Minnesota Wild Rice Research 1984

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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 WILD RICE FERTILIZATION - 1984

John Grava, Michael Meyer and Paul R. Bloom

Research during 1984 focused on nitrogen fertilization and nitrogen loss mechanisms in paddy soil and water. Soil, water and air temperatures were monitored during the growing season at Grand Rapids and St. Paul. A nitrogen source experiment was conducted with the K2 variety on a mineral soil at Grand Rapids, and a second experiment on peat in 4 x 4 ft. boses at St. Paul.

A. WEATHER CONDITIONS AND PLANT DEVELOPMENT

Average air temperatures at four locations were below normal during May, near normal during June, followed by below normal July and above normal during August (Table 1.).

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 boxes were conducted (Fig. 1 and 2).

At Grand Rapids, K2 wild rice emerged on May 26, reached the jointing stage on July 6, 41 days after emergence and was harvested on August 23, 91 days after emergence. At St. Paul, K2 wild rice was seeded on May 14, reached the jointing stage on July 5 and reached maturity on August 22.

B. NITROGEN SOURCE STUDIES ON MINERAL SOIL

A nitrogen source and placement experiment with 2nd year stand of K2 wild rice was conducted 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 (102 lb/A) and a medium level of exchangeable potassium (195 lb/A).

Nitrogen fertilizers included in the experiment were as follows: granular urea (GU), 46% N; sulfur coated urea (SCU), 37% N; isobutylidene diurea (IBDU), 31% total N (28% water insoluble, 3% water soluble). Nitrogen was applied at a rate of 40 lb/A, either on May 15 and incorporated into the soil by rototilling or topdressed at jointing on July 6. A radomized block design was used in this experiment. Each treatment was replicated four times. Individual plots occupied a 14 x 14 ft. area and were separated from adjoining plots by 5 ft. wide alleys. Water level was maintained at 8 to 12 inches. Ten plants were collected at random from each plot at jointing, and five plants at late flowering for weight measurement and plant analysis. A 32 sq. ft. area from each plot was hand-harvested on August 23.

Individual plants at jointing had accumulated over 2 grams of dry matter (Table 3). All nitrogen fertilizers increased the plant weight above the control when incorporated into the soil. Deep placed granular urea produced the largest plants which accumulated 75 milligrams of nitrogen each. Surface applied urea had no effect on growth, nitrogen concentration of 2nd leaf or N uptake by wild rice. Fertilization with IBDU was nearly as effective as deep placed granular urea. At late flowering the plant had accumulated from 8.69 to 12.43 grams of dry matter and from 116 to 170 milligrams of nitrogen (Table 4). The grain yield (7% moisture) ranged from 212 to 314 pounds per acre (Table 4). Although deep placed nitrogen fertilizers tended to produce bigger plants and more grain than the control, however, the differences were not significant.

The growth of wild rice in this experiment was affected by a heavy infestation of water plantain. Although the stand was hand-weeded on July the weed problem became more serious as the season progressed. Water plantain appear to affect the stand density, growth and tillering of wild rice and minimized the effectiveness of nitrogen.

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

Station Year	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
1984	45.0	52.6	63.4	67.8	70.2	59.8	2906
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
1984	44.6	50.8	63.8	67.8	69.6	59.3	2842
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	57.5,	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
1984	43.9	53.9M[5/]	64.4	69.1[5/]	69.3	60.1	2985
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
1984	47.7	57.2	69.1	72.2	73.9	64.0	3478

1/ Source: Climatological Data, Minnesota, Vol. 90 (1984), U.S. Dept. of Commerce.
2/ Normals for the period 1931-1960.
3/ M = less than 10 days record missing.
4/ Northwest Divisional Data.
5/ East Central Divisional Data.

Fig. 1. Mean air, water and soil temperatures
Grand Rapids — 1984

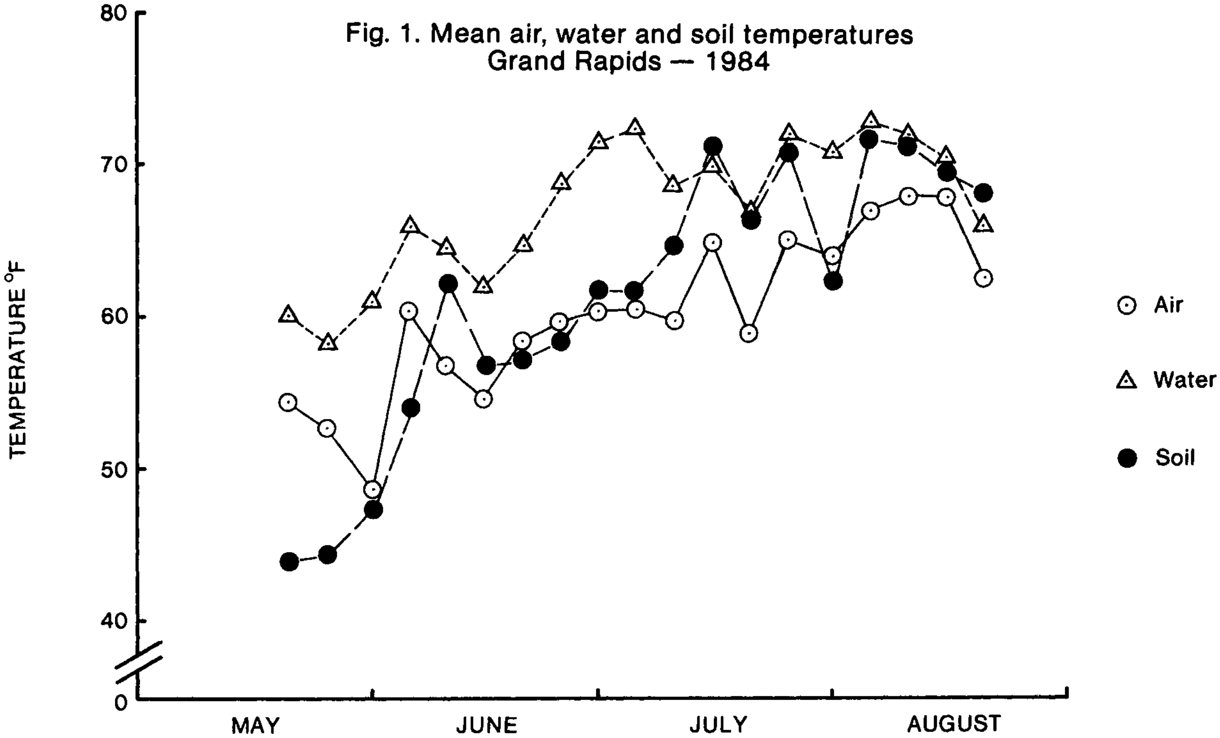

Fig. 2. Mean air, water and soil temperatures
St. Paul Campus — 1984

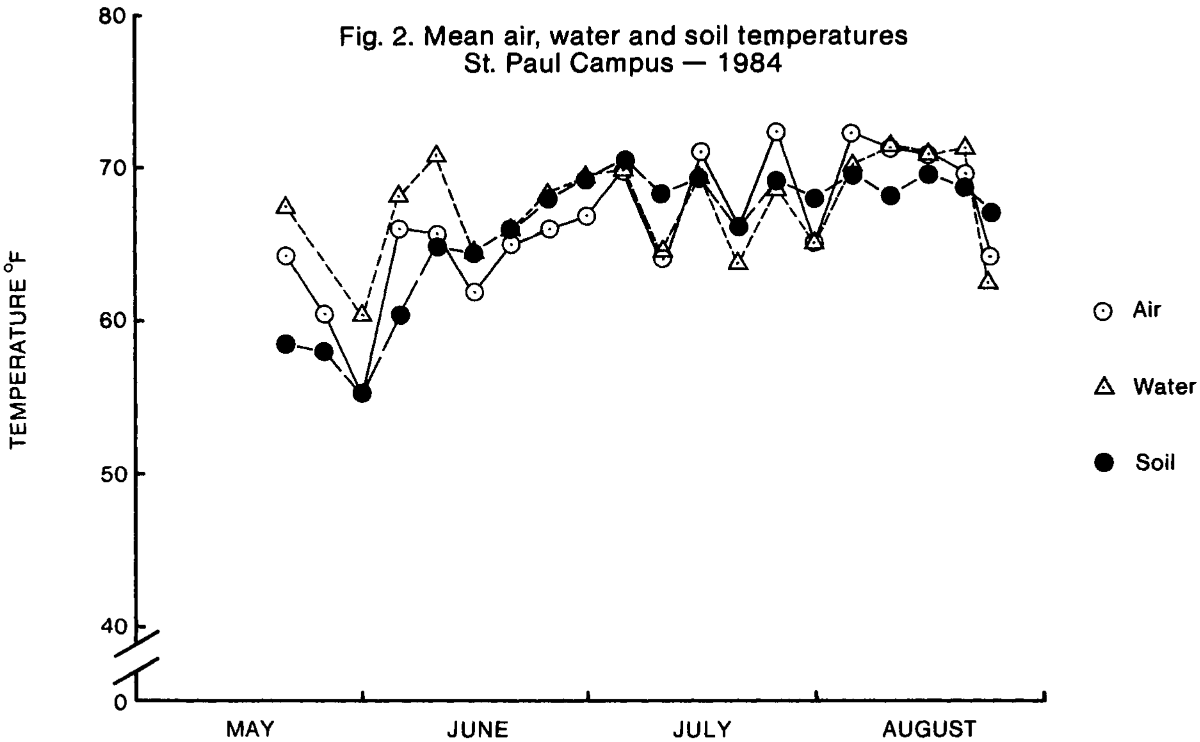

Table 2. Soil test values of experimental paddy No. 1 East, Grand Rapids[1)]

pH	Extract-able P pp2m	Exchange-able K pp2m	Nitrate-N lb/A	Organic Matter %	Zn ppm	S ppm	Cu ppm	Mg pp2m
5.6	102	195	17	2.8	7	8	1.7	514

1) Samples collected from 0-6 inch depth on 5/15/84.

Table 3. Effect of nitrogen source and placement on weight of dry matter, N-concentration in 2nd leaf, and total uptake of N by the wild rice plant at jointing. Grand Rapids, 1984.

Treatment	Dry matter grams per plant	N% in dry matter of 2nd leaf	N uptake in milligrams per plant
1. Control	2.08	3.05	49
2. GU, Surf applied	2.06	3.13	47
3. GU, 4-inch depth	2.92	3.30	75
4. SCU, 4-inch depth	2.20	3.23	57
5. IBDU, 4-inch depth	2.52	3.51	70
Significance	*	ns	**
BLSD (0.05)	0.11	0.43	15
C.V., %	13	7	17

Table 4. Effect of nitrogen source and placement on grain yield, dry matter production and total N uptake at late flowering. Grand Rapids, 1984.

Treatment	Grain yield lb/A[1/]	Dry matter at late flowering grams per plant	Total N uptake milligrams per plant
1. Control	224	8.91	119
2. GU, Surf applied	212	8.69	116
3. GU deep placed	300	12.43	170
4. SCU	282	11.34	164
5. IBDU	314	11.28	148
Significance	ns	ns	ns
BLSD (0.05)			
C.V., %	23	23	28

[1/] 7% moisture

C. NITROGEN SOURCE STUDIES IN BOXES

A nitrogen source and placement experiment was conducted in 4 x 4 wooden boxes on the St. Paul Campus. The following four nitrogen fertilizers were investigated: granular urea (GU); urea supergranule (USG), 2 gram granule; sulfur coated urea (SCU); and isobutylidene diurea (IBDU). Seven fertilizer treatments were replicated four times. Nitrogen fertilizers were applied at an 80 lb/A rate; all boxes received 60 lb P_2O_5/A and 120 lb. K_2O/A.

A 12-inch thick layer of partly decomposed hypnum peat (hemic), pH 6.4, was placed in the boxes. Properties of the peat are reported in Table 5. Phosphorus, potassium and deep placed nitrogen fertilizers were covered with a 4-inch unfertilized layer of peat. Seed of K2 variety was placed in rows and covered with about 1-inch layer of peat on May 14. On-surface application of nitrogen was made after seeding. Two extra boxes with deep placed granular urea were set up; No. 51 with wild rice and No. 52 without wild rice. The water depth in all boxes was maintained at 6 inches. In a split-application treatment, half of the granular urea was deep placed (4-inches) at seeding and half topdressed at jointing on July 5. Copper sulfate was applied to all boxes to control algae.

The wild rice plants were vigorous and lodged readily. Nitrogen produced dark green colored leaves and stems in contrast to the light green-yellowish colored plants of the control. Average plant density was 27 plants per box.

The grain yield (7% moisture) ranged from 173 to 274 grams per box (Table 6). Calculated on a field basis, the yield would correspond to 1179 and 1864 lb/A of grain. All applications of nitrogen produced significantly more grain than the control. Deep placed SCU and USG produced higher yield than IBDU and surface applied GU.

Ammonium N Depletion in Peat by Wild Rice

Two of the boxes at the St. Paul Campus were set aside for the study of the depletion of available nitrogen by a wild rice crop. Both boxes received 80 lb N/A as granular urea placed at the 4-inch depth. Box No. 51 was seeded with wild rice, Box No. 52 was maintained without plants. Wild rice in Box No. 51 produced 280 grams (1907 lb/A) of grain (7% moisture). Three ceramic cups 6.3 cm in diameter with 100 cm long plastic tubes were placed in each box to a depth of 15 cm. Soilwater was extracted from the tubes for ammonium N analysis.

Soil samples were collected from the boxes with a Macaulay peat sampler at 0-20 cm and 20-38 cm depths. Random triplicate samples were collected from each box on four different dates (6/11, 6/25, 7/13, 8/2). A grid sampling system insured that the same spot was not penetrated more than once with the sampler. Soil samples were extracted with 1M KCl and distilled. Ammonium N in soilwater was determined by direct distillation.

The amounts of ammonium N in soilwater and in the soil are reported in Tables 7 and 8. There was a slight increase in ammonium N from June 11 to June 25. This may have been due to mineralization of organic N in peat as the soil temperature increased. A striking decrease in ammonium N in soilwater and in the soil occurred in Box No. 51 with wild rice between June 25 and July 13. This coincided with the date of jointing on July 5, and early boot about a week later. Our previous research has shown that wild rice takes up 70% of total nitrogen between the jointing stage and maturity. It is evident that at the start of jointing the plant uptake of N is very great and acts as a sink for nitrogen.

In the box with wild rice, nitrogen depletion in the 20-38 cm zone was equal to that in the 0-20 cm zone. This demonstrates that wild rice in peat is able to utilize nitrogen from well below the reported rooting depth of 20 cm.

CONCLUSIONS

Nitrogen incorporation into the soil at the 4-inch depth during seedbed preparation was superior to on-surface application. Granular urea was as effective as the more expensive slow-release sources of nitrogen.

Table 5. Soil test values of peat. St. Paul, 1984

pH	Extract-able P pp2m	Exchange-able K pp2m	Zn ppm	S ppm	Cu ppm	Mg pp2m	Ash %
6.4	11	29	5.7	38	0.9	648	27.5

Table 6. Effect of nitrogen source placement and time of application on grain yield of wild rice grown on peat in 4 x 4 ft. boxes. St. Paul, 1984

Treatment	Grain yield grams per 14 sq. ft. area 1/
1. Control	173
2. GU, Surf applied	227
3. GU, 4-inch depth	242
4. USG, 4-inch depth	265
5. SCU, 4-inch depth	274
6. IBDU, 4-inch depth	221
7. GU, Split-application 2/	252
Significance	**
BLSD (0.05)	34
C.V., %	121

1/ 7% moisture

2/ Split-application = 1/2 prior to seeding, 4-inch depth; 1/2 topdressed at jointing.

Table 7. Soilwater ammonium N in 4 x 4 ft. boxes with and without wild rice - 1984[1/]

	Date of Sample Collection			
	6/11	6/25	7/13	8/2
	----Soilwater NH_4-N, μg mL^{-1}----			
With Plants	25.5	26.7	2.1	0.1
Without Plants	22.9	26.1	16.3	20.2

1/ Granular urea (80 lb N/A) was placed at 4-inch (10 cm) depth prior to seeding.

Table 8. KCl extractable ammonium N in the soil in 4 x 4 ft. boxes - 1984[1/]

		Date of Sample Collection			
	Depth	6/11	6/25	7/13	8/2
	cm	------------Soil NH_4-N, μg g^{-1}------------			
With Plants	0-20	134	236	23	20
	20-38	219	323	16	18
Without Plants	0-20	167	278	160	142
	20-38	275	307	250	221

1/ Granular urea (80 lb N/A) was placed at 4-inch (10 cm) depth prior to seeding.

ACKNOWLEDGEMENTS

Grateful acknowledgements are made to the following University of Minnesota personnel for their assistance during 1984 in obtaining the information reported here: Messrs. Rollo Walmon, Henry Schumer, Mike McClellan and Dr. E. A. Oelke.

WILD RICE PRODUCTION RESEARCH - 1984

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Cultural research in 1984 concentrated on weed control, plant population and disease interaction, reducing wild rice plant population with chemicals and use of plant growth regulators to reduce wild rice plant height. The research was conducted on University plot land in St. Paul and Grand Rapids and in growers' fields near Aitkin and Gully. A glass house and growth chambers at St. Paul were also utilized for some of the work. Temperatures during May and July were cool with normal temperatures during June and above normal temperatures during August resulting in a relatively good growing season for wild rice.

WEED RESEARCH

The research program started in 1983 by Sharon Clay, graduate student on the project, on the cultural and chemical control of giant burreed (*Sparganium eurycarpum* Engelm.) was continued by her in 1984. In 1983 giant burreed was found to be present in 90% of the wild rice acreage ranging from slight to heavy infestations. Giant burreed is a perennial and spreads by rhizomes which develop corms at the base of new plants. The corms overwinter and develop into new plants the following year. Some new plants may also develop from seeds although we have had difficulty in germinating the seeds. The upright leaves of giant burreed emerge from the water before wild rice. Several experiments on giant burreed were repeated in 1984 and some new ones initiated.

Effect of Giant Burreed Density on the Growth of Wild Rice

Giant burreed reduced wild rice yield in 1983 (see 1983 Wild Rice Research Report). A more extensive study was initiated at the Grand Rapids Experiment Station in 1984 to determine the effect of giant burreed densities on wild rice growth, development, and grain yield. The experimental design was a split plot design with nitrogen rates as the main plot (0 or 50 lb/A) and 4 corm densities (0, 0.6, 1.0 or 2.25 corms/ft^2) as subplots with 4 replications. Light readings were taken in the wild rice canopy 4 times throughout the season [early tillering (6/20), late tillering (6/28), boot (7/12), and anthesis (7/26)]. Other parameters measured at early tillering and boot included plant height, plant dry weight, and leaf area index of both the wild rice and burreed.

Light penetration was reduced at the 30- to 40-cm height and 30- to 35-cm height at early tillering and boot stages, respectively. Leaf area index and dry weight of wild rice were reduced at early tillering at the high density of burreed (Table 1). Wild rice plant dry weight, number of panicles and fertile tillers/plant and wild rice yield were reduced at harvest when compared to the non-weedy control plots (Table 2).

Table 1. Effect of burreed on wild rice leaf area index (LAI) and plant dry weight at early tillering - Grand Rapids - 1984.

Treatment	Wild rice LAI	Dry weight
corms/ft^2	cm^2/plant	g/plant
0.0	93.2	0.90
0.6	94.8	0.84
1.0	98.0	0.76
2.3	61.2	0.56
LSD $_{(0.05)}$	26.4	0.18

Table 2. Effect of burreed on wild rice at harvest - Grand Rapids - 1984.

	Wild rice				Grain	
Treatment	Plant density	Plant	Panicle density	Panicles	Panicle*	Yield*
corm/ft	plant/ft^2	g/plant	no/ft	no/plant	g/panicle	lb/A
0.0	1.95	12.78	4.97	2.6	1.04	491
0.6	1.39	9.32	2.78	2.0	0.99	275
1.0	2.04	6.46	3.48	1.7	0.82	270
2.3	1.30	4.89	1.78	1.4	0.83	144
LSD $_{(0.05)}$	0.60	1.39	0.83	0.3	0.10	66

* 7% moisture.

Table 3. The influence of removing giant burreed after 2, 5 and 14 weeks from wild rice - Grand Rapids - 1984.

Removal	Wild rice				
date	Plants	Panicles	Dry weight	Grain yield*	
week	no/m^2†	no/m^2	g/m^2	g/m^2	lb/A
2	17.3	55.8	270.9	60.7	542
5	22.7	61.8	281.5	66.0	589
14	18.0	36.3	148.8	32.0	286
Control	28.0	71.9	332.2	82.7	738
LSD $_{(0.05)}$	6.0	12.7	64.0	15.3	137

* 7% moisture.
† m^2 = 10.8 sq. ft.

Time of Giant Burreed Removal

Giant burreed at a density of 6 corms/m^2 was interplanted with wild rice (cultivar K_2) at the Grand Rapids Experiment Station. Burreed plants were removed at 2, 5, or 14 weeks after planting. The experimental design was a randomized complete block with 4 replications. Data measured at harvest included number of wild rice panicles and plants, dry weight of wild rice plants, and grain yield. Differences due to removal date were detected for each of the measured parameters (Table 3). Reductions in grain yield, and number of wild rice plants and panicles were detected after 2 weeks of competition. Competition from 2 to 5 weeks did not cause further reduction in the parameters measured, however, season long competition caused a greater reduction than if removal occurred between 2 and 5 weeks. This data implies that: 1) burreed must be controlled early if yield reductions are to be eliminated, and 2) if control measures cannot be undertaken in the first 2 weeks of growth, waiting until 5 weeks will not cause further reductions in grain yield.

Water Management and Temperature on Survival of Giant Burreed Corms

A laboratory experiment was initiated to determine if freezing (-2 ±1° C) was detrimental to corm survival when compared to above freezing temperature (2 ±1° C). Corms were separated into 4 sizes (<12 mm, 12-17 mm, 17-23 mm or >23 mm in diameter) and placed into 1-quart cups filled with 500 g of peat soil and watered to 70% of field capacity or flooded (210% field capacity). Corms were placed 7 cm deep in the soil or at the soil surface. Cups were placed into a cooler or freezer for 1, 3 or 5 months. The experimental design was completely random with 8 replications/treatment. Cups were moved to the greenhouse after the cold treatment. Surface corms were removed from each cup and placed in a cup 7 cm deep in peat soil and flooded. Germinated corms were counted at time of emergence. After 2 months in the greenhouse, non-germinated corms were moved to the cooler for 2 months (to make sure corms had an adequate chilling period to germinate) and moved to the greenhouse for germination. Corm size, cold treatment duration, or water management had no effect on corm survival. The corm survival averaged across all treatments was approximately 30%. Temperature and corm position were important in corm survival (Table 4). Corms that were kept at the cool temperature (2° C) germinated 6 times more frequently than corms subjected to freezing temperature. Corms placed on the soil surface had a greater survival rate than corms placed in the soil.

