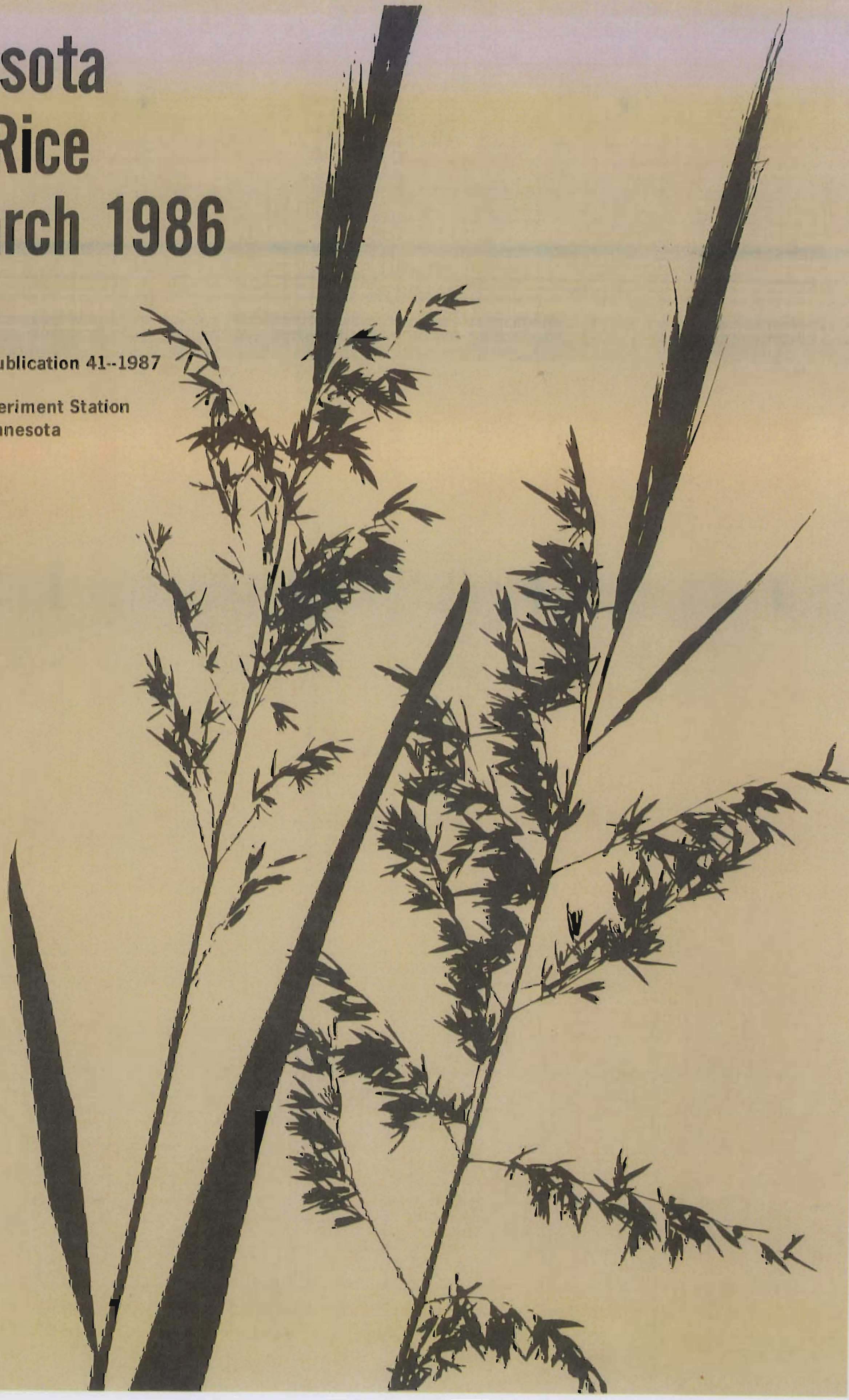
Minnesota Wild Rice Research 1986



Miscellaneous Publication 41--1987

Agricultural Experiment Station
University of Minnesota

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. Nyvall, 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. We are thankful also for the help of Drs. Rabas and Boedicker at the North Central Experiment Station, Grand Rapids. 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. Funding from the Minnesota Wild Rice Research and Promotion Council for some of the research was very helpful. The grant from Uncle Bens, Inc. helped support the economics research and was very much appreciated. We are also indebted to the Council for obtaining the necessary State funds to conduct research on a peat site in Aitkin County. We are especially grateful to Vomela Wild Rice, Inc. for the use of their land for this research and to George Shetka and Franklin Kosbau who helped in the construction of the site. We appreciate the continued support of the Agricultural Experiment Station for wild rice research.

Wild Rice Production Research - 1986

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1986 Wild Rice Season

April and May were much cooler than in 1985 while June and July were warmer at the Aitkin, Grand Rapids and Itasca locations (Table 1). August and the first part of September were also cooler than in 1985 at the three locations. The total growing degree days (GDD) was lower for the 1986 growing season than 1985, 1984 or the normal (long-term) average at Aitkin and Grand Rapids. GDD at Itasca were slightly higher than the 1985 total but less than normal.

Table 1. Growing degree days[a] comparisons for 1984, 1985, and 1986.

Month	Aitkin			Normal	Grand Rapids			Normal	Itasca			Normal
	1986	1985	1984		1986	1985	1984		1986	1985	1984	
April (15-30)	117	196	109	---	107	172	101	---	78	168	86	---
May	494	740	456	414	458	526	378	380	454	502	326	375
June	716	582	784	677	667	527	711	635	698	493	686	645
July	916	847	976	871	877	824	880	816	887	782	843	833
August	708	716	950	785	650	674	912	734	668	657	898	759
September (1-15)	234	291	227	---	205	283	206	---	201	255	183	---
Total	3185	3372	3502		2964	3006	3188		2986	2857	3022	

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

Total rainfall at Aitkin was higher in 1986 compared to 1985 and considerably higher than 1984 (Table 2). However, the 1986 total rainfall at Grand Rapids and Itasca was less compared to 1985 but much more than in 1984. The high rainfall in the Aitkin area caused harvest difficulties for some growers. The wild rice worm infestations were not severe enough to warrant control in most fields. Wild rice yield per acre was not as high as in 1984 but still very good.

Table 2. Precipitation (inches) comparison for 1984, 1985 and 1986.

Month	Aitkin			Normal	Grand Rapids			Normal	Itasca			Normal
	1986	1985	1984		1986	1985	1984		1986	1985	1984	
April (15-30)	3.78	4.04	1.74	---	2.56	4.13	1.06	---	3.83	2.39	1.11	---
May	2.67	3.77	2.18	3.39	2.49	6.11	3.24	3.16	1.90	8.54	1.50	2.80
June	5.65	4.31	8.14	3.83	6.10	4.03	7.44	3.79	8.15	5.62	5.93	4.33
July	6.24	6.03	1.36	4.79	5.45	3.84	1.32	4.12	4.95	4.39	1.67	3.34
August	5.39	5.00	1.14	4.19	2.34	2.96	1.51	3.38	1.72	4.50	4.85	3.47
September (1-15)	4.52	1.44	1.06	---	2.88	1.30	0.90	---	3.14	1.26	0.80	---
Total	28.25	24.59	15.62		21.82	22.37	15.47		23.69	26.70	15.86	

[1/] Professor, Research Plot Supervisor, Research Assistant and former Research Assistant.

Research

We continued our research on weed control, plant growth regulators to control plant height, shading effects on wild rice, drying of wild rice seed before storage and the effect of combine harvesting on wild rice seed storability and germination. The research was conducted on University plot land at Grand Rapids and in growers' fields near Aitkin. A glasshouse and growth chambers were utilized for the research at St. Paul. The wet spring caused delay in planting at Grand Rapids and resulted in fewer experiments being planted than in 1985.

Weed Control Research

Bentazon Applications on Wild Rice and Giant Burreed

Bentazon trials were continued in 1986 to define rates and dates of application which give acceptable giant burreed (*Sparganium eurycarpum* Engelm.) control. In one experiment wild rice and giant burreed corms were planted on June 6 at the Grand Rapids Experiment Station. Plots were 12 x 12 ft in size and half of each plot was planted to giant burreed and wild rice and the other half to wild rice only. After planting, metal rings (14 inches high and enclosing an 8 ft^2 area) were placed into each plot and the plots flooded to a depth of 6 inches immediately after planting. The plots were treated with herbicides on June 30 when giant burreed had 4 to 5 leaves exposed 8 inches out of the water. Wild rice had 3 to 4 leaves exposed 5 to 6 inches above the water. A total volume of 20 gal/A was applied with a hand CO_2 sprayer at 25 psi. Table 3 gives the treatment and wild rice and giant burreed data when they were grown together.

Visually, bentazon did not appear to control giant burreed or injure wild rice except at the 1.5 lb/A rate when crop oil was added. However, at all bentazon rates, except the wettable powder formulation, the number of giant burreed plants and the total dry weight of giant burreed was reduced compared to the check. Wild rice yield was reduced statistically only with 1.5 lb/A rate when crop oil was added. Bentazon appears to be more effective on giant burreed than 2,4-D or MCPA at the low rates used in this experiment.

Table 4 gives the influence of bentazon on wild rice without giant burreed in the plot. Wild rice yield was reduced statistically only when oil was added to 1.5 lb/A of bentazon. This was the same situation when giant burreed was planted with wild rice (Table 3). Thus giant burreed competition did not influence the effect of herbicide treatments on wild rice.

Table 3. Influence of bentazon applied when giant burreed had 4 to 5 leaves exposed 8 inches above the water and wild rice had 3 to 4 leaves exposed 5 to 6 inches, Grand Rapids - 1986.

		Wild Rice					Giant Burreed		
Treatment[a]	Rate	Injury rating[d]	Plant no.	Panicle no.	Panicle no.	Grain weight[b]	Injury rating[d]	Plant no.	Dry wt
	lb/A		/ft^2	/ft^2	/plant	lb/A		/ft^2	lb/A
Bentazon	0.50	1.0	2.4	4.9	2.2	822	1.0	1.7	826
	0.75	1.0	2.8	5.5	2.1	849	1.0	1.6	984
	1.00	1.0	3.1	5.9	2.0	1216	1.0	1.4	669
	1.50	1.2	3.5	6.2	1.8	947	1.0	1.4	748
	2.00	1.5	3.1	6.2	2.0	1159	1.2	0.8	944
Bentazon + oil	0.75	1.5	2.4	5.1	2.2	1099	1.0	1.2	1102
	1.50	8.5	1.3	2.5	2.0	209	7.0	1.5	1496
Bentazon-WP[c]	0.50	1.0	2.5	4.9	2.2	935	1.0	3.4	2991
2,4-D	0.25	1.0	2.4	4.9	2.1	971	1.0	2.5	2263
MCPA	0.25	1.0	2.4	4.9	2.1	1172	1.0	2.5	1614
Check	0	1.0	2.0	4.3	2.3	1048	1.0	2.5	2834
	LSD (5%)	0.5	1.0	2.0	0.9	416	5.5	0.7	1082

[a] Treatments were confined by metal rings. [b] 40% moisture [c] Wettable powder formulation. [d] 1 = no injury, 10 = complete kill.

Table 4. Influence of bentazon applied when wild rice had 3 to 4 leaves exposed 5 to 6 inches above the water, Grand Rapids - 1986.

		Wild Rice				
Treatment[a]	Rate	Injury rating[b]	Plant no.	Panicle no.	Panicle no.	Grain wt[c]
	lb/A		$/ft^2$	$/ft^2$	/plant	lb/A
Bentazon	0.50	1.0	3.3	6.1	1.8	1042
	0.75	1.0	3.7	6.6	1.8	1165
	1.00	1.0	3.0	6.6	2.2	1293
	1.50	1.2	3.6	6.6	1.9	1062
	2.00	1.5	3.1	6.6	2.2	1524
Bentazon + oil	0.75	1.3	2.3	8.5	3.9	795
	1.50	8.2	0.6	1.4	2.1	134
Bentazon-WP	0.50	1.0	3.7	6.0	1.8	1092
2,4-D	0.25	1.0	2.8	5.1	1.9	862
MCPA	0.25	1.0	2.9	6.2	2.2	1497
Check	0	1.0	2.9	5.4	1.9	1185
	LSD (5%)	0.5	1.0	2.0	0.9	415

[a] Treatments were confined by metal rings [b] 1 = no injury, 10 = complete kill [c] 40% moisture

In a second experiment bentazon was applied at 3 rates to giant burreed at a later stage of growth. Giant burreed corms were planted on June 5 in a 6 x 6 ft area at the rate of 1 corm/ft^2 at Grand Rapids. No wild rice was planted in these plots. The plots were immediately flooded to a depth of 6 inches. Bentazon was applied with a hand CO_2 sprayer on July 17 when giant burreed had 5 to 6 leaves exposed 10 to 12 inches above the water. A total volume of 20 gal/A was applied at 25 psi. Table 5 gives the injury ratings taken 3 weeks after treatment and giant burreed plant number and dry weight 5 weeks after treatment. An injury rating of 1 indicates no injury while a rating of 10 indicates a complete kill. All three rates of bentazon severely reduced the total dry weight of giant burreed per plot with the high rate (2 lb/A) giving almost complete control. The number of burreed plants was also severely reduced by the three rates. Control of giant burreed was much better at this later date compared to the earlier date in the first experiment.

Table 5. Influence of bentazon applied when giant burreed had 5 to 6 leaves exposed 10 to 12 inches above the water, Grand Rapids - 1986.

Treatment	Rate	Giant Burreed		
		Injury rating[a]	Plant no.	Dry wt
	lb/A		/ft^2	lb/A
Bentazon	0.75	3.0	0.8	271
	1.50	6.0	0.4	131
	2.00	7.5	0.3	23
Check	0	1.0	2.5	1298
	LSD (5%)	0.9	0.4	401

[a] 1 = no injury, 10 = complete kill

Based on the above and previous experiments, bentazon will control giant burreed at 2 lb/A without oil or 1.5 lb/A with oil. However at these high rates wild rice can be injured, thus if bentazon were to be cleared for wild rice it would best be applied with a wick or as a spot treatment in severely infested areas.

Comparison of rice, wild rice and giant burreed in the retention, absorption, translocation and metabolism of the rice herbicide bentazon.

