressure.

Cultivar	Control Yield	Disease Yield	% Reduction
Johnson	471a	46	90
K2	622	60	90
M3	639	184	71
Netum	693	167	76

a = weight as lb. dry weight per acre.

Figure 5. Analysis of Variance for Cultivar Fungal Brown Spot Study.

Term	Degrees of Freedom	Sum of Squares	Mean Square	F Test
Blocks	2	15569.0	7784.3	ns
Disease	1	0.1452 E+07	0.1452 E+07	**
Error - 1	2	12171.0	6085.5	
Cultivar	3	0.1092 E+06	36392.0	***
Disease x Cultivar	3	17807.0	5935.8	ns
Error - 2	12	32436.0	2703.0	
Total	23	0.1639 E+07		
Grand Average	1	0.3114 E+07		

Model: Y(ijk) = B(i) + D(j) + E1(ij) + DC(jk) + E2(ijk)
Where: & = yield, B = blocks, D = disease state, C - cultivar
ns = not significant
** = significant at 0.01 level
*** = significant at 0.001 level

Figure 6. Comparison of Yield Losses Associated with an Epidemic of Fungal Brown Spot over Varied Levels of Nitrogen.

	Level of Nitrogen			
	0 lb/A	30 lb/A	60 lb/A	90 lb/A
Yield (lb. D.W./Acre)				
Control Treatment	506	585	549	574
Disease Treatment	342	431	429	485
% Reduction of Control	32.4	26.3	21.9	15.5

B. Wild rice growth stage assessment. The wild rice - fungal brown spot interaction resulting in yield loss is strongly dependent upon the stage of plant development. Disease developing during or after the milk stage appears, from experimental evidence, to produce no significant affect on yield. Likewise, the stage of onset of disease has been shown in experiments done in 1982 to be important in affecting yield losses. To go one step further, the amount of disease in the field must be tied to the stage of plant development for the purpose of predicting losses and fungicide application decision-making.

Wild rice stages of development have in the past been limited to 12 categories: (1) emergence, (2) floating leaf, (3) second aerial leaf, (4) early tillering, (5) mid tillering, (6) jointing, (7) boot, (8) early flowering, (9) mid flowering, (10) late flowering, (11) early grain formation and (12) maturity. Crop stage Assessment was limited to determination of which of the above categories best represented the majority of the plants in the field. This method of description is too crude for the determination crop development for generation of expected losses and fungicide spray decisions. Refinements have been made to the more simple categories of plant development to allow more precise information concerning the actual development of the wild rice crop.

The wild rice growth characteristics, Figure 7., have been used to determine the growth stage of plants. These characteristics have been grouped into ten categories: Germination, Seedling and Early Growth, Tillering, Stem Elongation (Jointing), Booting, Influorescence (Flowering), Grain Development, Milk, Dough and Grain Ripening. Within each category, plant characteristics have been described and given a "decimal code." Two digit numbers are used, representing each characteristic, to record plant growth characters in the field.

Wild rice in a single field at any given time may be in several different stages of development. When this is the case, percentages of each decimal combination are used to portray the field. As an example, a field on June 7 might be described as: 30% (11), 40% (11, 13), 30% (13, 15). This would indicate 30 percent of the plants in the field were still submerged, 40 percent were in the single floating leaf stage and 30% had one partially aerial leaf (bow stage).

Figure 7. Wild Rice Growth Stages.

0) Germination

01 dormant
03 shoot emergence
05 primary root emerged
07 secondary root initiated

1) Seedling and Early Growth

11 submerged leaves
13 first floating leaf
14 second floating leaf
15 bow stage (partially aerial)
16 first aerial leaf
17 second aerial leaf
19 third aerial leaf

2) Tillering

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

3) Stem Elongation (Jointing)

20 nodes not separated
31 separation of nodes initiated
33 1-inch or more node separation
35 3-inch or more node spearation
37 6-inch or more node separation

4) Booting

41 Influorescence visible when dissected
43 boots just visibly swollen
45 boots fully swollen
47 first awns visible

5) Influorescence (Flowering)

50 first spikelet just visible
51 stigmata exposed
52 1/4 femal portion emerged
53 1/2 femal portion emerged
54 3/4 femal portion emerged
55 femal portion emerged
56 male portion emerged
57 anthers nondehiscent
58 anther dehiscence initiated
59 complete anther dihiscence

6) Grain Development

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

7) Milk

73 early milk
75 medium milk
77 late milk

8) Dough

83 early dough
85 medium dough
87 late dough

9) Grain Ripening

91 grain easily dented by thumbnail
93 first seeds turning brown
95 grain slightly dented by thumbnail
97 1/2 panicle's seed darkened
99 entire panicle dark and hard

A typical field on July 30 might be described as: 50% (25, 45, 47), 20% (25, 55), 30% (25, 59). This field was described as having 50 percent of the plants with fully swollen boots and the first awns visible; 20 percent of the plants were releasing pollen. All of the plants appear to have had two tillers in addition to the main stem.

Tillers of wild rice plants lag the main stem in development for most of the season. Generally, plant characters are assessed only on the main stem and the development of tillers is disregarded. If it appears the tiller will produce harvestable grain, those tillers should be taken into account in plant development assessment. This is especially important in thin first-year stands.

Most of the characters used to describe wild rice development may be assessed by examining the outside of the plant. Determination of some characteristics require more effort than others. Finding germination characteristics requires one to physically remove plants from the field for examination. Grain elongation is relatively easy to assess. Wild rice elongates in the developing husk before filling in girth. Grain elongation can be seen externally, aided by light passing through the translucent husk. Because grain individually elongates and matures at different rates on a single panicle of wild rice, estimates of this characteristic are based on the average development of the grain found on a panicle.

The determination of stem elongation (jointing) requires the dissection of the stems of several plants with a knife. At the time of stem elongation, premature flowers will have developed. Immediately below these immature flowers there is a node where stem elongation growth occurs. The distance between the top and bottom nodes when fit into one of the node separation groups provides the character description. External visual characters in conjunction with the internal findings should provide a good estimate of the crop's development with only a small number of plants dissected.

(Continued on page 64)

RESULTS

I. Chemical Control

A. Laboratory fungicide screening. Halacrinate (Tilt) at a concentration of 1.0 ug/ml controlled the growth of *B. oryzae* (12% of control) quite well through day five (Table 1-A). At 5 ug/ml and higher there was no evidence of growth throughout the entire experimental period. Rohm and Haas experimental fungicide RH-5787 (Table 1-B) appeared to be superior in controlling the growth of *B. oryzae* than RH-3756 (Table 1-C). RH-5787 resulted in good growth inhibition at 5.0 ug/ml at days five and ten with growth being 28 and 62% of the control. At concentrations 10 ug/ml and higher, little or no growth occurred through day fifteen (Table 1-B). Tilt was determined to be the most effective fungicide in controlling the growth of *B. oryzae* in culture and thus, was also field evaluated in 1983. Rhom and Haas' RH-5787 will be field tested in 1984.

B. Effect of carboxin and oxycarboxin in controlling seed-borne fungi. Carboxin (Vitavax) and oxycarboxin (Plantvax) at all concentrations, except for oxycarboxin at 10.8 g/kg (0.16 oz. 1 lb.) at day twenty, resulted in significantly less seed-borne fungal growth than the untreated control at the end of ten days (Table 2). After twenty days of fungicide treatment, only the oxycarboxin at 1.4 and 5.5 g/kg and carboxin at 10.8 g/kg resulted in less fungal growth. However, with a 30-day treatment of either carboxin or oxycarboxin, there was significantly less fungal growth than the control, regardless of chemical dosage (Table 2). It should be noted that there appears to be a reduction in overall seed-borne fungi with increasing storage periods. This preliminary experiment indicates that seed treatment with either chemical at the dosages examined thirty days before planting appears to reduce total number of seed-borne fungi.

To determine if the carboxin and/or oxycarboxin affected seed germination, approximately 600 seeds from each treatment were tested for germination. After 10 and 20 days of fungicide exposure, only carboxin at 10.8 g/kg and oxycarboxin at 1.4 g/kg resulted in germination equal to the untreated control (Table 3). All other fungicide treatments through day 20 resulted in a significant reduction in seed germination (Table 3).

In conclusion, even though carboxin and oxycarboxin can reduce total numbers of seed-borne fungi, there was no general increase in seed germination, except with oxycarboxin at 1.4 g/kg. The costs for such chemical treatment(s) appears to outweigh any possible benefits. The problem of low seed germination in storage appears at this time to be unrelated to the presence of seed-borne fungi. However, further investigation of seed storage and its effects on germiantion and seeding vigor is being planned.

C. Full evaluation of chlorothalonil (Bravo) and halacrinate (Tilt). Chlorothalonil at 2.3 l/ha (2 pt./a) with two or three sprays resulted in a significant decrease in disease severity and increased yield (Table 4). The percent leaf area infected at two and three applications were 216 (196) and 226 kg/ha (177 lb./A) dried gram (Table 4). Lesion sizes regardless of treatment were not significantly different from each other.

The effect of Bravo on fungal brown spot severity and yield for 1982 and 1983 at the University of Minnesota North Central Experiment Station at Grand Rapids, Minnesota, is summarized (Table 5). All rates and numbers of Bravo applications resulted in decreased disease severity and increased yields. The rate of 2.3 l/ha (2 pt./A) at either two or three applications gave good cost and biologically effective fungal brown spot control (Table 5). Depending upon favorable IR-4 residue analysis, Minnesota Department of Agriculture and grower support, it is hoped that Bravo may receive a label for use on cultivated wild rice in Minnesota in 1984.

Tilt, an egosterol fungicide having both protectant and eradicant (curative) activity was demonstrated to be extremely effective in controlling fungal brown spot (Tables 6-A, 6-B and 7). One application of Tilt at 123 (1.8), 185 (2.6) and 247 g/ha (3.5 of /A) resulted in significant yield increases of 15, 34 and 49 percent, respectively, over the untreated control (Tables 6-A, 6-B). Two applications at 123 (2.64) and 185 g/ha (2.64 of /A) resulted in a significant increase of 26 and 34 respectively, over the control (Tables 6-A and 6-B).

The severity of fungal brown spot infection was reduced by Halacrinate (Tilt) at all dosages and numbers of applications (Table 7). The percent of leaf area infected on the upper, middle and lower leaves was notably reduced with one application at 247 g/ha (3.5 of /A). Generally, the greater the number of applications and dosages resulted in less leaf area being affected by the fungus (Table 7). Therefore, Tilt appears to be quite effective in controlling fungal brown spot under conditions of artificial inoculation, irrigation (enhanced disease incidence and severity) and utilizing small experimental plots. Further field testing and evaluation will be done in 1984.