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

Temperature	Survival
--°C--	--%--
2 (±1)	53
-2 (±1)	8
LSD (0.05)	6

Position	Survival
	--%--
Surface	34
7 cm*	26
LSD (0.05)	6

* 1 cm = 2.54 inches.

Fall Water Management on Survival of Giant Burreed Corms

Giant burreed corms can be dispersed throughout an infested field soil profile due to fall tillage operations. An experiment was initiated at St. Paul, Minnesota in the fall of 1983 to determine the effect of fall flooding and burial depth on corm survival. Burreed corms were planted at 5 depths (0, 10, 20, 30, or 40 cm) in a peat soil in above ground deep fiberglass boxes and either flooded at the time of planting or kept dry until snowfall. Ten corms were planted per depth and each treatment was replicated 4 times. Soil temperatures were recorded approximately once a week from January through March. The lowest temperatures were recorded on January 20, 1984. Temperatures in the flooded boxes were -12, -9, -17, -10, and -8° C for the 0, 10, 20, 30 and 40 cm depth, respectively; and were -14 and 0° C at the 10 and 40 cm depth, respectively in the non-flooded boxes. The air temperature 30 cm above the boxes was -26° C. All boxes were flooded in early spring. Corm viability was monitored throughout the spring and summer by determining if a root and shoot were produced. Corms that had not germinated by June 26, 1984 were removed from the fiberglass boxes, placed in 0.96 liter cups filled with peat, placed in the greenhouse (temperature 25° C ±3° C) and monitored for viability until October.

Time of flooding was not a factor in corm survival. The average corm survival across all treatments (burial depth and time of flooding) was 27%. Burial depth affected viability (Table 5). Corms at the soil surface had greater viability when compared to all other depths. These results are contrary to water plantain research. Fall flooding of water plantain corms resulted in no viable rootstocks. Water plantain survival was greatest at the 7.5 and 15 cm depths with an average survival of 60% (see Wild Rice Research Report 1981).

Table 5. Giant burreed corm survival in the spring after burial in the soil at different depths - St. Paul - 1984.

Burial depth*		Survival
--cm--		--%--
0		65
10		31
20		16
30		13
40		11
	LSD $_{(0.05)}$	23

* 1 cm = 2.54 inches.

Fall Tillage and Chemical Treatment of Giant Burreed

Herbicide treatments were applied in September, 1983 to standing giant burreed in a field near Aitkin, Minnesota. The experimental design was a split plot with 4 replications. Tillage was the main plot and herbicide treatments were the subplots. The plots were harvested in August, 1984. Herbicide treatments included glyphosate, diclofop, MCPA, 2,4-D, bentazon, bentazon + crop oil, and 2,4-D + crop oil at various rates (Table 6). Herbicide treatment and rate of application had no significant effects on number of giant burreed plants, giant burreed dry weight, wild rice panicles/plant, or grain yield. Fall tillage increased the number of wild rice plants and panicles, increased grain yield, and decreased the number and dry weight of giant burreed plants when compared to non-tilled areas (Table 7). An increase in the number of wild rice plants was observed with diclofop at 0.5 lb/A and 2,4-D at 1 lb/A treatment (Table 6). Grain yield was not affected by herbicide treatment.

Spring Bentazon Treatment

A herbicide trial in 1983 (1983 Wild Rice Research Report) indicated that bentazon gave good control of giant burreed and resulted in an increase in wild rice grain yield. Therefore, a more extensive study with bentazon in 3 formulations (liquid, liquid + crop oil, or granular) and at 3 application dates (preemergence, 2-, or 5-leaf wild rice growth stages) was initiated in 1984 in a field near Aitkin, Minnesota. Each treatment was enclosed in a 5-foot diameter metal ring to minimize bentazon diffusion between plots. The experimental design was a randomized complete block with 4 replications. Parameters measured included visual injury (2 and 5 weeks after application), number of and dry weight of burreed, number and dry weight of wild rice, and grain yield.

The number of giant burreed plants/plot was reduced from weedy check in the handweeded control areas (Table 8). Giant burreed dry weight was reduced by several treatments including: 1 lb/A granular at preemergence, 1 or 2 lb/A liquid application at the 2-leaf stage, 2 lb/A liquid application at the 5-leaf stage, 0.5 lb/A liquid + crop oil application at both the 2- or 5-leaf stage, and bentazon 1 lb/A liquid + crop oil at the 5-leaf stage of crop growth. Wild rice yield, number, or dry weight of plants were not affected by any of the treatments.

Table 6. The influence of fall chemical treatment of giant burreed on its control and wild rice - Aitkin - 1984.

Treatment	Rate	Wild Rice		
		Plants	Grain yield*	
	lb/A a.i.	no/16ft^2	g/16ft^2	lb/A
Bentazon	0.50	56.3	30.8	330
	0.75	62.6	31.4	337
	1.00	70.7	39.7	426
Bentazon + crop oil	0.50	60.4	37.0	397
	0.75	69.8	35.6	382
	1.00	72.1	38.6	414
Diclofop	0.25	73.0	38.8	416
	0.50	85.4	45.5	488
	1.00	70.6	35.9	385
Glyphosate	0.50	60.8	36.6	392
	0.75	74.5	35.4	379
	1.00	69.6	38.3	411
MCPA	0.50	63.5	34.7	372
	1.00	62.5	38.7	415
2.4-D	0.50	62.8	36.4	390
	1.00	85.0	43.6	467
	2.00	61.5	33.3	357
2,4-D + crop oil	0.25	77.0	40.8	437
	0.50	72.5	43.9	471
	1.00	64.0	39.5	423
	1.50	62.3	37.8	405
Control	--	68.1	40.2	431
LSD (0.05)	--	15.3	ns	ns

* 7% moisture.

Table 7. Fall tillage influence on giant burreed control - Aitkin - 1984.

Tillage	Giant burreed		Wild rice			
	Plants	Dry weight	Panicles	Plants	Grain yield*	
	no/16ft^2	g/16ft^2	no/16ft^2	no/16ft^2	g/16ft^2	lb/A
No Till	32.7	160.3	51.7	29.6	24.0	257
Rotovate	12.6	39.4	131.3	106.8	52.5	563
LSD (0.05)	4.1	56.1	44.4	54.3	11.9	128

* 7% moisture.

Table 8. Effect of spring bentazon treatments on giant burreed growth and wild rice yield - Aitkin - 1984.

Time of application	Bentazon formulation	Rate lb/A	Giant burreed Plants	Giant burreed Dry weight	Wild rice Grain yield*	
		a.i.	no/m²†	g/m²	g/m²	lb/A
Preemergence	Granular	1.0	21.3	49.3	22.1	179
		2.0	36.2	133.6	34.3	306
2-leaf	Granular	1.0	24.0	93.5	36.1	322
		2.0	17.3	60.5	34.4	307
	Liquid	1.0	13.5	36.3	17.2	153
		2.0	21.8	51.0	21.8	195
	Liquid + crop oil	0.5	14.5	36.8	28.1	251
		1.0	22.3	65.8	23.8	213
5-leaf	Liquid	1.0	17.0	58.5	20.1	179
		2.0	13.5	25.8	26.5	237
	Liquid + crop oil	0.5	26.3	55.8	32.6	291
		1.0	19.8	54.7	29.2	261
Weedy control		-	33.0	117.8	29.4	263
Handweeded control		-	0.6	0.8	28.6	255
LSD $_{(0.05)}$			20.0	61.6	ns	ns

* 7% moisture.
† m^2 = 10.8 sq. ft.

Spring Herbicide Trial

Herbicide trials for control of giant burreed were continued in 1984 near Aitkin, Minnesota. Herbicide treatments included bentazon, MCPA, propanil, and 2,4-D amine applied at 1, 2, or 4 lb/A at the 5-leaf stage of wild rice growth. The experimental design was a randomized complete block with 4 replications. Herbicide by rate interactions were not evident as in 1983 (1983 Wild Rice Research Report). All herbicide treatments reduced the number of burreed plants/m^2 (Table 9). Herbicide treatment (except propanil) reduced the dry weight of burreed. Wild rice panicles and grain yield were reduced with MCPA when compared to the handweeded check. Grain yield was reduced in the weedy check when compared to the handweeded check. Yield in herbicide treated areas was not different from the weedy control.

Table 9. The influence of applying 5 chemical treatments onto giant burreed and wild rice - Aitkin - 1984.

Treatment*	Giant burreed		Wild rice			
	Plants	Dry weight	Panicles	Plants	Grain yield†	
	no/m²§	g/m²	no/m²	no/m²	g/m²	lb/A
Bentazon	14.7	51.6	25.3	14.3	8.1	72.3
MCPA	2.9	6.7	8.7	5.4	3.5	31.3
Propanil	22.8	104.9	26.7	17.3	10.9	97.3
2,4-D amine	7.5	21.8	28.2	15.7	9.3	83.0
2,4-D amine + crop oil	14.3	6.5	22.5	12.4	6.5	58.0
Handweeded control	1.5	3.6	35.3	15.9	15.8	141.1
Weedy control	42.4	158.4	13.7	11.4	4.0	35.7
LSD $_{(0.05)}$	14.3	57.8	23.3	11.6	9.3	83.0

* Averaged over all treatment rates.
† 7% moisture.
§ m^2 = 10.8 sq. ft.

PLANT POPULATION

Reducing Plant Population with Chemicals

An experiment to reduce high wild rice populations with MCPA or glyphosate applied with a modified pipewick applicator was repeated in 1984. In 1983 the pipewick used had alternate 6-inch spaces without ropewicks. The 6-inch spacings were found to be too narrow in 1983, thus the spacings without ropewicks were increased to 10 inches and two ropewicks were placed in the alternate 10-inch spacings instead of one in 1984. In 1983 the narrow spacings resulted in too many wild rice plants killed with the modified ropewick. The yields were reduced compared to the control. The 1984 experiment was conducted in a grower's field. MCPA or glyphosate were applied with the modified pipewick when wild rice was in the early tillering or early stem elongation growth stage. MCPA solution consisted of 1 gallon MCPA (4 lb a.i./gal) mixed with 1 gallon of water. The glyphosate solution also consisted of 1 gallon glyphosate mixed with one gallon of water. Table 10 gives the results from this experiment.

Table 10. Reducing wild rice plant population with use of a modified pipewick applicator - Aitkin - 1984.

Chemical	Date, growth stage	Rate*	Plant height	Stem number	Plant number	Grain yield
			cm	no/ft^2	no/ft^2	lb/A†
Glyphosate	6/18, early tillering	Single	146	10.4	8.0	551
		Double	158	9.6	5.9	603
MCPA	6/18, early tillering	Single	144	13.2	11.7	616
		Double	151	12.2	9.9	600
Glyphosate	6/25, early stem elongation	Single	146	10.5	10.5	524
		Double	145	9.1	8.5	430
MCPA	6/25, early stem elongation	Single	159	13.7	10.9	751
	Unthinned	--	148	9.8	10.7	634
	Mechanically thinned by grower	--	170	6.9	3.7	673

* Single=one application; double=two applications over the same area.
† 40% moisture.

MCPA was not effective in reducing the plant population. The number of plants per square foot after MCPA applications was similar to the unthinned plots. Glyphosate was more effective in reducing the plant population. Rows of plants were evident in the plots treated with glyphosate. However, some injury to wild rice was present at the later application date, particularly when the plots were treated twice. The best chemical treatment was one application of glyphosate when wild rice was in the early tillering growth stage. The plant population was reduced by 45% with this procedure; however, mechanically thinning by the grower reduced the plant population by 65%. With additional refinement of the chemical thinning procedure it may be possible to chemically thin wild rice in the future with a pipewick applicator.

Plant Population and Brown Spot Disease

In cooperation with Dr. Percich, a trial at Grand Rapids to investigate the relationship of wild rice plant population and incidence of brown spot disease was repeated for a third year. Wild rice (K2) was solid seeded at 4 rates. 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, 1983 and 1984 are given in Table 11.

Table 11. 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 - 1982-84*.

Treatment of leaf canopy	1982				1983					1984				
	Plant no.	Stem no.	Leaf area infected†	Grain yield§	Plant no.	Stem no.	Leaf area infected†	Lodging rating‡	Grain yield§	Plant no.	Stem no.	Leaf area infected†	Lodging rating‡	Grain yield§
	/ft^2	/ft^2	%	lb/A	/ft^2	/ft^2	%	no.	lb/A	/ft^2	/ft^2	%	no.	lb/A
Moistened	1.1	4.0	7	682	5.1	3.9	26	1	390	2.5	5.8	20	2	760
	2.0	5.1	22	762	8.4	4.6	1	3	429	4.1	8.0	25	3	758
	3.1	5.4	5	822	5.8	5.2	19	3	408	7.4	11.2	42	6	593
	3.8	7.2	10	880	4.7	4.7	24	5	362	7.7	18.4	78	10	245
	3.8	8.6	15	1007	6.0	4.6	17	3	397	5.4	10.8	41	5	590
	2.8	6.1	12	831										
Moistened and inoculated	1.7	5.4	28	595	4.1	3.9	10	1	368	2.2	6.2	15	2	850
	2.0	5.6	26	660	8.3	5.1	39	3	408	3.4	6.9	32	2	760
	1.7	5.2	28	892	8.4	5.4	42	3	176	5.0	9.3	40	8	382
	4.2	6.5	28	882	9.9	8.7	68	8	48	6.4	8.1	92	10	212
	3.3	8.2	25	832	7.6	5.8	40	4	250	4.2	7.6	45	6	552
	2.6	6.2	27	772										
Treated with Dithane M-45	1.5	5.1	3	818	4.8	3.7	2	2	285	2.4	6.0	15	2	808
	2.0	6.1	1	870	6.8	6.1	7	1	501	4.1	7.9	22	3	738
	1.9	5.9	2	1118	6.4	4.8	3	6	511	5.1	10.6	45	8	655
	3.7	7.2	1	1128	8.7	5.8	2	5	363	9.0	14.2	52	8	550
	3.0	8.1	1	1232	6.7	5.1	4	4	415	5.2	9.7	34	5	675
	2.4	6.5	2	1033										
Untreated	1.7	5.6	1	815	2.6	4.9	4	0	418	1.5	5.8	18	1	872
	1.5	5.4	2	888	7.7	6.6	6	0	368	2.5	5.9	22	4	567
	2.4	6.1	2	828	11.1	7.8	26	6	304	4.4	6.2	50	9	468
	2.1	5.8	4	1035	8.2	5.6	39	6	322	6.6	8.0	60	10	317
	2.6	6.2	3	1028	7.4	6.2	19	3	353	3.8	6.5	38	6	553
	2.1	5.8	2	918										

* For each leaf canopy treatment the values are listed in order of increasing seeding rates. Five seeding rates were used in 1982 and four in 1983 and 1984.

† Upper third of leaf canopy

§ 40% grain moisture.

‡ 0 = no lodging; 10 = complete lodging.

The 1984 experiment results confirmed those of the previous 2 years. Keeping the leaf canopy moist during the day resulted in more disease, particularly when the plant populations were 5 plants per square foot or higher. Dithane M-45 applications decreased disease incidence and lodging at the two highest plant populations. On the average, the Dithane M-45 treated plots yielded the highest because of higher yields at the two highest plant populations compared to the other treatments. On the average over the 3 years, a plant population from 2 to 4 plants per square foot is the most desirable range for wild rice fields. Lodging and diseases are more prevalent at higher plant populations.

PLANT GROWTH REGULATORS

Plant growth regulators (PGRs) to reduce plant height and lodging in small grains have been used for a number of years in Europe and are receiving considerable attention in the United States in recent years. Experiments were initiated in 1984 to determine if PGRs may have a possibility in wild rice production. Ethephon and chlormequat chloride are two anti-lodging plant growth regulators that were tried in 1984. Ethephon reduces plant height in small grains by passing through the plant's cuticle and breaks down into ethylene (a normal plant hormone). With increased concentration of ethylene, cell elongation is reduced and structural components in cells are increased providing a shorter, stronger stalk. Chlormequat chloride inhibits gibberellin synthesis in small grains also resulted in a shorter, stronger stalk. Cerone® brand ethephon was applied at Grand Rapids at 1/4, 1/2, 1 and 1 1/2 lbs a.i. per acre just before stem elongation, at early stem elongation and at boot growth stages. Another treatment was the application of 1/4 lb. a.i. per acre just before stem elongation and at early stem elongation. Terpal, a mixture of ethephon and chlormequat chloride, was also applied at the above rates and growth stages except not at the single 1/4 lb. a.i. per acre rate. At Excelsior the two chemicals at the above rates were only applied at the early stem elongation and boot growth stages.

No lodging occurred in any of the plots. Plant height, grain yield, last internode length and panicle length were not influenced by any of the treatments. Wild rice apparently is not as sensitive to these chemicals as other small grains. We plan to continue rate and timing studies with these two and other plant growth regulators. We feel plant growth regulators should have a possibility in wild rice because of the tall stature and lodging susceptibility of the wild rice plant.

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 also appreciated. Several growers provided land or seed for our research and their continued support has been very helpful.

PHYSIOLOGICAL MATURITY OF GRAIN

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

Introduction

Physiological maturity (PM) of grains occurs when maximum kernel dry weight is achieved. Growers need to be aware when grain has reached its maximum weight so as not to harvest before the majority of grains are completely filled. 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. The 1984 study had the same objective as the study conducted in 1983.

Materials and Methods

Wild rice, variety Netum, was grown at St. Paul 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). In 1983 germinated seedlings were transplanted into the boxes when a floating leaf 1 to 1.5 inches long was present. In 1984 wild rice seed was broadcast seeded into the boxes and the boxes were thinned when the floating leaf appeared. In both years the seedlings were spaced approximately 8" apart to obtain a final 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 gram/box twice prior to flowering. In 1983 all panicles were bagged in nylon mesh bags to prevent shattering losses of marked kernels. In 1984 kernels were marked with acrylic paint which also bonded the kernel to the panicle.

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 approximately two day intervals for twenty five 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 48 hours at 36 degree 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 when 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. Planting, flowering and physiological maturity dates for the two years are given in Table 1.

Results and Discussion

The date PM occurred according to Duncan's Multiple Range Test was 24 days after flowering (DAF)in 1984 (Table 2). The date maximum kernel weight was reached occurred 32.4 days after flowering (Figure 1). This contrasted with 1983 when PM occurred 26.6 days after flowering (Table 3).

In 1984 the date "brown vein" (brown coloring of the vascular strand) occurred in 100% of the kernels was 27 DAF and the date 100% of the kernels first showed collapse of the vein was 31 DAF. Brown vein occurred three days after the Duncan's Multiple Range Test PM date and preceded the differentiated PM date by 5.4 days. The date 100% of the kernels showed collapse of the vascular bundle followed the Duncan's Multiple Range Test PM date by seven days and preceded the differentiated PM date by 1.4 days. This compares with seven days and .6 days respectively in 1983.

Moisture values were 60% on the Duncan's Multiple Range Test PM date and 26% on the differentiated PM date in 1984. The final kernel moisture obtained in our samples was 27% (Table 3). These values were all higher than those obtained in last year's sampling (Table 3). However, in both years the period of rapid moisture loss and attainment of maximum kernel weight were closely followed by the collapse of the vascular bundle. On the other hand, the appearance of brown vein anticipates PM.

The indicator of harvest maturity which is presently used is the presence of dark color on 35% of the kernels from a random sample of panicles from a field. In our study this indicator was variable in its time of appearance. In 1983 it occurred between 19 and 21 days after flowering. In 1984 it occurred between 13 and 15 days after flowering or six days earlier.

The growing season of 1984 differed considerably from that of

1983. The planting date was 2 weeks later and cooler temperatures occurred during grain fill. This difference accounts for the prolonged grain filling period of 1984. Stand establishment was delayed in 1984 because replanting was necessary, as a result plant height was reduced by approximately one foot at flowering. Because flowering was delayed until mid-August and because of the lower temperatures the number of heat units received during grain filling was lower than that received in 1983 although the grain filling period was longer. In addition seed set was reduced in 1984. In spite of the differences in growing seasons, the close relationship between the collapse of the vascular strand and the differentiated PM date occurred in both 1983 and 1984. However, the relationship between the differentiated PM date and pericarp color was not as consistent.

Because our study evaluates grain development on an individual kernel basis, the 1983 and 1984 results should be considered cautiously. The samples represent only a small number of the total number of caryopses in the panicle . This number was determined by the number of florets pollinated prior to fixed marking dates and was dependent on environmental conditions. In addition the individual kernels sampled were prevented from shattering even after an abscission layer had formed. In order to relate our results to production fields, bulk samples taken progressively through grain filling would be necessary to relate yields to the occurrence of brown vein, and collapse of the pigment strand.

Table 1

Comparison of 1983 and 1984 planting, flowering and physiological maturity dates and number of heat units accumulated.

	1983	1984
Planting date	31 May	16 June
Flowering date	26 July	16 August
Duncan's PM date	14 August	9 September
Differentiated PM date	22 August	18 September
	Heat Unit Accumulation*	
Planting to flowering	1822.5(57 days)**	2020.5(62 days)
Flowering to PM (differentiated)	964.0(26 days)	851.0(33 days)

* Heat Units = (Maximum + Minimum Temperature)/2 - 40' F
** Number of days in which heat units were accumulated.

Table 2. Kernel weight, presence of brown vein, presence of collapsed vein and percent grain moisture during maturation of the grain-1984.

Day after Anthesis	Kernel Dry Wt (Mg.)	Brown Vein as % of sample	Collapsed vein as % of sample	Actual $\%H_2O$
13	14.6	0	0	62.5
15	12.6	38	24	66.5
19	20.5	69	11	53.5
21	17.8	73	31	53.0
23	15.4	97	81	62.5
24	13.0	94	36	65.2
27	32.0	100	58	43.9
31	41.4	100	100	21.2
****************** PM ************************				
33	28.1	100	100	26.3
35	26.1	100	100	24.6
37	27.6	100	100	27.0

Final kernel weight- 27.0 mg.

Table 3. Kernel weight, presence of brown vein, presence of collapsed vein and percent grain moisture during maturation of grain-1983.