Previous work with bentazon on wild rice has shown that wild rice has some tolerance to bentazon but much less than rice. Giant burreed has been controlled with bentazon but at higher rates than can be used on wild rice. An experiment with radioactive bentazon (supplied by BASF Wyandotte Corp.) was done to determine if there is a difference in retention, absorption, translocation and metabolism of bentazon among the three species. Knowing why wild rice is less tolerant to this herbicide than rice could help us in selecting better herbicides for wild rice tolerance.

Rice, wild rice and giant burreed were grown in the glasshouse and plants of each treated with bentazon in a spray chamber using a volume of 20 gal/A for the retention information and with radioactive bentazon for the absorption, translocation and metabolism information. All treatments were replicated three times in a completely random design. The retention experiment was conducted three times and the absorption and translocation study was conducted twice. Details of the experimental procedures for this study are given in "Interference and Control of Giant Burreed (Sparganium eurycarpum) in Wild Rice (Zizania palustrus), Ph.D. Thesis, Univ. of Minnesota by S.A. Clay, 1986.

Retention results: Larger plants retained more bentazon on a whole-plant basis than smaller plants (Table 6). The amount of solution retained on a dry weight basis was not affected by growth stage in rice or giant burreed. Wild rice at the five-leaf (three-aerial-leaf) stage retained nearly twice as much bentazon as wild rice at the other two growth stages when analyzed on a dry weight basis. The cuticle of the younger leaves of wild rice may not have been well developed, allowing for more herbicide to be retained.

Table 6. Retention on whole-plant and dry weight basis of bentazon applied at 1 lb/A by rice and wild rice at three growth stages and at two growth stages of giant burreed.

	Bentazon retained[a]					
	Rice		Wild Rice		Giant Burreed	
Growth stage	Total plant	Dry weight	Total plant	Dry weight	Total plant	Dry weight
	(μg)	(μg/mg)	(μg)	(μg/mg)	(μg)	(μg/mg)
Three-leaf	19.4	1.44	--	--	135	1.44
Five-leaf	16.5	0.55	34.3	1.74	--	--
Six-leaf	--	--	--	--	633	0.98
Seven-leaf	--	--	73.8	1.03	--	--
Early tiller[b]	54.7	0.65	224.0	0.77	--	--
LSD (5%)	14.5	ns	64.2	0.46	237	ns

[a] Means averaged over treatments with and without crop oil
[b] Not more than one tiller on the plant.

Wild rice retained more bentazon than rice on a total plant basis at growth stages which have the same number of leaves above the water although rice plants were 1 to 2 weeks older than wild rice. The upright leaves of giant burreed retained approximately the same amount of bentazon as wild rice and rice on a μg/g dry weight basis (Table 6). However, giant burreed retained more bentazon than either rice or wild rice on a whole plant basis. The major reason for increased retention of bentazon on wild rice and giant burreed was that wild rice had 10 times more leaf area and giant burreed had 30 times more leaf area than rice plants with comparable number of aerial leaves. Increased retention may be a factor in the differential bentazon susceptibility of rice, wild rice, and giant burreed.

Absorption and translocation results: Recovery of ^{14}C expressed as a percentage of the total applied ranged from 85% for giant burreed and wild rice to 96% for rice. Generally, increased amounts of ^{14}C absorbed and translocated, or both, decreased the amount of radioactivity recovered in the plants.

The amount of radioactivity absorbed by rice, wild rice, and giant burreed 1 DAT (day after treatment) was 21, 50, and 64% of the total ^{14}C applied, respectively. Absorption of ^{14}C-bentazon in giant burreed and wild rice did not increase over the 5-day period (b=0). Absorption in rice showed a linear response ($y=21 + 5.5x$, $r^2=0.85$, P=0.05) for the same period. However, the amount of ^{14}C absorbed in rice at the last harvest date (42) was significantly less than the other species. Absorption of bentazon may be a factor in tolerance or susceptibility of the three species to bentazon.

The amount of radioactive material translocated from the treated leaf was less than 10% of the amount absorbed in each species 1, 2, and 5 DAT (Tables 7 and 8). Differences in the amount translocated between species over time were not detected. Distribution of ^{14}C material to plant parts was similar among species (Table 7 and 8). Specific activity of giant burreed was lower than that of rice and wild rice because of large plant dry weight rather than low bentazon absorption. Harvest date by plant part interaction was not observed for plant part accumulation of radioactive material. Movement of radioactivity in all three species was acropetal. Radioactivity accumulated in younger leaves rather than in roots or older leaves. Rice and wild rice stems and shoots above the treated leaf had the highest specific activity rankings except for the treated leaf (Table 8). Youngest leaves of giant burreed accumulated more ^{14}C than roots or oldest leaves (Table 8). Since translocated amounts and accumulation patterns of radioactivity were similar in the three species, it is unlikely that translocation had a major impact on the species tolerance or susceptibility to bentazon.

Table 7. Specific activity of plant parts of rice and wild rice, after application of 0.3 μCi of ^{14}C-bentazon to the third leaf of rice and the third aerial leaf of wild rice[a].

Plant part	Species Rice	Wild Rice
	--- (dpm/mg dry weight) ---	
Treated leaf	15580	16204
Stem portion[b]	687	485
Shoot above treated leaf	166	185
Stem portion[c]	166	171
Leaves below treated leaf	84	39
Roots	27	6
LSD (5%)	1442	1539

[a] Means of each plant part averaged over the 1, 2, and 5 day harvest dates.
[b] Stem portion from the treated leaf to the next oldest leaf.
[c] Stem portion from leaf below treated leaf to base of plant.

Table 8. Specific activity of plant parts of giant burreed after application of 0.3 μCi of ^{14}C-bentazon to the third developed leaf[a].

Plant part	Specific activity
	(dpm/mg dry weight)
Treated leaf	3050
Leaves younger than treated leaf	73
Base of plant below soil	58
Leaves older than treated leaf	15
Roots	12
Planted corm	T[b]
LSD (5%)	345

[a] Means of each plant averaged over the 1, 2, and 5 day harvest dates.
[b] Trace of radioactivity

Metabolism results: Metabolism of bentazon has been shown to be an important factor in tolerance to bentazon in several species. Metabolism of bentazon was different between rice and wild rice and giant burreed (Figure 1). Bentazon metabolites (identified by thin layer chromatography) were not found on the leaf surface of any of the studied species, indicating that metabolism occurred within the leaf. The ^{14}C-bentazon standard had an Rf=0.96. Leaf extracts from wild rice and giant burreed treated leaves had 98% of the ^{14}C co-chromatographing with ^{14}C-bentazon at all harvest dates (Figure 1). Extracts from the treated rice leaf had virtually no radioactivity co-chromatographing with ^{14}C-bentazon. Peak radioactivity was observed at Rf=0.43 (M#1) for all three harvest dates. Soybean leaf extracts from plants treated with 0.71 μCi of ^{14}C-bentazon which were co-chromatographed with rice extracts indicated that the metabolites in rice corresponded to a soybean metabolite. Mine et al. (1975, Pestic. Biochem. Physiol. 5:566-574) reported that 85% of the applied bentazon was metabolized in rice (cultivar Nihonbare) 24 h after treatment. The major rice metabolite was identified as 6-(3-isopropyl-2,1,3-benzthiadiazin-4-one-2,2-dioxide)-O-B-glucopyranoside. In the study by Mine et al., bentazon and the major metabolite had Rf values of 0.59 and 0.24, respectively. Therefore, further studies would need to be conducted to identify the metabolite described in this study.

Greater retention and absorption of bentazon by wild rice and giant burreed may be important in susceptibility when compared to rice. However, metabolism appeared to be the major difference between the susceptibility of wild rice and giant burreed and the tolerance of rice.

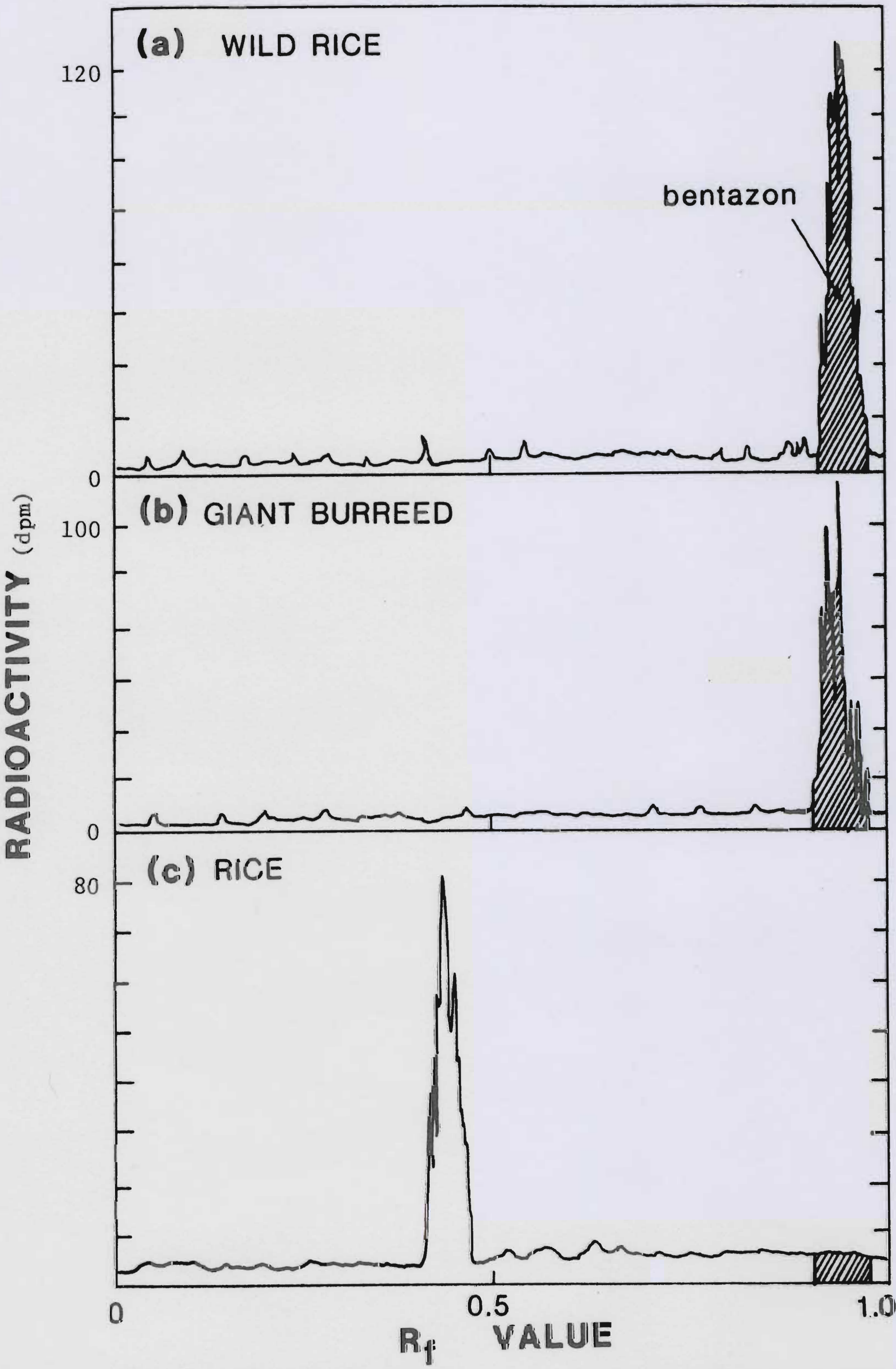


Figure 1. Radioactive compounds extracted from treated leaves of (a) wild rice, and (b) giant burreed 5 days after treatment and (c) rice 1 day after treatment with 0.3 μCi of ^{14}C-bentazon. The bentazon treated leaves were extracted with cold, absolute methanol and chromatographed on a silica gel thin-layer plated, and radioactivity detected with a TLC linear analyzer.

Growth and Development

Influence of shade on growth and development of wild rice. Weeds such as common waterplantain and giant burreed emerge from the water before wild rice and shade the young, floating wild rice plants. Some of the yield reductions from these weeds could be the result of this shading. A study to identify the effects of shade on wild rice was conducted in a growth chamber experiment with a split plot treatment arrangement with shade levels of 30%, 47% and full light as the main plot treatment and time of shade removal (2, 4, 6, or 12 weeks) as the subplot treatment. The shading levels were accomplished with black plastic screening with two different mesh sizes that can be purchased for these two levels of shading. Pots were paired, with one set of plants harvested at each shade removal date and the other set harvested after 12 weeks of growth. The experiment was conducted three times with four replications each time.

Four wild rice seeds were planted in 30-cm diameter pots lined with a 4-liter plastic bag filled to within 4 cm of the top with greenhouse soil mix of soil, sand, peat, and manure (4:3:3:3 v/v/v/v). Pots were placed in a growth chamber and immediately flooded to a 4-cm depth. Wild rice was thinned to two plants per pot after 2 weeks of growth. Plants were grown under 16-h days for the entire experiment with day/night temperatures of 68/45 F for the first 6 weeks and 75/54 F for the duration of the experiment. Full light in the growth chamber was measured at 800 $\mu Em^{-2}s^{-1}$.

At each shade removal date, plant height and growth stage were recorded from both shaded and full light treatments. Plants from one set of pots were harvested and plant dry weight was recorded after drying at 150°F for 3 days. The number of days from planting to panicle emergence was recorded for each plant remaining after the 6-week harvest. Plant height and number of wild rice panicles and tillers per plant were recorded at the 12-week harvest. Plants were separated into leaf and stem material and dry weights were recorded.

Table 9. The effects of 30 and 47% shade on wild rice dry weight after 2, 4, and 6 weeks of growth in a controlled environment.[a]

Treatment	Harvest date 2-week	4-week	6-week
	(%)[b]		
Full light	100	100	100
30% shade	84	62	104
47% shade	27	21	39
LSD (5%)	42	38	57

[a] Averaged over three trials with four replications per trial.
[b] Wild rice dry weight as % of full light treatment.

The growth stages of wild rice at the 2-, 4-, and 6-week harvest dates were the floating-leaf (three leaves), two- to three-aerial leaf (five to six leaves), and early tiller stage of development, respectively. Wild rice dry weight was reduced from the full light treatment by the 47% shade treatment at the 2-, 4-, and 6-week harvest dates (Table 9). The dry weight reduction was due to a reduction in stem dry weight (authors' unpublished data). Shading of wild rice plants over a 12-week period in growth chamber experiments resulted in a loss of stem dry weight and reduction in the number of panicles produced per plant (Table 10). Shading of 47% reduced these parameters more than the 30% level of shade.