D. <u>Greenhouse evaluation of Triphenyltin hydroxide (Super-Tin) to control fungal stalk rot</u>. Triphenyltin hydroxide (Super-Tin) was very effective in controlling the mycelial growth of <u>Sclerstium oryzae</u> in culture at all concentrations of the chemical. The following table is a summary of the results:

Incubation (days)	Growth as Compared to Control (%) Super-Tin (ug/ml)				
	0	1	5	10	100
0	-	100	100	100	100
5	-	42	37	37	25
10	-	22	30	25	17
15	-	32	27	20	15

Super-Tin at 100 ug/ml was most effective in inhibiting the growth of S. oryzae. This concentration would be realistic in the field because Super-Tin is classified as a protectant compound. However the fungicide may penetrate into the host tissue of young seedlings (sugarbeet and rice), it may be an effective agent to kill or inhibit the growth of S. oryzae. However, our results did demonstrate some activity against the fungus in the limited greenhouse testing; field evaluation of the chemical has not been performed. The results are summarized below:

Treatment l/ha (of/A)	Disease Severity	Phytotoxicity No./Total
0 (0)	4.0	0/30
0.4 (5)	2.3	0/30
0.8 (10)	2.4	0/30
1.6 (20)	2.2	6/30
3.2 (40)	2.0	7/30

All fungi treatments did reduce the severity of stalk rot; however, all plants did become infected. The recommended label rate of stalk rot control on rice is approximately 0.8 l/ha (10 oz./A). Increasing above this rate did not improve the fungicides's performance. In fact, evidence of chemical toxicity was noticeable at both 1.6(20) and 3.2 l/ha (40 oz./A). Further work with this fungicide is in order before any definitive conclusions can be made regarding its efficacy against S. oryzae on wild rice under field conditions.

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TABLE 1. EFFECT OF VARIOUS FUNGICIDES IN POTATO DEXTROSE BROTH (PDB) ON THE GROWTH *BIPOLARIS ORYZAE*, CAUSAL ORGANISM OF FUNGAL BROWN SPOT OF WILD RICE.

A. Tilt (Halacrinate)

Incubation (days)		Average Dry Wt. (µg)				
		T.H (µg/ml)				
	0	0.1	1.0	5.0	10.0	100
0	20	20	20	20	20	20
5	570	280	70	20	20	20
10	750	530	200	20	20	20
15	870	820	340	30	20	20

B. RH·5787 (Rohm & Haas Experimental)

Incubation (days)		Average Dry Wt. (µg.)				
		RH·5787 (µg.ml)				
	0	0.1	1.0	5.0	10.0	100
0	20	20	20	20	20	20
5	600	680	670	170	20	20
10	740	810	720	460	25	20
15	880	870	800	720	24	20

C. RH·3756 (Rohm & Haas Experimental)

Incubation (days)		Average Dry Wt. (µg.)				
		RH·3756 (µg/ml)				
	0	0.1	1.0	5.0	10.0	100
0	20	20	20	20	20	20
5	580	570	600	190	62	20
10	740	760	730	380	65	20
15	860	840	810	680	65	20

TABLE 2. EFFECT OF CARBOXIN AND OXYCARBOXIN ON SEED-BORNE FUNGI OF CULTIVAR K2 WILD RICE.

Treatment (g/kg)		Percent Fungal Growth[x]		
		Days		
		10	20	30
Carboxin				
	1.4	30b[y]	47d	23b
	5.5	40c	58c	23b
	10.8	23a	37b	20b
Oxycarboxin				
	1.4	40c	37b	30c
	5.5	43c	30a	33c
	10.8	53d	40c	13a
Control		53d	43c	37d

[x] Percent fungal growth--based on 100 seeds per treatment

[y] Means in each column followed by the same letter are not significantly different at P=05 level, according to Duncan's multiple range test.

TABLE 3. EFFECT OF CARBOXIN AND OXYCARBOXIN ON SEED GERMINATION OF CULTIVAR K2 WILD RICE

Treatment (g/kg)	Percent Germination[x]		
	Days		
	10	20	30
Carboxin			
1.4	39^{2}[y]	41^{2}	41^{a}
5.5	41^{a}	44^{a}	47^{b}
10.8	47^{b}	43^{a}	48^{b}
Oxycarboxin			
1.4	44^{a}	57^{c}	54^{c}
5.5	43^{d}	46^{b}	49^{b}
10.8	41^{a}	48^{b}	49^{b}
Control	49^{b}	56^{c}	48^{b}

[x] Percent germination. Based on approximately 600 seeds per treatment period.

[y] Means in each column followed by the same letter are not significantly different at P=05 according to Duncan's multiple range test.

TABLE 4. EFFECT OF CHLOROTHALONIL AT 2.31/ha(2pt/a) ON FUNGAL BROWN SPOT SEVERITY AND RESULTING YIELD IN 1983.

NOS. APPLICATIONS	LEAF AREA INFECTED (%)	LESION SIZE	SEED WEIGHT kg/ha(lb/a)	YIELD INCREASE OVER CONTROL (%)
A. 3	2.5	4.6[a]	226(205) a[x]	16a
B. 2	5	5.2[a]	226(196) b	11b
C. Control	17	5.2[a]	195(177) c	

[x]Means in each column followed by the same letter are not significantly different at P=05 according to Duncan's multiple range test.

TABLE 5. EFFECT OF CHLOROTHALONIL AT VARIOUS RATES ON DISEASE SEVERITY AND YIELD ON CULTIVAR K2 WILD RICE INFECTED WITH FUNGAL BROWN SPOT IN 1982 AND 1983.

TREATMENTS RATE kg/ha(lb/a)	NOS. APPLICATIONS	LEAF AREA INFECTED	YIELD kg/ha(lb/a)
A. 4.6(4)	4	1.3	220(198)
	3	3.1	216(194)
B. 3.5(3)	3	2.5	210
	4	2.0	204(184)
C. 2.3(2)	4	1	191(172)
	3 (1982)	<1	183(165)
	3 (1983)	1	226(205)
	2 (1983)	5	216(196)
D. Control	0 (1982)	21.2	163(147)
	0 (1983)	17.0	195(177)

TABLE 6-A. EFFECT OF TILT^{R} ON THE YIELD OF WILD RICE INFECTED WITH FUNGAL BROWN SPOT CAUSED BY *BIPOLARIS ORYZAE*.

TREATMENT (g ai/ha)	YIELD (Dry Wt.)[x] (kg/ha)	YIELD OVER CONTROL	% OF CONTROL
A. 280			
1 appl	98.7b	13.2a	15.4a
2 appl	108.3c	22.8b	26.0b
B. 420			
1 appl	114.9d	29.4c	34.0c
2 appl	114.6d	29.1c	34.0c
C. 560			
1 appl	129.0c	43.5d	50.0d
D. Control	85.5a		

[x] Means in each column followed by the same letter are not significantly different at P=05 according to Duncan's multiple range test.

TABLE 6-B. EFFECT OF TILT^{R} ON THE YIELD OF WILD RICE INFECTED WITH FUNGAL BROWN SPOT CAUSED BY *BIPOLARIS ORYZAE*.

TREATMENT (oz ai/A)	YIELD (Dry Wt.)[x] (lb/a)	YIELD OVER CONTROL	% OF CONTROL
A. 4			
1 appl	217b	29a	15d
2 appl	238c	50b	26b
B. 6			
1 appl	253d	65c	34c
2 appl	252d	64c	34c
C. 8			
1 appl	281e	93d	49d
D. Control	188a		

[x] Means in each column followed by the same letter are not significantly different at P=05 according to Duncan's multiple range test.

TABLE 7. EFFECT OF TILT^R ON THE SEVERITY OF BROWN SPOT ON WILD RICE CAUSED BY <u>BIPOLARIS ORYZAE</u>.

TREATMENT oz ai/A(g ai/ha)	NOS. APPLICATIONS	LEAF AREA AFFECTED (%) UPPER	MIDDLE	LOWER	LESION SIZE(mm) UPPER	MIDDLE	LOWER
A. Control		6	16	35	3	4	4
B. 4 (280)	1	4	16	31	3	3	4
	2	2	9	24	3	3	4
C. 6 (420)	1	3	10	25	3	3	4
	2	2	7	20	3	3	4
D. 8 (560)	1	1	4	9	2	3	4

TABLE 8. EFFECT OF "CARRIER" ('FILLER') MATERIAL WHEN ADDED TO WILD RICE SEED (CULTIVAR K-2) AND SUBSEQUENT EMERGENCE.

TREATMENT (CARRIER CC.:250 CC. WILD RICE)	NOS. OF WILD RICE SEEDLINGS	PERCENT EMERGENCE COMPARED TO CONTROL
Barley		
250	62	10
500	70	27
750	68	26
Oats		
250	104	41
500	52	20
750	30	12
Perlite		
500	161	63
Sphagnum		
500	176	69
Vermiculite		
500	255	99
Control		
Seed alone[a]	256	

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[a] Approximately 500 seed per 250 cc.

COMBINE HARVEST STUDIES - 1983

J. J. Boedicker, C. E. Schertz, K. Wichettapong, M. C. Lueders

This research has been directed toward 1) development of a procedure for defining the performance of the combine cylinder for selected operating parameters and 2) selected tests to assist in defining the performance. Data from previous years from use of complete combines have been difficult to interpret because of the limitations on the use of the comnbine, the limitations of the range of operating conditions and the interaction of other combine components on the component selected for investigation. These difficulties, experienced in actual harvest operations in obtaining good qualilty data in amounts sufficient to adequately characterize combine performance over suitable ranges in relevant machine and crop parameters, prompted the development of substitute equipment and procedures for obtaining these data. Because combine performance is so heavily influenced by performance characteristics of the threshing cylinder, it was decided to limit current investigations to evaluation of cylinder performance.

The wild rice harvest research in 1983 was directed toward the development of a procedure and the completion of selected tests in relation to spike-tooth cylinder concave performance.

Equipment

Equipment for testing cylinder performance consists of 1) a specially modified, grain combine and 2) a conveyor used for feeding plant material into the combine. Figure 1 is a schematic of the combine and conveyor arrangement.

The combine, an IH Model 303, is the same one adapted earlier for use in studying performance in separation of wild rice grain at the cylinder-concave, transition grate, and along the straw walkers. This model was selected for that purpose because of (1) its similarity to the IH Model 915, a combine make and model used by many wild rice growers in Minnesota; (2) its roughly 42 percent shorter cylinder length and similarly smaller straw walker area which permits the use of smaller, more manageable quantities of plant material in performance tests than would be required for similar tests with a Model 915, and (3) its ready availability. Those modifications included removal of the sieves and the troughs below the straw walkers; placement of a mult-compartmented tray below the cylinder concave, transition grate, and walkers; and the addition of a moveable shutter canvas above the tray which permitted tracking of a particular portion of plant material on its travel through the combine. For purposes of evaluating cylinder performance alone, the shutter canvas is omitted and the tray has only one partition located below the rear portion of the transition grate. A baffle affixed within the combine extending from below and near the rear of the transition grate to near the top of the tray partition helps insure an accurate division of material separated before and after this point within the machine. (A second baffle and tray partition could be added if desired to isolate material separated at the concave from that separated at the transition grate.) Slide rails extending from the rear of the combine facilitate removal and insertion of the tray.