Day after anthesis	Kernel dry wt (Mg.)	Brown Vein as % of sample	Collapsed vein % as of sample	Actual % H_2O
13	12.4	0	0	29.4
14	11.4	0	0	37.5
15	16 2	0	0	28.9
16	13.9	0	0	23.5
17	17.1	0	0	41.3
18	21.0	0	0	34.3
19	20.0	0	0	25.5
20	22.8	17	17	28.9
21	24.7	80	0	30.5
22	18.0	100	8	19.6
23	21.8	36	9	31.1
24	22.7	90	64	22.0
25	21.3	85	83	19.7
26	24.3	100	100	20.7
******************** PM ************************				
27	26.3	92	54	15.7
28	24.4	96	86	21.7
29	20.5	100	100	15.1
30	23.3	100	100	13.9

Final kernel weight- 24.2 mg.

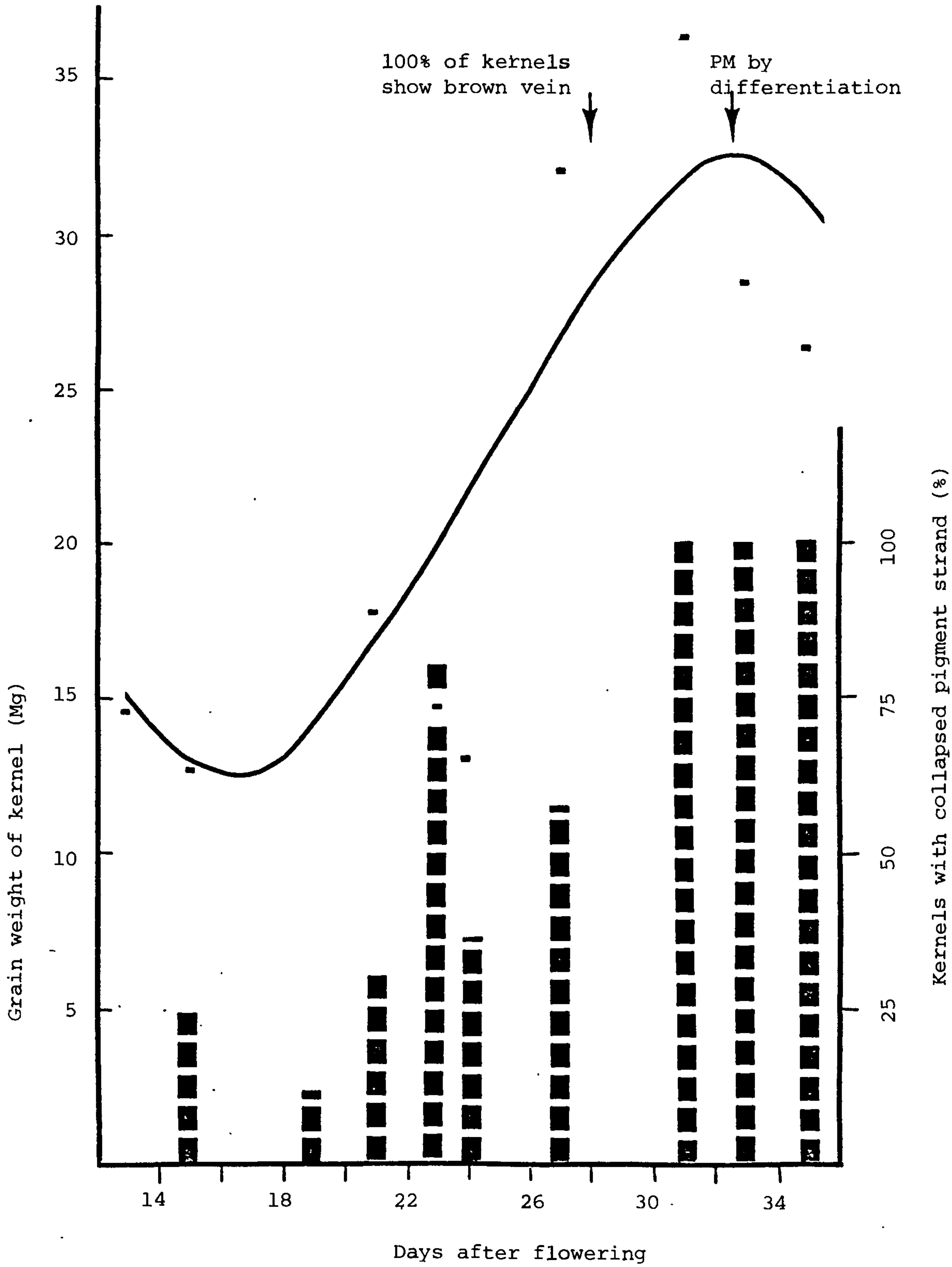

Figure 1. The dry weight accumulation of wild rice kernel and percent of kernels with a collapsed pigment strand during grain filling in wild rice in 1984. The solid curve represents the predicited curve for dry weight accumulation. Physiological Maturity (PM) calculated by differentiation method was at 32.4 days after flowering.

WILD RICE BREEDING--1984

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The 1984 research season was variably successful for the plant breeding project. A problem of seed storage and its resulting effect on germination caused very poor stands in plots seeded with varieties, seed of which had been stored in bulk in our cold room. We were able to obtain additional K2 seed from a grower; thus, K2 stands were good in our plots. All other varieties or populations which we stored over winter in bulk had very poor germination. Experiments using genetic materials which were stored over winter in petri dishes in the cold room had generally good stands. Most of these experiments were part of graduate student research; the results are not yet available for reporting herein.

The overall subjects of research for 1984:

1) Increase of breeder seed of Dwarf population
2) Tiller synchrony experiments
3) Selection for plant type and maturity in the Dwarf X Johnson population cross
4) Preliminary yield trial of selected populations
5) Dry weight accumulation experiments
6) Inter-genotypic competition in wild rice plots
7) Evaluation of gain from selection among half-sib families
8) Evaluation of M3 X Netum half-sib families
9) Miscellaneous genetic nurseries

1) The experimental population 'Dwarf' was increased at Grand Rapids in 1984. The following proposal and supporting materials were presented to the Minnesota Crop Variety Review committee, November 1984. The increase and release of the population was approved. Release date will be February 15, 1985, and seed should be available for production planting in fall, 1986. Most of the supporting data have been presented in previous progress reports.

PROPOSAL TO RELEASE WILD RICE EXPERIMENTAL POPULATION "DWARF."

The "Dwarf" population was initiated in 1979 by mass selection for short plant height (less than 100 cm) in an open-pollinating population of plants assembled by W. A. Elliott. The base population consisted primarily of short plant types which segregated from the populations related to Netum plus some short materials brought to the Minnesota Agricultural Experiment Station by D. L. Woods, from the phased-out wild rice program of the University of Manitoba. Following the initial cycle of mass selection in 1979, continued selection was practiced by avoiding harvest of tall late segregates in the population. Approval for preliminary seed increase of Dwarf was granted by the Crop Variety Review Committee, November, 1982.

The Dwarf population is characterized by very early maturity, short plant height and reduced foliage in the canopy compared to other wild rice cultivars. It has large seed size and we believe better than average resistance to shattering. On the negative side, Dwarf frequently is low yielding and will likely be extremely susceptible to bird damage because of its earliness.

Supporting Data

Data from replicated tests (1981 through 1983) are presented in Table 1. The striking attributes are that Dwarf is about 3 weeks earlier than Netum (and thus about 3 weeks earlier than Voyager) and about 2 feet shorter. Dwarf has occasionally yielded equal to Netum but should not be considered competitive in yielding ability to the presently grown cultivars of wild rice. Dwarf would make a good replacement for the shattering strains of wild rice which are still being grown and probably will out-produce or at least equal the production of the old Johnson variety.

Seed size of Dwarf is larger than the presently grown paddy wild rice cultivars (Table 2) and may equal seed size of wild rice from natural stands (data not available). Results from seed retention experiments in a M.S. thesis showed Dwarf to be very good in seed retention compared to the other cultivars. Observation on guard rows of yield trials indicate that Dwarf holds its seed well for 2 or 3 weeks when protected against bird feeding.

Plans to recommend Dwarf for release in November of 1983 were delayed when the 1 acre production paddy at Landreth farms suffered heavy bird damage and thus produced a low quantity of seed. Also, the plants in both the paddy and the 1983 yield trials showed extreme heterogeneity for plant height and maturity. In 1984 the breeding project planted a .75 acre increase at Grand Rapids. Three quarters of the paddy were planted with seed from Landreths and one quarter was planted with Breeder Seed from a Rosemount isolation paddy. At harvest, we took random plant height measurements in 4 quadrants of the paddy to check on the possibility of a genetic shift in the seed from the Landreth paddy and on the possibility of a qualitative segregation for plant height. Figure 1 shows the plant height distribution by sets (quadrants); set 4 was planted with Breeder Seed from Rosemount. The average difference in plant height sets

Table 1.
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.

Table 2. 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

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.

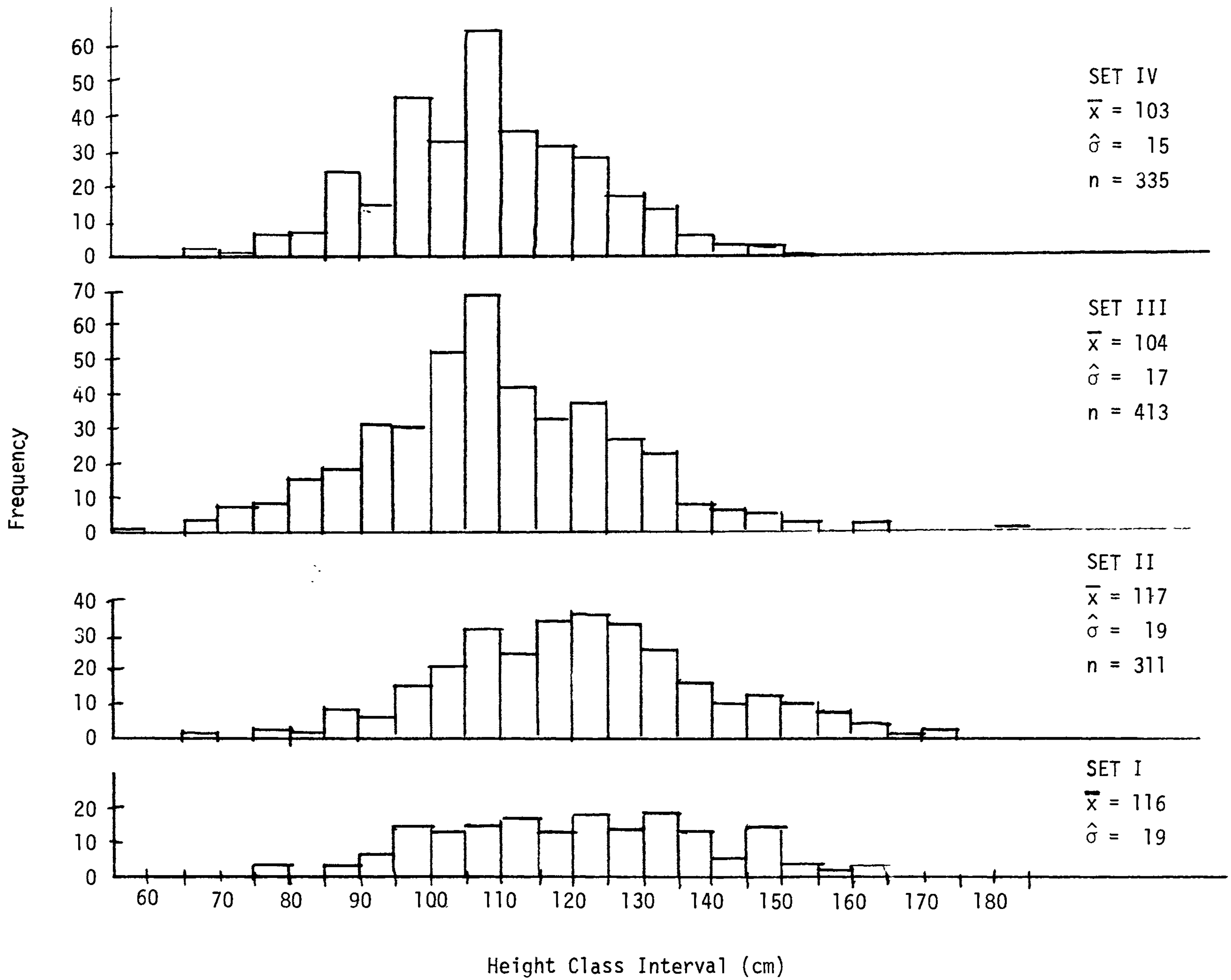


Figure 1. Height distributions of four sets of plants from the Dwarf population. Sets I-III are plants from the Landreth seed source and Set IV is comprised of plants from Rosemount Breeder Seed.

1 and 2 versus sets 3 and 4 can be explained by a water depth change across the paddy. Figure 2 shows the composite distribution after sets 3 and 4 were adjusted for the height difference. The two questions--genetic shift and qualitative segregation--seem to be answered in a favorable response; there is no evidence to support the idea that a genetic shift occurred and there is no evidence supporting qualitative segregation for height in the population. We believe the population should be released but have requested that the plant breeder decide when to harvest the Foundation Seed paddy. The date will be established to put continued pressure on the population for earliness--and thereby select against the tall late plants.

Seed Increase Plans

Approximately 120 pounds of Breeder Seed are available to plant about 2 to 3 acres of Foundation Seed (water seeded--Spring 1985.) We expect sufficient seed--400 to 800 lb--to plant 20 to 40 acres of Certified Seed, Fall of 1985. We encourage MCIA to establish 2 fields of production. A major seed sale would then be available in the Fall of 1986. A limited sale of this variety seems desirable until more large scale experience is obtained. Thus, the low seed supply does not seem a problem to the wild rice researchers.

END OF PROPOSAL

2) Selection for tiller synchrony is in progress. In the context of our research, tiller synchrony is defined as the uniform maturation of the mainstem and a previously identified number of productive tillers. Given the present level of shattering resistance in wild rice, greater synchrony may increase recoverable yield. Currently, if the mainstem is harvested at maturity, much of the potential yield of tillers will be sacrificed. On the other hand, if the plants are harvested at tiller maturity, much of the mainstem yield may be lost due to shattering. Differences in tiller synchrony have been observed by other wild rice researchers. The objectives of this research by P.M. Hayes for his Ph.D. thesis include determining if these differences are heritable, identifying a suitable measure of tiller synchrony, and developing more synchronous populations.

Plants which we believed to be synchronous (S) and those most asynchronous (AS) were selected via a grid system in half-sib families of Voyager in the summer of 1983. Controls (C) were taken at random within the grid restriction as well. Of this material, 100 S, 40 AS and 40 C plants were identified as having sufficient viable seed for testing; the seed from each plant constitutes a half-sib family. These three sets of families--synchronous, asynchronous and controls--were planted in separate "blocks in reps" designs of four replicates each at Rosemount, MN in 1984. Two plants within each family per replication were chosen at random. The following observations were made on the plants: date of first pistillate floret emergence for the mainstem (MS) and tillers 1 through 3 (T1-T3); date of complete inflorescence emergence of MS and T1 through T3; height of each culm at harvest; and synchrony rating (1 = complete synchrony through 5 = complete asynchrony). On a plot basis, plant height, number of plants, and green weight of grain were recorded.

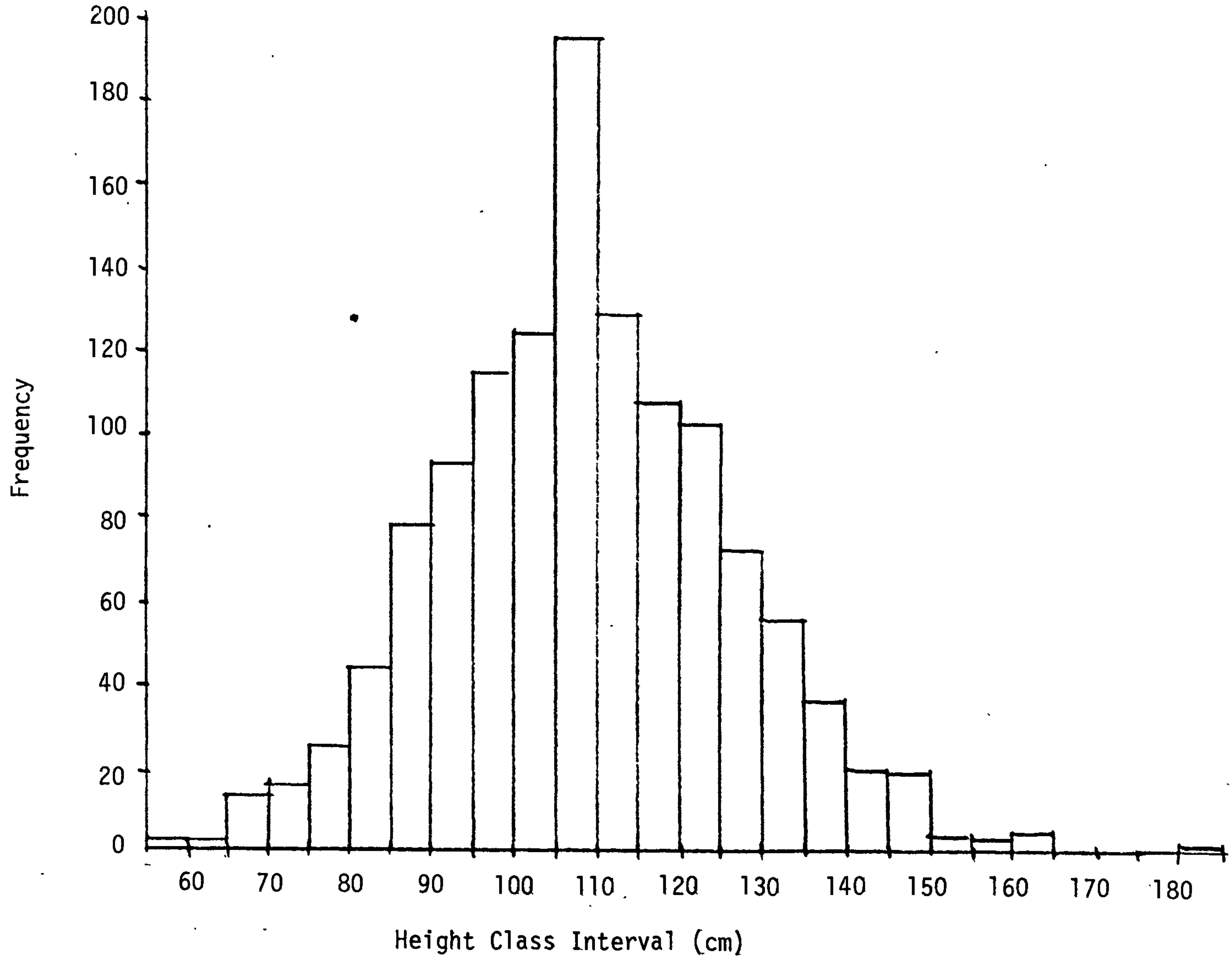


Figure 2. Distribution of plant height in the Dwarf population after adjusting sample sets to a common height mean. Adjustment is based on water depth effect.

The data thus generated will be used to evaluate three measures of tiller synchrony 1) visual rating; 2) synchrony range SR = Tn - M, where Tn = number of days from seeding to a given developmental stage (first pistillate or complete inflorescence emergence) of a specified tiller (the n^{th} tiller) and M = number of days from seeding to the same developmental stage for the mainstem; and 3) synchrony measure SM = T1 + T2 + ... + Tn - nM where Tn and M are the same values as above, and n = the number of tillers being considered. A preliminary analysis using 1) and 2) suggests that tiller synchrony may be moderately heritable. A range of 8 to 20 days between mainstem and third tiller inflorescence emergence was observed, with a mean equal to 13 days. In 1985, selected families will be evaluated for synchrony, another cycle of selection will be practiced, and an examination of plant spacing effects on synchrony expression is contemplated.

As an early measure of selection, equal quantities of seed from each plant of the three populations were bulked to form populations for testing. They were evaluated in a preliminary yield trial at Grand Rapids. We used two-row plots ten feet in length and replicated the entries six times. The comparisons of interest involve the first four entries in Table 3. Voyager, note the poor stand, is a logical variety for check comparison since we made the selections out of it. The only item that is of interest involves the harvest date; possibly selecting for tiller synchrony resulted in a slight increase in earliness. The other traits do not show much evidence of change. Of course, we would not expect a great deal of change to show up in the first stage of selection. Our results from next year should be more definitive.

Since the initiation of the experiment, we have seen a rather high frequency of plants (in other paddies) which appear to have a high degree of tiller synchrony. Most of the plants are widely separated from other plants and frequently they appear to be in a site of low fertility. Such incidences suggest that the character "tiller synchrony" may be affected more by environment than by genetic control. Hayes will attempt to investigate the plant density effect on synchrony in 1985.

3) Selection for plant type and maturity in the Dwarf X Johnson population cross. The Dwarf X Johnson population cross was made with the expectation of selecting new types of plants which would incorporate some of the desirable characteristics of both populations. In the summer of 1983, we selected plants which were categorized as having short plant height and early maturity, short plant height and medium maturity or medium plant height and medium maturity. Selections were based on visual mass selection using an approximate grid approach to avoid some of the confounding effects of paddy environmental variation.

Selected plants were harvested individually to permit evaluation as half-sib families in 1984. All families were evaluated in a replicated trial in one paddy at Grand Rapids. The plots were grouped by plant type-maturity categories. We used a blocks-in-replicates experimental design with 4

Table 3. Results of the 1984 preliminary yield trial at Grand Rapids (6 replicates).

Entry	Characteristic						
	Plants per plot	Stems per plot	Stems per plant	Plant height -inches-	Dry Wt. yield -lb/A-	% Dry weight	Harvest date [4]
Synchronous[1] Bulk	64	224	3.6	63	944	62.7	73
Control[1] Bulk	47	190	4.4	66	930	63.0	75
Asynchronous[1] Bulk	51	205	4.1	62	1026	63.4	76
Voyager	27	173	6.5	67	798	62.7	77
DJ-MM[2]	70	199	2.9	66	869	64.2	76
DJ-SM[2]	69	239	3.5	65	956	64.2	76
DJ-SE[2]	71	223	3.2	62	742	66.2	72
Dwarf	24	133	5.9	48	479	76.1	69
Loon[3]	66	285	4.3	67	733	64.2	78
M3xNet	21	127	6.3	67	702	63.4	77
LSD(.05)		32	1.0	4.0	149	1.5	--

[1] Populations from tiller synchrony selections in 1983.
[2] 1983 selections out of the Dwarf X Johnson population: MM--medium height and medium maturity SM--short height and medium maturity; and SE--short height and early maturity.
[3] Experimental population from a lake collection crossed to Netum and selected for non-shattering heads.
[4] Days after June 1.

replicates. The short-early group (DJ-SE) was represented by 48 families; the short-medium group (DJ-SM) consisted of 42 families; and the medium height-medium maturity group (DJ-MM) was comprised of 60 families. The evaluation trial appeared to be satisfactory to good, with only a few missing families due to inadequate seed supply or poor germination. Notes were recorded by family for plant height, and maturity based on flowering date. Green seed weight was recorded at harvest but dry weight was not measured since all available seed was needed for the next cycle of selection and for evaluation of progress from selection.