Table 10. The influence of shade on wild rice growth and development at the 12-week harvest in a controlled environment.[a]

Treatment		Stem dry weight		Total dry weight		Panicles/plant	
Shade	Light	30%	47%	30%	47%	30%	47%
- -(weeks)- -		- - - - - - - - - - - -		(%)b - - - - - -		- - - - - -	
2	10	67	57	68	62	67	22
4	8	64	57	68	62	70	22
6	6	80	86	85	91	128	25
12	0	36	59	52	66	47	22
LSD (5%)		28		29		46	

[a] Averaged over three trials with four replications per trial.
[b] Expressed as % of the 12-week full light treatment (12-week full light=100%).

A field experiment at Grand Rapids was also conducted using the same black plastic screening as was used in the growth chamber to accomplish 30 and 47% shading of wild rice. Wild rice was planted on June 3 in one foot wide rows and 8 x 8 foot areas were covered with the netting on June 17 when wild rice was in the floating leaf stage. The number of weeks of shading was done to simulate control of giant burreed 4 and 6 weeks after planting or not controlled (full season shading).

Table 11. The influence of shade on wild rice growth and development, Grand Rapids -1986

Treatment			Plant number		Panicles/plant		Leaf area/plant		Yield	
Normal light	Shaded	Normal light	30%[a]	47%[a]	30%	47%	30%	47%	30%	47%
----- weeks ----			-- /ft^2 --		--- no.- --		--- cm^2 ---		-- lb/A- -	
2	2	13	6.1	6.3	2.1	1.8	204	151	1107	909
2	4	11	5.6	6.3	2.3	2.1	247	176	1195	1116
2	15	0	6.2	4.9	2.3	2.2	172	164	1310	1023
15 (check)	0	0	5.8		2.2		245		1232	
	LSD (5%)[b]		1.8		0.6		60		389	

[a] 30 and 47% reduction of normal daylight with plastic mesh screening. [b] For comparison of individual treatments with check (15 weeks normal light) or each other.

The number of plants per square foot, panicles per plant and yield were not statistically different for the treatments (Table 11). However, the average grain yield for the 47% shade was lower than for the 33% shade treatments. The difference was the greatest for the all season shading. Leaf area per plant on July 17 (wild rice in late tillering) was reduced by all season shading at 33% and by 47% shading for 2 and 4 weeks in addition to all season shading.

The field results do not agree entirely with the growth chamber work. The number of panicles per plant were not reduced in the field by shading but were in the growth chamber. This may be because the light intensity in the field was much higher than in the growth chamber. There probably still was enough light even in the shaded plots in the field so that tiller number per plant was not reduced due to lack of light.

Plant Growth Regulators

Four plant growth regulators were evaluated at Grand Rapids to determine if they would reduce plant height and decrease lodging thus increase yield. Wild rice (variety K2) was planted at the rate of 50 lb/A in one foot rows ten feet long on June 2 at Grand Rapids. Plant density at harvest was 6 plants/ft^2. Each plot consisted of four rows and the four plant growth regulators were applied at an early (7/22) and a late flag leaf (7/28) growth stage of wild rice. The chemicals were applied with a hand CO_2 sprayer delivering 20 gal/A at a pressure of 25 psi. The rates of each growth regulator and wild rice plant height and yield are given in table 12. Lodging did not occur in any of the plots, thus the effects on lodging could not be measured.

Plant height generally was not reduced by the growth regulators except for Terpal when applied on the late date and at the high rate. Lodging however was not evident in any of the plots nor was wild rice yield increased. Growth regulators have been effective in reducing lodging in wheat and barley especially at high fertility levels, thus we plan to try plant growth regulators at a higher fertility level next year to see if they might be more effective.

Table 12. The influence of four growth regulators applied at several rates at early and late flag leaf growth stages of wild rice, Grand Rapids - 1986.

Growth regulator	Rate		Application date 7/22		Application date 7/28		Application date 7/22		Application date 7/28	
	lb/A		Plant height (cm)				Yield lb/A[a]			
Cycocel	.0625		181		185		1679		1529	
	.125		185		171		1632		1510	
	.25		174		176		1542		1573	
	.50		175		175		1710		1480	
		Ave.		179		177		1640		1523
Ethephon	.50		170		176		1688		1543	
	1.00		172		176		1532		1878	
	1.50		178		181		1822		1797	
	1.75		162		178		1527		1643	
		Ave.		170		178		1642		1715
Terpal	.50		170		164		1260		1479	
	1.75		181		161		1540		1443	
	1.00		171		172		1676		1772	
	1.50		167		159		1579		1592	
		Ave.		172		164		1514		1572
X1019	.025		178		178		1823		1634	
	.05		171		182		1640		1695	
	.10		171		168		1473		1536	
	.5		166		174		1604		1838	
		Ave.		172		176		1635		1676
Check				179				1602		
		LSD (5%)[b]		18				312		

[a] 40% moisture. [b] For comparing individual treatments to the check or with each other.

Seed Storage

Fall Seed Handling and Storage

Experiments were continued for a second year to determine if allowing wild rice seed to remain out of water either spread out or in bags on a table before storage for a period of time would decrease viability of the seed the following spring. Immediately after harvest (fall 1985), seed of the variety K2 was spread out on a laboratory bench and random samples (300 ml volume) taken 11 times during a 7 day period. The laboratory temperature was 70-76°F and the humidity was 40%. The samples were divided into two equal portions. Percent grain moisture for one portion was obtained by drying at 150°F for 7 days and the other portion was immediately put into water at each sampling. The seed in water was stored in a cooler at 38°F and germination checked the following spring. Germination was determined by placing the seed into a beaker (250 ml) of water kept at 70-76°F. The beakers were kept on the laboratory bench and the water changed every two days. Germinated seeds were counted and removed after 1, 2, and 3 weeks. Seeds were counted as germinated when the coleoptile had grown longer than the length of the seed. Two seed lots were evaluated; one that was cleaned for seed purposes by a commercial seed cleaning firm and one directly from the combine. Figure 2 shows the loss in grain moisture over the drying period and Figure 3 the germination in the spring of 1986.

The percent moisture declined about 5% per day from 46 down to 10.5% for the 7 day drying period (Figure 2). This was true for the cleaned and uncleaned seed lots. Germination, although somewhat erratic, declined about 4% per day for the cleaned seed and 3% per day for the uncleaned seed (Figure 3). Based on these and the 1985 results loss of germination does occur if the seed is allowed to dry in the fall before storage in water. However some germination still occurs even if the seed is dried to 10% moisture.

Some of the same seed was also allowed to remain in plastic mesh bags (15 lbs each) on the laboratory bench and seed samples were removed every 2 days for a period of 22 days. This was similar to the 1984-85 experiment. Percent grain moisture was determined at each sampling period and some seed at each sampling date was stored in water until the following spring (1986) when germination was determined. Seed was taken from the center of the bag at each removal date. Grain moisture and germination were determined as previously described. The experiment was conducted on two seed lots, one that was cleaned for seed and the other directly from the combine. Figure 4 gives the loss in seed moisture during the sampling period.

The loss in seed moisture was not as great as the seed spread out on the bench (Figure 3 and 4). This was expected since the seed was confined in a mesh bag. The moisture decreased to only 20% compared to 10% for the seed on the bench. However, mold was evident on the hulls during the later sampling periods. Also the seed heated to 110°F in the bags during the first few days. Germination percentages are given in Figure 5. There was actually an increase in germination for the cleaned seed during the first 11 days and then it remained constant. Initially, the uncleaned seed decreased in germination but increased again to about the same level as the initial germination. We don't have a good explanation for this except that these bags heated up more than the cleaned seed. In both cases the germination of the seed in the center of the bags was as good or better after 22 days in the bags than the initial germination. Based on the results for the past two years it still is desirable to keep seed moist and cool in the fall before seeding or storage.

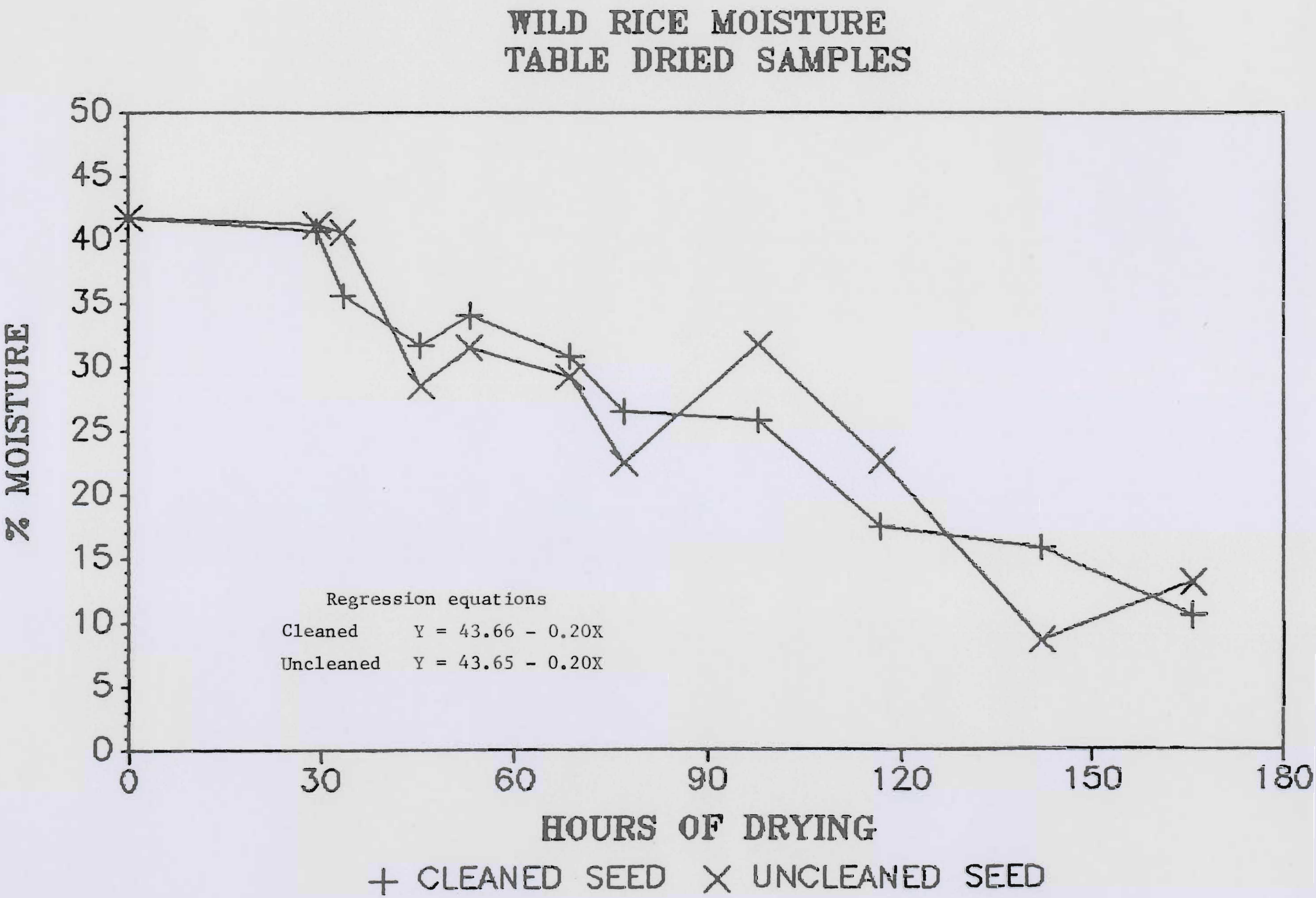

WILD RICE MOISTURE
TABLE DRIED SAMPLES
% MOISTURE
50
45
40
35
30
25
20
15
10
5
0
30
60
90
120
150
180
HOURS OF DRYING
+ CLEANED SEED X UNCLEANED SEED
Regression equations
Cleaned Y = 43.66 - 0.20X
Uncleaned Y = 43.65 - 0.20X

Figure 2

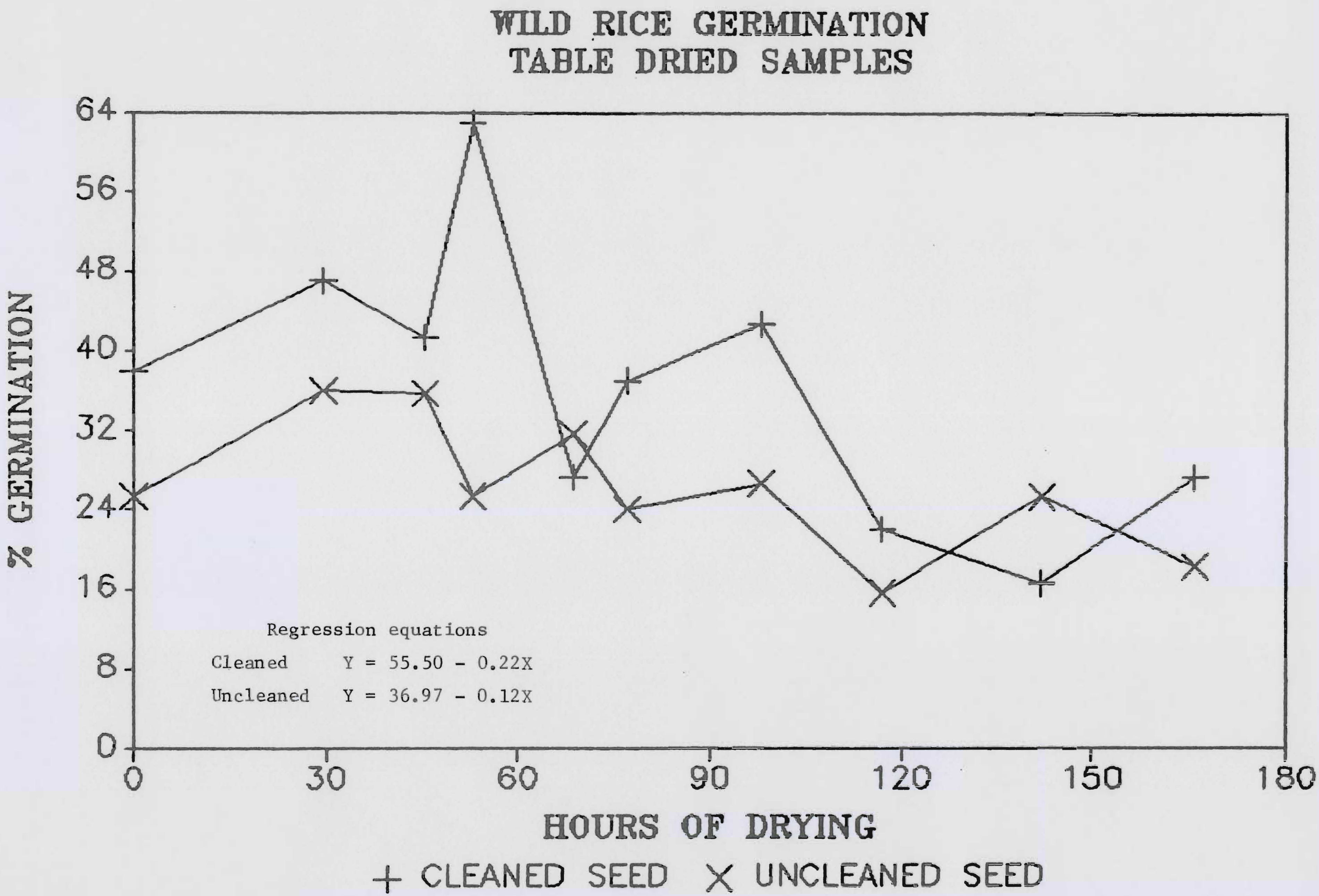

WILD RICE GERMINATION
TABLE DRIED SAMPLES
% GERMINATION
64
56
48
40
32
24
16
8
0
0
30
60
90
120
150
180
HOURS OF DRYING
+ CLEANED SEED X UNCLEANED SEED
Regression equations
Cleaned Y = 55.50 - 0.22X
Uncleaned Y = 36.97 - 0.12X