The combine, less header and undershot conveyor, is equipped with an inclined sheet metal chute for feeding plant material directly to the combine cylinder. The chute is enclosed on all sides to confine plant material as it moves down the chute. The upper part of the chute is attached by arms from brackets bolted to the combine frame. The bottom edge of the chute is attached with brackets and wire to the upper front edge of the cylinder concave where a close fit is provided to prevent leakage of any loose grain before it can be drawn into the threshing elements.

This combine has capability for use in testing the influence of practically all major cylinder design and performance related parameters which can normally be varied in the set-up and operation of a conventional combine in wild rice. These include cylinder and concave type, cylinder peripheral speed, concave setting at both the front and rear, as well as various crop parameters such as cutting height and feed rate. However, because changing the cylinder and concave type requires considersable time to execute this year's work was restricted to the spike-tooth cylinder-concave system.

The conveyor, a 30 ft. long dual-chain flight elevator, is positioned in front of and directly in line with the combine. Material, moved up the conveyor, is dropped straight into the chute on the combine. A feed table is located on one side near the lower end of the conveyor to aid in loading material onto the conveyor. By varying (1) the amount of plant material used in a particular series of test runs, (2) the distance on the conveyor over which material is loaded, (3) drive pulley sizes and (4) engine speed, wide variations in equivalent feed rate and feed time can be achieved. However, for a given feed time, as much of the conveyor length as practical is utilized to help insure more uniform flow of material to the cylinder.

Test Procedure

For each test run, a predetermined weight of wild rice plant material is cut and carried by hand to the combine and conveyor located outside the field. Material used for each run is cut immediately before the run to minimize drying and its possible effects on threshing characteristics of the grain.

Plant material is loaded onto the conveyor by hand. Placement is made as uniformly as practical over a prescribed distance on the conveyor. Stalks are arranged with panicles (heads) generally in the up position as this orientation has been found to promote smoother flow of material off the end of the conveyor, down the chute and into the cylinder than a butt-first or random placement. To help further insure smooth flow, stalks are bent (crimped) by hand during the loading operation to reduce their strength with the longest stalks being crimped at 4 or 5 points distributed over the length of the stalk. This crimping also simulates to some extent the mechanical damage stalks would sustain in the cross auger chamber and undershot conveyor of a combine in actual harvest.

Before each actual test run following a change in one or more machine parameters, at least one "dummy" or fake run is made in an attempt to equilibrate the combine at the new settings(s). One function of a dummy run is to stabilize the grain storage at various points within the combine on both the quantity and condition (broken kernels) of grain separated from actual test-run plant material. Another is to condition the cylinder and/or concave for the new settings to help insure that the amount and condition of plant material that might be stored (caught) on these components at the beginning of an actual test run would be similar to that stored on the components at any time during equivalent steady state operation at the particular test conditions.

As the material goes through the combine, some grain (and pieces of other plant material) falls into the tray compartment below the concave and transition grate, some falls into the tray compartment below the straw walkers, and the rest, principally long straw, is discharged from the end of the walkers into a catch cloth. When walker discharge has ceased, the machine is stopped and the tray; is slid out the rear of the combine. For actual test runs, material in each tray compartment along with the material discharged from the walkers is collected and placed in separate plastic bags and saved for analysis. For dummy runs this material is discarded.

Analysis of Output Material

All plant material collected in cylinder performamnce tests is analyzed for both loose grain and unthreshed grain content. Separation of loose grain is accomplished with a small water-bath sesparator (shown in schematic in Figure 2) in a process similar to that developed in 1981 and 1982. This was a large mechanically-assisted, water-bath separator for use in separating loose grain from combine walker discharge samples obtained in actual wild rice harvest operations. The process takes advantage of specific gravity (and resulting buoyancy) differences between straw and loose kernels of wild rice.

The water-bath separator, shown in schematic in Figure 2, consists of a rectangular steel tank with an open top, a liner sewn from plastic window screen conforming to the shape of the tank and fastened to a rectangular wood frame supported on the top edge of the tank, and a 1 inch square wire mesh faced, wood-framed plunger (with handles) sized slightly smaller than the inside length and width dimensions of the tank. In using the separator, which is filled nearly to the top with water and with the screen liner in place, plant material is placed into the water and gently agitated first by hand and then with the plunger, confining the straw below the water surface. When agitation is stopped but with the straw still confined below the plunger face, floaters are skimmed from the surface. The plunger is then taken out of the tank allowing the straw to rise to the surface where it too is removed. Finally, the sinkers are retrieved by removing the screen liner from the tank and emptying its contents onto a table. The individual sinker, floater, and straw fractions are then placed in separate cloth bags and dried under low temperature to preserve the material for analysis later at a laboratory.

At the laboratory, the dried plant material is analyzed to determine the amount of grain in each fraction on a dehulled, oven-dry basis. All material is analyzed similarly, except that the straw fractions, assumed to contain unthreshed kernels only, are first put through a plot thresher. Grain from the sinker amd floater fractions is further analyzed to determine breakage as an indication of cylinder induced grain damage. For this purpose, a kernel or kernel piece is assumed to be broken if it is retained in a cup separator with 1/4 inch diameter cups.

Tests Conducted

Because this year marked our first attempt at isolating the combine cylinder-concave system for detailed investigation some of this year's research was directed toward investigating the suitability of the procedure. This consisted of special runs to determine (1) requirements for establishing "steady state" conditions within the test system and (2) the influence of input duration (feed time) on performance results.

In addition to the tests for assessing suitabiity of procedures, two experiments were conducted to investigate the influence of selected parameters on cylinder-concave performance. One experiment was designed to determine the influence of cylinder speed and concave adjustment. Another experiment was designed to determine the influence of feed rate and concave adjustment. A three-second input duration was used for both experiments. Cylinder performance is compared principally on the bases of threshing efficiency, grain separation at the concave, grain damage and straw breakup. Straw breakup is evaluated on basis of nongrain material passing through the concave.

Results

Preliminary results from the experiment to determine the influence of cylinder speed and concave adjustment on cylinder-concave performance are contained in Table 1. The word "preliminary" is emphasized since final processing and analysis are not completed. Data for the percent broken kernels included in Table 1 are depicted graphically in Figure 3 to more clearly illustrate the results that were obtained. Conclusions from this experiment are that:

- percent broken kernels increased sharply as cylinder speed increased.
- concave setting had little influence on percent broken kernels at low cylinder speeds.
- percent separation at the concave varied directly with cylinder and concave spike-teeth overlap.
- grain separated at the concave had a lower percent broken kernel content than grain going onto the walkers.

Results from the experiment to determine the influence of feed rate and concave adjustment on performance are contained in Table 2. preliminary conclusions from this experiment are that:

- percent separation at the concave varied inversely with feed rate.
- percent separation at the concave increased with the amount of cylinder and concave spike-teeth overlap.

The percent separated at the concave is higher than that observed in previous threshing and previous studies with 1/2 to 1 minute input durations and subsampling within that time period. The reason for this difference is not known.

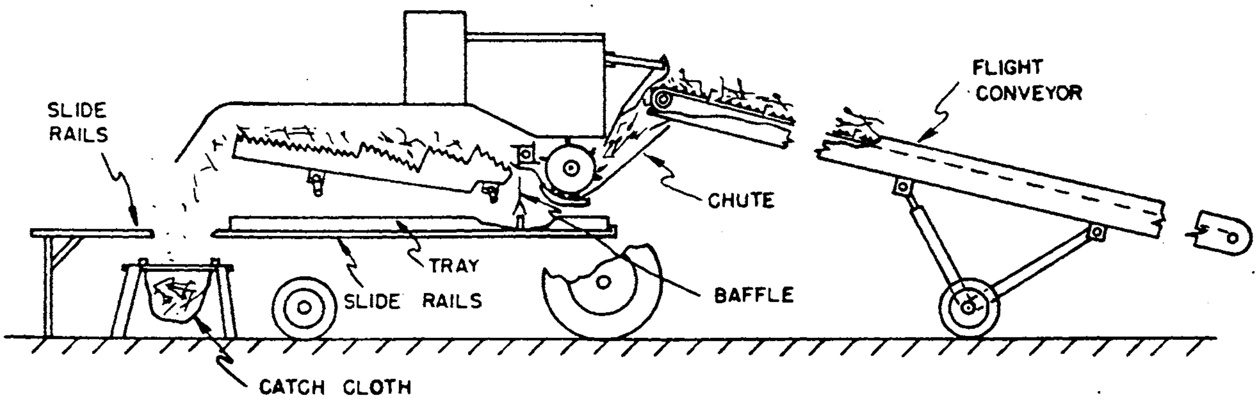

Figure 1. Schematic of combine and conveyor equipment.

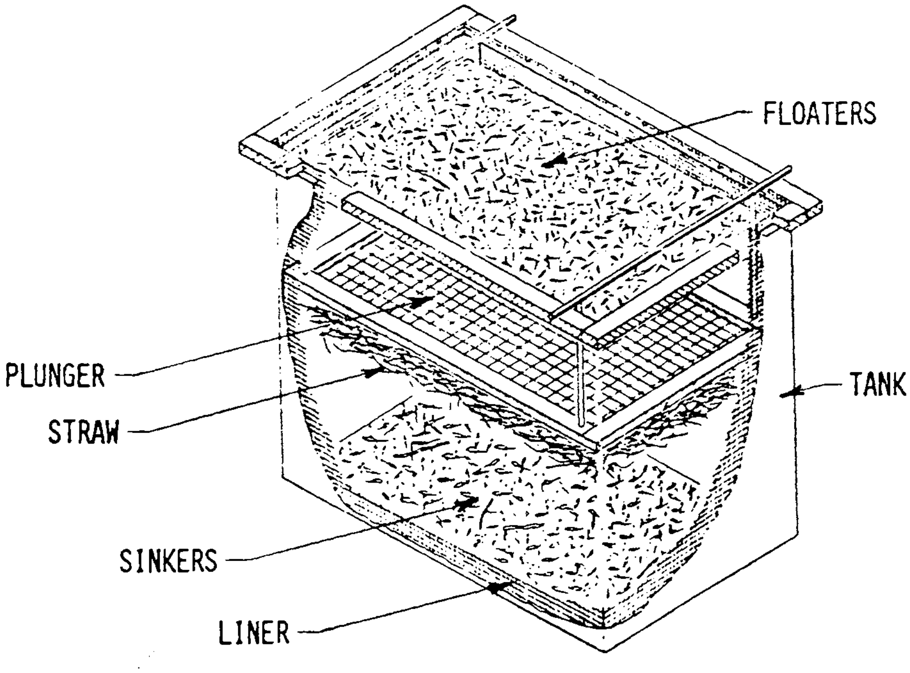

Figure 2. Schematic of hand-operated, water-bath separator.