The data from this experiment will be used for a Master of Science research thesis by Tri Hutomo. In order to obtain information on progress from the first cycle of mass selection, we bulked a few seed from each plant (in each group of plants) so we could evaluate the populations in a small variety test. The results are presented in Table 3. The suitable control population (random seed of the Dwarf X Johnson population) was lost due to seed storage problems in our cold room. None of the seed germinated.

The results of the preliminary trial are interesting to us. Since the Dwarf population itself was included in the trial, we have a useful "control" variety. Stands in terms of plants per plot were similar for the three DJ populations and much better than for Dwarf--approximately 3.5 plants per square foot (2 row-plots 10 feet in length replicated 6 times) versus about 1 plant per square foot for Dwarf. The DJ populations were 14 to 18 inches taller than Dwarf; they were later in maturity and considerably better in yielding ability (Table 3). We were primarily interested in the SM (short-medium) population and it looks good for yielding ability and maturity. Of course, our intensive selection will be done based on the half-sib family results of 1984. We would like to have a short population with a maturity intermediate between Dwarf and Voyager and with yield similar to Voyager. Tests completed in 1985 will give us some idea of our chances of achieving our goal.

4) Other entries in the 1984 Preliminary Yield Trial. The experimental population affectionately labeled Loon is the result of a population cross of a natural stand population and Netum. The progeny of intermated plants from the cross were selected for non-shattering head type. The results in the trial are not impressive but additional selection may be useful. A relatively high frequency of shattering plants occurred in the 1984 plots. Thus, Loon's yield potential is considerably better than the test results. Plant height and harvest date were acceptable. We will continue some selection in this population.

The other entry M3XNetum was affected by a low stand density. It is continuing in our breeding materials (see section 8 of this report), but I am beginning to lose interest in its potential as a variety.

5) Dry weight accumulation experiments. The second year of this experiment was completed in 1984. See the 1983 wild rice breeding progress report for first year results. We evaluated three entries in 1984 at Grand Rapids. The entries were planted in a split-plot restriction of a randomized complete block design with six replicates. The entries formed the whole plot treatments and 20 rows (10 feet in length and spaced one foot apart) were available as sub-plots. We harvested two rows of each variety in each replicate at each of ten dates of harvest. Our objective was to estimate the rate of dry weight accumulation in wild rice paddies and to estimate the rate of increase in % dry matter. The first harvest was timed to hit approximately 55 to 60% dry matter so we could follow the increase in maturity. Results are presented in Tables 4 and 5.

The plots of Netum and M3 had very poor stands due to our seed germination problem. Nevertheless, the results were of good statistical quality, particularly for % dry matter. The rate of increase in % dry weight and in dry matter are presented graphically in Figures 3 and 4. The % dry weight response is remarkably similar for the three varieties. The statistics presented at the bottom of Table 4 indicate that on the average wild rice cultivars at Grand Rapids increase in % dry weight of grain at a rate of about ½ a percentage point per day after about 60 % dry matter. The difference between the graph lines (Figure 3) are indicative of relative maturity. The strange drop in % dry matter at day 88 is likely due to moisture which increased green weight of the samples for a 4 or 5 day period. Reference to Table 5 and Figure 4 indicates that dry weight of grain did not drop significantly at this time period. Thus, the loss in % dry matter is not likely due to shattering. The statistics given at the bottom of Table 5 indicate that accumulation of dry weight of grain itself was not a nice linear increase for K2 and for Netum.

Reference to the 1983 results for dry weight accumulation in K2 and Voyager shows a very similar response in percent dry weight, including a precipitous drop at about day 82 in 1983. Also, in 1983, the dry weight of grain itself did not drop to explain the loss in percent dry weight. We intend to study weather records to see if we can gain some insight into the cause.

Aside from the strange drop that occurred for a short period of time in both 1983 and 1984, we are impressed by the repeatibility of the results. We believe the results have some useful implications for growers' use in harvest scheduling. An estimate of % dry weight in the low 60% range could be used to predict how many days of additional time would be needed to reach some fixed higher level of % dry weight. For instance, we would bet a paddy at 62% dry weight would reach 65% dry weight in 5 to 6 days of good growing conditions. We would also bet we could show that a paddy which has suffered some considerable losses to shattering at near optimum harvest stage would increase in % dry weight (or % recovery) but that the actual dry weight of grain will not recover. These sorts of "guesses" seem to be good candidates for research in grower's fields in the coming years. We believe that % dry weight can be used to estimate % recovery by considering hulls and trash to amount to approximately 22 to 24% of green weight. This too would need investigation in grower fields before a usable system could be developed.

Table 4. Percent dry weight of grain for 3 varieties sampled over 10 dates. Experiment grown at Grand Rapids, 1984 in six replicates.

Sampling Date	Variety K2	Variety Netum	Variety M3	Mean over Varieties
Aug 14 (75)[1/]	58.9	58.2	--	58.6
Aug 16 (77)	59.7	60.6	55.4	58.5
Aug 17 (78)	61.0	61.0	58.7	60.2
Aug 21 (82)	62.6	62.3	58.3	61.1
Aug 22 (83)	63.7	63.5	59.3	62.1
Aug 24 (85)	65.5	64.9	61.6	64.0
Aug 27 (88)	69.2	70.4	65.2	68.2
Aug 29 (90)	66.6	67.8	62.2	65.5
Aug 31 (92)	68.6	67.5	63.5	66.5
Sept 3 (96)	69.8	71.5	65.9	69.0
Standard error of means	.49	.68	.98	.42
Regression Coeff. (b)	.56	.61	.50	.54
Coeff. of Det. (r^2)	.92	.90	.91	.88

[1/] Date expressed as days after June 1 to compute rate of change per day.

Table 5. Dry weight of grain (hulls not removed) for 3 varieties sampled over 10 dates. (Grand Rapids, 1984).

Sampling Date	Variety K2	Netum	M3
	grams per plot		
75[1/]	103	53	--
77	95	63	37[2/]
78	119	83	35
82	150	103	50
83	125	68	64
85	120	84	73
88	127	88	82
90	112	96	82
92	128	86	88
96	89	61	92
LSD(.05)	29	24	22
Reg. Coeff. (b)	NS	.63	3.2
Coeff. of Det. (r^2)	.01	.07	.92

1/Days after June 1.
2/Poor stands are responsible for the low yields. Multiply by 4.8 to convert yields to pounds per acre.

Figure 3. Increase in % dry weight as a function of sampling time (Grand Rapids, 1984).

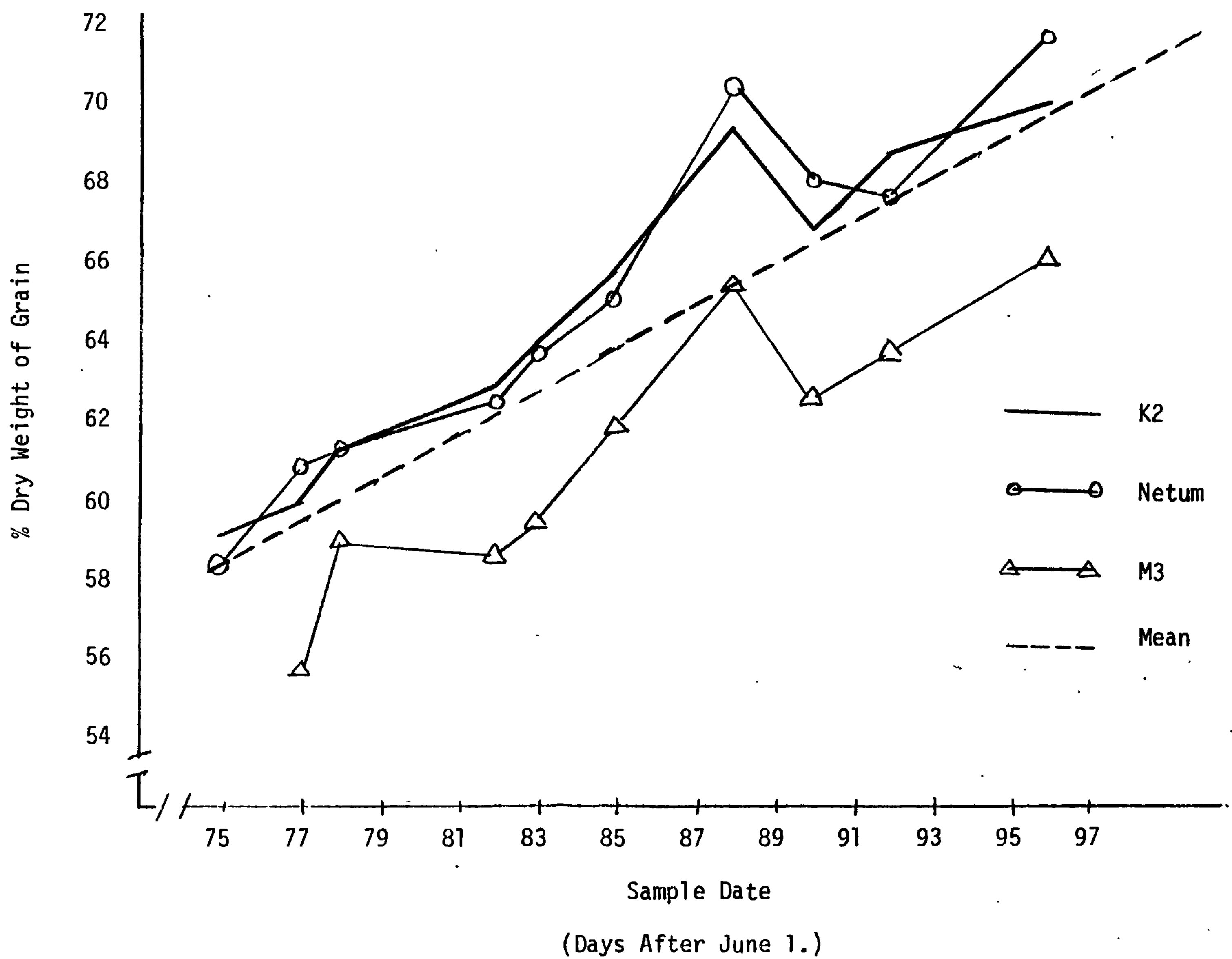
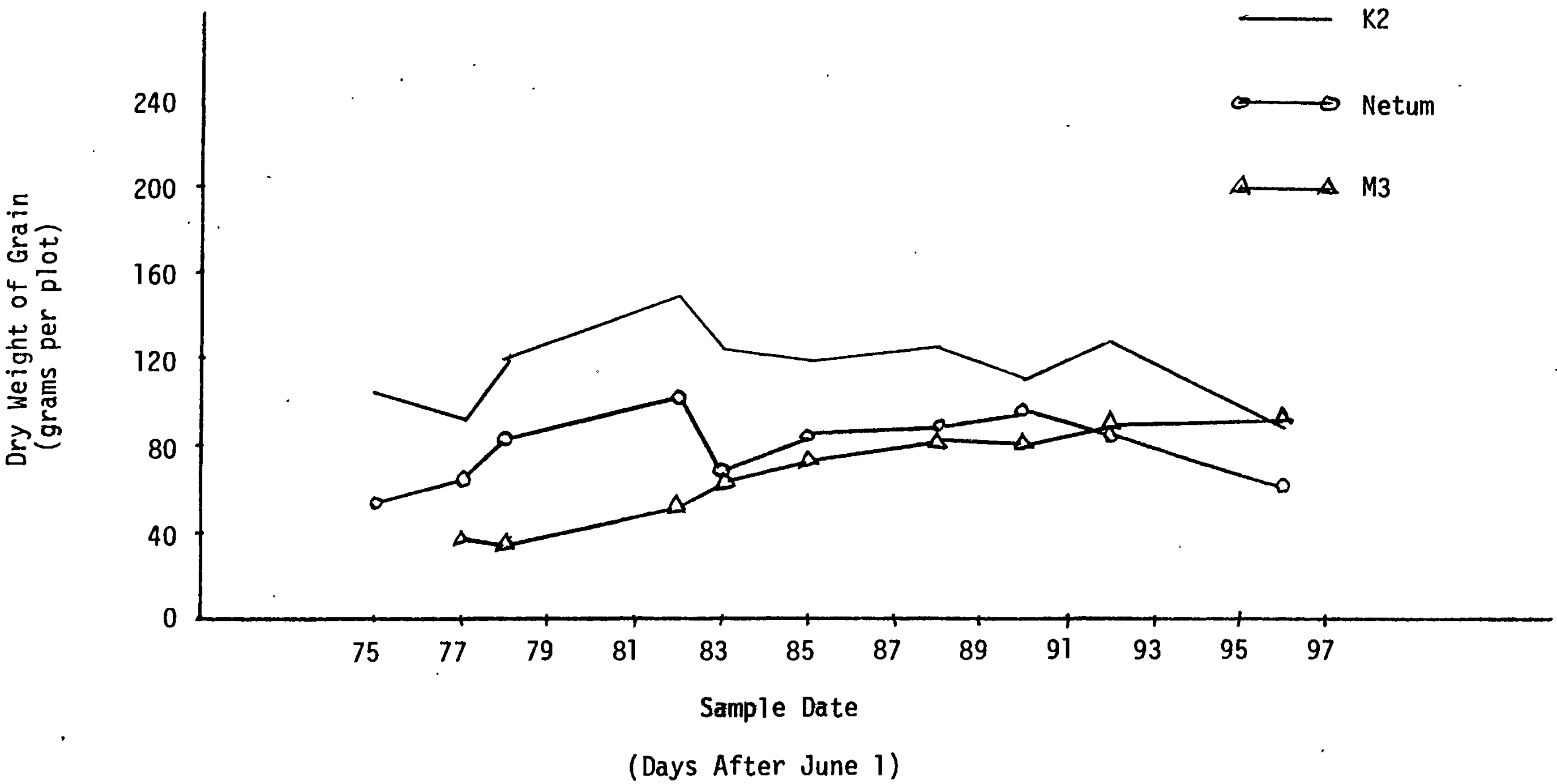


Figure 4. Dry weight of grain accumulation over sample date (Grand Rapids, 1984).



6) Intergenotypic competition in wild rice plots. This subject is of significance to the wild rice breeding project in regard to evaluation of breeding materials. The 1984 season provided the second year of data on the subject, which is being used by Jose Hernandez for his Ph.D. research. The details of the experiment can be found in the 1983 wild rice breeding section of the 1983 Progress Report.

Data for results from 1984 Grand Rapids and Excelsior tests are provided in Tables 6 through 9. The germination problem with M3, Netum, Voyager and M3XNetum resulted in poor stands for 1984. Nevertheless, statistical analysis, Table 6, indicates that intergenotypic competition occurred for stems per plot in Voyager and M3 and for plants per plot within K2 and Netum at Grand Rapids. Translated, this means that the performance of a variety grown in a single row of our breeding trials is affected by the variety grown in the neighboring plots. Results at Excelsior (Table 7) showed M3XNetum to be significantly affected by competing varieties for the traits grain dry weight, plants per plot, stems per plot and plant height. M3 was affected in performance in stems per plot and plant height. Means from the two test locations are given in Tables 8 and 9. The competition rating system given therein is a way to combine results from the experiments for the dry weight trait.

More analyses are necessary before conclusions can be reached. The poor plots in 1984 cast doubt on the value of the experimental results. However, we believe we will be able to demonstrate that intergenotypic competition exists in single-row rice plots, but we doubt if the degree of interference is serious. Results in other field crops are similar in nature. In the case of wild rice, we believe that unbordered plots are likely to show a much greater effect on yield expression than any problem which comes from intergenotypic competition that occurs from using single-row plots without skip rows or border rows.

7) Evaluation of gain from selection among half-sib families. We completed a second year of evaluation of progress from selection among half-sib families. The 1983 progress report included details of the experiment. Our major objective was to determine if we could make genetic progress by selecting for yield of replicated half-sib families evaluated in single-row six-foot long plots. The families used in the 1984 evaluation test were selected for high or low yield, short versus tall plant height and early versus late flowering. The families came from Voyager and were evaluated at Grand Rapids in 1983. The selections were made based on the data collected on three replicates of six-foot long plots which were spaced two feet apart.

Approximately equal quantities of open-pollinated seed of the selected families were bulked to form the new populations. In addition, we bulked seed of every family to form a random bulk population of Voyager, and we bulked open-pollinated seed of half-sib families of the bottle brush phenotype from Voyager. See the 1983 wild rice breeding progress report for specifics. The varieties Voyager, K2, and Netum, and the experimental

Table 6. Analysis of variance of characters measured in the one-row intergenotypic competition experiment; Grand Rapids, spring planted, 1984.

Source of Variation	df	Mean Squares: Grain Dry Weight (g/plot)^2	Plants per Plot	Stems per Plot	Plant Height (cm)^2	% Dry Weight
Replications	5	2052.35	146.37	399.87	2880.69	16.18
Treatments	(27)	(1985.03)	(185.24)	(736.64)	(661.18)	(23.80)
Within K2	6	127.72	65.41*	122.02	76.48	3.24
Within Voyager	6	195.32	6.00	182.37[1/]	191.03	14.07
Within M3	6	429.09	30.43	379.88*	77.84	7.78
Within Netum	6	457.38	94.38**	265.38	244.17	5.54
Among Pop'ns	3	15446.25**	1166.72**	4730.46**	1603.86**	152.94**
Error	133	300.34	30.18	166.15	168.73	8.02

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

[1/]Significant at .95 probability if exact test is used.

Table 7. Analysis of variance of characters measured in the one-row intergenotypic competition experiment; Excelsior, spring planted, 1984.

Source of Variation	df	Mean Squares				
		Grain Dry Weight $(gm/plot)^2$	Plants per Plot	Stems per Plot	Plant Height $(cm)^2$	% Dry Weight
Replications	5	6013.99	128.42	1909.62	968.65	55.22
Treatments	(27)	(1542.07)	(382.60)	(2229.46)	(333.75)	(36.38)
Within K2	6	1061.40	71.98[1/]	1154.52*	178.30	18.44
Within M3X Netum	6	1492.40*	230.71**	1831.82**	462.11*	7.46
Within M3	6	873.58	33.37	825.02[1/]	420.44*	8.76
Within Netum	6	326.74	22.43	154.82	149.65	2.50
Among Pop'ns	3	6370.39**	2726.42**	12132.78**	582.75**	25.31**
Error	135	566.90	59.64	441.08	172.64	10.42

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

[1/]Significant at .95 probability if exact test is used.

Table 8. Effects of intergenotypic competition in single-row plots of wild rice; Grand Rapids, 1984.

Tested variety	Competing variety	Stems per plot	Grain dry weight	Plant height	Competition rating[1/]	Mean competition rating
			-gm/plot-	-cm-		
K2	K2	67	84.2	171	4	3.25
"	Voyager	58	90.0	180	2	--
"	M3	67	90.6	176	1	--
"	Netum	66	89.8	177	3	--
Voyager	K2	39	45.8	157	2	--
"	Voyager	50	52.7	159	1	1.25
"	M3	42	39.5	144	4	--
"	Netum	39	40.8	148	3	--
M3	K2	40	48.4	167	3	--
"	Voyager	60	65.9	178	1	--
"	M3	52	60.7	173	2	2.5
"	Netum	43	48.0	172	4	--
Netum	K2	54	53.6	167	4	--
"	Voyager	70	80.4	176	1	--
"	M3	59	62.1	162	3	--
"	Netum	62	65.9	174	2	3.0
LSD (.05)		15	20	21		

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

Table 9. Effects of intergenotypic competition in single-row plots of wild rice; Excelsior, 1984.

Tested variety	Competing variety	Stems per plot	Grain dry weight	Plant height	Competition rating	Mean competition rating
			-gm/plot-	-cm-		
K2	K2	98	98	173	2	2.0
"	M3XNet	74	72	166	3	--
"	M3	112	104	172	1	--
"	Netum	72	71	163	4	--
M3XNet	K2	84	78	170	2	--
"	M3XNet	67	66	149	3	2.5
"	M3	77	81	152	1	--
"	Netum	49	52	170	4	--
M3	K2	35	44	163	3	--
"	M3XNet	49	59	171	2	--
"	M3	66	67	176	1	1.75
"	Netum	37	36	155	4	--
Netum	K2	64	80	173	1	--
"	M3XNetum	67	76	163	2	--
"	M3	56	69	166	4	--
"	Netum	60	70	165	3	3.75
LSD(.05)		24	27	15		

population M3XNetum were included in a yield trial with the selected populations (Table 10). These were evaluated in a randomized complete block design at Excelsior in 1984. We used four-row plots 12 feet in length, the rows spaced one foot apart and we skipped a row between each plot. A bulk of all remnant seed of Voyager half-sib families from 1983 was used to plant a common border for all the entries (the two outside rows of the four-row plot). Data were recorded on plants of the center two rows. We measured green weight grain yield, dry weight (unhulled) grain yield, and plant height. Number of plants in the center two rows was obtained, and we computed the % dry weight at harvest from the green weight and dry weight data.

Analysis of variances showed highly significant differences for plant height, % dry weight and dry weight yield. However, orthogonal contrasts showed most of the difference to occur between the mean of the check entries and the mean of the Voyager selected populations (Table 10). In retrospect, some of the lack of significance due to divergent selection (high yield versus low yield, tall versus short and early versus late) should have been expected. Since we selected stringently for early flowering in the variety K2 to develop Voyager, we should have expected that Voyager would not have a great deal of genetic diversity for date of flowering. Thus, selection for early or late plants probably should not have been effective. Similarly, because of a genetic correlation between shorter plant height and early maturity, we probably should have expected to find reduced genetic variation for plant height among Voyager half-sibs compared to K2 half-sibs. Yield itself would likely be unaffected by early flowering selection. Indeed, the difference in yield between the high yield population and the low yield population was significant at about 94% probability.

The preliminary conclusion from our half-sib selection work in short-row plots is that progress for yield will not be as easily attained as progress for maturity or plant height. Further, progress from cyclic family selection for plant height and/or maturity may be achieved quickly, such that only one or two cycles are necessary to make use of the genetic variation present in a population.

8) Evaluation of M3XNetum half-sib families. We extracted 140 half-sib families from the 1983 isolation paddy of M3XNetum, the intermated population of the cross between early M3 plants and Netum (made in 1979). The half-sib families were grown for yield evaluation at Excelsior in 1984. We used the same evaluation design as was used for yield selection in K2 and Voyager half-sib families in 1982 and 1983, respectively. The one-row plots were six feet in length, spaced two feet apart and were evaluated in blocks in replicates design with three replicates. The 1984 data are not analyzed. We expect to discard about 50% of the families and bulk the remaining families to form the selected population for testing in 1985.