Figure 3

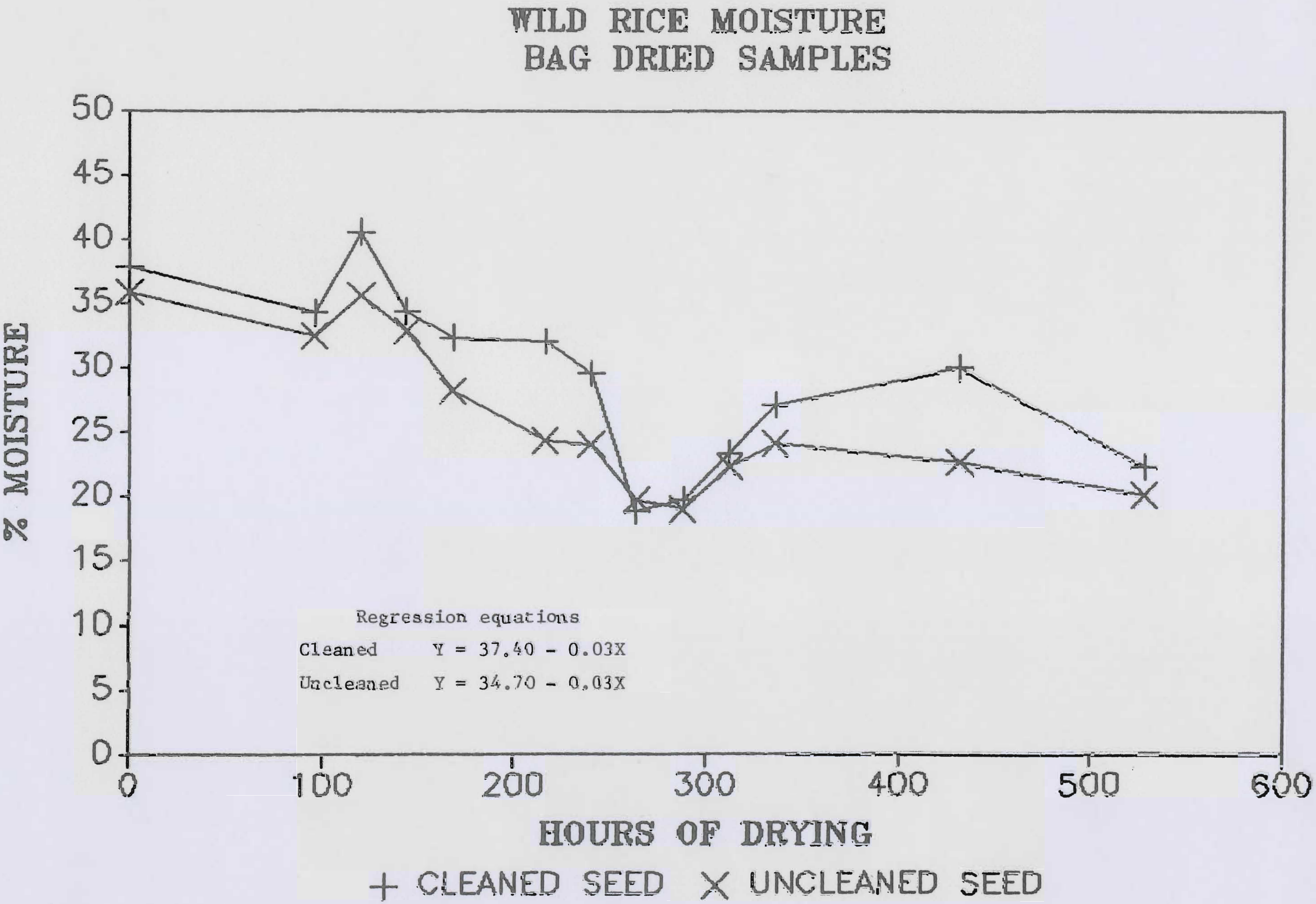

WILD RICE MOISTURE
BAG DRIED SAMPLES
% MOISTURE
50
45
40
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
HOURS OF DRYING
+ CLEANED SEED X UNCLEANED SEED
Regression equations
Cleaned Y = 37.40 - 0.03X
Uncleaned Y = 34.70 - 0.03X

Figure 4

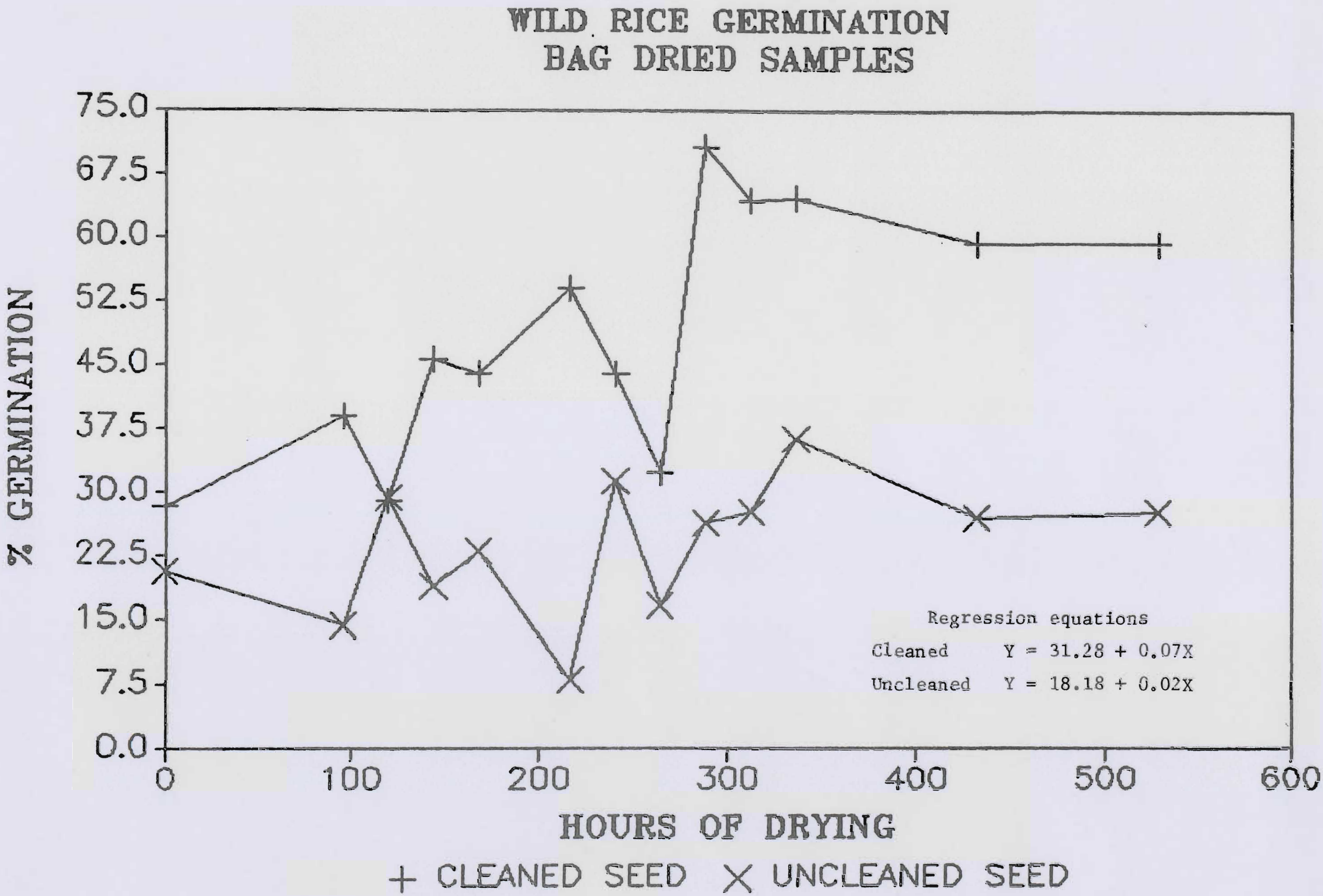

WILD RICE GERMINATION
BAG DRIED SAMPLES
% GERMINATION
75.0
67.5
60.0
52.5
45.0
37.5
30.0
22.5
15.0
7.5
0.0
0
100
200
300
400
500
600
HOURS OF DRYING
+ CLEANED SEED X UNCLEANED SEED
Regression equations
Cleaned Y = 31.28 + 0.07X
Uncleaned Y = 18.18 + 0.02X

Figure 5

In the fall of 1985, seed samples were hand harvested from 12 different fields of the K2 variety. Seed samples from the grower's combine in the same field were also collected. Seed samples from 3 fields of the Voyager variety were sampled as well. All of the samples were immediately placed into plastic bags and taken to St. Paul where they were stored in water in a cooler at 38°F. A similar experiment was conducted in the fall of 1986 for germination testing in 1987. Seed germination in the spring of 1986 was determined on the hand and machine harvested samples. The germination procedure was the same as previously described. Table 13 gives the germination comparisons.

Table 13. Germination comparison of hand and combine harvested wild rice seed

Harvest method	Variety K2	Variety Voyager	Ave.
	- - - - % germination	- - - - -	
Hand	50.9	17.7	38.4
Combine	26.7	12.8	21.5
		LSD (5%)	9.5

Germination percentage was reduced by nearly 50% for the K2 variety by harvesting with a combine (Table 13). This was not true for the Voyager variety, however the germination of Voyager was very low in both cases. It appears that care must be taken when combining seed wild rice. It may be desirable to reduce cylinder speeds and open concaves more than for combining wild rice for processing to avoid possible kernel damage. The seed should then be cleaned to remove the light kernels and debris.

Acknowledgement

We wish to thank Henry Schumer, plot coordinator at Grand Rapids, for his continued support. The help of Drs. Nyvall, Boedicker and Rabas at Grand Rapids was also appreciated. A number of growers allowed us to sample fields and their cooperation is greatly appreciated. Financial support and the supply of radioactive bentazon from BASF was very helpful in conducting the herbicide research.

Fertilizing Wild Rice and Speculations Concerning Silica

Mike Meyer and Paul Bloom[1]
Soil Science

CONTENTS

A. Nitrogen.

1. Which form of nitrogen is best?

The two most common forms of nitrogen available to wild rice growers are granulated urea and UAN (urea ammonium nitrate), also called 28% liquid nitrogen. UAN obtains 14% of its N from urea, 7% of its N from ammonium and 7% from nitrate. Nitrate is not an effective nutrient on flooded soils because it will be lost by denitrification, a process that converts nitrate to nitrogen gas. As a result, UAN is effectively only 21% nitrogen when used on flooded soils.

Granulated urea is 46.7% nitrogen. Plants do not utilize urea directly. In moist or flooded soils urea breaks down in a matter of days to ammonium. It is ammonium that wild rice takes into its roots.

One ton of UAN contains 420 lbs of nitrogen (2000 lbs x .21) and one ton of urea contains 934 lbs of nitrogen (2000 lbs x 0.467). Assuming that urea is about $120 per ton and UAN about $90 per ton, we can calculate the price per pound of nitrogen.

urea nitrogen = $120/934 = 12.8 cents per lb.
UAN nitrogen = $90/420 = 21.4 cents per lb.

Urea is clearly cheaper. You can make similar calculations as the price of fertilizer varies from year to year.

The most important factor for efficient use of urea is placement. We strongly recommend placement 6 to 8 inches deep in 16 to 18 inch rows. Deep placement prevents denitrification. It also keeps nitrogen away from weeds and algae. (The same holds true for phosphorous. Furthermore, banding of phosphorous will reduce adsorption in the soil and make it more available to plants.) Urea can be fluidized if you find that application of a liquid meets your needs better than application of a solid. Urea can be dissolved in water to give a solution that is 20 to 25% nitrogen. Anhydrous ammonia can also be dissolved in water to give aqua ammonia at 35% nitrogen. Talk to your local fertilizer dealer about the feasibility of handling these liquid forms of nitrogen.

1. Research Assist. and Assoc. Prof.

2. Summer Field Study (1986).

A paddy yield study with nitrogen and potassium was conducted in the summer of 1986 on organic soil at Menomin Development. In the Fall of 1985 the paddy was too wet to inject nitrogen. Nitrogen and potassium were broadcast and deeply rotovated (6 to 8 inches) to maximize nitrogen efficiency. Two treatments of potassium, 40 and 250 lbs/acre and four treatments of nitrogen, 0, 30, 75, and 150 lbs/acre, were replicated 4 times in a randomized block design.

In the spring of 1986 10 lbs/acre of actual zinc and 10 lbs/acre of actual copper (both as dry crystal sulfates) were flown on the paddy after thinning.

There was no yield increase with the high treatment of potassium. For this paddy the University of Minnesota soil test results and recommendation (40 lbs/acre) for potassium was most satisfactory.

The results of the nitrogen treatments are presented in Figure 1. The top line is the hand harvested finished (processed) yield vs. nitrogen (actual nitrogen) application. Yields did not significantly increase from 75 to 150 lbs/acre. The 75 lb. treatment increased yield by 32% over the zero nitrogen treatment.