Table 1. Influence of cylinder speed and concave setting on broken kernels and separation at concave. (Feedrate equivalent to 250 lb/min for a 4 ft. wide cylinder.)

	Concave Adjustment			Broken Kernels (< 1/4")		
Cyl. speed, RPM		Setting No.	Overlap of Spike-teeth, 1/16 inch	Grain through concave, %	Grain onto walker, %	Grain separated at concave, % of total grain
350	close	0	22	3.9	5.0	86
↓		3	18	3.9	2.6	84
		5	14	4.2	4.6	83
	wide	10	9	3.8	3.0	80
610	close	0	22	4.6	5.8	88
↓		3	18	3.9	4.8	86
		5	14	3.8	4.6	86
	wide	10	9	4.2	5.8	82
870	close	0	22	6.8	11.2	88
↓		3	18	7.2	12.6	88
		5	14	8.4	11.0	87
	wide	10	9	6.0	9.2	85
1125	close	0	22	19.4	24.7	88
↓		3	18	14.9	18.4	87
		5	14	14.0	18.2	88
	wide	10	9	13.8	16.0	82

Table 2. Influence of feedrate and concave adjustment on grain separated at concave (cylinder speed - 780 RPM; duration of run - 3 sec.).

Concave adjustment			Percent grain separated at concave			
			Feedrate equivalent for 4-ft. wide cylinder, lb/min			
	Setting No.	Overlap of spike-teeth, 1/16 in.	125	250	500	Avg.
wide	5	14	88	86	80	85
intermediate	3	18	90	87	81	86
close	0	22	91	87	84	87
		Avg.	90	87	82	

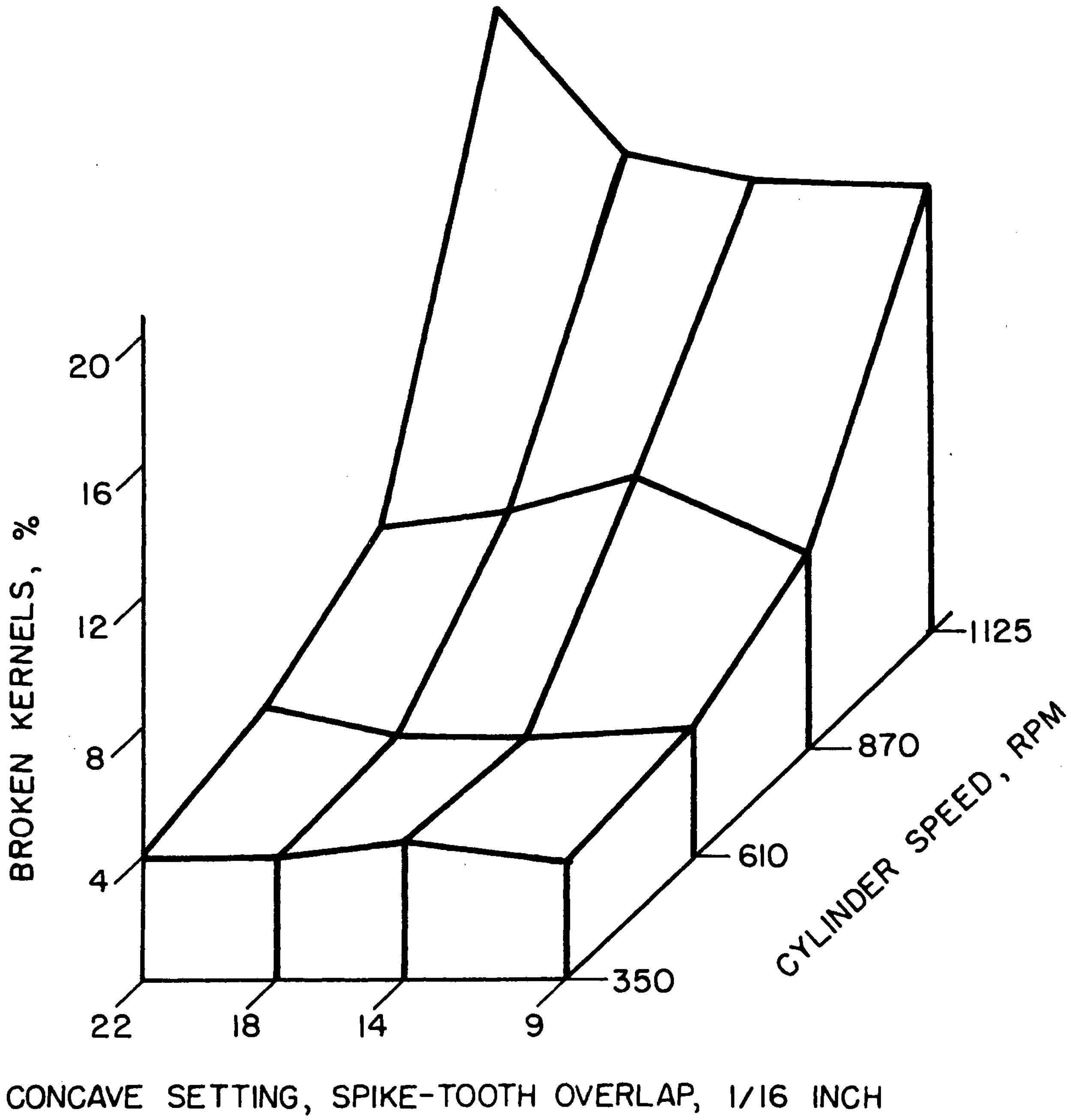

Figure 3. Broken kernel percentage for grain through concave as influenced by concave setting and cylinder speed.

Wild Rice Parching and Hulling Research

John Strait, E. J. Donaldson, Arni Sigurdson, Mitchell Voehl and J. J. Boedicker

Wild rice processing research conducted during 1983 included: (a) collection of performance data from the prototype continuous flow parcher (b) the design and construction of an experimental huller for use with the continuous flow parcher and the collection of performance data therefrom (c) laboratory studies related to hulling and including the influence of material properties and operating variables upon kernel damage and hull removal.

Continuous Flow Parcher

Operation and Results

The continuous flow parcher was operated approximately 306 hours during the period of August 22 to September 22, 1983. An estimated 310,000 pounds of green wild rice were parched.

Green wild rice was parched at the rate of about 1000 pounds per hour. Resident time was 40 minutes. The temperature of the superheated steam leaving the heat exchanger was maintained at 295°F to 305°F. Stack gas temperature was observed to be within the range of 565 to 585°F. Temperature of the gas leaving the furnace was limited to about 1400°F in order to adequately protect the heat exchanger tubes.

Table 1 is a summary of performance data collected during six test runs. Moisture contents of the green rice to the parcher varied from about 38% to 54% while the feed rate, after the first 25 hours of operation, was maintained close to 1000 lbs/hr. The flowrate of parched rice was about 600 lbs/hr at moisture contents ranging from 3.2 to 6.6% on a wet basis. Test 3 was completed during a period when the agitators were not in operation. Propane consumption varied from 9.2 to 10.7 gallons per 1000 lbs of green rice parched.

The mechanical systems of the continuous flow parcher worked well throughout the entire season. Operation of the parcher was essentially automatic from the time green rice was dumped into the feeder. The automatic level device which controls the operation of the primary feeder malfunctioned occasionally--about once in 24 hours of operation. Consideration is being given to replacing that control with a mechanical sensor which would probably be more reliable.

In last year's report we stated that it is perhaps unlikely that the continuous flow parcher can produce kernels as resistant to breakage as those from a well operated rotary drum parcher where the resident time is much longer and provided the rice is in good condition when parched. We still believe this to be true. However, if the rice from the continuous flow parcher is hulled with rolls of 65 to 70 durometer neoprene, equal or less breakage and improved hulling efficiency can be obtained as compared to rice parched in rotary drum parchers and hulled with 80-90 durometer rubber rolls.

Hulling

Much of our research for 1983 involved hulling experiments to reduce kernel damage and improve hulling efficiency. Laboratory experiments were continued and an experimental huller was designed and constructed.

Experimental Huller

An experimental huller (UM) was constructed and used at Deerwood throughout the 1983 processing season. The huller incorporated several experimental features and systems. There were two sets of hulling rolls. One set was the 62 durometer hypalon rolls used on last year's model huller. The second set had 62 durometer neoprene rolls. An oscillaing multipath feeder designed to give uniform flow of rice across the entire length of the rolls was included in the huller design. A distributor was provided to receive the parched rice from a belt conveyor and direct all the parched rice to either set of rolls or to divide the flow to simultaneously feed both sets. A roll conditioning system was provided which was to be used frequently to maintain the rolls in good operating condition. A soft rubber covered baffle was provided to intercept the hulled rice rather than allow it to be thrown against a hard surface. An oscillating pan received the hulled rice for delivery to the conveyor.

Each set of rolls was provided with a separate electric motor and drive system. To recondition a set of rolls, all the parched rice was directed to the other set and the reconditioning system operated. After the rolls were trued they were stopped for adjustment of the clearance by the use of feeler gauge stock. Clearance was usually set at .005".

All the wild rice from the continuous flow parcher and a considerable amount from the Deerwood rotary drum parchers was hulled in the experimental unit. An estimated 250,000 pounds of finished rice was hulled by the UM huller.

Performance data were collected on the experimental huller and the Deerwood huller at intervals throughout the season with wild rice parched in both the continuous flow and rotary drum parchers.

Table 2 shows results from individual tests. The key at the bottom of Table 2 explains the abbreviations used. Aspiration was provided for rice through the Deerwood huller by a nozzle over the discharge conveyor and by an aspirator unit located downstream from the scarifiers. Therefore, samples collected prior to scarification may have been aspirated by the nozzle over the conveyor as indicated or collected directly from the huller. None of the rice parched in the continuous flow parcher and none hulled in the UM huller was scarified. The results shown in Table 2 exhibit a considerable degree of variability which would be expected considering the many variables which are difficult to control under plant conditions. Variations in the condition and adjustment of the hulling rolls and the moisture content of the parched rice and the condition of the rice prior to parching are examples of factors which are present and tend to cause seemingly inconsistent results and make it difficult to compare the performance of different processes and systems. Table 3 is a summary of the results shown in Table 2 arrived at by first averaging replicated samples and then by calculating overall averages.

As shown in Table 3 in 6 tests with rice parched in the rotary drum parchers and hulled in the Deerwood huller, there was an average of 13.8% broken and 8.4% unhulled kernels for samples collected directly from the huller. For samples collected after scarification and aspirated at the conveyor and after the scarifier, there was an average of 17.4% broken and 0.7% unhulled kernels. The scarifiers were achieving nearly complete hulling but causing considerable kernel damage. Rice from the rotary drum parches hulled in the UM device had fewer broken kernels but hulling efficiency was not as good as with the Deerwood huller. Wild rice from the continuous flow parcher and hulled by the neoprene rolls of the UM huller and with no aspiration averaged 10.8% brokens and 3.8% unhulled. With the hypalon rolls there were 6.7% brokens and 13.9% unhulled. Kernel damage was slightly greater but the hulling efficiency was considerably better with the neoprene rolls as compared to the hypalon rolls.