Table 10. Results of gain from divergent selection among Voyager half-sib families (Excelsior, 1984).

Entry	Plant height	Dry weight yield	% Dry weight	Plants per plot
	-inches-	-lb/acre-		
M3XNetum	59	324	64.0	14
Netum	62	359	65.2	25
K2	62	677	63.0	47
Voyager	57	472	67.9	36
Voyager bottle brush	58	627	67.4	46
Voyager random bulk	57	714	68.2	59
High yield selection	59	749	68.4	58
Low yield selection	58	645	68.0	48
Early selection	60	714	68.7	65
Late selection	59	710	67.4	49
Short selection	58	726	67.5	66
Tall selection	61	739	67.1	52
LSD(.05) one tailed t-test	3.0	112	2.0	--

9) Miscellaneous genetic materials. We still are maintaining some M3-early selected plants which we hope to increase for testing. In the 1985 greenhouse, we expect to cross some large-seeded lake types with Dwarf as a source of non-shattering head type. This phase of the breeding program will be expanded in 1985 and 1986 in an attempt to get greater genetic diversity into our materials. (The seed size research will be handled by G. G. Wandrey as part of his Ph.D. research.) Work on bottle brush inheritance and inheritance of pistillate head type is being continued.

Acknowledgements:

We appreciate the assistance of our undergraduate laborer, Mr. Tim Carlson, and the work force at Grand Rapids under the direction of Henry Schumer, Research Plot Coordinator for wild rice. We also appreciate the advice, interest and other offers of assistance from several growers, the professional group at Grand Rapids (Rabas, Rust and Boedicker), Gerald Ochocki, Research Plot Coordinator, Horticultural Research Center at Excelsior, and David Sandstrom, Research Plot Coordinator at the Rosemount Agricultural Experiment Station.

WILD RICE DISEASE RESEARCH -- 1984

January 24, 1985

Dr. James A. Percich, Project Leader
Cathy Huot, Research Associate
Clint Kohls, Research Assistant
Laura Schlickli, Research Assistant

INTRODUCTION

In 1984 the plant pathology wild rice program graduated Laura Schlickli and Clint Kohls with a M. Sci. and Ph.D., respectively. The Research Associate position was filled by Ms. Cathy Huot. The 1984 research efforts have centered on the areas of fungal brown spot epidemiology and crop-loss, role of nitrogen and potassium fertilization on the incidence and severity of stalk rot, early infection studies of *Bipolaris oryzae*, the possible use of Tilt[R] and Dithane M-45[TM] for control of fungal brown spot, and the influence of stand density on the severity of fungal brown spot (in cooperation with Dr. E. Oelke, Dept. of Agronomy and Plant Genetics). This research report will cover some of the above plant pathology research effort during the past year.

INFLUENCE OF FERTILIZATION ON THE INCIDENCE AND SEVERITY OF STALK ROT

Experimental Methods — Nitrogen Studies

Nitrogen. In 1982, a study was initiated to determine if nitrogen applied at the pre-plant and/or at the boot stage of plant development at various rates would have an effect on the incidence and severity of stalk rot caused by *Sclerotium oryzae* Cav.

Sixty-four seedlings of the wild rice cultivar Netum were planted in 122 x 122 cm (4 x 4 ft) square wooden boxes. The boxes contained 20.3 cm (8 in) of Grand Rapids peat soil flooded to a depth of 12.7 cm (5 in). Sclerotia of *S. oryzae* were obtained from flooded paddies in Aitkin County. A needle attached to a syringe was used to inoculate plants with approximately 35 sclerotia/ml at the 3rd aerial leaf stage of development.

Pre-plant nitrogren urea (46-0-0) was incorpoated prior to flooding at either 68 kg/ha (60 lb/A) or 136 kg/ha (120 lb/A). The top-dress applications were broadcasted onto the water at the boot stage of plant development. Potassium-K_2O (0-0-60) and phosphorus -P_2O_5 (0-40-0) were applied pre-plant and kept constant throughout at 45 kg/ha (40 lb/A) and 68 kg/ha (60 lb/A), respectively. Four treatments were replicated four times. These treatments were as follows:

Total Nitrogen kg/ha (lb/A)	Pre-plant	Boot
0	0	0
136 (120)	136 (120)	0
136 (120)	68 (60)	68 (60)
136 (120)	0	136 (120)

At harvest, ten plants from each box (40 per/treatment) were collected for analysis. The analysis consisted of leaf and stem dry weight determinations as well as grain yield, grain quality, nutrient uptake and disease severity. Disease severity was determined for each treatment by rating each tiller according to the method of Krause and Webster. Their disease index scale is as follows:

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

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

Results of this investigation indicated that delayed nitrogen application of 136 kg/ha (120 lb/A) at boot will reduce stalk rot. These results support published data on white rice. In 1983 this study was repeated. However, the peat obtained for the study was highly acidic (pH 3.8) in nature. This resulted in poor plant growth and uneven stands. Consequently, this research was abandoned in mid-July.

In 1984 a similar experiment was conducted. The inoculation with S. oryzae, harvesting, grain yield, grain quality, leaf and stem dry weights, and disease severity determinations were the same as described above. Nutrient uptake was not determined. The wild rice cultivar K-2 was utilized in this study. The levels of potassium -K_2O (0-0-60) and phosphorus P_2O_5 (0-46-0) were applied pre-plant and kept constant at 45.4 kg/ha (40 lb/A) and 68 kg/ha (60 lb/A), respectively. Nitrogen urea (46-0-0) at either 68 kg/ha (60 lb/A) or 136 kg/ha (120 lb/A) was hand-broadcasted onto the water at the boot stage of plant development. Six treatments were replicated four times. These treatments were as follows:

Treatment kg/ha (lb N/A/)	Inoculated	Non-inoculated
136 (120)	X	
68 (60)	X	
136 (120)		X
68 (60)		X
0	X	
0		X

Results — Nitrogen Studies

There were not significant differences in stalk rot severities, yields and grain quality between S. oryzae inoculated or non-inoculated wild rice plants at various nitrogen rates (Table 1).

When the effect of nitrogen was examined in S. oryzae inoculated and non-inoculated plants on dry stem and leaf weights, no significant differences could be found (Table 2).

Data from 1982 also showed no significant differences in disease index and grain quality between the various nitrogen treatments in S. oryzae infected plants (Table 3). Also, in 1982 there were no significant differences between dry weight of leaves and stems at the various nitrogen treatments. The data of the 1982 and 1984 investigation were rather limited. Only 40 plants per treatment were analyzed for percent nitrogen, dry weight and disease. Also, the plants were artificially inoculated to ensure infection, while most studies on white rice have been conducted in naturally infested fields. Small box studies also present some problems in plant growth and development which appear to significantly affect treatment results.

Therefore, after 4 years of study, it appears that infection of wild rice cultivar K-2 by Sclerotium oryzae under controlled conditions will result in the following:

1. Only moderate infection of otherwise healthy wild rice plants (Krause and Webster Disease Scale).

2. No significant reduction in grain quality, stem and leaf dry weight.

3. No consistent reduction in grain yield.

4. Significant increase in lodging of infected plants after harvest and drain-down.

5. No significant effect of nitrogen, regardless of rate and/or timing of application on disease severity and grain quality.

Evidence is beginning to indicate that stalk rot of wild rice caused by Sclerotium oryzae does not cause significant biological damage in otherwise normal and healthy plants which would result in economic loss. Future study of this disease on a large paddy scale with several years of constant wild rice culture, utilizing several different cultivars at a recommended nitrogen fertilization may give a more realistic indication of the true effects of stalk rot on cultivated wild rice production. Such a "disease nursery" would also be an ideal site to evaluate potential new wild rice varieties.

Experimental Methods — Nitrogen and Potassium Study

In 1982, a study was initiated to determine if differing rates of nitrogen (46-0-0) and potassium (0-0-60) could reduce stalk rot incidence and severity at a recommended 45.4 kg/ha (40 lb/A) and at a high rate 136 kg/ha (120 lb/A) of nitrogen applied pre-plant. Potassium (K_2O) was applied at 68 kg/ha (60 lb/A) or 227 kg/ha (200 lb/A). The level of phosphorus -P_2O_5 (0-46-0) was held constant at 45.4 kg/ha (40 lb/A). The phosphorus was also applied pre-plant. The inoculation with S. oryzae, harvesting, grain yield, grain quality, leaf and stem dry weights, and disease severity determinations were the same as previously described. The wild rice cultivar was Netum and a nutrient analysis was performed.

Pre-plant applications of 120 lb N/A resulted in an increase in grain yield and total N uptake by the plant. Grain yield was significantly higher, 1188 and 1229, highest for plants receiving 68 kg/ha (60 lb/A) and 227 kg/ha (200 lb/A) potassium, respectively, compared to other treatments (Minn. Wild Rice Res. 1982 p.69). Plants receiving the recommended 45.4 kg/ha (40 lb/A) exhibited typical nitrogen deficiency symptoms, indicating a higher amount of nitrogen fertilizer is necessary for normal growth of wild rice in 1.2 x 1.2m (4 x 4 ft) boxes than under paddy conditions. The effects of various amounts of nitrogen and potassium on stalk rot severity was not clearly established. As with the nitrogen study in 1983, acidic soil conditions resulted in an uneven stand which led to abandonment of the study.

In 1984 the study was repeated. The recommended rate of 45.4 kg/ha (40 lb/A) was increased to 90.8 kg/ha (80lb/A) and the wild rice cultivar K-2 was used. A nutrient analysis of the plants at harvest was not performed. Each of the six treatments was replicated four times. These treatments are outlined below:

Treatment	Nitrogen kg/ha (lb/A)	Potassium kg/ha (lb/A)
1	90.8 (80)	0
2	90.8 (80)	68 (60)
3	90.8 (80)	227 (200)
4	136 (120)	0
5	136 (120)	68 (60)
6	136 (120)	227 (200)

Results — Nitrogen and Potassium Study

Nitrogen and Potassium. With the exception of the stem dry weights, no significant differences between treatment were found for the various parameters measured (Tables 4 and 5). However, the trends were similar to those found in the 1982 study. As with the nitrogen study, perhaps a larger sample size would be helpful for statistical analysis. Small plots, artificially inoculated present an unrealistic view of what may be actually occurring in the field.

On white rice, it appears that increased levels of potassium to the soil will decrease stalk rot caused by *Helminthosporium sigmoideum*. The results from our study on wild rice are inconclusive.

This study, like the nitrogen investigation, needs to be repeated in controlled conditions as well as in the field where larger numbers of plants may be evaluated under more realistic conditions of plant growth and development. But, perhaps the biggest road block is the lack of controlled management and subsequent evaluation of nitrogen, potassium and/or phosphorus in flooded peat soils. Also, the precise nutrient needs of wild rice at all stages of growth under both defined and controlled experimental conditions have not been accomplished. Until wild rice can be cultivated in a defined nutrient medium under the correct quantity and quality of light and temperature, studies of nutrient-disease interactions will be difficult.

CONTROL OF FUNGAL BROWN SPOT WITH DITHANE M-45 AND TILT

Introduction

Mancozeb fungicide (Dithane M-45 flowable, Rohm and Haas Co., Philadelphia, PA) has been used to manage fungal brown spot (FBS) disease of wild rice since the Environmental Protection Agency (EPA) approval in 1974. Mancozeb is a protective fungicide with a recommended application spacing of 7 to 10 days on wild rice. Until September 1984 (personal communication with Minn. Dept. of Agriculture) it was the only fungicide registered for use on wild rice in Minnesota. Propiconazol (Tilt by Ciba-Geigy Corp., Greensboro, NC) is a systemic fungicide with eradicative and protective properties. It was registered for use on wild rice with an emergency use permit (section 18) by the EPA, for the 1984 growing season. Propiconazol has recently been tested extensively on wheat. It has shown activity against ascomycetes, basidiomycetes and deuteromycetes but little against phycomycetes. The present study evaluates the use of propiconazol and mancozeb in sequential application combinations for control of FBS, caused by Bipolaris oryzae (Breda de Haan) Shoem., and the yield reductions associated with it. The possibility of yield depression by propiconazol, an egosterol inhibitor, was also investigated.

Experimental Methods

Wild rice seed, cultivar K-2, was planted May 21 into 2.13 by 3.05m (7 x 10 ft) plots to a final density of 26 plants/sq m (3.28 ft_2) and 3 tillers/plant. The paddy had previously been prepared by rototilling and amending the soil with nitrogen at a rate of 22.5 kg/ha (20 lb/A). A second application of nitrogen, 8 kg/ha (7 lb/A), was applied at the early grain elongation stage of plant development. Volunteer seed was eliminated by fumigation of the soil the previous fall with methyl-bromide. The study employed a randomized complete block design with nine treatments, each assigned to a separate plot, and six blocks.

Fungicides were applied with a hand held, CO_2 pressurized canister sprayer. Application volume was 1/3 l (0.09 gal)/plot for both fungicides. Mancozeb (Dithane M-45, Rohm and Haas Co., Philadelphia, PA) was applied at the recommended rate of 2.25 kg/ha (2 lb/A). The rate of application for propiconazol (Tilt, Ciba-Geigy Corp., Greensboro, NC) was determined from previous experiments with FBS on wild rice. Propiconazol was applied at a rate of 0.28 kg ingredient/ha (4 oz/A).

The fungicide application and inoculation schedule (Table 6) indicates the treatments of the study. Treatments were coded with three letter descriptors which indicate the pattern of fungicide use. The three letter codes use 'M' for an application of mancozeb and a `P` for an application of propiconazol fungicide. Four treatments were designated as controls. Control treatment descriptors begin with a 'C' whereas inoculated treatment descriptors contain an 'I'. The second and third letters of the descriptor indicate whether the treatment was an individual fungicide used twice — both letters the same, a single fungicide used once — the last letter an 'I,' or the two fungicides used in sequence — an 'M' and `P.'

The healthy control treatments were used to determine if the fungicides were phytotoxic. Phytotoxicity would be evident by decreased yields in non-diseased treatments. The controls also provided a basis for comparison between healthy and diseased treatments with similar but unchallenged fungicide protection.

The CMM treatment received five applications of mancozeb at a 7-day interval (Table 6). The CPP treatment received two applications of propiconazol at a 17-day interval. The CPM and CMP treatments received two applications of mancozeb at a seven-day interval and one application of propiconazol, 17 days before the first mancozeb application or 10 days after the last mancozeb application, respectively. The IPP treatment received the same fungicide applications as the CPP treatment but was also inoculated. The IPI treatment was similar to the IPP treatment but did not receive the second propiconazol application. The IPM treatment was similar to the CPM treatment except that it was inoculated and did not receive a second application of mancozeb. The second application of mancozeb was applied August 9, when most of the plants had attained mid milk stage. Application of mancozeb at this stage does not affect fungal brown spot (FBS) related yield losses but will curtail disease increase. The MIP and IMP treatments were similar to the CMP treatments except that they were both inoculated and each received only one of the two early mancozeb applications. All treatments that were inoculated received 5 applications of inoculum.

The procedure for inoculum increase and application followed the methods described previously (Minn. Wild Rice Res. 1982 pp 59-60). No misting system was used in this study. Disease intensity ratings were periodically recorded in each experimental plot. When disease levels were below 1 percent, lesions were categorized according to size and counted on each of the three upper leaves of the wild rice plant. As disease levels increased percent leaf area on each of the leaves was used to assess disease severities.

Panicles were harvested from the inner 1.22 by 1.83m (4 x 6 ft) area of each plot by hand. After drying at 60 C (140 F) they were threshed and counted. The grain was hulled, graded and weighed. Wild rice greater than 1.245mm dia. (grade #3) was used to determine final yields.

Results

The non-inoculated treatments had disease levels of approximately 1% or less on all leaves throughout the growing season (Table 7). Disease levels were recorded on August 10 when approximately 33 and 67% of the plants were in mid-grain elongation and mid-milk stages of development, respectively. The trace level of disease found on August 10 in the non-inoculated treatments has been shown not to cause detectable reductions in yield (2,3). The inoculated treatments had more disease throughout the season than the non-inoculated treatments. Disease levels increased from a few lesions on July 23 to mean disease severities of 6, 11 and 27% on the flag, second and third from the topmost leaves, respectively, by August 20. The inoculated treatments had mean disease severities at the milk stage of development of approximately 2, 3 and 4% on the flag leaf, second leaf from the top and third leaf from the top, respectively. This level of disease may cause noticeable yield reduction. Fungicide treatments were a significant factor in the analysis of variance table of treatment yields. The blocks were significantly different at the 6% level but not at the 5% level. The treatment yield means are shown in Table 8. Those treatments underlined did not show significant differences at the 5% level as determined by Duncan's multiple range test. The yield of the CMP treatment was significantly (5% level) higher (Table 8) than either of the two control treatments (CPP and CPM) receiving the first application of propiconazol on July 16. Application of propiconazol at the full boot stage of plant development decreased yields compared to the non-diseased CMP treatment. However, the CMP treatment yield was not significantly higher than the IPM treatment yield. The IPM treatment was inoculated and also received the July 16 application of propiconazol. The CMP treatment yield was significantly higher than the yields from the IMP and MIP treatments, indicating that disease did significantly decrease yields (Table 8). CMM and CMP treatment yields are not significantly different at the 5% level. This indicates that an application of propiconazol at the early grain elongation stage of wild rice development does not decrease yield in the absence of disease.

The IMP and MIP treatment yields were not significantly different from the IPP treatment yield, at the 5% level. The application of propiconazol at full boot, does not seem to significantly decrease yield when comparing treatments with yields already reduced by disease. The IPP treatment yield is not significantly different from the IPI treatment yield (Table 8). This indicates that the propiconazol application at the grain elongation stage did not significantly increase yield under the low levels of disease in this study. Because the CMP and CMM treatment yield comparison does not show significant differences, the comparison of IPP and IPI is not confounded by a yield reduction due to the propiconazol application at early grain elongation. However, the comparison of IPP and IPI may be inappropriate because of the confounding effects of a propiconazol application both received at the full boot stage. This application of propiconazol decreased yields significantly in non-inoculated treatments (Table 8).

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

Discussion

Propiconazol controlled several foliar fungal diseases of wheat in experimental trials in Minnesota. Propiconazol treatments of wheat yielded less than treatments with protective fungicide treatments, reducing yield to levels comparable with unprotected diseased treatments. Recent studies with wild rice showed propiconazol increased yields compared to unprotected disease controls. No unprotected disease control was included in this study. Previous yield loss studies indicate an inoculated disease control would have had severe disease-related yield losses. It is expected that the inclusion of unprotected, heavily diseased treatments would have shown yield increases with propiconazol use similar to those demonstrated in 1983. Disease levels were relatively low in spite of the fact that treatments were inoculated 5 times. Both propiconazol and mancozeb controlled FBS. Mancozeb's fungicidal property is of a protective nature only. Propiconazol has the additional attribute of being able to eradicate disease. Wild rice growers should welcome the additional flexibility that an eradicative fungicide such as propiconazol will give in disease management. This study has shown that propiconazol may decrease yields by approximately 16% when applied at the full boot stage without disease. But with disease present prior to propiconazol application at the full boot stage there was no significant decrease in yield when compared to both non-diseased or diseased treatments. One or two applications of propiconazol with inoculations throughout the season had significantly lower yields when compared to only one propiconazol application at the full boot stage followed by mancozeb at early grain elongation. However, resulting yields from an application of propiconazol at full boot on inoculated plants with or without a second application at grain elongation, was not significantly different from one application at early grain elongation followed by a single mancozeb application at either full boot or early flowering stages. The contrasting results obtained between the inoculated and non-inoculated treatments does not lend support to the conclusion that a propiconazol application at full boot has a depressive effect on yield.

THE EFFECT OF INTERMITTENT AND CONTINUOUS WET PERIODS ON INFECTION OF WILD RICE BY *BIPOLARIS ORYZAE*

Currently, fungicide spray scheduling to control fungal brown spot of wild rice is based on either a calendar schedule, starting near the beginning of July or as a response to high disease severity conditions. The former method of scheduling often results in the application of unnecessary sprays, while the latter method is usually too late for adequate disease control with a protectant fungicide. Knowledge of the environmental conditions necessary for the infection and disease progress in many commercial fields provides a third alternative for scheduling applications of the protective fungicide Dithane M-45. According to this method, applications of Dithane M-45 should be applied only when weather conditions or predictions indicate the environment is or will be favorable for infection.

The objectives of this study were to determine the effect of temperature under conditions of continuous and interrupted wetness on infection of wild rice by *Bipolaris oryzae*.

Experimental Methods

The intermittent wet period (IWP)study employed a factorial design with seven temperatures, 5, 10, 15, 20, 25, 30 and 35 C, three initial wet period durations, 2, 4, and 6 hr, followed by six dry period durations, 4, 6, 8, 10, 12 and 14 hr. The dry period was followed by 14 hr of continuous wetness. The continuous wet period (CWP) study was run concomitantly with the IWP study. CWP times were 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 28, 32, 36 and 44 hr.

The uppermost fully expanded leaf from plants in the early boot to full boot stage of growth were inoculated with a single isolate of B. oryzae (BO 8305), isolated August 10, 1983, in Aitkin County, Minnesota.

After incubation, the plants were returned to standard greenhouse conditions for lesion development. Seven days after initiation of the wet period the delineated target areas were excised from the plant, placed in individual, labelled, breeding head bags, Lawson Co., and stapled shut. The samples were pressed and allowed to dry under laboratory room temperature of 68-73 F (20-23 C) at 20% relative humidity.

Lesion density, measured as lesions per square centimeter, was collected from the dried, pressed samples after rehydration for 30 to 40 minutes in 250 ml deionized water mixed with one drop of Tween 40 from a pasteur pipette. Leaf sections were examined under a magnifying lens and lesions were counted.

Results

Infection of wild rice flag leaves occurred over a broad temperature range (Table 9). In the continuous wet period study, increasing temperatures up to 30 C resulted in higher maximum infection rates (Table 9). Lesion density was lower at 35 C (45 F) than at 30 C (86 F). Within a given temperature, increasing dew periods increased lesion number up to a maximum for that wet period. The analysis of variance for the continuous wet period study demonstrated that the factors such as length of wet period, temperature of incubation and the interaction of wet period and temperature on infection were all significant at the 0.5% level.

Infection rates in the intermittent wet period study increased with increasing temperatures to 25 C (77 F) and declined at 30 C (86 F) and 35 C (95 F) (Table 10). The analysis of variance for the intermittent wet period study indicated that temperature significantly (0.5% level) affects the infection rate. Also, the initial wet period length and the length of the dry period after an initial wet period significantly (0.5% level) affected infection rate. Increasing the length of either the initial wet period or the dry period, at a given temperature, decreased the infection rate.