The middle line represents the net earnings per acre. This was calculated assuming rice is $2.00 per pound and then deducting the price of urea (7.5 cents per lb.) from the gross earnings. There is a subtantial increase in earnings with 30 and 75 lbs per acre but a small increase with 150 lbs per acre.

The bottom line represents net earnings if rice sells at $1.50 per pound and urea is 7.5 cents per lb. We see a significant increase in earnings with 30 and 75 lbs of urea but not with 150 lbs. This enforces an old economic principle of agricultural economics, as farm commodity prices drop farmers fertilize less because it simply doesn't pay to use the higher rates. A further disadvantage with the 150 lb treatment is that it delayed maturity and tended to increase lodging.

If we could have injected urea in the Fall of 1985 our earnings would have been better. It is possible that placing 30 to 50 lbs. of nitrogen at 6 or 8 inches would be about the same as the 75 lb. rotovated treatment.

It should be pointed out that our hand harvested yields were collected about 1 to 2 weeks before maturity. Fortunately, we harvested early or much of the yield would have been lost to heavy rain and wind. But, even with the early harvest yields were very respectable, 265 lbs. per acre with zero N to 350 lbs. with 75 lbs. of N. The 350 lb. yield converts to about 900 to 1000 lbs. green yield. Since this field was harvested early it is possible that the 75 lb. treatment could have added another 500 lbs green weight. Many of the harvested seeds were small and green (both on the 75 lb treatment but especially on the 150 lb treatment) which indicated they would have added considerable weight in 1 to 2 weeks. Unfortunately, heavy rain and wind devastated the paddy before the combine could harvest the paddy. As a result, combine yields did not adequately represent the nitrogen treatments in the paddy.

B. Copper, Zinc, and Sulfur.

Copper and zinc are often deficient in organic soils. Regrettably, copper is also one of the most expensive micronutrients to purchase. In flooded conditions both copper and zinc become even more deficient because of the lack of oxygen and the formation of sulfide (the rotten-egg smell) which forms the precipitates of copper sulfide and zinc sulfide. These two compounds can not be absorbed by plant roots.

The practice in California is to place copper sulfate and zinc sulfate on the surface of the soil where oxygen prevents the formation of sulfide. The fiberous root system at the surface of the soil will then utilize the zinc and copper more efficiently.

There are few experiments with copper and zinc on wild rice. We have conducted preliminary growth chamber studies on organic soils that tested low or are at marginal levels in copper and zinc. Plants were harvested at the boot stage. The addition of 10 lbs/acre of zinc improved stem strength. The addition of 10 lbs/acre of copper increased leaf width, produced a more extensive root system, and increased plant mass.

Presently, a good guideline to check if you should add copper or zinc is to have a soil test. In deficient areas 10 to 20 lbs/acre of zinc (actual zinc) and 5 to 10 lbs of copper (actual copper) may be required. The most inexpensive sources are the crystal sulfates of these nutrients. Furthermore, for every 10 lbs of copper (or zinc) you get 5 lbs of sulfur which could benefit some soils. For example, in growth chamber experiments sulfur increased plant mass by 45% on a poorly decomposed fibric-type peat.

We recommend surface application of copper and zinc in the Fall or after thinning. It is important to apply these nutrients early, that is, before jointing. Application at boot or heading may be of limited benefit.

C. Benefits of Fallowing.

Fallowing organic soils is actually a method to compost the soil. Several important changes take place with fallowing.

In continuously flooded soils it has been found that zinc becomes more and more deficient in white rice. Organic soils in Minnesota often do not dry well in the Fall which leads to a situation where these soils experience the same effects as continuous flooding. The white rice literature recommends two approaches to solve the zinc deficiency problem: 1) add more zinc (as discussed above) or, 2) fallowing. After fallowing zinc uptake by the plant is significantly improved. It is likely that the same holds true for wild rice. Future research at the new experimental paddy will help to answer this question.

Fallowing has the important benefit of killing pathogens that cause plant disease. Fallowing improves nitrogen supplying capacity of the soil by increasing the rate of cellulose break down and decreasing the carbon to nitrogen ratio. Also, toxins that may buildup in flooded conditions are broken down with fallowing. Toxins may be a more serious problem on peat soils with pH below approximately 5.0 than on soils with higher pH's.

D. Silica: will it help wild rice?

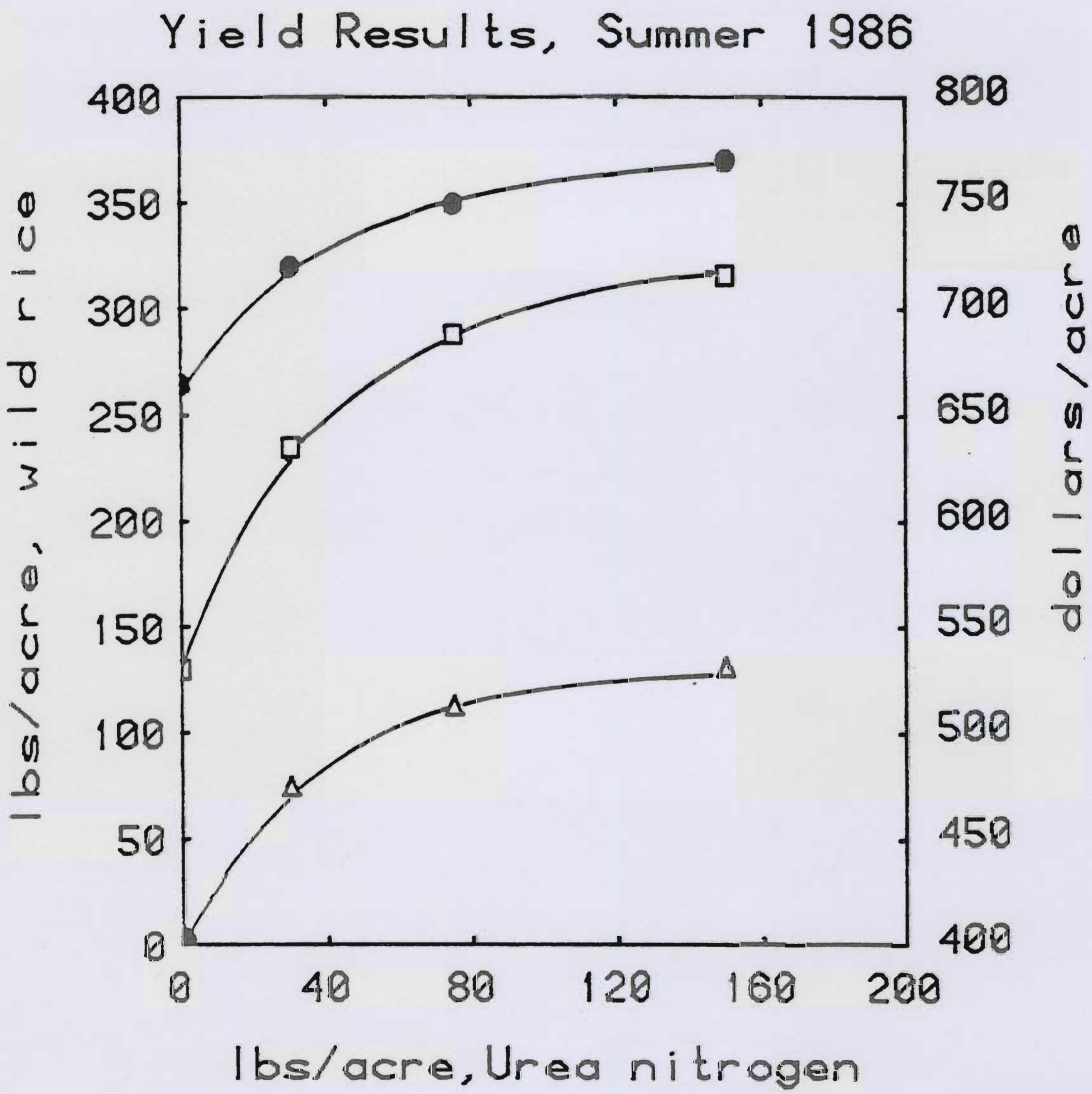
Silica is a new and possibly important area of research that may improve wild rice growth on organic soils in Minnesota. Silica (SiO_2) is actually the chemical formula for sand. However, in grasses, like wild rice, silica is in the form of small silt sized opals. Sand is not very soluble and therefore a poor source of silica. Most clay found in Minnesota is a good source of silica but requires large amounts per acre, from 25 to 50 tons.

Not all crops require silica, however, barley, white rice, and, sugarcane show dramatic loss of photosynthetic ability, disease resistance, lodging resistance and yield potential when deprived of an adequate supply of silica. Growth chamber (M. Meyer) and green house (J. Percich) experiments are presently being conducted to see if wild rice will respond to silica treatments. Initial results are encouraging but require more research.

Some organic soils in Florida are typically low in soluble forms of silica. Addition of blast furnace slag that contains abundant soluble forms of silica (calcium and magnesium silicates) increased sugarcane yield as much as 130% and white rice as much as 40%. However, this required about 10 tons of slag per acre. Mineral soils generally have high amounts of silica and do not require silica treatment.

Preliminary analysis of paddy grown wild rice indicates that the plant will utilize from 600 to 800 lbs per acre of silica (SiO_2). Analysis of soluble silica in some organic soils indicates that silica might be low and unable to supply this uptake. We are, therefore, looking into various sources of soluble silica (such as taconite tailings, blast furnace slag, and fly-ash) for Minnesota organic soils. Again, more research in the next year should help to clarify the silica question and whether it is important for wild rice and if we should try to amend our soils with silica.

Figure 1.



● Hand harvested finished yield

□ Net earnings per acre with wild rice at $2.00/lb

△ Net earnings per acre with wild rice at $1.50/lb

Wild Rice Breeding

R.E. Stucker, G.L. Linkert, G.G. Wandrey, and N.J. Page[1/]

Department of Agronomy and Plant Genetics

The 1986 experiments were planted later than usual because fumigation of the paddies was not completed in the summer of 1985; rather, we had to fumigate in the spring of 1986. Some cooperative experiments with the Plant Pathology project were planted at Excelsior but stand establishment was inadequate and the materials were discarded. A reduced number of experiments in our experimental paddies permitted us to concentrate on observing plants in grower fields. Our efforts--see section on selection for shattering resistance--resulted in a large number of families being collected. While we regret the loss of some of our experiments, we are enthusiastic about the materials collected (and fall planted). We are also enthusiastic about opportunities for research at the Aitkin site (Vomela farm). We anticipate spring planting a variety test there and will use the rest of the .25 acre paddy (assigned to the breeding project) for a mass selection effort on shattering resistance.

This report emphasizes results from G.G. Wandrey's Ph.D. research studies on inheritance of seed size. It addresses briefly some new areas of study initiated in the fall of 1986: selection for resistance to shattering; reproduction biology studies, and selection against dormancy.

Studies on Inheritance of Seed Size

The expansion of wild rice production during the past 10 years is, in part, due to the increased availability and popularity of wild rice sold as packaged blends with other types of rice. Blends account for nearly 70% of wild rice sales while pure wild rice sales account for the remaining 30%.

Seed length is an important quality consideration in the utilization of wild rice. Shorter seed is preferred in blends with white rice since the more uniform seed length allows for better texture, a more consistent cooking time and a higher proportion of wild rice kernels in a given blend. Pure wild rice, on the other hand, is more appealing and marketable to the retail consumer if it is long seeded. Current commercial cultivars have medium seed length and because of the need for shorter seed in the increasingly important blend market, wild rice growers and processors have encouraged wild rice breeders to develop short-seeded cultivars.

[1/] Professor, Junior Scientist, and Graduate Research Assistants, respectively.

Little quantitative information is available concerning the inheritance of seed length of wild rice. Visual inspection of wild rice seed indicates that substantial variation exists for this trait among and within populations of wild rice. In one of the few published accounts examining seed length variation of wild rice, Foster and Rutger (Can. J. Plant. Sci. 1980. 60:1-4) reported that narrow sense heritability and predicted gain from selection for seed length of 100 half sib families of wild rice were 58% and 4%, respectively. They indicated that mass and/or family selection could be used to alter seed length.

Because of interest in short seed in the blend market, two studies were initiated to obtain information on the inheritance of seed length. The objectives of these studies were to:

1. Characterize seed length variation in a series of half sib families.
2. Estimate heritability of seed length.
3. Evaluate progress from one cycle of bidirectional half sib family selection for seed length.
4. Assess the relationship between seed length and other agronomic traits.

Half sib families were evaluated for seed length and other agronomic traits and selected families were evaluated for progress from one cycle of selection for seed length.

MATERIALS AND METHODS

Half Sib Family Evaluation

The 147 maternal half sib families that were evaluated came from individual plants harvested at random from a cultivated field of K2 in August of 1984. The families were hand planted in a research paddy at the University of Minnesota Horticultural Research Center near Excelsior on 22 May, 1985. Plots were five feet long, spaced one foot apart and separated by four-foot alleys. A sets in replicates design with three replicates was used. Each of the seven sets contained 21 families. Proper management procedures were used to insure good plant development. Plots were thinned to three plants per linear foot of row at the floating leaf stage.

During the 1985 growing season, data were recorded for pistillate heading date (days after planting), mature plant height, and number of plants and stems per plot. Heading dates were recorded when 50% of the plants in a plot had at least a single pistillate floret exposed. Plant height was measured on two random plants in each plot. Plant and stem numbers were counted at harvest.

At maturity, approximately 20 g of seed per family was harvested and placed in cold water storage to serve as the seed source for the 1986 growing season. The 20 g of seed was obtained by bulking samples of mature seed from each of the three replications of each family. Plots were then hand harvested several times to obtain seed for length measurement. Harvested seed was weighed, dried and weighed again to obtain green and dry weights. Dried seed was hulled with a mechanical huller and chaff was removed from the seed by passing it through a blower.

The hulled seeds were sized by passing it over a series of aluminum plates which were mounted on a motorized shaker. Each plate had holes of a specific diameter that were designed to trap seeds shorter than that diameter. Seeds longer than the diameter of the holes fell off the plate and were passed over the next plate which had holes 1.6 mm (one-sixteenth in.) greater than the previous plate. The holes were drilled with a bottoming-out bit to a depth of 3.5 mm (one-eighth in.). The hole diameters of the plates ranged from 4.8 to 17.5 mm (three-sixteenths to eleven-sixteenths in.) and increased in increments of 1.6 mm (one-sixteenths in). One hundred-seed weights were taken on the same seed samples that were measured for seed length.