A test was completed in which the feedrate to the UM huller was varied. The rice was from the rotary drum parchers and had a moisture content of 6.6%. The results are shown in Table 4 and in Figure 1. As the feed rate increased from 350 to 700 pounds per hour brokens increased from about 6.5 to 9.0 percent while the unhulled kernels increased from about 5 to 6.5 percent.

All the experimental systems incorporated in the huller performed in a satisfactory manner. Some minor alterations need to be made. New neoprene rolls will be ordered with the hardness specified to be as close as possible to 67 durometer.

Laboratory Experiments

The 1982 report described a hulling device for use in laboratory experiments where two 10-inch diamter by 20-inch long standard huller rolls were trued and six strips of neoprene of varying degrees of hardness were fastened to the rolls with an adhesive. The strips were 3 5/16" wide and about 3/8" thick. A feeder that could be positioned along the length of the rolls over any one of the test strips provided means to hull and collect comparable samples from each of the strips. Five neoprene strips of 50, 56, 66, 73 and 86 durometer and a 66 durometer silicone rubber strip were used. The finished rolls measured 10 18" in diameter. Roll clearance was adjustable.

Lots of K-2 and Netum were parched in the laboratory continuous flow parcher. The parched rice was divided into test samples and hulled by successive sections of the rolls. Roll clearance was varied from .002" to .020". After cleaning, broken and unhulled kernels were sorted and weighed. Results were included in last year's report.

In early 1983, a similar set of rolls were constructed. Five hypalon and two neoprene strips were assembled onto a steel core. The rolls had hypalon strips of 50, 60, 69, and 76 durometer hardness and a 60-76 durometer combination strip (a 60 durometer strip was placed on one roll opposite a 76 durometer strip on the other roll). Two neoprene strips of 66 and 81 durometer were also included. The finished diameter of the rolls was 11 3/8". The thickness of the covering material after truing was 5/16".

Tests with the newly constructed rolls were completed using medium and heavy fractions of wild rice parched in the laboratory continuous flow parcher. The samples were prepared and analyzed as in the 1982 experiments.

Results of these experiments are shown in Figures 2 through 7 for roll clearances of .002", .005", .01", .015" and .020".(1) The results show that for a given roll clearance setting, as the durometer increases the incidence of brokens increases while the percent of unhulled kernels decreases. For a given durometer, as the roll clearance increases, the percent of broken kernels decreases but the percent of unhulled kernels increases. These results are consistent with results reported from 1982 research.

Broken and unhulled kernels are plotted against roll clearance in Figures 2 and 3 for a heavy fraction. Figures 4 and 5 show similar graphs of results obtained with parched wild rice from a medium fraction. The graphs show consistent relationships previously observed and noted in the preceding paragraph. A best roll hardness must be a compromise between kernel damage and hulling efficiency. One cannot maximize both performance criteria in the same huller. A comparison of Figures 2 through 5 with last year's results show similar trends although absolute values differ. All test data to date show that neoprene is superior to hypalon for hulling wild rice when all performance criteria are considered.

Figure 6 shows the influence of hardness upon hulling characteristics of hypalon. Figure 7 shows the influence of roll clearance upon the performance of 66 durometer neoprene rolls. Based upon all our studies to date we believe that huller rolls of 67 durometer neoprene would give the best possible overall results.

A second set of laboratory experiments are in progress to study the influence of relative roll speeds upon hulling characteristics of the laboratory huller equipped with 12-inch diameter, 62 durometer polyurethane rolls. An analysis of the results to date indicate a relationship as shown in Figure 8 for roll spacings of approximately .003" and .007". These are very preliminary results and should be interpreted in that light.

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(1) Numerical data in tabular form for 1982 and 1983 tests will be supplied upon request.

Table 1. Performance data collected from the continuous flow parcher during 1983 processing season.

		Rice to Parcher		Rice from Parcher		Propane Used	
Test No.	Date	M.C. % W.B.	Feed Rate lb/hr	M.C. % W.B.	Flow Rate lb/hr	Gal/hr	Gal/ 1000 lb Green
1	8/23	40.0	711	3.0	440	7.6	10.7
2	8/26	44.0	1026	4.2	600	9.7	9.5
3(1)	8/26	39.6	848	5.2	540	8.7	10.2
4	8/31	54.0	1036	6.6	510		
5	8/31	47.2	1055	4.8	585	10.8	10.3
6	9/7	38.4	943	3.2	600	8.7	9.2

(1) Agitators were not in operation.

Table 2. Results of hulling and parching experiments with 1983 crop at Deerwood with wild rice parched in the Deerwood rotary drum parchers and the U of M continuous flow parcher.

						Moisture Content				Finished Rice		
Date	Time	Test	No. of Samples	Parcher	Huller	Green	Parched	Aspirated	Scarified	Hulled Whole, %	Broken %	Unhulled %
8/25	4:30 P.M.	10	1	R.D.	Dwd.		8.4	Yes	No	84.6	8.7	6.8
		11	3	R.D.	Dwd.		8.4	Yes	Yes	87.5	11.2	1.3
8/25	5:20 P.M.	12	1	R.D.	UM-N		9.8	No	No	78.9	4.5	16.6
8/25	5:45 P.M.	13	1	R.D.	UM-N		9.8	No	No	78.6	5.0	16.4
8/25	5:55 P.M.	14	1	R.D.	Dwd.		7.5	Yes	No	82.0	11.4	6.6
		15	1	R.D.	UM-N		7.5	No	No	86.0	6.3	7.7
8/25	6:00 P.M.	16	1	R.D.	Dwd.		7.4	Yes	No	84.1	9.6	6.4
		17	1	R.D.	Dwd.		7.4	Yes	Yes	77.4	21.7	0.9
		18	1	R.D.	UM-N		7.4	No	No	86.5	6.1	7.4
8/26	8:50 A.M.	19	1	R.D.	Dwd.		8.2	No	No	79.0	9.0	12.0
		20	1	C.F.	UM-N		5.5	No	No	81.8	13.3	5.0
8/26	10:06 A.M.	21	1	R.D.	Dwd.		7.1	No	No	69.6	23.1	7.3
		22	3	C.F.	UM-N		6.6	No	No	87.0	9.6	3.4
8/26	10:25 A.M.	23	2	R.D.	Dwd.		7.8	No	No	80.1	10.2	9.6
		24	3	R.D.	Dwd.		7.3	Yes	No	84.4	10.1	5.5
		25	3	R.D.	Dwd.		7.3	Yes	Yes #1	84.7	14.4	0.9
		26	3	R.D.	Dwd.		7.3	Yes	Yes #2	84.1	15.2	0.7
8/26	10:45 A.M.	27	3	C.F.	UM-N		6.7	Yes	No	86.6	9.9	3.5
8/26	12:50 P.M.	28	3	C.F.	UM-H	44.0	7.2	No	No	74.6	6.2	19.1
		29	3	C.F.	UM-N	44.0	7.2	No	No	85.3	9.5	5.1
8/26	2:48 P.M.	30	1	C.F.	UM-H	39.6	5.2	No	No	75.4	6.8	17.8
		31	1	C.F.	UM-N	39.6	5.2	No	No	85.4	10.1	4.5
9/1	9:30 A.M.	32	1	R.D.	Dwd.		6.2	No	No	76.3	12.3	11.5
		33	1	C.F.	UM-H+N		6.0	No	No	85.6	10.4	6.1
9/1	1:35 P.M.	34	1	R.D.	Dwd.		7.8	No	No	77.0	18.9	4.2
		35	1	R.D.	Dwd.		7.8	Yes	Yes	72.9	27.1	0.0
		36	1	R.D.	UM-H		7.5	No	No	74.7	7.5	17.8
		37	1	R.D	UM-N		7.5	No	No	79.5	8.5	12.0
9/7	2:00 P.M.	38	1	R.D.	Dwd.	38.4	9.4	No	No	85.0	9.5	5.5
		39	1	R.D.	Dwd.	38.4	9.4	Yes	Yes	84.9	14.8	0.2
		40	1	C.F.	UM-H	38.4	3.2	No	No	88.0	7.2	4.8
		41	1	C.F.	UM-N	38.4	3.2	No	No	88.7	10.4	0.9

Key:

R.D.	Deerwood rotary drum parchers
Dwd.	Deerwood huller, rubber rolls, 80 durometer
UM-H	UM huller--hypalon rolls, 62 durometer
UM-N	UM huller--neoprene rolls, 62 durometer
UM-H+N	UM huller--both sets of rolls

Table 3. Summary of results from Table 2 for UM experimental huller with 62 durometer neoprene and hypalon rolls and Deerwood huller with 80 durometer rubber rolls.

Number of						Finished Rice			
Tests	Samples	Parcher	Huller	Aspirated	Scarified	Moisture Content, % W.B.	Hulled Whole, %	Broken, %	Unhulled, %
6	7	R.D.	Dwd.	No	No	7.8	77.8	13.8	8.4
4	6	R.D.	Dwd.	Yes	No	7.7	83.8	10.0	6.3
6	12	R.D.	Dwd.	Yes	Yes	7.9	81.9	17.4	0.7
1	1	R.D.	UM-H	No	No	7.5	74.7	7.5	17.8
5	5	R.D.	UM-N	No	No	8.4	81.9	6.1	12.0
3	5	C.F.	UM-H	No	No	5.2	79.3	6.7	13.9
5	9	C.F.	UM-N	No	No	5.6	85.6	10.6	3.8
1	3	C.F.	UM-N	Yes	No	6.7	86.6	9.9	3.5
1	1	C.F.	UM-H+N	No	No	6.0	85.6	10.4	6.1

Table 4. Summary of results from UM huller feed rate trials.