The interaction of wet period length with dry period length did not affect lesion density significantly. The interaction of wet period length by temperature of incubation (W x T) was also not significant. The interaction of dry period length and temperature of incubation (D x T) was significant at the 0.3 E-10 level and the wet period length, dry period length and temperature of incubation interaction (W x D x T) was significant at the 0.5% level. The linear contrasts for wet period and dry period were significant at the 0.5% level.

Discussion

Significant rates of infection by Bipolaris oryzae occur in a narrower temperature range than germination. Germination studies with B. oryzae on water agar, between 15 to 35 C (59-95 F), have shown absolute germination rates of 80 to 90 percent after two hours. Significant rates of infection require at least 12 hours of continuous wetness at 59 F. Germination of B. oryzae is much slower at 5 or 10 C (41 to 50 F). Very little infection was found with continuous wet periods of more than 24 hours at these temperatures. At 10 C at least 18 hr of continuous wetness was required for even a very low infection rate.

Some of the variation in successful lesion development found in the continuous wet period study appears to be from variability in the method of inoculation. Lesion density decreases within a given temperature with longer wet periods. This variability is believed to be due in part to variation in leaf to leaf inoculations. Lesion density at 20 C (68 F) was lower than at either 15 or 25 C with wet periods exceeding 18 hours. This variability may be due to the fact that inoculation and incubation of the 15 C (59 F) and 25 C (77 F) leaves was on a different day from the 20 C (68 F) and 30 C (86 F) leaves.

Dew periods in commercial wild rice fields in northern Minnesota occur nightly and are often of 10 to 12 hours duration in the middle of the canopy. Cultivated wild rice at maturity may be 2 m (7 ft) in height, leaves 1 to 1.5 m (3.3 to 4.9 ft) in length and profusely tillered. Thus, the plant canopy produced in a typical wild rice field creates a range of microenvironments vertically. The understory, densely packed with older leaves and stems, is characterized by long dew periods and poor penetration by wind or aerially applied fungicides. The upper canopy is more sparsely populated, characterized by shorter dew periods, good air circulation and good fungicide penetration. The differences in wet period lengths in the canopy create a situation where the flag leaf may have only a few small lesions, while the third leaf from the top has a very high disease severity rating.

WILD RICE YIELD LOSSES ASSOCIATED WITH GROWTH STAGE SPECIFIC FUNGAL BROWN SPOT EPIDEMICS -- A REVIEW (1982- 1983)

Experimental Methods: Refer to : "Minnesota Wild Rice Research," 1983. pp. 64-66.

Summary of Results

The effects of fungal brown spot disease, caused by *Bipolaris oryzae* (Breda de Haan) Shoem., during various growth stages of wild rice (*Zizania palustris* L.) and subsequent reduction of yields were studied over two years. Disease onset treatments of full boot, full heading, 1/4 grain elongation and mid-milk resulted in yield reductions of 67, 56, 32 and 0% compared to a non-diseased control (Table 11). Disease curtailment treatments consisted of disease initiation at full boot with disease progress to 1/2 grain elongation, milk and ripe and resulted in yield reductions of 39, 74 and 74%, respectively, when compared to a non-diseased control (Table 12). A critical point model, derived from multiple linear regression analysis of disease severity data on the three uppermost leaves at the milk stage of plant development accounted for 87% of the variation in yield in the disease onset treatments.

Discussion

The timing of aerially applied, protective fungicide applications to wild rice should be related to expected gains against the risk of disease related yield reductions. As with other cereal diseases, yield losses are dependent on epidemic progress, mediated by environmental conditions, inoculum levels and growth stage. Since weather conditions and inoculum levels are usually favorable to fungal brown spot disease increase late in the growing season, scheduling of the last application should be related primarily to growth stage and disease levels.

During the milk stage, neither disease initiation, nor a fungicide application to an ongoing epidemic, caused any variation in yield from healthy or diseased controls, respectively. However, initiating disease 12 days prior to the milk stage resulted in a 32 percent loss in yield, and in an ongoing epidemic, a single fungicide application 9 days before the milk stage resulted in a 35 percent gain in yield. Based on these findings, protective fungicide applications are not recommended during or after the milk stage. With conditions favorable to disease increase, applications during the early grain elongation stage, approximately 10 to 12 days before the milk stage, are highly recommended.

Rating disease severity by the three leaf method has advantages over a system employing only one overall rating for the entire plant. Dissimilar readings on the upper three leaves of a wild rice plant is typical of fungal brown spot symptoms found in commercial fields. This is believed to be due to the microenvironmental differences found vertically in the foliage. A single disease severity value could lead to several different ratings depending on the way averaging is done among the three leaves.

The relative importance of these leaves to grain filling has not been determined. Rating plants for disease by the three leaf method may however, also have advantages in estimating yield reduction due to fungal brown spot. Both epidemic onset and epidemic curtailmnet studies indicate disease progress during or after the milk stage of plant development does not decrease yield. Disease severity ratings at this stage of plant development should give an indication of the yield reduction incurred from disease. A critical point model using disease severities on the upper three leaves at milk stage was developed. Multiple linear regression analysis was used with the epidemic onset disease severity (DS) data at the milk stage and yield data to derive Equation 1. It accounted for 87% of the variation in yields found in the experimental plots.

<u>Equation 1</u>

$$\text{Yield (Diseased)} = \text{Yield (Healthy)} - 11.5 * \%DS\ (\text{leaf } 1) - 12.1 * \%\ DS\ (\text{leaf } 2) - 2.2 * \%DS\ (\text{leaf } 3)$$

Application of this critical point yield loss equation to experimental plots in the epidemic curtailment study, which had a healthy yield potential of only 501 lb/A (561 kg/ha), 62% of the epidemic onset healthy yield from which the equation was derived, produced results that consistantly overestimated disease related yield losses. Equation 1 and the disease severity ratings of the milk stage in the epidemic curtailment study gave disease loss estimates which were 21 (+/- 3) percent (of the estimate) higher than those actually found.

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Table 1. The effect of nitrogen fertilization on infection of wild rice cultivar K-2 by *Sclerotium oryzae*, causal organism of stalk rot of wild rice.

Treatment lb/A	Inoculated	Non-Inoculated	Disease Index	Yield[1] lb/A	Grain Quality[3] % 4	3	2
120	X		1.6 a	1526 a[2]	55 a[2]	44 a[2]	1 a[2]
60	X		2.3 a	1422 a	50 a	40 a	10 a
120		X	1.8 a	1372 a	56 a	40 a	4 a
60		X	1.7 a	1663 a	55 a	43 a	2 a
0	X		2.3 a	1302 a	50 a	45 a	5 a
0		X	1.7 a	1003 a	50 a	44 a	6 a

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

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

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

Table 2. The effect of nitrogen on stem and leaf dry weights in inoculated and non-inoculated cultivar K-2 wild rice plants with *Sclerotium oryzae*.

Treatment lb/A	Inoculated	Non-inoculated	Stem Dry Weight[1] (g)	Leaf Dry Weight[1] (g)
120	X		27.41 a[2]	4.46 a[2]
60	X		24.36 a	3.46 a
120		X	20.54 a	3.06 a
60		X	28.43 a	4.39 a
0	X		26.01 a	4.38 a
0		X	27.18 a	4.48 a

1 Mean weight for 10 plants/treatment.

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

Table 3. The effect of nitrogen rate and time of application on severity of stalk rot and plant yield and grain yield on wild rice cultivar Netum.

Nitrogen tmt. (lb/A)		Disease Index	Yield[1] (lb/A)	Grain Quality[3] Percent
Preplant	Boot			
0	0	2.2 a[2]	849 a[2]	61 ab[2]
120	0	2.3 a	1222 b	51 a
0	120	1.5 a	1327 c	66 a
60	60	2.4 a	1554 d	56 ab

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

[2] Means in each column followed by the same letter are not significantly different at the p = .05 level according to Boniferoni's LSD.

[3] Grain quality refers to seed size. The numbers represent top quality seed with a diameter of 4/64th of an inch or larger.

Table 4. The effect of nitrogen and potassium application on stalk rot severity yield and grain quality on wild rice variety K-2 infected with Sclerotium oryzae.

Treatment lb/A		Disease Index	Yield[1] lb/A	Grain Quality[3] %		
Nitrogen	Potassium			4	3	2
80	0	2.3 a[2]	871 a[2]	48 a[2]	45 a[2]	7 a[2]
80	60	2.4 a	1152 a	49 a	43 a	8 a
80	200	2.0 a	682 a	50 a	43 a	7 a
120	0	2.4 a	1201 a	53 a	44 a	3 a
120	60	2.7 a	949 a	58 a	40 a	2 a
120	200	2.3 a	1227 a	55 a	41 a	4 a

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

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

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

Table 5. The effect of nitrogen and potassium application on leaf and stem dry weights of wild rice variety K-2 infected with *Sclerotium oryzae*, causal organism of stalk rot of wild rice.

Treatment lb/A Nitrogen	Potassium	Stem Dry Weight[1] (g)	Leaf Dry Weight[1] (g)
80	0	18.58 a[2]	3.04 a[2]
80	60	25.56 ab	3.87 a
80	200	18.51 a	2.91 a
120	0	19.68 a	2.65 a
120	60	29.83 b	4.42 a
120	200	27.39 b	3.58 a

1 Mean weight for 10 plants/treatment.

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

Table 6. Fungicide application and inoculation (I) schedule for the comparison of propiconazol (Tilt[TM]) and mancozeb (Dithane M-45) for the control of fungal brown spot on wild rice cultivar K-2.

Elapsed		Non-inoculated				Inoculated				
Days	Date	CMM	CPP	CPM	CMP	IPP	IPI	IPM	MIP	IMP
0	Jul 14					I	I	I	I	I
2	Jul 16	M	P	P	M	P	P	P	M	
6	Jul 20					I	I	I	I	I
9	Jul 23	M			M					M
16	Jul 30	M				I	I	I	I	I
19	Aug 02		P	M	P	P		M	P	P
23	Aug 06	M				I	I	I	I	I
26	Aug 09			M		I	I	I	I	I
30	Aug 13	M								

I = Inoculation with *Bipolaris oryzae*.
M = Mancozeb application.
P = Propiconazol application.

Table 7. Incidence and severity of fungal brown spot on the flag, 2nd and 3rd topmost leaves of wild rice cultivar K-2 with differing chemical treatments at various stages of plant development.

Chemical Treatment	July 23[A]			Aug. 10[B]			Aug. 20[C]		
	F	2nd	3rd	F	2nd	3rd	F	2nd	3rd
CMM	0	0	0	0	0	0	tr	<1	<1
CPP	0	0	tr[D]	tr	tr	tr	0.6	1.0	1.3
CPM	0	0	tr	tr	tr	tr	0.3	0.5	0.7
CMP	0	tr	tr	tr	tr	tr	0.2	0.4	0.5
IPP	tr	tr	tr	1	3	5	7.0	15.0	42.0
IPI	tr	tr	tr	3	4	5	8.0	11.0	33.0
IPM	tr	tr	tr	1	2	3	5.0	7.0	10.0
MIP	tr	tr	tr	2	3	5	7.0	14.0	39.0
IPM	tr	tr	tr	1	3	2	9.0	11.0	13.0

[A] Plants flowering (23% male portion emerged; 56% female portion emerged; first spiklet visible)

[B] Plants - grain fill (33% - 1/4 grain elongation; 67% medium milk)

[C] Plants - grain ripening (50% grain darkened)

[D] Tr - trace disease - no associated yield loss (individual lesions)

Table 8. The effects of Dithane M-45 and Tilt on the yield of wild rice cultivar K-2 in inoculated and non-inoculated plots.

Treatment	Mean Dry Weight		DMR[1]
	Plot (oz)	Acre (lb)	
CMP	7.1	805	a
CMM	6.6	749	ab
IMP	6.5	737	abc
CPP	6.1	691	bcd
CPM	5.9	669	bcde
IMP	5.6	635	bcde
MIP	5.5	623	cde
IPP	5.2	590	cd
IPI	4.8	545	e

[1] Duncan's Multiple Range Test. Treatment means followed by the same letter are not significantly different at the 5% level.

Table 9. Mean number of lesions produced per square centimeter (0.39 in sq) by Bipolaris oryzae on wild rice under conditions of continuous moisture.

Incub	Incubation - Temperature C (F)						
Hr.	5 (41)	10(50)	15(59)	20(68)	25(77)	30(86)	35(95)
2	0	0	0	0	0.3	0	0
4	0	0	0	0.3	0.2	0.1	0
6	0	0	0	0.4	0	0.3	0
8	0	0	0	0.3	0	0.4	0
10	0	0	0	2.0	0.2	2.2	0.1
12	0	0	0	4.7	9.5	9.2	0.2
14	0.3	0.3	2.3	5.4	4.1	13.4	1.5
16	0	0	0	1.6	12.3	11.2	3.1
18	0.3	0.1	2.1	4.7	32.2	14.1	13.5
20	0	0.6	4.0	1.3	24.0	19.8	5.9
24	0	0.1	12.1	3.0	10.9	15.0	4.7
28	0	0.1	12.0	2.8	16.3	16.3	8.7
36	0	0.4	10.0	1.8	28.0	10.2	2.7
44	0	0.5	23.0	4.7	20.4	9.1	3.2

Table 10. Mean number of lesions produced per sq centimeter (0.4 sq in) by <u>Bipolaris oryzae</u> on wild rice under conditions of wet followed by dry periods.

Hours		Incubation - Temperature C (F)				
Wet	Dry	15(59)	20(68)	25(77)	30(86)	35(95)
2						
	4	0.8	0.5	12.0	7.3	0.1
	6	5.1	0.7	4.2	5.7	2.6
	8	1.4	0.2	11.2	1.9	1.0
	10	1.6	1.1	3.2	0.6	0.5
	12	0.2	0.4	1.3	0.1	0.5
4						
	4	0.3	0.1	10.2	5.5	2.2
	6	1.0	1.7	8.8	0.2	1.9
	8	0.2	1.1	4.5	1.1	0.7
	10	0.3	7.6	1.0	0.1	0
	12	0.4	0.1	0.3	0	0
6						
	4	1.0	0	7.8	1.3	0.2
	6	1.0	0.4	9.4	2.7	0.4
	8	0.5	0.3	7.2	2.1	0.1
	10	1.5	0.3	3.4	0.8	0
	12	0.1	0.6	0.2	1.2	0.2

Table 11. Disease severities and mean wild rice yields associated with four fungal brown spot epidemics started at progressively later stages of wild rice growth for 1982 - 1983.

Date	Plant Stage	Treatments: Boot	Heading	1/4 elon	Milk	Control
Jul 13	Full Head	0/1/1 a	0%	0%	0%	Trace
Aug 03		0/1/1	0/1/1	0%	0%	Trace
Aug 07	1/4 elong					
Aug 09		Tr/2.5/70	Tr/1.5/50	Tr/1/30	Tr	Trace
Aug 19	Mid milk					
Aug 21		6.2/20/100	4.25/14/82	3.4/8/76	Tr	Trace
Yield (lb D.W./A)		258 a[1]	343 a	525 b	776 c	806 c
% Yield reduction		67+/-10	56+/-6	32+/-10	0+/-14	0+/-14

a = Top leaf/second leaf/third leaf

Tr = Trace = [<< 1%]

[1] = LSD 0.05 = 114.2

Table 12. Disease severities and wild rice yields associated with four fungal brown spot epidemics initiated at the boot stage of wild rice development and curtailed at later stages.

Date	Plant Stage	Treatments: Disease Progress Boot → 1/2 elong	Milk	Ripe Light	Ripe Normal	Control
Jul 24	Full boot	0%	0%	0%	0%	Trace
Aug 05	1/2 elong	2/5/60 a	2/5/60	2/5/60	2/5/60	Trace
Aug 13	50% mid milk 50% late milk	2/7/60	6/16/97	4/13/95	5/18/100	Trace
Yield (lb D.W./A)		303	131	154	127a	501
% Yield Reduction		39+/-14	74+/-24	69+/-13	74+/-27	0+/-8

a = Top leaf/second leaf/third leaf

PERFORMANCE COMPARISONS OF SPIKE TOOTH VS. RASPBAR CYLINDER AND ROTARY VS. CONVENTIONAL COMBINE

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

Combine harvest research work in 1984 consisted of (1) improvements to the stationary combine system developed in 1983 for evaluating threshing cylinder/concave performance, (2) the use of this equipment in an experiment to investigate the influence of cylinder type on cylinder/concave performance and (3) a field performance comparison of a rotary type and a conventional type combine.

Stationary Combine System Improvements

Three modifications were made to the stationary IH 303 combine testing system in 1984 for improved testing efficiency and experimental design flexibility. These were:

1) installation of nested sprockets on the cylinder drive system to permit cylinder speed to be quickly changed as required between test runs simply by moving the drive chain from one corresponding set of sprockets to another instead of the slower method of changing sprockets as done in 1983.

2) development of methods employing a mobile hoist whereby cylinder and matching concave type can now be switched in less than 30 minutes as compared to the two hours required previously. In experiments comparing cylinder types, making this switch quickly is desirable to minimize potential effects of time-of-day changes in crop conditions on cylinder performance.

3) elimination of a "dummy" run prior to each actual test run, thus cutting the time required to complete an actual run by nearly one half.

Spiketooth vs. Raspbar Cylinder

An experiment was conducted with the stationary combine in 1984 to compare performance of a spike tooth cylinder and concave to that of a raspbar cylinder and grate concave, each over a range of cylinder speed and concave setting. A feed rate equivalent to 250 lbs/min for a 4'-0" cylinder was used in this experiment. This feed rate is considered representative of wild rice harvest operations. Performance was evaluated based on the following criteria:

- unthreshed grain, %
- threshed grain separated at the concave, %
- broken ($\leq$ 1/4" length) grain, %
- straw break-up

Results of this experiment are contained in Figures 1 through 6. The experiment was not replicated because of limitations on time and availibility of labor. This lack of replication may explain some of the scatter evident in the data. Some general conclusions are:

1. Unthreshed grain percentage varied inversely with cylinder speed for both cylinder/concave types.

2. Unthreshed grain percentage varied directly with concave spacing for both cylinder/concave types.

3. The effects of cylinder speed and concave spacing on unthreshed grain percentage appeared to be relatively independent.

4. Percent of threshed grain separated at the concave varied directly with cylinder speed and inversely with concave spacing for both cylinder/concave types.

5. Percent brokens varied directly with cylinder speed for both cylinder/concave types.

Rotary vs. Conventional Combine

In 1984 we had the opportunity to compare performance of a rotary combine, an IH 1460, to that of a conventional combine, an IH 915, in a grower's field. While rotary combines have reportedly been used for wild rice harvest in California, this is believed to be the first time a rotary has been used for wild rice harvest in Minnesota. We appreciate the cooperation of the grower in allowing us to conduct this test.

Harvest had been in progress at the farm for several days prior to the day of the test. During this time, the rotary combine had been used concurrently with the grower's other combines and had covered considerable acreage. IH engineers had been at the farm to observe the harvest and to assist in adjusting the combine prior to our arrival. A dealer representative remained at the farm and was observed making periodic adjustments to the combine's threshing elements.

Both combines had similar 16' wide headers. The IH 915 was equipped with a spike tooth cylinder and concave. The IH 1460 had raspbars on the rotor and a grate concave. In the test, the 1460, considered to have a higher capacity than the 915, was operated at a higher travel speed.

The test consisted of three side-by-side test runs with each combine. Crop conditions were judged to be uniform in the test area. Testing procedures were similar to those used in past years. Net yield in each test run was based on the amount of grain conveyed to the combine grain tank over a 100-foot distance. Combine discharge losses were based on analysis of discharge samples collected over a 30-foot distance within the same 100 feet. Discharge collection equipment permitted collection of sieve discharge (both combines) separate from walker/rotor discharge (conventional/rotary combine).

The IH 1460 had a straw chopper at the discharge end of the rotor that also propels the straw to the rear of the combine beyond the end of the sieve. Unfortunately, additional threshing probably caused by the straw chopper on the rotary combine made it impossible to accurately differentiate between threshing loss and rotor separation loss. Therefore the two combines cannot be directly compared for these losses.

Discharge material was partially analyzed on site, and preliminary sieve loss and walker/rotor loss results were available the next day. All material was saved for laboratory analysis to determine threshing loss, walker/rotor loss, sieve loss and percent brokens on a finished basis.

Results of the conventional/rotary combine comparison test are contained in Tables 1 and 2. Caution should be observed in interpreting results since there is no assurance that either combine was performing optimally. Nevertheless, at least with respect to sieve loss and total loss, results are believed to reflect quite accurately how both combines were performing at the time of the test. Observations from the comparison test are that:

1. Travel speed of the rotary combine was about 50 percent higher than that of the conventional combine.

2. Walker/rotor MOG discharge in lb/ac averaged nearly the same for both combines (4410 vs. 4130).

3. Walker/rotor MOG discharge in lb/min for the conventional combine averaged 70% of that for the rotary combine (280 vs. 400).

4. Sieve MOG discharge in lb/ac for the conventional combine averaged nearly four times that for the rotary combine (420 vs. 110).

5. Sieve MOG discharge in lb/min for the conventional combine averaged nearly 2 1/2 times that for the rotary combine (27 vs. 11).

6. Total walker/rotor discharge loss as a percent of net yield averaged 2.2% (1.0% unthreshed grain plus 1.2% free grain) for the conventional combine and 6.9% for the rotary combine.

7. Total sieve discharge loss as a percent of net yield averaged 3.4% (2.2 + 1.2) for the conventional combine and 0.7% (0.5 + 0.2) for the rotary combine.

8. More than half of the unthreshed grain lost from the conventional combine was discharged from the sieve whereas, with the rotary combine, most was discharged from the rotor.

9. Total discharge loss as a percent of net yield averaged 5.6% for conventional combine and 7.6% for the rotary combine.

10. Percent brokens, while slightly higher for the rotary as compared to the conventional combine (2.2 vs. 1.6%), were unexpectedly low.