A weighted mean seed length for each plot was calculated as the sum of the seed weight trapped on each plate multiplied by the plate's hole diameter divided by the total weight of the sized seed. Seeds on the plates with hole diameters of 4.8, 6.4 and 7.9 mm were not included in the seed length calculations because of the high proportion of broken seeds on these plates.

Estimates of narrow sense heritability and predicted gain from half sib family selection were calculated for all measured traits. Phenotypic correlations among traits were calculated on a family mean basis. Narrow sense heritability was calculated as:

$$h^2 = \frac{\sigma^2_{F:S}}{\sigma^2_{F:S} + \frac{\sigma^2_e}{r}}$$

where $\sigma^2_{F:S}$ is the variance among maternal half sib families, σ^2_e is the experimental error, and r is the number of replications. Predicted gain from selection was computed as:

$$\Delta G = \frac{k\ c\ \sigma^2_{F:S}}{\sqrt{\sigma^2_{F:S} + \frac{\sigma^2_e}{r}}}$$

where k is the standardized selection differential based on a 10% selection intensity ($k = 1.76$), and c is the pollination control factor with a value of 0.5 since only the female parent was controlled. ΔG applies to half sib families in which open pollinated seed rather than remnant seed of selected families was recombined.

The longest-seeded 10% of the families and the shortest-seeded 10% of the families were identified in order to conduct one cycle of bidirectional selection. Four families from each of the seven sets were selected and advanced to the gain from selection experiment in 1986. Two families per set were selected for their long seed length and two families for their short seed length. This selection procedure resulted in 14 families in the long seeded population and 14 families in the short seeded population.

Gain from Selection Experiment

Stored seed of the 14 long-seeded families, 14 short-seeded families and a population bulk made up the entries in the 1986 gain from selection experiment. The population bulk was derived by bulking several seeds from each of the original half sib families. The three entries were spring planted in a randomized complete block design with six replications at Rosemount and at Grand Rapids, MN on 19 May and 21 May 1986, respectively. Entries were planted in two-row plots, 10 feet long, spaced 12 or 15 inches apart and separated by four-foot alleys. Plots were thinned to three plants per linear foot of row at the floating leaf stage.

Data were recorded for pistillate heading date (days after planting), plant height and number of plants and stems per plot. Plant height was computed as the average height of six random culms per plot. Plots were end-trimmed to a length of eight feet just prior to harvest. Plots were hand harvested on every third day until all seed in a plot had been harvested. Only seeds which had reached their mature color were harvested on a given day. A weighted maturity date was calculated based on the weight of seed collected on each harvest date and expressed as a proportion of the total harvested seed weight. Green and dry weights were recorded prior to the removal of hulls. Hulled seed was sized using the plate system previously described. Mean seed length was calculated using the formula described above. Simple correlations among traits were computed.

Estimates of realized heritability (RH) for seed length were calculated as:

$$RH = \frac{\text{Actual gain from selection (1986)}}{\text{Selection differential (1985)}}$$

where actual gain from selection is the 1986 difference in mean seed length between selected populations and the bulk population and the selection differential is the 1985 difference in mean seed length between selected families and all half sib families.

RESULTS AND DISCUSSION

Half Sib Family Evaluation

The among family source of variance in the analysis of variance was highly significant for all traits, indicating genetic differences among families. The detection of significant genetic variation among families was expected since families were derived from a population that had not been subjected to previous selection.

Frequency distributions for the two seed size traits, mean family 100-seed weight and mean family seed length, are given in Figures 1 and 2, respectively. Both distributions are approximately symmetrical and, given the above-mentioned genetic difference among families, these traits appear to be quantitatively inherited. Population means can probably be altered by discarding undesirable families and/or selecting desirable families.

Frequency distributions of family means for green weight, plant height and heading date are shown in Figures 3, 4, and 5, respectively. The distributions for green weight and plant height appear relatively symmetrical while the distribution for heading date appears to be skewed slightly toward lateness.

Estimates of means, genetic variances and error variances for the several traits measured in half sib families are given in Table 1. The two measures of seed yield, green weight and dry weight, were high for the plot size used because plots were hand harvested several times. The mean family seed length of 10.7 mm would be considered medium according to the grading system proposed by several wild rice processors, which classifies seed as medium if the seed is between 8 and 12 mm long.

Estimates of narrow sense heritability and predicted gain from selection are shown in Table 2. In general, these estimates are comparable to those reported by other wild rice researchers at the University of Minnesota. Although the estimates of narrow sense heritability for green and dry weight were only moderate in size, the high values for predicted gain from selection indicate that considerable progress could be made by selecting for these traits per se.

Estimates of heritability for 100-seed weight and seed length were fairly high (Table 2), both nearly 70%. The similarity of heritability estimates for these two traits is not surprising since they both measure seed size. Predicted gains from selection for 100-seed weight and seed length were 4.1 and 2.3%, respectively. The higher predicted gain for 100-seed weight was encouraging because 100-seed weight is easier and faster to measure than seed length. Selection for 100-seed weight and seed length should result in changes of 0.1 g and 0.25 mm, respectively, per cycle of selection.

Because half sib families were evaluated in only one environment, the genetic component of variance, $\sigma^2_{F:S}$, may be biased upward by the unestimated genotype x environment component of variance. The potentially biased value of $\sigma^2_{F:S}$ would lead to inflated estimates of narrow sense heritability and predicted gain from selection because $\sigma^2_{F:S}$ is in the numerator of both parameters.

As mentioned earlier, open pollinated seed of selected families was recombined to form the populations evaluated for gain from selection. Recombining open pollinated seed of selected families rather than remnant seed of selected families results in one half of the gain from selection because only the female parent is controlled when open pollinated seed is recombined. Recombining open pollinated seed was necessary because seed dormancy and poor seed production under greenhouse conditions severely limit the opportunity to recombine remnant seed in the greenhouse (Palm, 1984). Additionally, the seed used during the sizing process was artificially dried and therefore, no longer viable.

The phenotypic correlation between a pair of traits gives an indication how one trait may be affected if selection is conducted for the second trait. In general, phenotypic correlations among traits were low, although they were often statistically significant (Table 3). The correlation of primary interest, that between seed length and 100-seed weight, was a modest 0.56. Although additional information is needed, this correlation provides optimism for replacing the laborious task of measuring actual seed length with the relatively easy task of measuring 100-seed weight.

The high correlation between green weight and dry weight ($r = 0.99$) supports the results reported by Palm in the 1983 Progress Report. This correlation suggests that selection for yield can be conducted on a green weight basis, thus saving the time and labor required to obtain dry weights.

The correlation between number of stems per plot and green weight ($r = 0.75$) suggests that tillering is an important factor in determining grain yield in wild rice. This observation is supported by the somewhat lower correlation between number of plants per plot and green weight ($r = .47$). Of some surprise was the low correlation between plant height and dry weight ($r = 0.21$). Other researchers have obtained much higher correlations between these two traits. Palm (1983 Progress Report) and Hayes (1985 Progress Report) reported correlations among these traits from 0.52 to 0.69 depending on the year and the population evaluated.

Correlations between heading date and the two seed size traits (100-seed weight and seed length) were negative and fairly low ($r = -0.40$ and $r = -0.21$, respectively). These correlations indicated that families with early heading dates tended to be large-seeded.

Trait means of selected families and of all families are shown in Table 4. In general, the population trait means were intermediate to the means of selected families. Families selected for long seed length were slightly earlier and taller and considerably higher yielding than families selected for short seed length. As mentioned above, there was a fairly strong relationship (Table 3) between green weight and number of stems per plot. One hundred-seed weight of the long selections was

14% higher than that of the short selections (2.63 g versus 2.31 g). The relatively high 100-seed weight of the long-seeded families provided some support to the statement made above concerning substituting seed length measurements with 100-seed weight measurements.

Gain from Selection

The genetic material used in the 1986 gain from selection study consisted of populations obtained by bulking seed from families selected for short seed length (short population) and families selected for long seed length (long population). A third population (bulk population), obtained by bulking several seeds from each of the original families, was used as a check to measure progress from selection.

Differences among the long, short and bulk populations for green weight, dry weight and 100-seed weight were significant at both locations (Table 5). Populations also differed for heading date and seed length at Grand Rapids. Row spacings, (12 in. between rows versus 15 in. between rows) differed for green weight and dry weight at Rosemount. Large row spacing effects were not obtained or expected since the two spacings differed by only three inches. From a practical standpoint, the 15 in. spacing allowed us to move more easily between plots during planting, thinning and harvesting.

The combined analysis of variance revealed differences among locations for all traits except seed length (Table 6). Populations differed for heading date, 100-seed weight and seed length. The location by population interaction mean squares were significant for green weight, dry weight and 100-seed weight.

Location means for traits measured at Rosemount and Grand Rapids are given in Table 7. Plants developed much faster at Rosemount than at Grand Rapids (see heading date and maturity date means in Table 7). There was nearly a 10 day difference in maturity despite the fact that planting dates at the two locations were only two days apart. The longer growth cycle and better growing conditions at Grand Rapids were probably responsible for the higher yields and increased plant height there compared to Rosemount.

Population means for agronomic and seed size traits for Rosemount and Grand Rapids are shown in Table 8 and Table 9, respectively. We were surprised at the seed size data at Rosemount (Table 8). We expected the bulk population to be intermediate to the long and short-seeded populations in 100-seed weight and seed length but it was shortest and lightest. The reasons for these unexpected results are not clear. At Grand Rapids, the bulk population was, as expected, intermediate to the other populations for both seed size traits. The long-seeded population had signicantly greater seed length than the short-seeded population at both locations (Table 8 and Table 9).

Mean seed lengths (Table 10) of selected families and populations were used to calculate selection differentials and actual gains from selection. Selection differentials, computed as the difference between means of the selected families in 1985 and the mean of all families in 1985, were +0.6 mm for the long-seeded selections and -0.5 mm for the short-seeded selections (Table 11). Actual gain from selection, computed as the difference between means of the selected populations in 1986 and the bulk population in 1986, were from +0.4 to +0.5 mm for the long-seeded population and from +0.1 to -0.3 mm for the short-seeded population (Table 11).

Realized heritability, defined as the fraction of the selection differential achieved by selection, is often used to gauge progress from selection. Realized heritabilities for the long-seeded and short-seeded populations are given in Table 11. Combined over locations, realized heritability was only 20% for the short-seeded population. This low estimate was primarily due to a reverse response (-20%) at Rosemount where the short-seeded population had a longer mean seed length than the bulk population. Good progress was made from selection for long seed length as shown by the combined realized heritability of 75%.

We were disappointed by the lack of progress from selection for short seed length especially considering the importance of short seed to the blend market. We are not sure why the response was so poor at Rosemount. However, it would probably be premature to abandon half sib selection for seed length based on the results from one year at one location.

Simple correlations among traits measured in the 1986 gain from selection study are shown in Table 12. In general, correlations in 1986 were similar in magnitude and direction to correlations in 1985. An exception was the somewhat higher correlation between plant height and dry weight ($r = 0.53$ in 1986 versus $r = 0.21$ in 1985). The relatively high correlation between 100-seed weight and seed length ($r = 0.70$) confirmed results from 1985 regarding the relationship between these two traits; selection for increased 100-seed weight should result in longer-seeded wild rice.

CONCLUSIONS

1. Half sib selection was more effective in increasing seed length than in decreasing seed length. The effectiveness of selection depended on the environment in which the selected populations were evaluated.
2. Based on correlations among traits, selection for seed length does not appear to adversely affect other traits of agronomic interest.
3. The relatively high correlation between 100-seed weight and seed length and the ease of obtaining 100-seed weight provides optimism for using 100-seed weight as a preliminary measure of seed size.

Selection for resistance to shattering--1986

Our primary applied breeding objective for 1987 and subsequent years will be selection for resistance to shattering. The procedure will involve a subjective evaluation of seed retention; initially an upward, stripping motion on a panicle grasped loosely by a closed hand will be used to judge shattering tendencies of individual plants. This procedure was considered to be ineffective by Dr. W.A. Elliott (former University of Minnesota wild rice breeder) in earlier evaluations but has been considered to be promising by Dr. Ken Foster in California (personal communication). Economics requires that we try the procedure for a few cycles of selection to see if it has promise. We believe that a successful selection program must involve evaluation of a large number of entries and the previously used tensile strength meter (see Minnesota Wild Rice 1980 Progress Report, page 65) cannot be used on a large number of families. Our efforts will be further complicated by maturity differences between plants; green immature seeds adhere more tightly on the panicle than do ripe dark seeds. Thus, our selection program must involve a means of adjusting for maturity differences. The California history of selecting for shattering resistance by delaying harvest resulted in dramatic changes to late maturity. In addition to shattering resistance and maturity, we believe attention should be given to plant height. Accordingly, we intend to assess some selection index concepts in a breeding program which will evaluate large numbers of families for shattering resistance, maturity and plant height in 1987.

Several trips were made to growers' fields in the summer of 1986 for the purpose of collecting half-sib families with better shattering resistance. We would walk along a harvest line of a combine; after ten steps, a "good plant" from the standing plants next to the swath was visually mass selected and another ten steps would be taken to repeat the selection procedure. A "good plant" was early to medium in maturity and retained its male florets and seed better than the surrounding plants. The resulting families will provide the initial materials of our 1987 selection studies.

On August 12, 1986, 327 individual selections were made from a K2 field at Kosbau's farm. The heads were hand threshed and stored in our cold-room. On August 18, 835 individual plant selections were made from another K2 field at Kosbau's. On August 20, 600 M3 selections were made from an M3 field at Manomin's farm.

In October, 1986, 1100 K2 half-sib families were planted in single rows, four feet long and 15 inches apart, at the North Central Experiment Station, Grand Rapids, MN. In November 1986, 600 M3 half-sib families were planted in single rows, five feet long and 15 inches apart, at the Rosemount experiment station. At both locations, 200 families of the respective variety were replicated in order to obtain estimates of genetic and non-genetic variation. At both locations, a modified blocks in replicates experimental design was used.

Additional selections were made in other growers' fields for traits such as seed length (short and long), bottle brush, pistillate, and shatter resistance. These selections are being stored for spring planting in 1987.