Feed Rate, lbs/hr	M.C., % W.B.	Hulled Whole, %	Broken, %	Unhulled, %
353	6.6	88.9	6.8	4.4
360	6.6	88.0	6.6	5.4
413	6.6	87.3	6.3	6.4
443	6.6	87.1	7.5	5.4
513	6.6	86.4	8.5	5.2
531	6.6	88.0	6.9	5.1
596	6.6	84.7	9.0	6.3
697	6.6	84.4	9.2	6.5

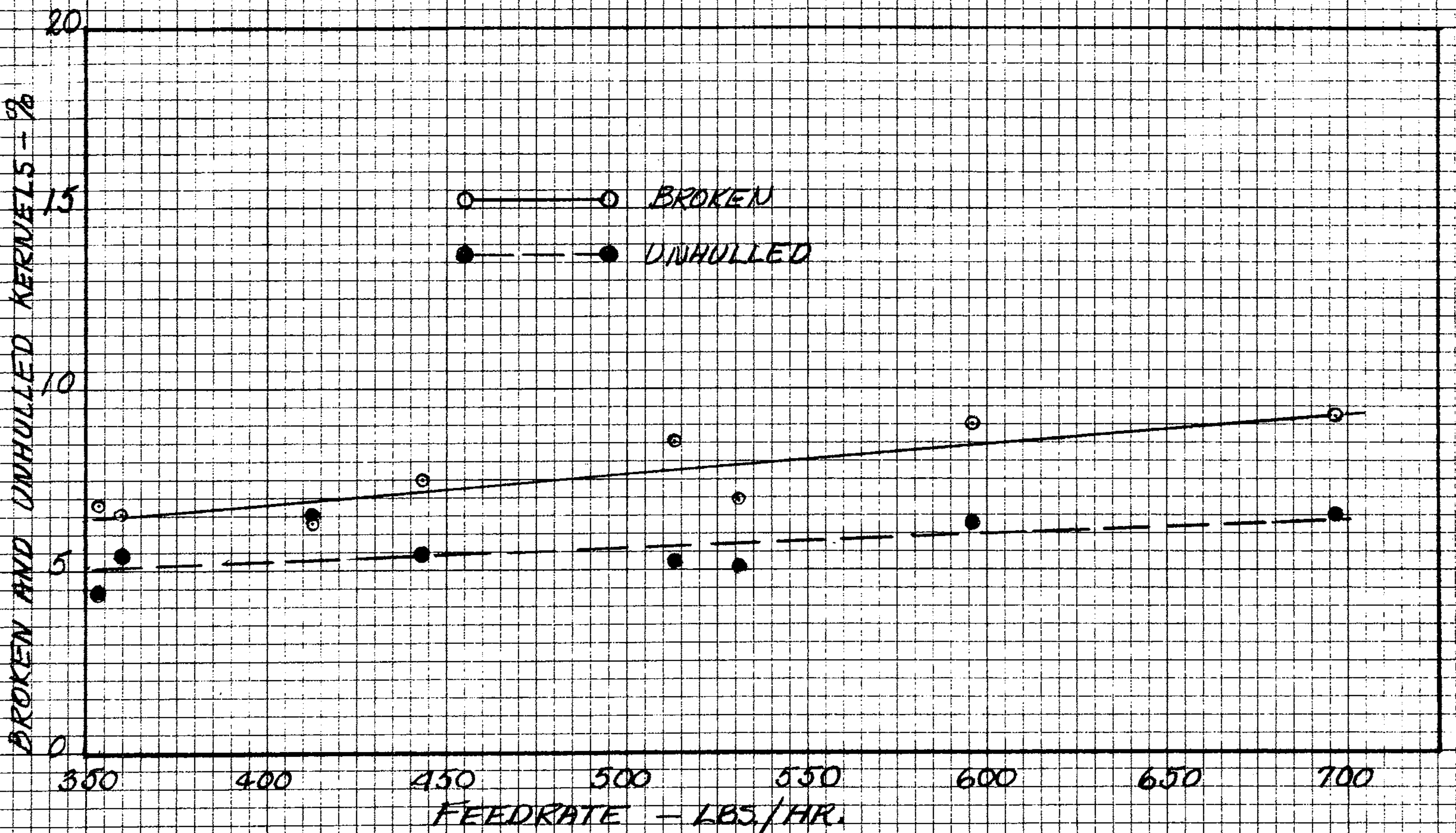

Figure 1. Influence of rate of feed on the hulling characteristics of UM experimental huller. Rice was from rotary drum parchers. M.C. = 6.6%. 62 durometer neoprene rolls.

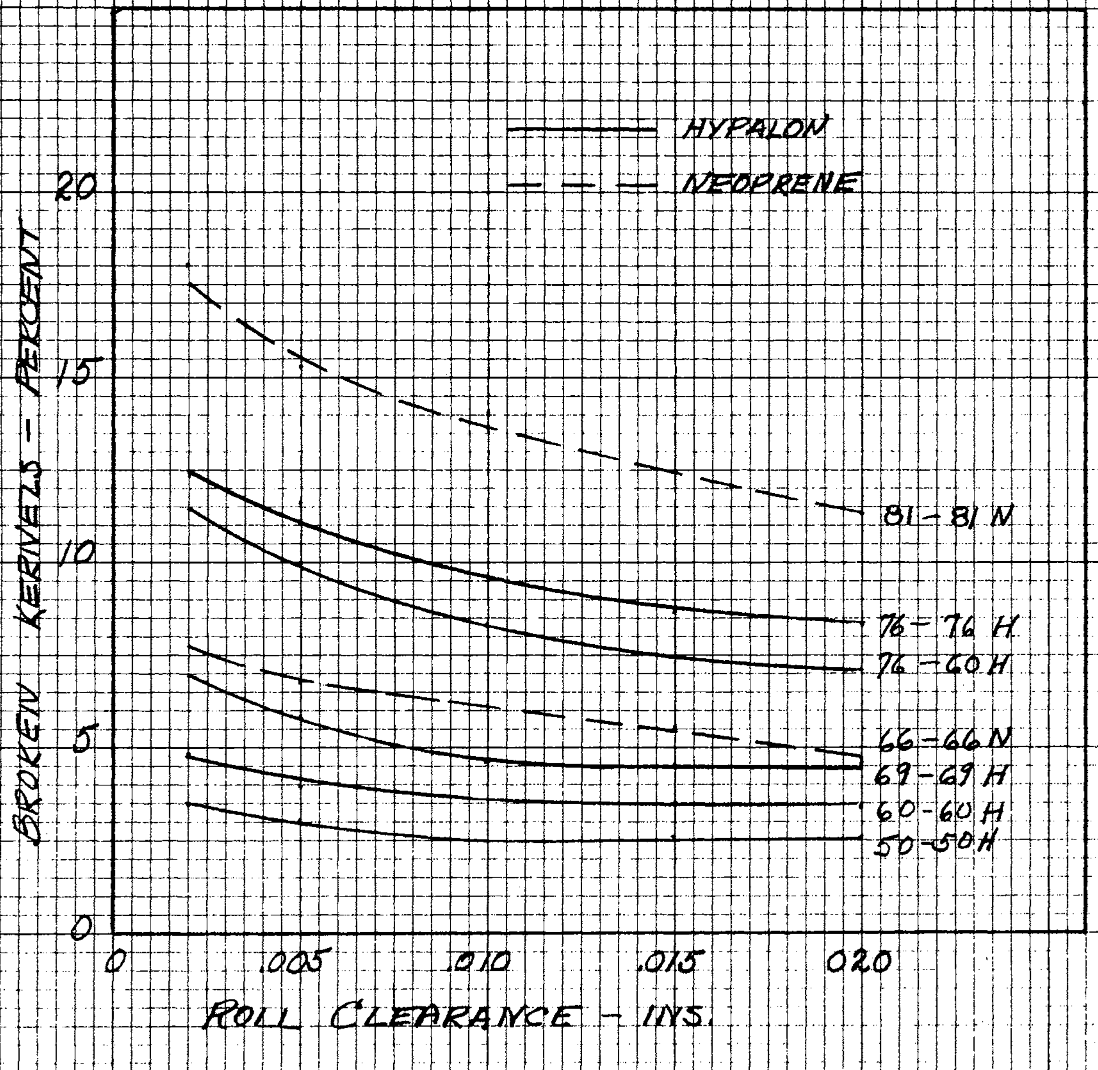

Figure 2. Percent broken kernels from heavy fraction as influenced by roll clearance and hardness for 11 3/8" diameter hypalon and neoprene rolls. M.C. = 5.2%.

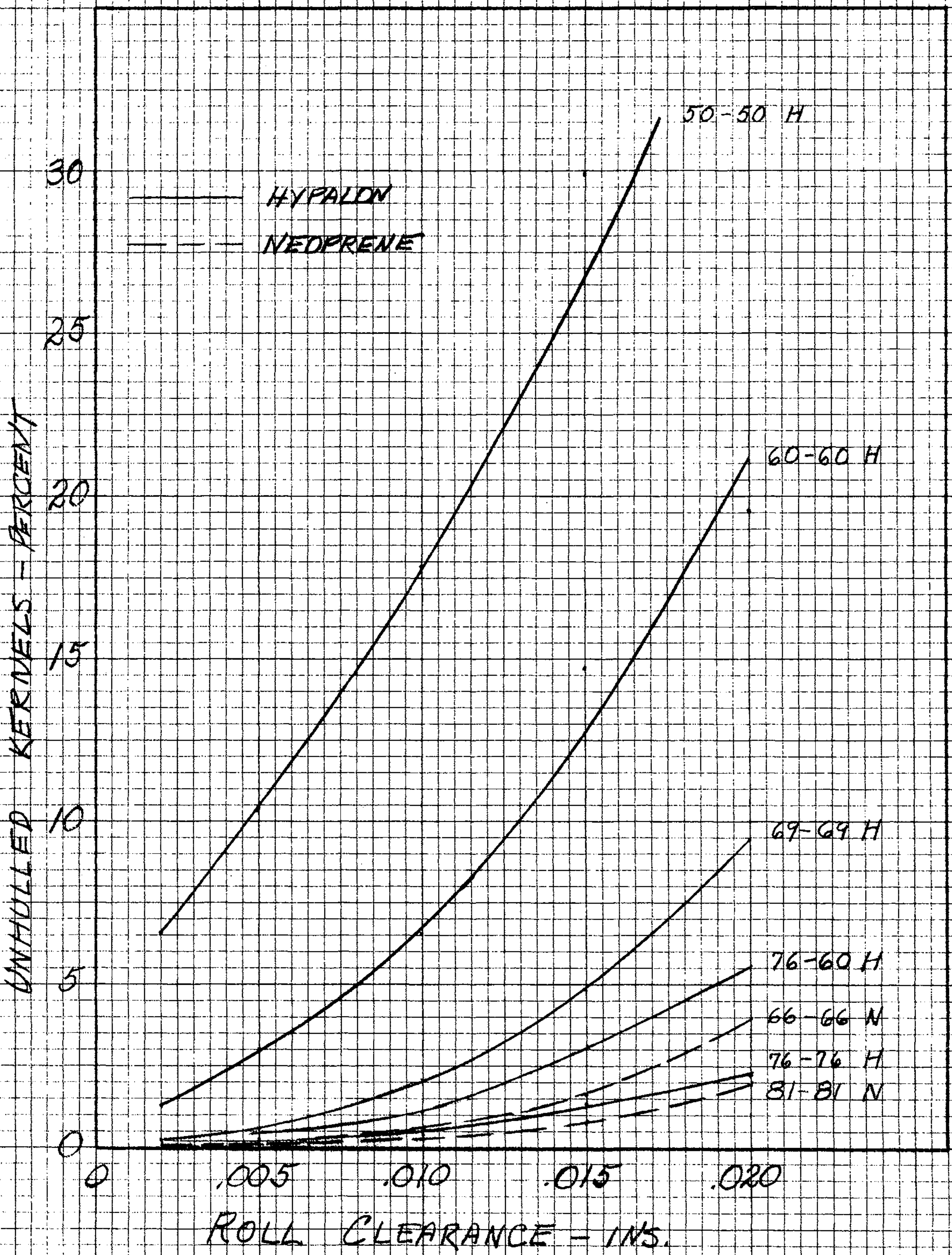

Figure 3. Percent unhulled kernels from heavy fraction as influenced by roll clearance and hardness for 11 3/8" diameter for hypalon and neoprene rolls. M.C. = 5.2%.