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

Run No. 84-	Type combine[c]	Travel speed mph	Net yield green, lb/ac	MOG discharge Mat'l other than grain: walker/rotor lb /min	walker/rotor lb /ac	sieve lb /min	sieve lb /ac	Discharge losses[b]: walker/rotor lb/ac	walker/rotor % of net	sieve lb/ac	sieve % of net
101	R	3.8		513[d]	4330[d]						
102				359	2920						
103				306	2410						
Average				390	3220						
201	R	3.0	577	374	3870	10	100	18.0[e]	3.1[e]	1.1	0.2
202		3.0	520	381	3890	11	109	26.4	5.1	1.2	0.2
203		3.1	574	460	4640	13	127	24.5	4.3	1.1	0.2
Average		3.0	560	400	4130	11	110	22.9	4.2	1.1	0.2
204	C	1.9	558	297	4730	26	408	3.9	0.7	3.5	0.6
205		2.1	555	286	4280	22	336	3.0	0.5	4.9	0.9
206		2.0	634	272	4220	33	508	3.8	0.6	11.5	1.8
Average		2.0	580	280	4410	27	420	3.6	0.6	6.6	1.1

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

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

c) Type combine -- R for rotary and C for conventional.

d) Sieve and rotor discharge collected together as single samples. Quantities are for the total weight of both the sieve and the rotor discharge.

e) The straw chopper stator blades were removed but the chopper was still powered to propel the rotor discharge material rearward. Therefore it is likely that the chopper knocked free some kernels that were still attached. These kernels then had the opportunity to be separated in the water separator.

Table 2. Data from lab analysis of samples.

Run No. 84-	Net yield: % Re-covery[f]	Net yield: Pro-cessed[f] lb/ac	Net yield: % Bro-ken[g]	Discharge losses[h]: walker unthreshed lb/ac	walker unthreshed % of net	walker free grain lb/ac	walker free grain % of net	rotor free grain & unthreshed lb/ac	rotor free grain & unthreshed % of net	sieve free grain lb/ac	sieve free grain % of net	sieve unthreshed lb/ac	sieve unthreshed % of net	Total walker/rotor & sieve lb/ac	Total walker/rotor & sieve % of net
101	--	--	--					41.6[d,e]	--					41.6	--
102	--	--	--					16.2	--					16.2	--
103	--	--	--					17.3	--					17.3	--
Avg.								25.0						25.0	
201	34.8	201	1.6					12.3[e]	6.1[e]	0.8	0.4	0.2	0.1	13.3	6.6
202	36.2	188	2.3					13.9	7.4	0.8	0.4	0.4	0.2	15.1	8.0
203	33.0	189	2.8					13.9	7.3	1.0	0.5	0.3	0.2	15.2	8.0
Avg.	34.7	193	2.2					13.4	6.9	0.9	0.5	0.3	0.2	14.6	7.6
204	35.9	200	1.7	2.5	1.3	2.5	1.2			3.7	1.8	1.3	0.7	10.0	5.0
205	35.4	196	1.4	1.3	0.7	2.0	1.0			3.4	1.7	2.1	1.1	8.8	4.5
206	36.4	231	1.8	2.5	1.1	2.9	1.3			7.1	3.1	4.1	1.8	16.5	7.1
Avg.	35.9	210	1.6	2.1	1.0	2.5	1.2			4.7	2.2	2.5	1.2	11.8	5.6

d) Sieve and rotor discharge collected together as single samples. Quantities are for the total weight of both the sieve and the rotor discharge.

e) The straw chopper stator blades were removed but the chopper was still powered to propel the rotor discharge material rearward. Therefore it is likely that the chopper knocked free some kernels that were still attached. These kernels then had the opportunity to be separated in the water separator.

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

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

h) By dehulling, sorting for over 2-1/2/64" width, drying, weighing and calculating at 7% Mwb. (This included both the "sinker" kernels and the "floater" kernels.)

Fig. 1-Percent unthreshed vs. cylinder rotational speed at four concave settings (spike tooth)

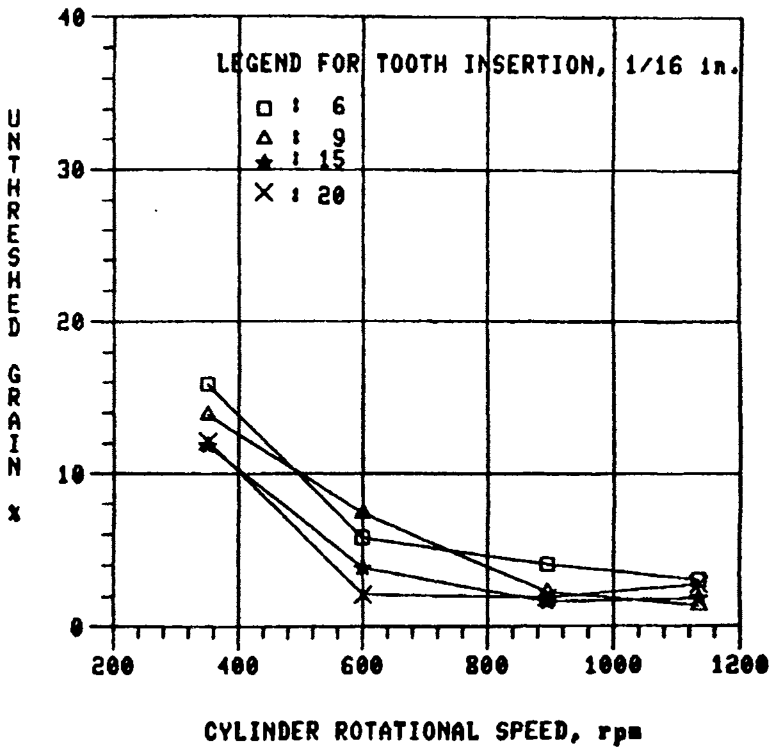


Fig. 2-Percent unthreshed vs. cylinder rotational speed at four concave settings (rasp bar).

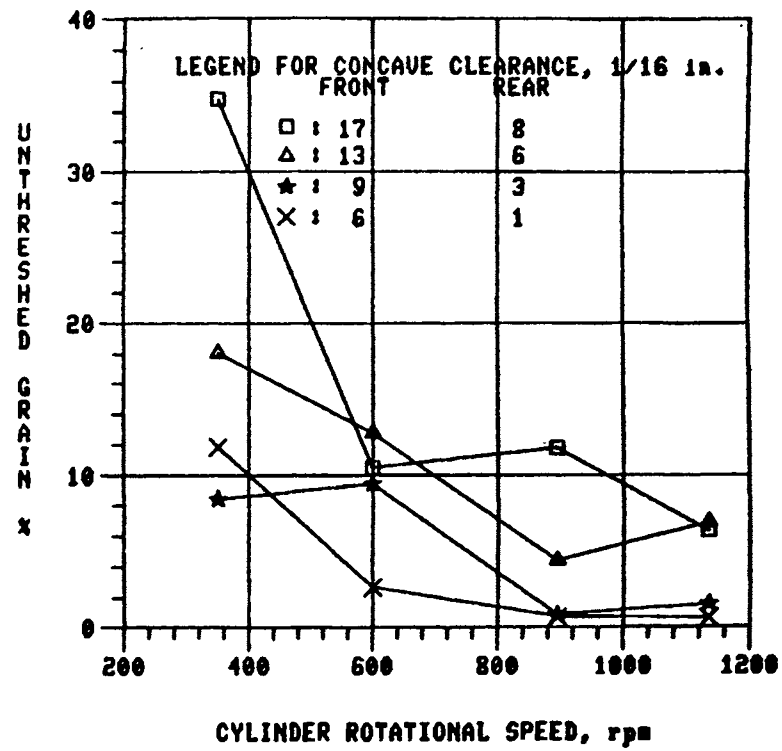


Fig. 3-Percentage of threshed grain separated at the concave vs. cylinder rotational speed at four concave settings (spike tooth).

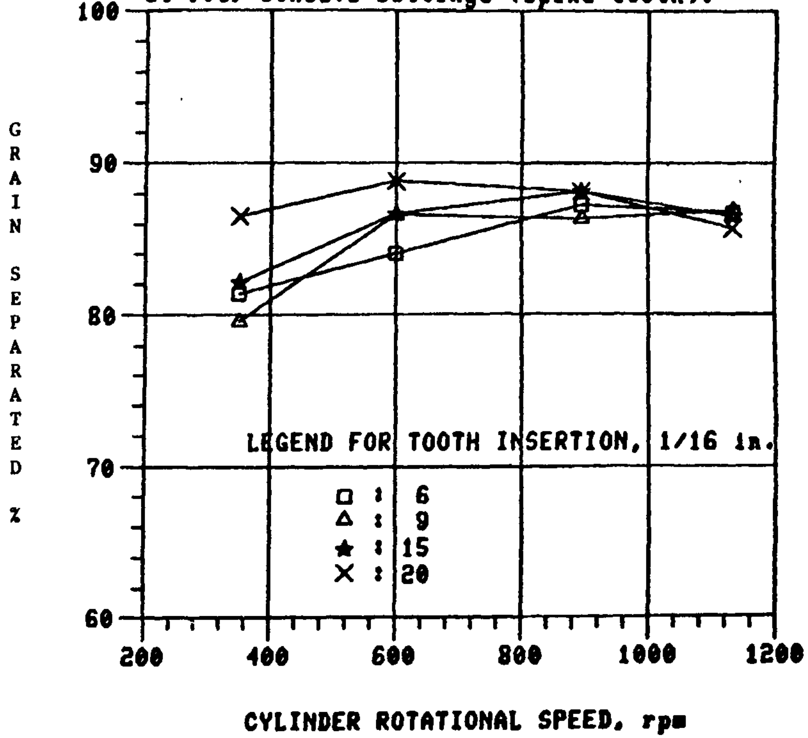
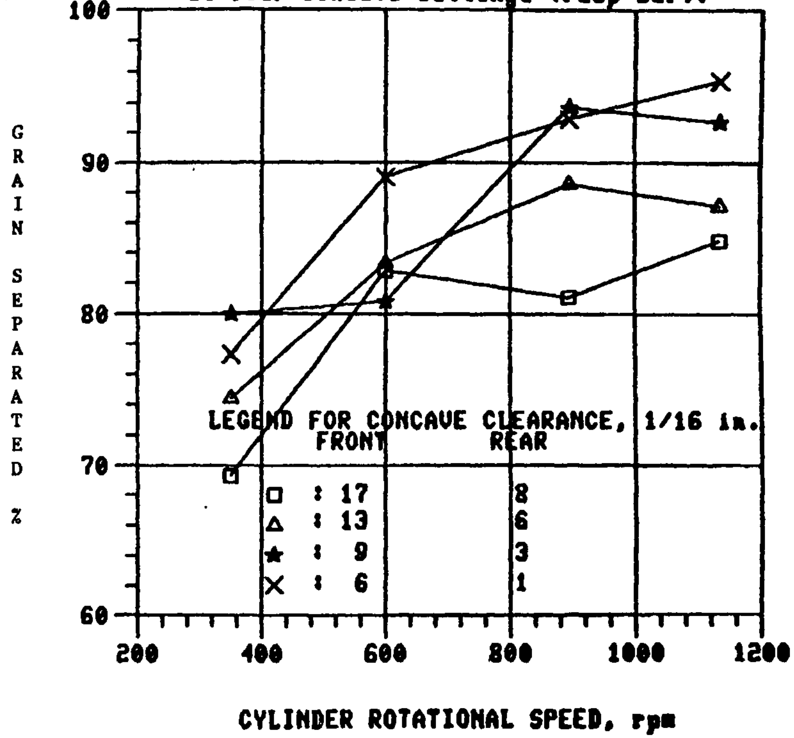


Fig. 4-Percentage of threshed grain separated at the concave vs. cylinder rotational speed at four concave settings (rasp bar).



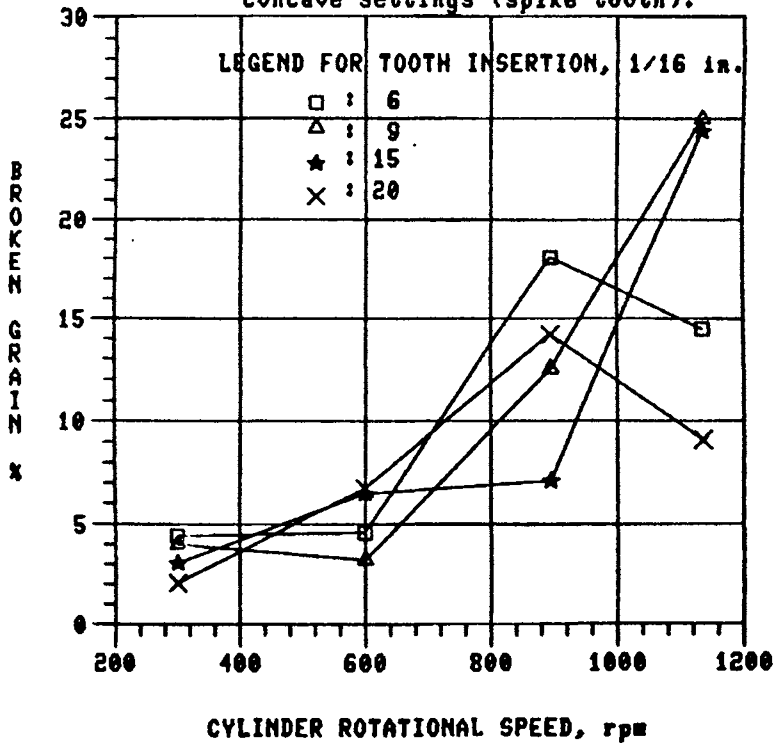


Fig. 5-Percentage of broken grain vs. cylinder rotational speed at four concave settings (spike tooth).

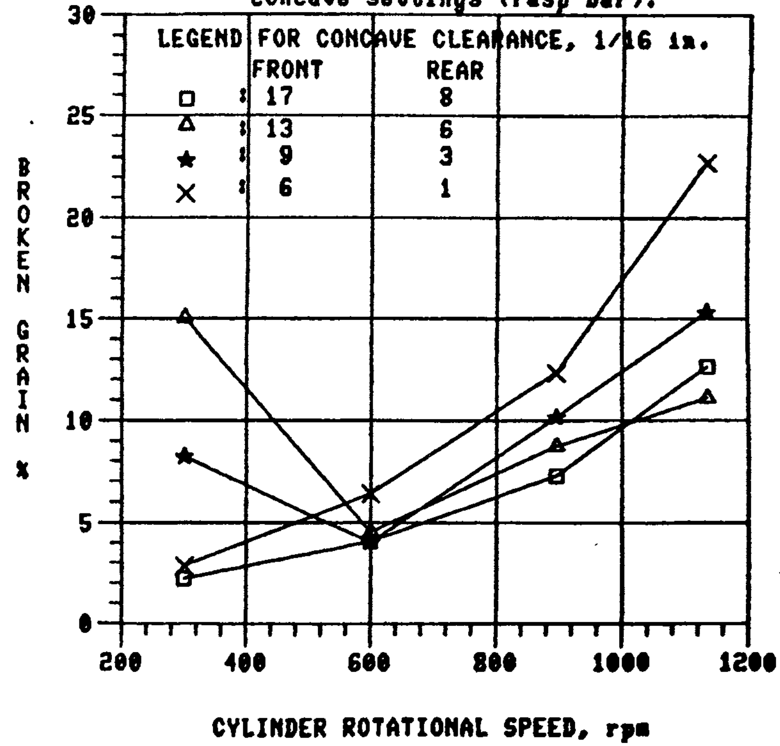


Fig. 6-Percentage of broken grain vs. cylinder rotational speed at four concave settings (rasp bar).

WILD RICE PROCESSING RESEARCH

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

The wild rice processing research conducted in 1984 was directed primarily to the improvement of hullers. The research included both laboratory and prototype studies to determine the influence of selected operating variables and machine features upon the hulling process. Some data were collected at Deerwood to study the interaction between parching methods and huller performance. Samples were collected from other processing equipment beyond the huller and analyzed to determine the effects of specific processing procedures upon the wild rice. Research including that for a M.S. thesis has been started to determine design parameters for improved separation of hulls and unhulled kernels from rice as it comes from the huller.

Hulling Research

Studies at Deerwood

The experimental huller described in our 1983 research report was used at Deerwood to hull all wild rice parched in the continuous flow parcher and a considerable amount from the rotary drum parchers. New rolls covered with 67 durometer neoprene 5/8" in thickness were installed in the huller. Some minor changes were made in the roll reconditioning system to slow the rate of oscillation of the reconditioning bars. The 36 grit abrasive was replaced with 40 grit abrasive.

Table 1 shows the results obtained from six sample sets and shows performance data from the UM experimental huller and the Deerwood plant huller with wild rice parched in the continuous flow parcher and the rotary drum parchers. Samples 1 through 4 were collected at approximately 2-hour intervals on August 21 during normal processing operation. Samples 5 and 6 were similarly collected on August 28. The samples were later sorted in the laboratory in St. Paul. The wild rice to the two types of parchers while similar was not necessarily substantially identical. The rubber covering on the rolls of the Deerwood huller measured 90 durometer early in the season. On August 28th the durometer indicated a value of 81.

The data from Table 1 show that the hulling efficiency of the UM huller as measured by the percentage of unhulled kernels was at least equal to that of the Deerwood huller. Kernel damage as indicated by percentage of broken kernels was consistently less with the UM huller. The table further shows that performance characteristics of the combination of the continuous flow parcher and the UM huller was better overall than that of the combination of the rotary drum parcher and Deerwood huller. The greater kernel damage associated with the Deerwood huller is considered to be almost entirely due to the harder roll

Table 1. Performance Data from UM experimental huller and the Deerwood plant huller with wild rice, parched in the UM continuous flow and the Deerwood rotary drum parchers.

Sample Set No.	Date	Parcher	Huller	Kernel MC %	Whole Kernels, %	Broken Kernels, %	Unhulled Kernels, %	Trash, %
1	Aug. 21	CF	UM	4.12	80.3	12.9	4.5	2.3
	Aug. 21	RD	Dwd	3.75	72.5	20.4	6.0	1.2
2	Aug. 21	CF	UM	4.53	81.8	11.1	4.9	2.2
	Aug. 21	RD	Dwd	3.45	68.3	25.0	5.6	1.1
3	Aug. 21	CF&RD	UM	4.76	83.2	10.5	4.9	1.4
	Aug. 21	RD	Dwd	4.25	78.0	16.2	5.1	0.6
4	Aug. 21	CF	UM	5.71	84.5	9.3	4.6	1.6
	Aug. 21	RD	Dwd	10.39	82.6	8.2	8.8	0.3
5	Aug. 28	CF&RD	UM	5.70	81.0	14.5	2.4	2.1
	Aug. 28	RD	Dwd	3.20	65.6	29.2	3.9	1.3
6	Aug. 28	CF&RD	UM	4.30	78.1	16.1	3.6	2.3
	Aug. 28	RD	Dwd	5.90	75.1	19.9	3.7	1.2

covering material used. It is noted from the results shown in Table 1 that the moisture content of the parched rice from the continuous flow parcher was more uniform than that from the rotary drum parchers.

The roll conditioner, feeder and discharge systems included in the design of the experimental huller functioned well and are considered to merit inclusion in the design of a wild rice huller. Some problems with hull accumulation due to static electricity were encountered early in the processing season which required the removal of the semi-cylindrical rubber covered elements located below rolls as described in the 1983 report.

Laboratory Studies

The 1983 research report referred to laboratory experiments in progress to study the influence of relative roll speeds (speed ratio) upon the performance characteristics of wild rice hullers. Speed ratio is defined here as the RPM of the higher speed roll divided by the RPM of the lower speed roll. The experments included test series where roll clearance, absolute roll speeds and moisture content of the wild rice were varied over appropriate ranges. The tests were conducted on 11 3/8" diameter rolls using the 66-67 durometer neoprene strip as described in the 1983 report. The feed rate was about 26 lb/hr per inch of roll width. The rice for the variable moisture content series was parched in the laboratory scale rotary drum parcher. The rice for the other series was parched in the laboratory continuous flow parcher.

The speed ratio tests were carried out by changing one of the pulleys on the rolls, and running one or two samples through the huller for each speed ratio. The percent of broken and unhulled kernels were then determined for each sample, and used as the criteria for measuring the performance of the huller. Eight different speed ratios were tested. These are listed in table 2, both theoretical, as calculated from the pitch diameters of the pulleys, and the measured ones, obtained by measuring the rotational speed of the rolls, using a stroboscope.

Table 2. Theoretical and measured speed ratios (RPM higher speed roll/ RPM of lower speed roll)

Theoretical Speed Ratio	Measured Speed Ratio	Faster Pulley Diameter (in)	Slower Pulley Diameter (in)
1.78	1.71	4.6	8.2
1.71	1.65	4.8	8.2
1.64	1.58	5.0	8.2
1.57	1.52	5.2	8.2
1.46	1.43	5.6	8.2
1.36	1.34	6.0	8.2
1.28	1.26	6.4	8.2
1.17	1.15	7.0	8.2

The results of these tests are shown in Figures 2 through 8[1]. Since the rolls were not perfectly true, the clearances have been given as ranges rather than a single value.

Figure 2 shows the influence of speed ratio upon the percent of broken and unhulled kernels for a lot of heavy fraction wild rice. An increase in the speed ratio resulted in a decrease in unhulled kernels, but an increase in broken kernels. The high percent of broken kernels indicated by curve for 0 to .005" clearance appears to be inconsistent with prior and expected results and that test will be rerun.

Figure 3 shows what may be regarded as the overall hulling efficiency where the percent of whole hulled kernels for 3 roll clearance values are plotted against speed ratio. The low efficiency values for the 0-.005" clearance reflects the high percentage of brokens referred to in discussing Figure 2 and will likely change when the test is rerun.

Figures 4 and 5 are comparable to Figures 2 and 3 except the tests from which Figures 4 and 5 were run with medium fraction rice. Figure 4 shows that as the speed ratio increases, hull removal is improved but brokens increase. Also, with the medium fraction material roll clearance is very important if good hull removal is to occur. Figure 5 shows that the overall hulling efficiency is highly dependent upon roll clearance and that precise control of roll clearance is very important if good overall huller performance is achieved.

Figure 6 shows the results of tests to determine the effects of moisture content of the rice upon the percent of unhulled and broken kernels for different speed ratios. The wild rice was from the heavy fraction and the roll clearance was set at .005 to .010 ". In general, the results show that a decrease in moisture content within the range tested resulted in fewer broken kernels and better hull removal for any specific speed ratio. These results with respect to hull removal are in close agreement with other tests and observations, but the decrease in broken kernels may be interrelated with parching variables peculiar to these specific tests.

The effect of the absolute speed of the hulling rolls upon huller performance for different speed ratios are shown in Figure 8. It is seen that at a speed ratio of about 1.5 or greater, hull removal approaches maximum efficiency. For any given absolute speed of the slower turning roll, brokens increase with increasing speed ratio. For a given speed ratio, hulling efficiency improves and brokens increase as the speed of the slower revolving roll increases.

1/ The graphs used here were included in a prior report, and the figure numbers are retained. Figures 1 and 7 are not included in this report.