Reproduction Biology Studies

When we use pollination techniques described by Dr. W. Anson Elliott (Wild Rice, pp. 721-731, in Hybridization of Crop Plants, W.R. Fehr and H.H. Hadley, Eds., ASA Publisher, 1980), we find recurring problems with low seed set. Since successful controlled pollinations, including self- and cross-pollinations, are a necessary part of a productive plant breeding program, we have initiated research on factors which affect seed set in wild rice controlled pollinations. Initially the research (by Nat Page, a new graduate student on the Plant Breeding project) will focus on receptivity of stigmas to pollen and the optimum time of pollination to achieve good seed set. We don't have good information on how long exposed stigmas remain receptive to pollen, the optimum time of day, nor duration of pollen grain viability.

Our first experiments with stigma receptivity (November, 1986) failed to produce seed. We believe pollen inviability was responsible. Results of the November 1986 experiments on time of optimum pollen viability are presented in Table 13. We used four replications (ten emasculated plants per replicate) and ten times of pollination starting at 6:00 a.m. and hourly thereafter until 3:00 p.m. An emasculated plant in each replicate was pollinated at each of the pollination times.

A relatively wide range of times was found at which at least 10% seed set was achieved. The 7 and 8 o'clock a.m. pollinations and the 1:00 p.m. pollination had seed set greater than 16%, but better seed set must be achieved. Our experimental approach will be expanded to seek specific factors which affect seed set. Given some reasonable progress in our greenhouse studies, we would like to investigate crossing techniques for use in field environments. Previous studies using glassine bags to prevent unwanted pollination have resulted in moldy panicles under the bag and no seed set.

Selection against dormancy

Recent evidence provides some optimism regarding survival of wild rice seed at moisture levels lower than 30%. Oelke (1986 Progress report) reported some seed germination at moisture levels as low as 10%. We need to continue this research to identify populations (genotypes) which can be stored at moisture levels low enough to prevent germination and spoilage, but high enough to maintain seed viability. If such types can be developed, we can initiate a breeding program designed to eliminate the dormancy system in wild rice. Our long range objective would be to develop varieties which would not survive winter in the field. Volunteer growth from shattering of the previous year's crop would be eliminated and annual reseeding could be used to establish a current year's crop. The achievement of this long-range objective would enhance selection for resistance to shattering and should permit growers to control their stand density annually by varying seeding rate.

The objective of the 1987 dormancy study is to select early germinating seeds on a continuing basis from successive generations of selection. Freshly harvested seed will be stored for a designated amount of time, then seed will be removed from storage and tested for germination. Resulting plants will be allowed to intermate; seed will be harvested and stored to initiate another cycle of selection. With each generation the time of storage will be decreased.

The first generation of selection was started November 10, 1986 after the seed had been in cold storage 98 days. Initial germination rate was 15%. Approximately 250 plants were transplanted into greenhouse pots and will be intermated.

Nondormancy studies have been tried before on our project. In September 1977, one pound (approximately 14,600 seeds) of fresh harvested seed was planted in 3 boxes in the greenhouse, but only 8 plants germinated by February 1978. A second dormancy study was started in November 1984, but seed set was poor due to insect problems and selection was abandoned.

Table 1. Population statistics for traits measured in half sib families at Excelsior in 1985.

Trait	Population mean	Genetic variance	Error variance
Heading date[1]	64.2 ± 1.1	4.5 ± 0.7	3.9
Plants per plot	11.0 ± 1.5	7.1 ± 1.1	7.0
Stems per plot	44.8 ± 6.2	98.0 ± 16.8	115.7
Green weight (g)	78.0 ± 13.9	250.7 ± 55.8	576.1
Dry weight (g)	50.1 ± 9.1	104.3 ± 23.5	245.9
100-seed weight (g)	2.4 ± 0.1	0.02 ± 0.004	0.03
Plant height (cm)	139.1 ± 4.7	21.2 ± 5.6	66.7
Seed length (mm)	10.7 ± 0.2	0.1 ± 0.02	0.1

[1] Days after planting

Table 2. Estimates of narrow sense heritability and predicted gain from selection for traits measured in half sib families Excelsior in 1985.

Trait	Narrow sense heritability	Predicted gain[1]
	(%)	(%)
Heading date[2]	77.6 $\pm$ 12.2	2.6
Plants per plot	75.3 $\pm$ 11.7	18.6
Stems per plot	71.8 $\pm$ 12.3	16.5
Green weight (g)	56.6 $\pm$ 12.6	13.4
Dry weight (g)	56.0 $\pm$ 12.6	13.4
100-seed weight (g)	66.2 $\pm$ 12.4	4.1
Plant height (cm)	48.8 $\pm$ 12.9	2.0
Seed length (mm)	69.5 $\pm$ 12.3	2.3

[1] Expressed as a % of the population mean.
[2] Days after planting.

Table 3. Phenotypic correlations among traits measured in half sib families at Excelsior in 1985 (n = 145).

	Plants per plot	Stems per plot	Green weight	Dry weight	100-seed weight	Plant height	Seed length
Heading date	-.13	-.17	-.03	-.06	-.40	.22	-.21
Plants per plot		.76	.47	.47	.08	-.08	.09
Stems per plot			.75	.75	.11	.00	.23
Green weight				.99	.19	.23	.33
Dry weight					.22	.21	.34
100-seed weight						-.04	.56
Plant height							.12

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

Table 4. Trait means of the population of half sib families and the half sib families selected for long seed length and short seed length (1985).

Group	Heading date[1]	Plants/ plot	Stems/ plot	Green weight	Dry weight	100-seed weight	Plant height	Seed length
	(days)			(g)	(g)	(g)	(cm)	(mm)
Long selections	63.3	11.0	48.4	90.8	59.3	2.63	139.0	11.3
Population	64.2	11.0	44.8	78.0	50.1	2.44	139.1	10.7
Short selections	64.5	9.5	38.8	66.9	42.6	2.31	137.4	10.2

1)Days after planting.

Table 5. Analysis of variance for agronomic and seed size traits measured in the 1986 gain from selection study at Rosemount (upper symbol) and Grand Rapids (lower symbol).

Source	Trait: Heading date	Green weight	Dry weight	Maturity date	100-seed weight	Plant height	Seed length
Spacings	ns[1]	*	*	ns	ns	ns	ns
	ns	ns	ns	ns	ns	ns	ns
Populations	ns	*	*	ns	*	ns	ns
	**	*	*	ns	*	ns	**

*,** Significant at the 0.05 and 0.01 levels of probability.

1) Nonsignificant.

Table 6. Analysis of variance for agronomic and seed size traits measured in the 1986 gain from selection study combined over locations.

Source	Trait						
	Heading date	Green weight	Dry weight	Maturity date	100-seed weight	Plant height	Seed length
Locations	**	**	*	**	*	**	ns
Spacings	ns	*	*	ns	ns	ns	ns
Populations	**	ns	ns	ns	**	ns	**
Locations x Populations	ns	**	**	ns	*	ns	ns

*,** Significant at the 0.05 and 0.01 levels of probability.
1) Nonsignificant.

Table 7. Location means for agronomic and seed size traits measured in the 1986 gain from selection study at Rosemount and Grand Rapids.

Trait	Location	
	Rosemount	Grand Rapids
Heading date[1)]	56.8	61.7**
Plants per plot	48.6	49.1
Stems per plot	142.2	140.7
Green weight (g)	252.0	326.2**
Dry weight (g)	170.0	214.8**
Maturity date[1)]	96.4	106.1*
100-seed weight (g)	2.45	2.37*
Plant height (cm)	161.7	195.0*
Seed length (mm)	10.4	10.4

*,** Significant at the 0.05 and 0.01 levels of probability.
1)Days after planting.

Table 8. Population means for agronomic and seed size traits measured in the 1986 gain from selection study at Rosemount.

Population	Trait						
	Heading date[1)]	Green weight	Dry weight	Maturity date[1)]	100-seed weight	Plant height	Seed length
	(days)	(g)	(g)	(days)	(g)	(cm)	(mm)
Long	55.3	217.1	146.4	96.2	2.52	162.2	10.7
Bulk	56.7	245.7	165.3	96.2	2.34	163.9	10.2
Short	58.3	293.2	198.4	96.8	2.48	159.0	10.3
LSD (0.05)	2.1	54.9	35.4	ns	0.15	ns	0.4

[1)]Days after planting.

Table 9. Population means for agronomic and seed size traits measured in the 1986 gain from selection study at Grand Rapids.

Population	Trait						
	Heading date[1)]	Green weight	Dry weight	Maturity date[1)]	100-seed weight	Plant height	Seed length
	(days)	(g)	(g)	(days)	(g)	(cm)	(mm)
Long	60.5	364.6	242.8	105.7	2.47	197.8	10.8
Bulk	62.2	325.9	213.2	106.3	2.37	194.2	10.4
Short	62.5	288.2	188.5	106.2	2.26	193.2	10.1
LSD (0.05)	1.1	45.8	30.9	ns	0.12	ns	0.1

[1)] Days after planting.

Table 10. Mean seed length of the long selections, short selections and bulk population in 1985 and 1986.

Location	Year	Population		
		Long[1)]	Short[1)]	Bulk[2)]
		----------------	mm	----------------
Excelsior	1985	11.3	10.2	10.7
Rosemount	1986	10.7	10.3	10.2
Grand Rapids	1986	10.8	10.1	10.4
Combined	1986	10.75	10.2	10.3

1) Refers to the selected families in 1985 and the populations obtained bulking seed of selected families in 1986.

2) Refers to the mean of all families in 1985 and the population obtained by bulking seed from all families in 1986.

Table 11. Estimates of gain from selection, selection differential and realized heritability for the short-seeded and long-seeded populations.

Population	Location	Gain from Selection	Selection Differential	Realized Heritability[1)]
		(mm)	(mm)	(%)
Short	Rosemount	0.1	-0.5	-20
	Grand Rapids	-0.3	-0.5	60
	Combined	-0.1	-0.5	20
Long	Rosemount	0.5	0.6	83
	Grand Rapids	0.4	0.6	67
	Combined	0.45	0.6	75

1) Realized heritability = Gain from selection/Selection differential.

Table 12. Simple correlations among traits measured in the 1986 gain from selection study combined over locations (n = 36).

	Plants per plot	Stems per plot	Green weight	Dry weight	Maturity date	100-seed weight	Plant height	Seed length
Heading date	-.03	-.15	.25	.21	.78	-.29	.58	-.09
Plants per plot		.54	.27	.29	.03	.31	-.14	.19
Stems per plot			.72	.73	.00	.23	.05	.12
Green weight				.99	.54	.03	.57	.20
Dry weight					.49	.07	.53	.21
Maturity date						-.33	.90	.00
100-seed weight							-.24	.70
Plant height								.10

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

Table 13. Time of pollination effects on seed set in greenhouse grown wild rice (November, 1986).

Time of pollination	Total florets	Total seeds	% seed set
6:00	421	45	10.7
7:00	316	51	16.1
8:00	467	76	16.3
9:00	372	12	3.2
10:00	450	54	12.0
11:00	398	11	2.8
12:00	410	0	0
1:00	436	77	17.7
2:00	479	41	8.5
3:00	402	1	.2

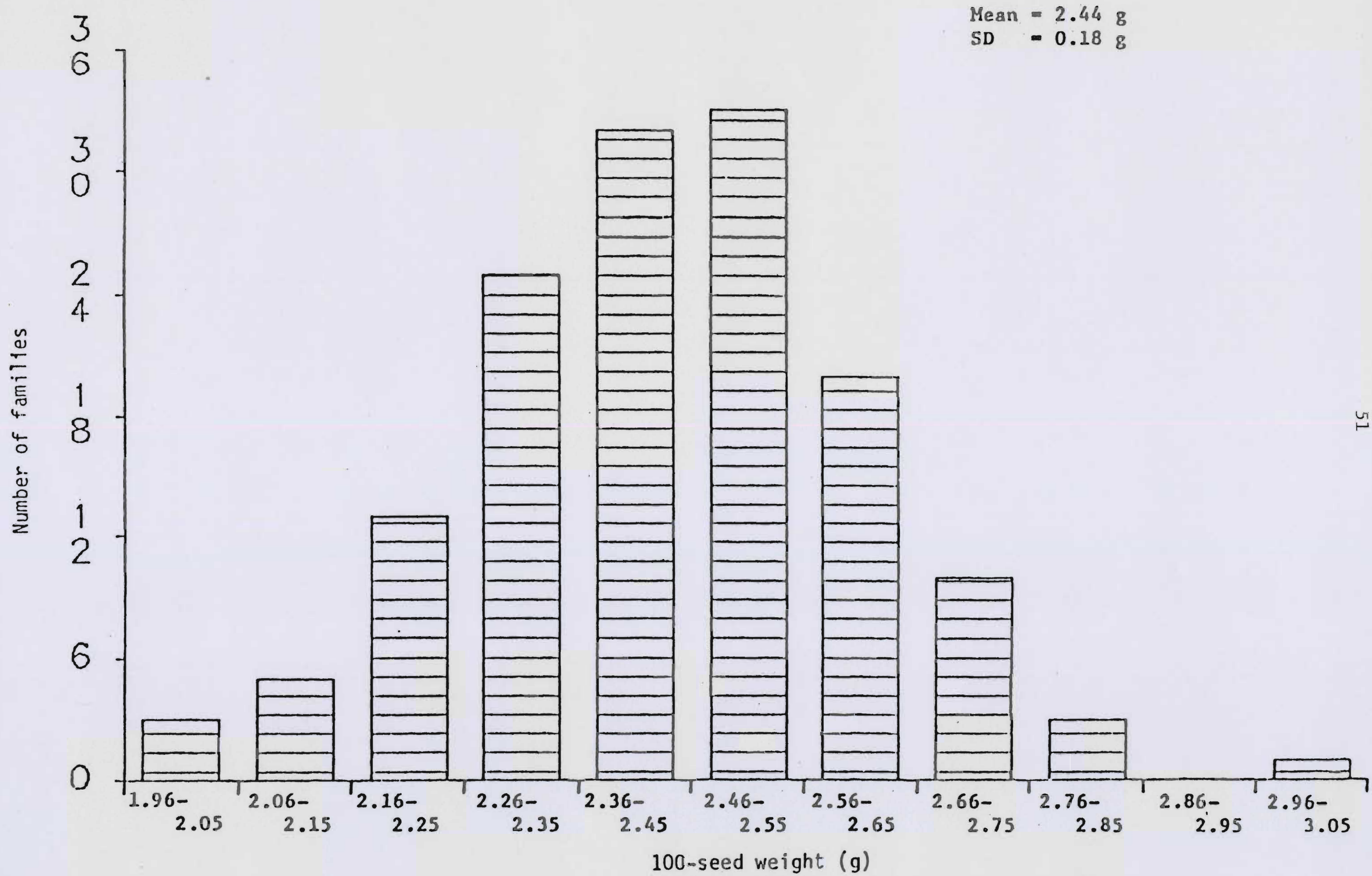


Figure 1. Frequency distribution of half sib family means for 100-seed weight (1985).