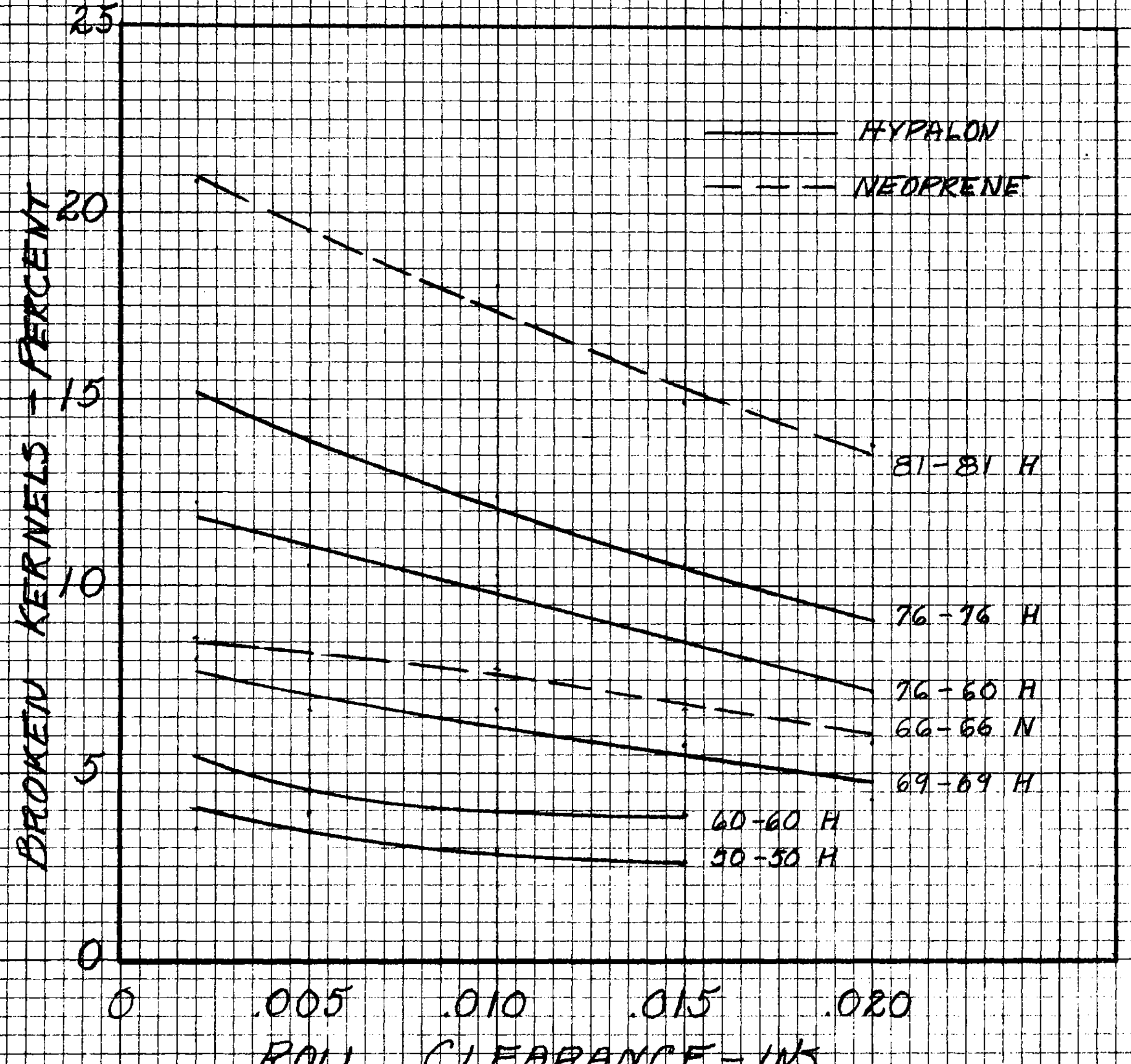

Figure 4. Percent broken kernels from medium fraction as influenced by roll clearance and hardness for 11 3/8" diameter hypalon and neoprene rolls. M.C. = 3.7%.

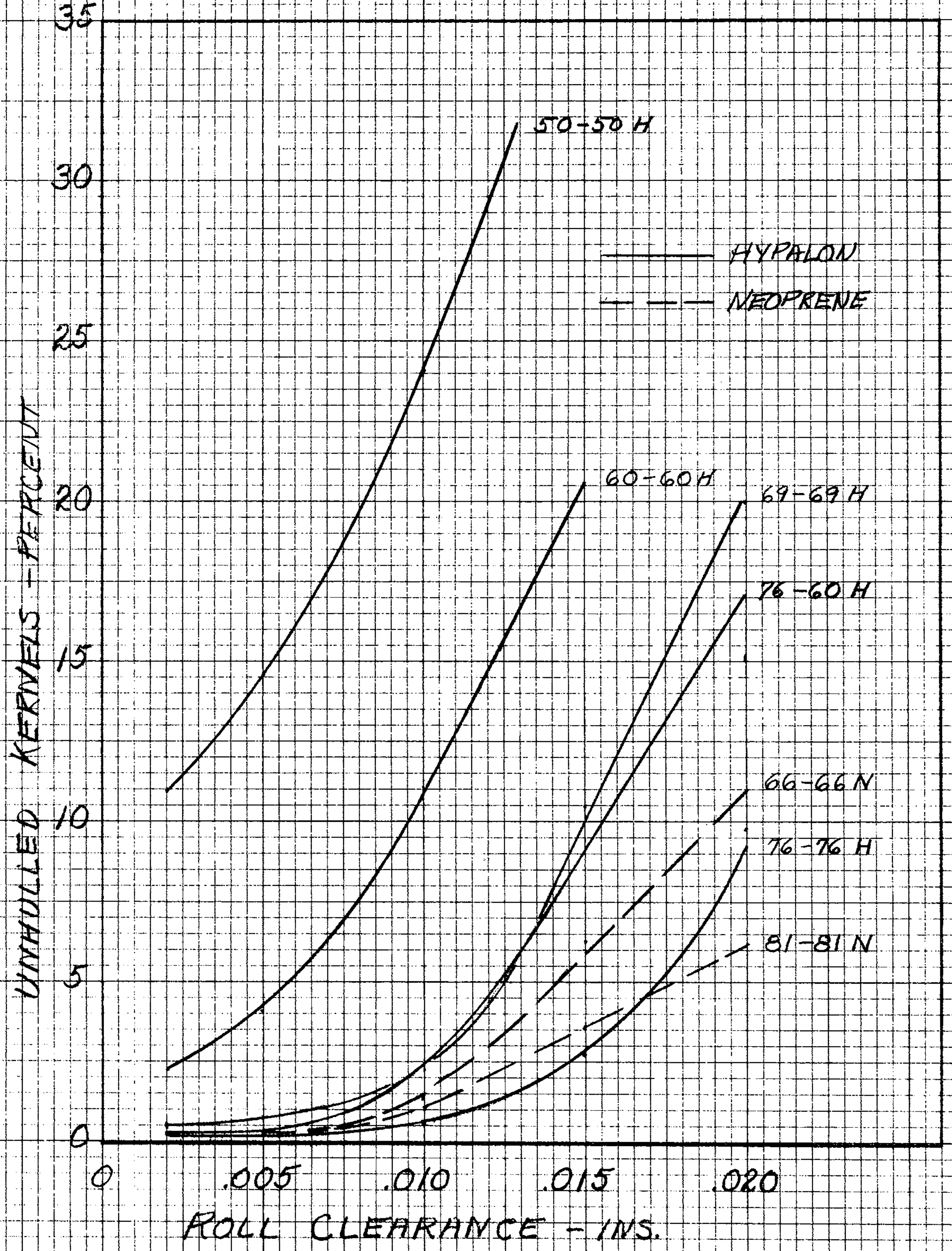

Figure 5. Percent unhulled kernels from medium fraction as influenced by roll clearance and hardness for 11 3/8" diameter hypalon and neoprene rolls. M.C. = 3.7%.