Processing Line

Six sets of samples were collected from different locations in the processing line at the Deerwood plant. The wild rice was parched in both the continuous flow and rotary drum units. All the rice through the Deerwood huller was parched in the rotary drum units. After hulling it was aspirated by air inlets over the transfer conveyor enroute to the scarifiers. All the rice through the Deerwood huller was scarified. Wild rice from sets 1, 2 and 4 through the UM huller was parched in the continuous flow parcher while sample sets from 3, 5 and 6 were from mixed rice from both the continuous flow and rotary drum parchers. Wild rice from the UM huller was added to that from the scarifiers prior to being elevated to the aspirator. The main aspirator is a fractionating type device made by Superior Separator Co. and is apparently no longer in production.

The results obtained from the analysis of the six sample sets are given in Table 3. Average values are given. Certain comparable figures for individual samples can be found in Table 1. Table 3 shows that the scarifiers substantially reduce the unhulled kernels, but also substantially increase the percentage of broken kernels. The main aspirator appeared to function well.

Hull Separation

Some research has been initiated to develop an effective device to separate hulls and to some extent unhulled kernels from wild rice immediately after discharge from the huller. An M.S. thesis is underway to study the aerodynamic properties of wild rice kernels which may serve as a basis for the design of such a device.

Table 3. Results from six sample sets collected at specified locations in the wild rice processing line at Deerwood.

Sample Set No.	Location	Parcher	Huller	M.C., %	Whole Kernels %	Broken Kernels, %	Unhulled Kernels, %	Approx. Flow Rate, lb/hr
1,2,4	After UM huller	CF	UM	4.8	83.9	11.3	4.8	450
3,5,6	After UM huller	CF&RD	UM	4.9	82.4	14.0	3.7	650
1-6	After Deerwood huller	RD	Dwd	5.3	74.5	20.0	5.5	1050
1-6	Before scarifiers	RD	Dwd		76.4	17.9	5.7	
1-6	After scarifiers	RD	Dwd&UM		75.6	22.8	1.6	
1-6	Inlet to aspirator	RD&CF	Dwd&UM	5.1	78.2	19.2	2.7	1500
1-6	After aspirator, rerun	RD&CF	Dwd&UM		43.8	37.0	19.3	11
1-6	After aspirator and indent	RD&CF	Dwd&UM					
	a. *Whole kernel fraction*				98.4	0.0	1.6	1254
	b. *Broken kernel fraction*				0.0	99.9	0.0	150

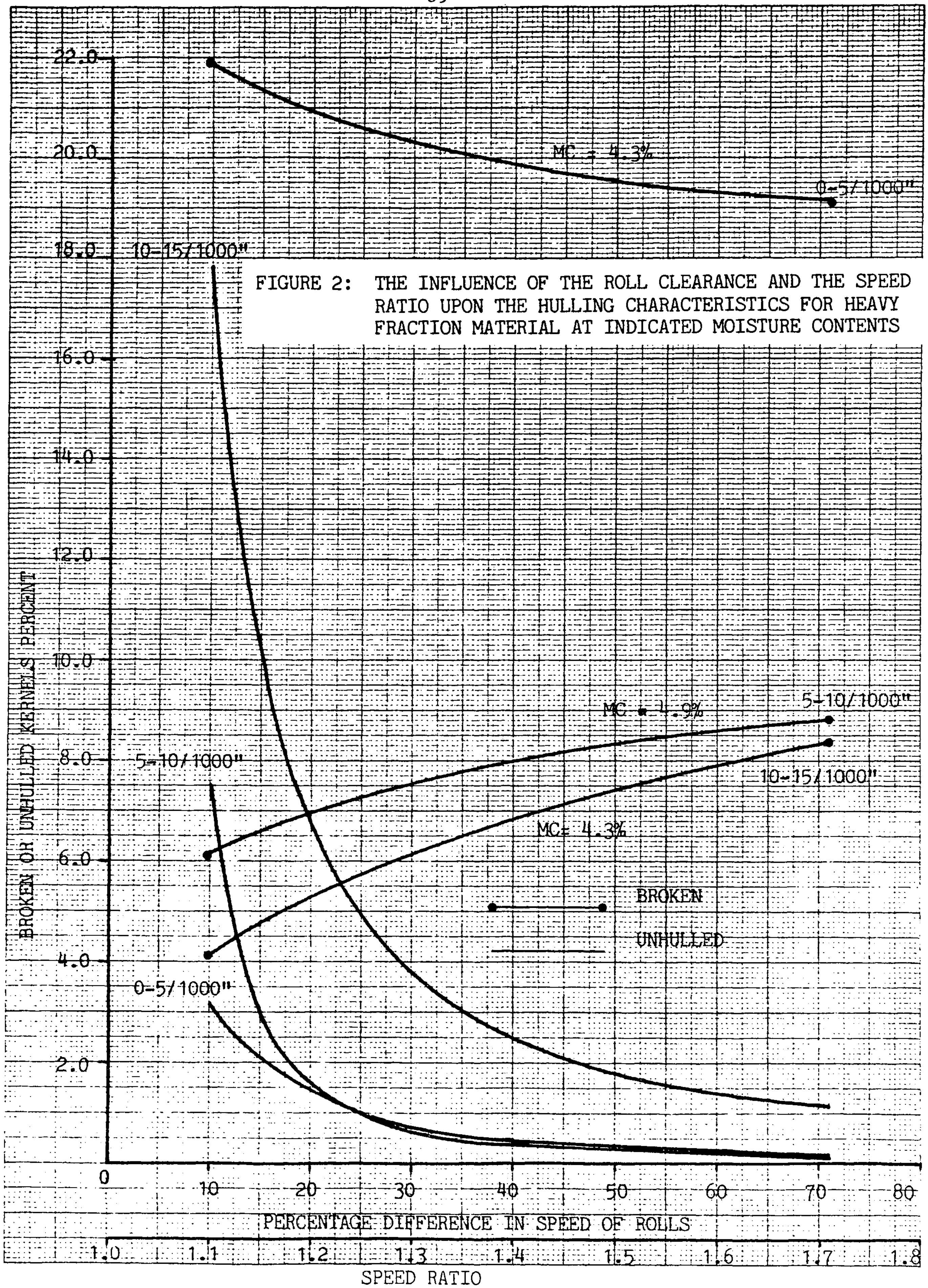


FIGURE 2: THE INFLUENCE OF THE ROLL CLEARANCE AND THE SPEED RATIO UPON THE HULLING CHARACTERISTICS FOR HEAVY FRACTION MATERIAL AT INDICATED MOISTURE CONTENTS

FIGURE 3: THE INFLUENCE OF THE ROLL CLEARANCE AND THE SPEED RATIO UPON THE HULLING EFFICIENCY FOR HEAVY FRACTION MATERIAL AT INDICATED MOISTURE CONTENTS (BASED ON ONE RUN)

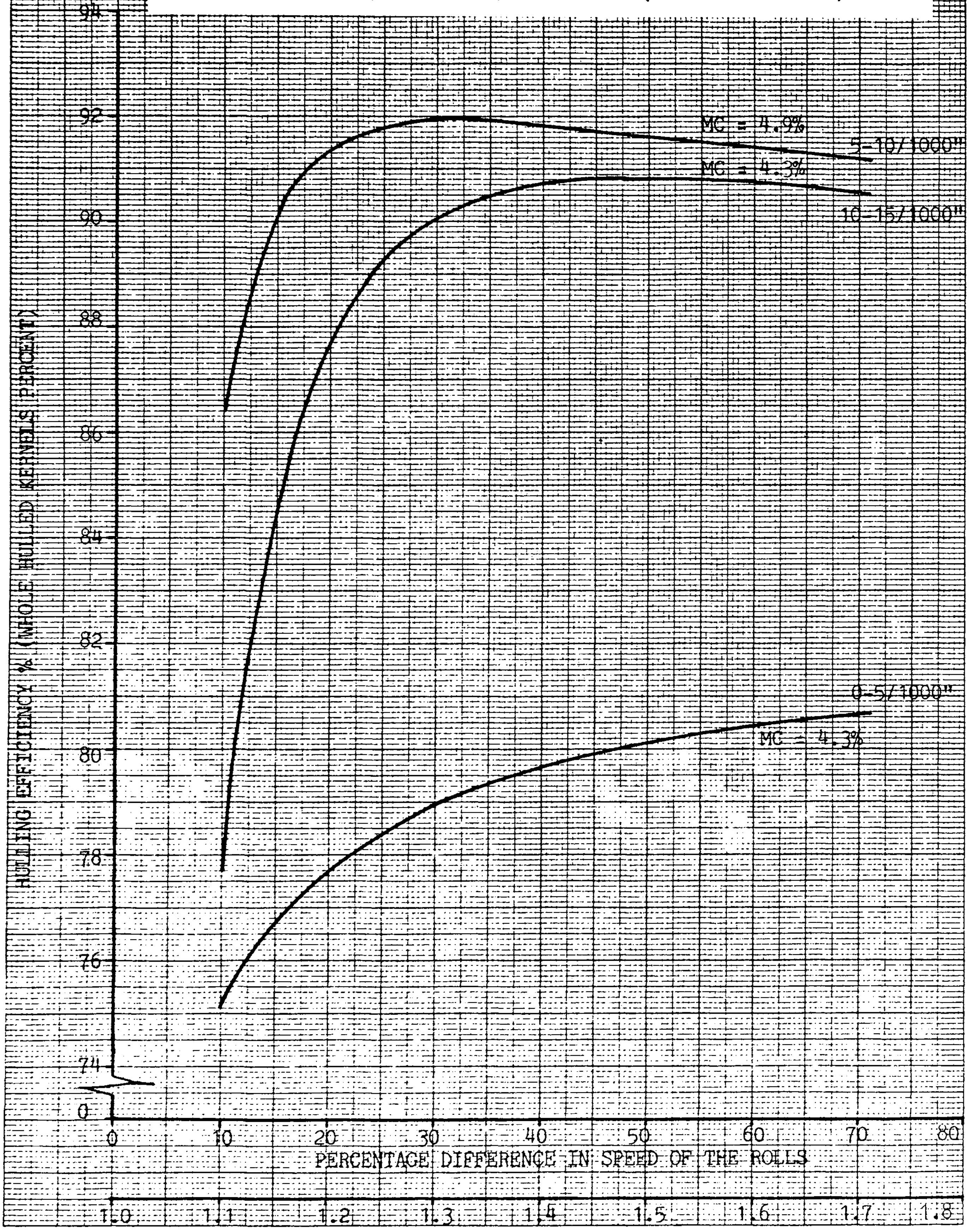


FIGURE 4: THE INFLUENCE OF THE ROLL CLEARANCE AND THE SPEED RATIO UPON THE HULLING CHARACTERISTICS FOR MEDIUM FRACTION MATERIAL AT INDICATED MOISTURE CONTENTS

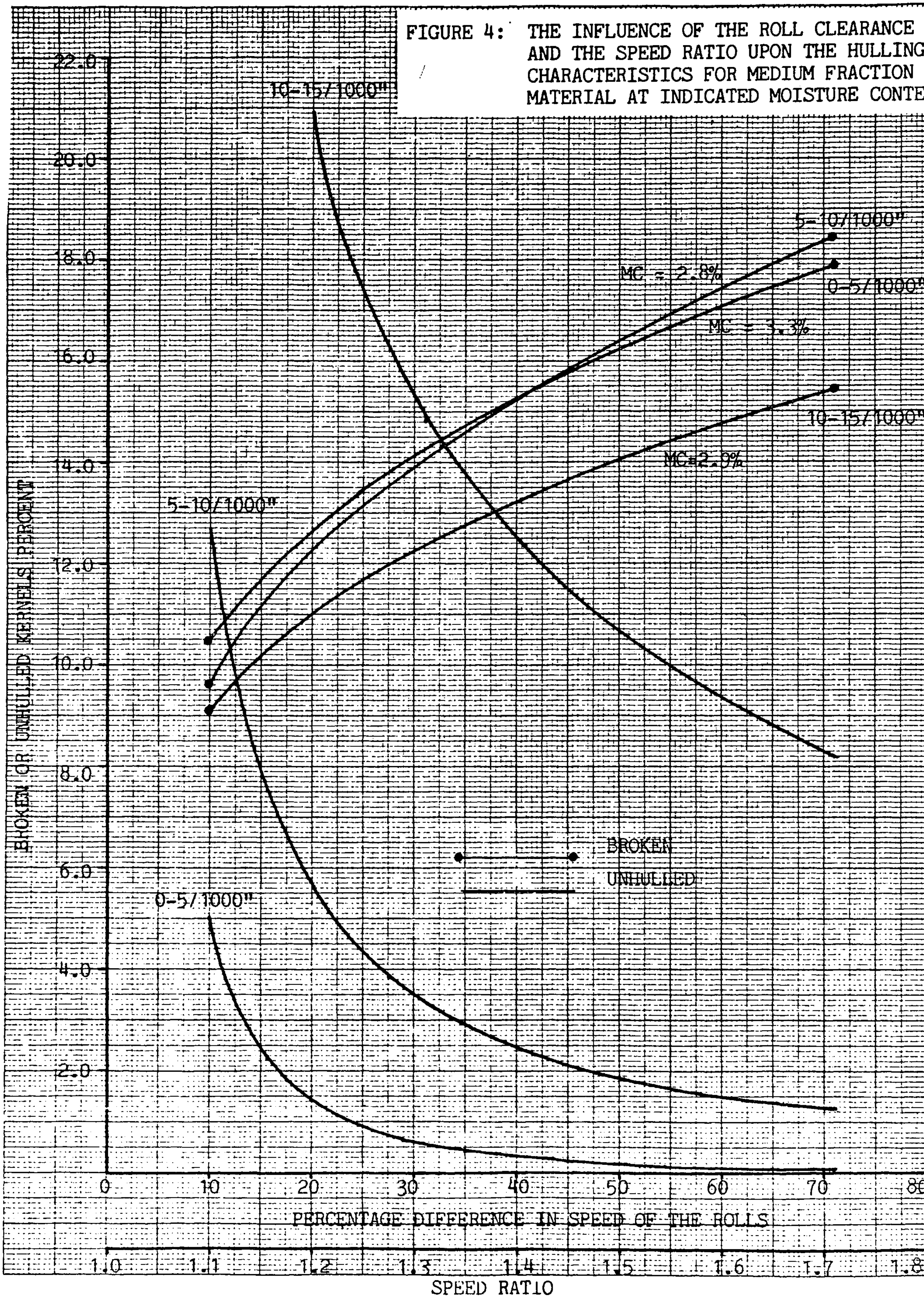


FIGURE 5: THE INFLUENCE OF THE ROLL CLEARANCE AND THE SPEED RATIO UPON THE HULLING EFFICIENCY FOR MEDIUM FRACTION MATERIAL AT INDICATED MOISTURE CONTENTS (BASED ON ONE RUN)

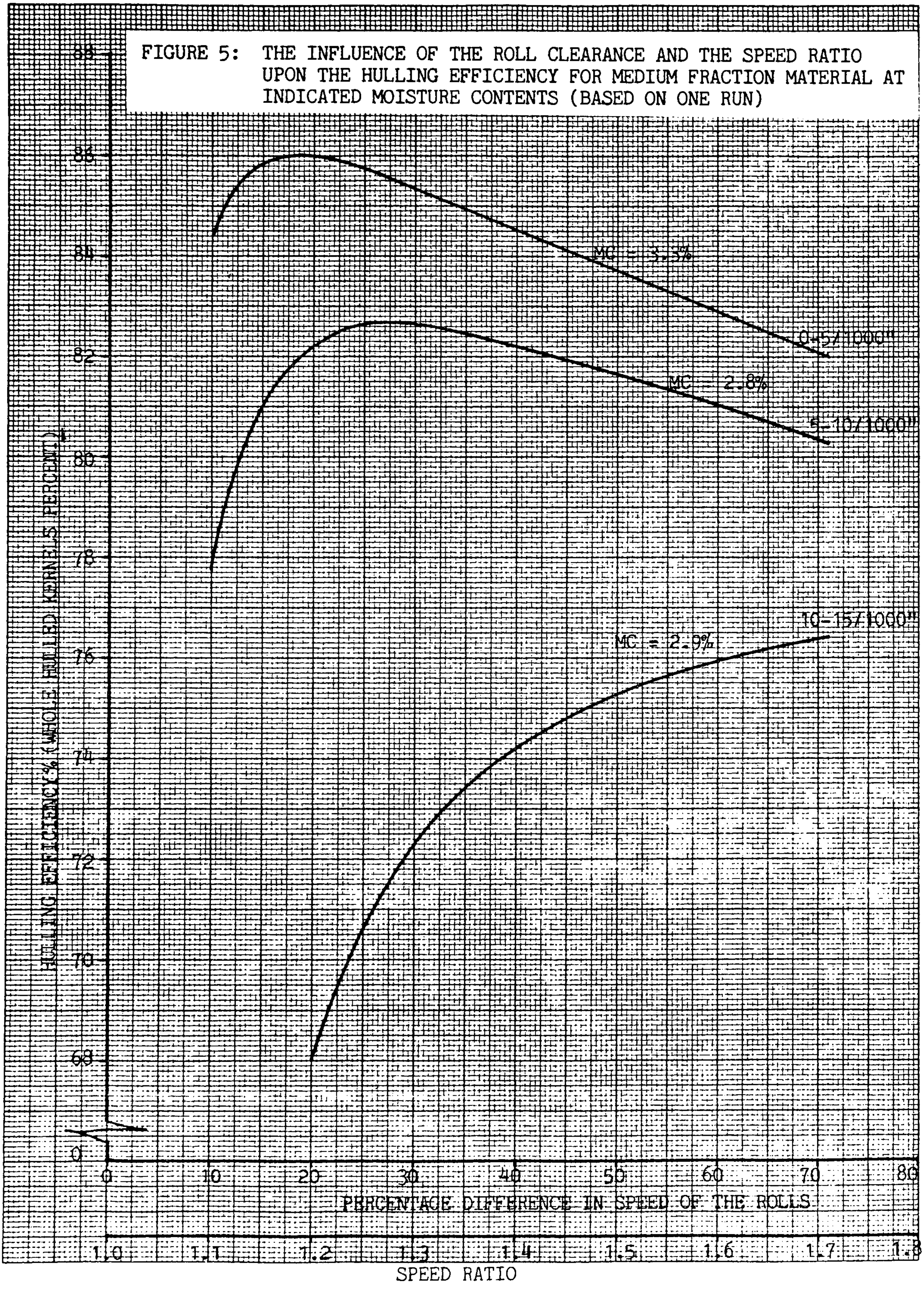


FIGURE 6: THE INFLUENCE OF THE MATERIAL'S MOISTURE CONTENT AND THE SPEED RATIO UPON THE HULLING CHARACTERISTICS FOR HEAVY FRACTION MATERIAL AND A ROLL CLEARANCE OF 5-10/1000"

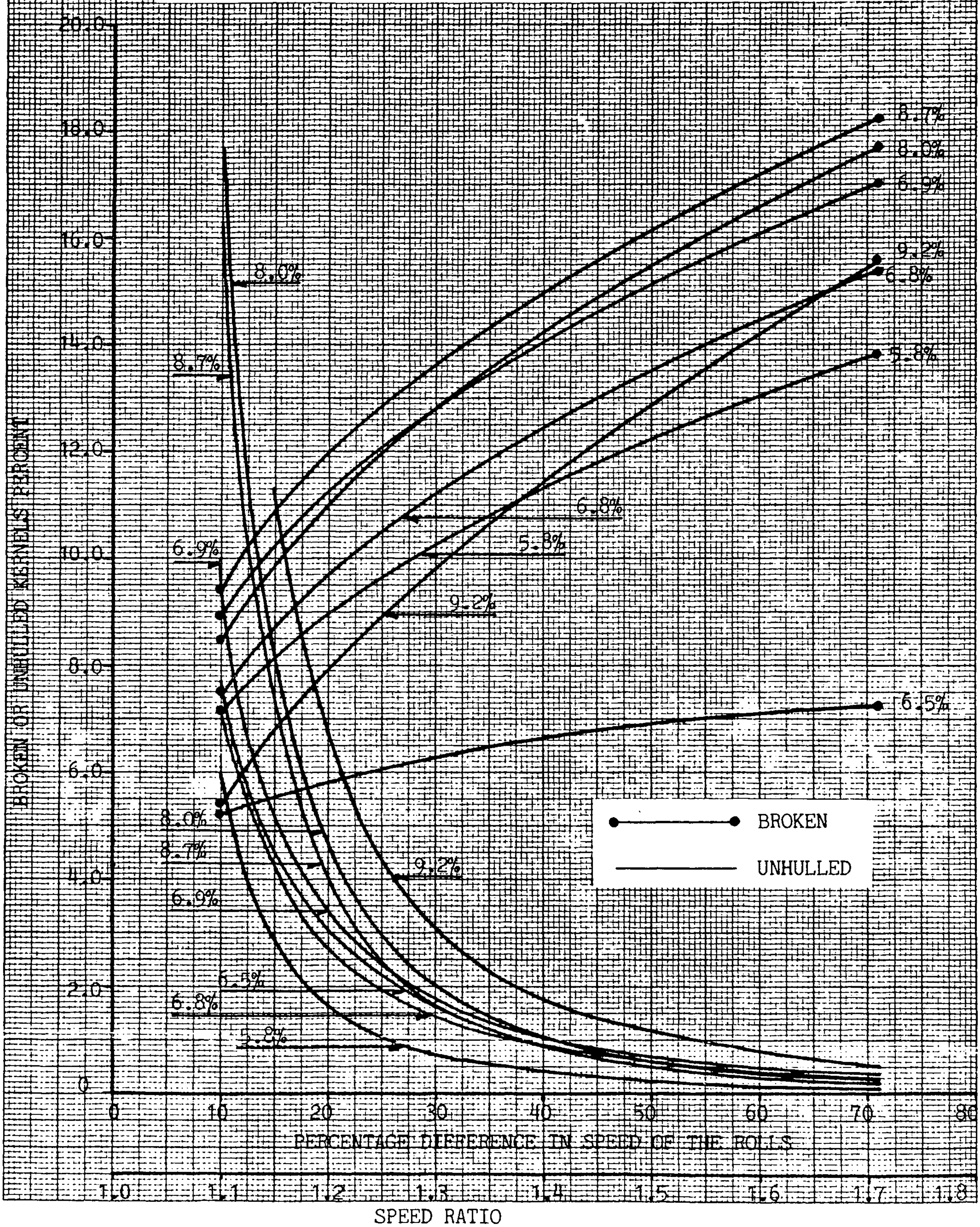


FIGURE 8: THE INFLUENCE OF THE ABSOLUTE SPEED OF THE ROLLS AND THE SPEED RATIO UPON THE HULLING CHARACTERISTICS FOR HEAVY FRACTION MATERIAL, AT A 4.3% MOISTURE CONTENT AND A ROLL CLEARANCE OF 10-15/1000"