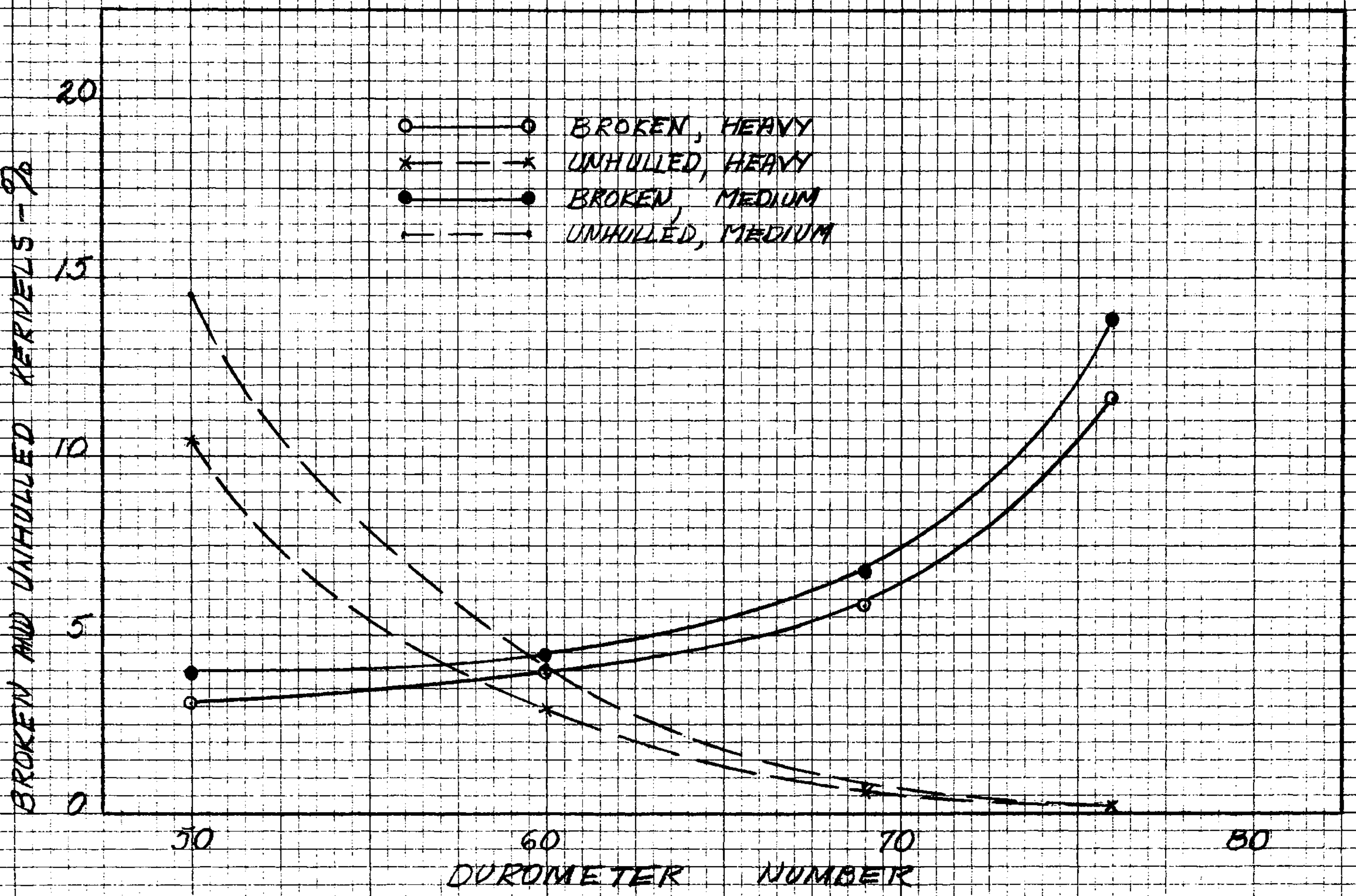

Figure 6. Influence of hardness of hypalon rolls on the percent of broken and unhulled kernels from heavy and medium fractions. Roll clearance = .005%, M.C. heavy = 5.2%, M.C. medium = 3.7%, roll diameter = 11 3/8".

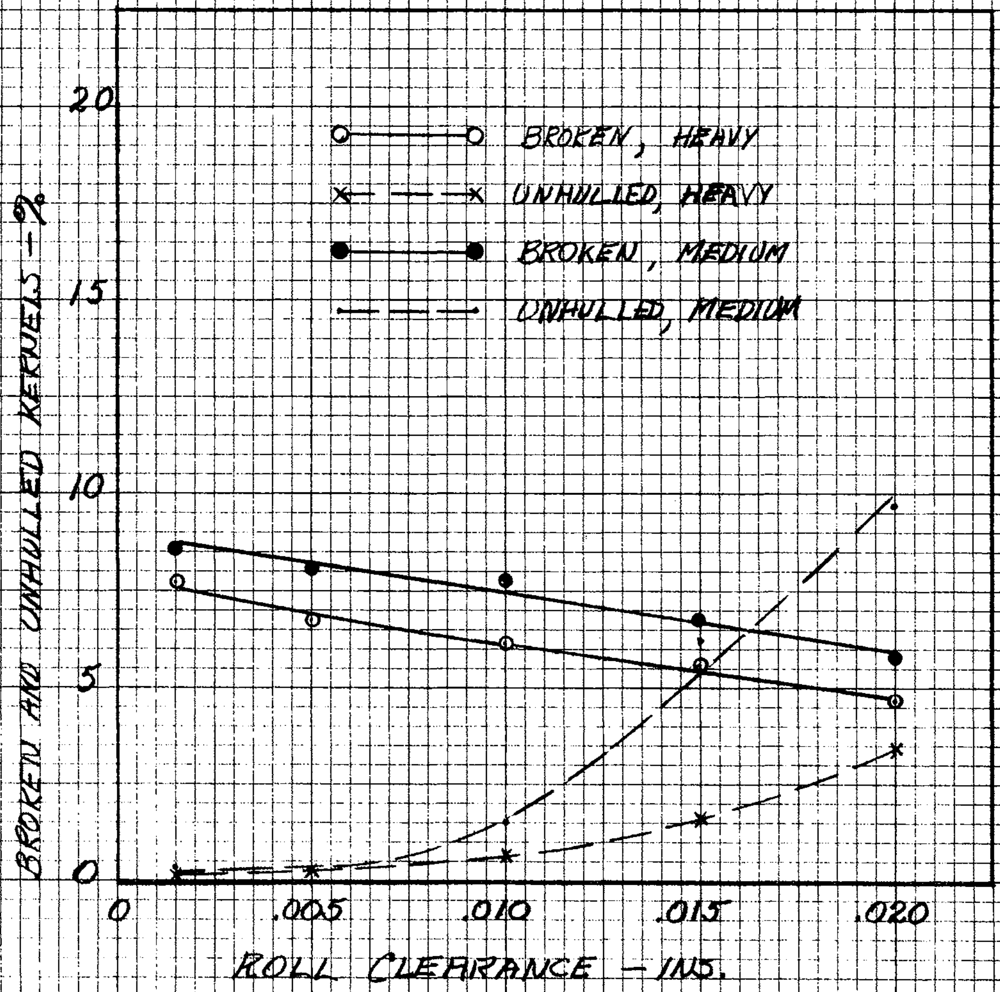

Figure 7. Percent broken and unhulled kernels from heavy and medium fractions with 66 durometer neoprene rolls as influenced by roll clearance. M.C. heavy = 5.2%, M.C. medium = 3.7%, roll diameter = 11 3/8".

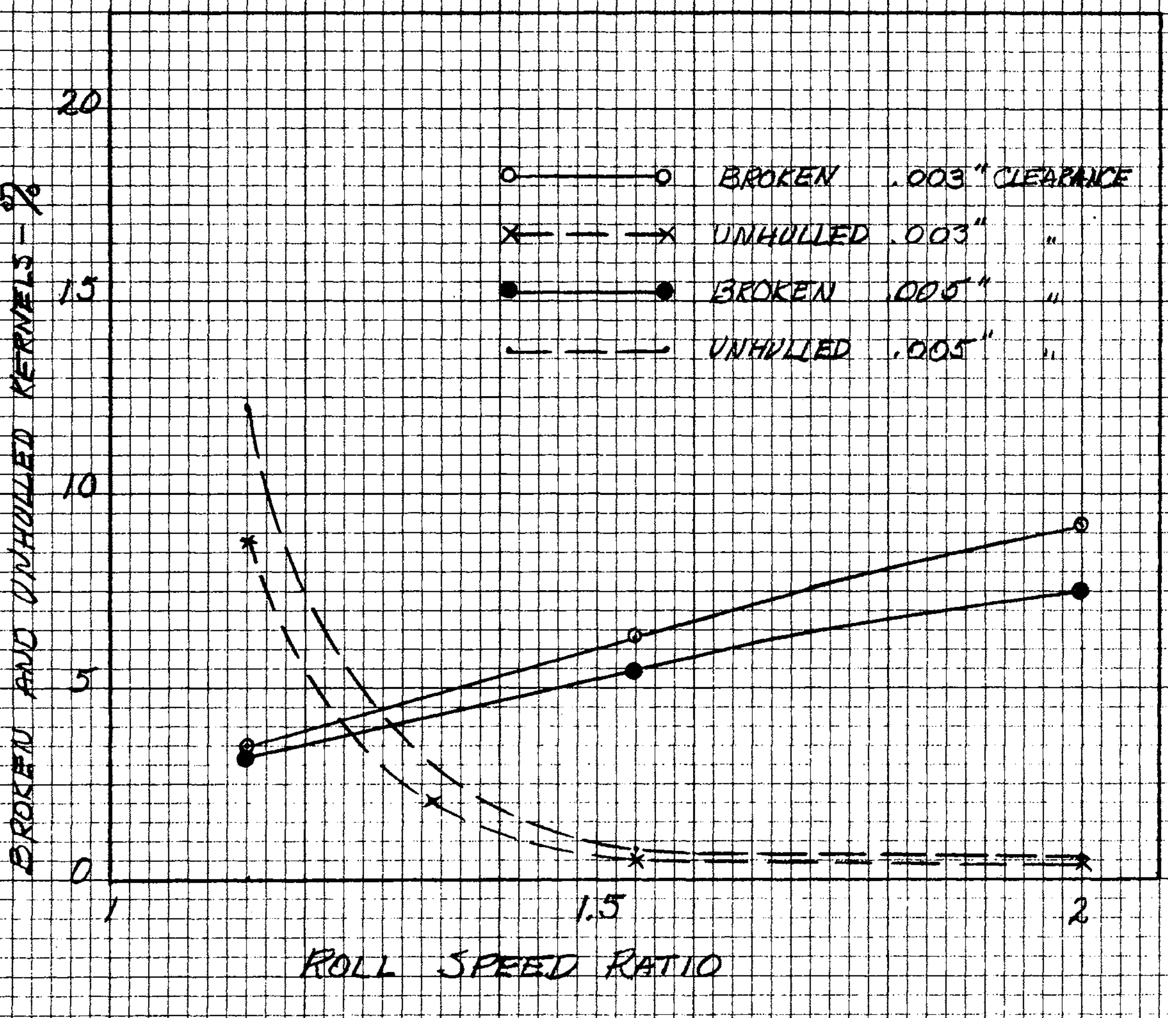

Figure 8. Influence of relative roll speed upon broken and unhulled kernels from heavy fraction. Lab huller with 12" diameter, 62 durometer polyurethane rolls. Roll clearance = .003" and .007". Speed ratio is RPM high speed roll ÷ RPM low speed roll. M.C. = 4.5%.

Wild Rice Marketing Research

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A survey of Minn. cultivated wild rice producers was conducted and a preliminary report prepared for distribution at the meeting of the Intl. Wild Rice Growers' Assoc. Nearly 70% of Minnesota's 58 wild rice farms are family farms that produced 60% of Minnesota's 2.7 million pounds of cultivated wild rice in 1982. The median size farm has 291 acres paddies. Farms in excess of 291 acres produce 83% of the wild rice. Twelve percent of the farms with 1,000 acres or more produce 41% of the total. The farms had 25,084 acres of paddies of which 4,917 acres were fallowed in 1982. About 60% of Minnesota's cultivated wild rice is marketed through two cooperatives: United Wild Rice, Inc. with 13 members and Minn. Rice Growers with seven members. The remaining 40% of the cultivated wild rice is produced by 38 independent growers who often market through their processor.

From 1974 to 1982, production of cultivated wild rice in Minn. increased at an annual rate of 13%. No new wild rice farms have entered the industry since 1979, but planned acreage expansion on existing farms indicate that production may reach 4.5 million pounds in 1985. Several growers indicated that expansion would enable them to harvest a constant number of acres while fallowing more acres.

A survey of Minn. processors of wild rice was also completed to obtain information on marketing practices and market outlets. This information is currently being summarized and analyzed along with information on wild rice production in Calif. and lake wild rice in Canada.