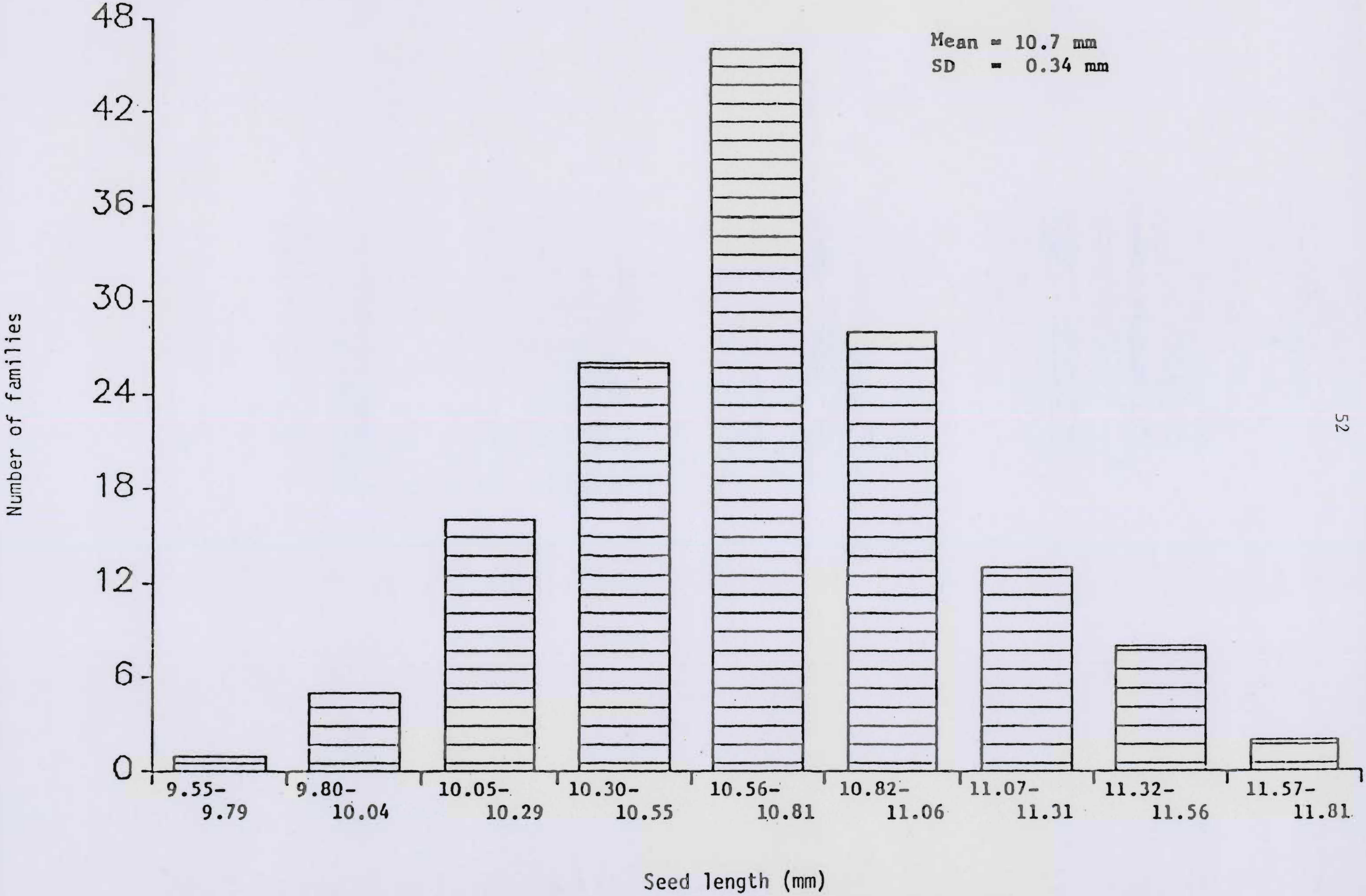


Figure 2. Frequency distribution of half sib family means for seed length (1985).

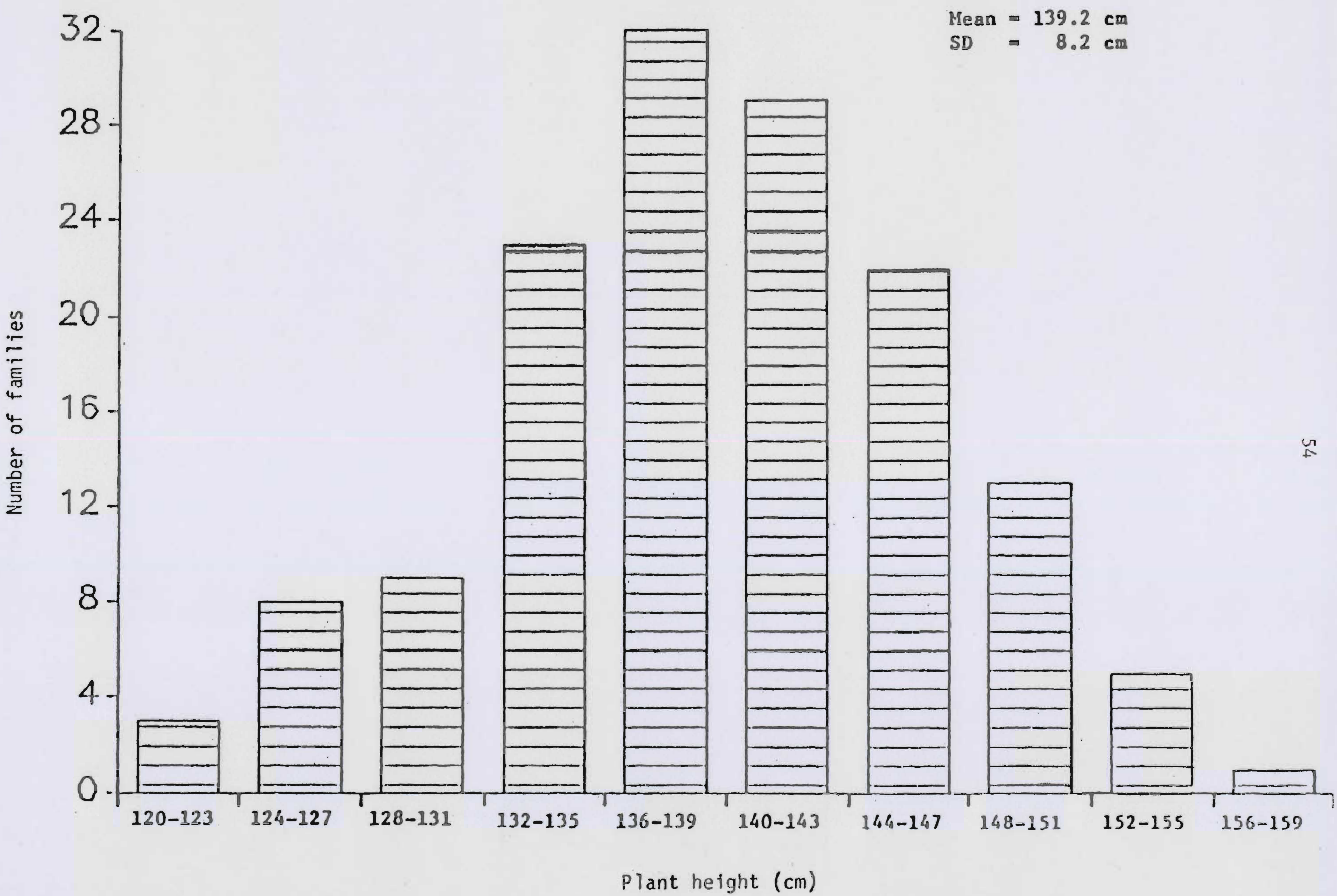


Figure 4. Frequency distribution of half sib family means for plant height (1985).

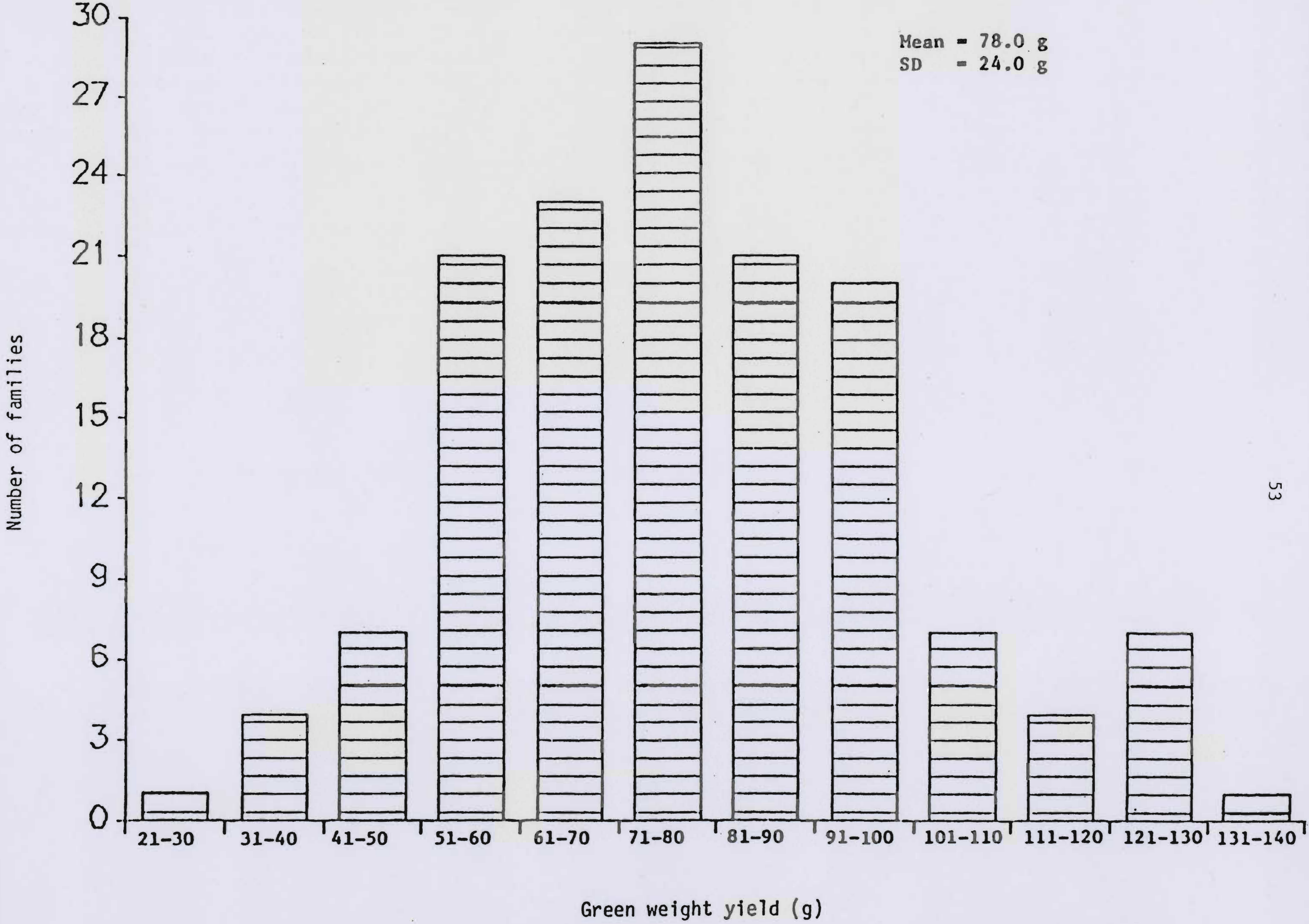


Figure 3. Frequency distribution of half sib family means for grain green weight yield (1985).

Results and Discussion

In 1986 all propiconazol (Tilt™) treatments resulted in significantly (P=.01) higher yields than the untreated control (Table 1). Plants treated with the fungicide at a rate of 8 oz /A at boot and heading resulted in a higher yield than any other chemical treatments. Yields were significantly increased with increasing rates of propiconazol when applied at either boot and/or boot and heading stages of plant development Table 1). One application of the fungicide at 8 oz /A resulted in a significantly higher yield when compared with either the 4 or 6 oz /A rates applied at both boot and heading (Table 1).

Table 1. The effect of propiconazol (Tilt™) rate on the yield of wild rice cultivar K-2 inoculated with **Bipolaris oryzae**, the causal organism of fungal brown spot in 1985 and 1986

Rate oz/A	Stage of plant development	Yield lb/A 1985	Yield lb/A 1986
4	boot and heading	281 a*	370 b*
6	boot and heading	278 a	444 d
8	boot	359 b	523 e
8	boot and heading	448 c	544 f
10	boot	293 a	392 c
Control		317 a	264 a

* Means followed by the same letter are not significantly different at the p=.10 and p=.01 in 1985 and 1986, respectively according to Duncan's new multiple mange test.

The 1985 Tilt Rate Study also showed that the maximum significant yields were obtained with either one or two applications of the fungicide at 8 oz per acre.

In both 1985 and 1986 a decrease in yield was observed in teatments receiving a single application of Tilt™ at 10 oz /A during the boot stage stage of plant development. Phytotoxicity was expressed as leaf tissue necrosis at the site of fungicide contact.

planted in a 1.5 X 2.1 m (5 X 7 ft) blocks. The wild rice cultivar K-2 was used.

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

Wildrice plants were inoculated on the July 30 and August 6 beginning at the boot stage of plant development. The inoculation process was as follows: Approximately 1 liter of the dried inoculum was mixed with 3 liter of water immediately prior to inoculation. The resulting spore suspension was sieved through a 300 micron (U.S. Standard Sieve Series No. 50 W.S. Tyler Co., Mentor, Ohio) screen. This procedure was repeated 4 times. Each plot was inoculatedusing a backpack sprayer (Hudson Stainless steel Suprema 67367, H.D. Hudson Mfg. Co., Chicago, IL). Immediately following inoculation, plants were misted every 15 minutes for 2 minutes up until the fungicide was applied. Fungicides were applied with a hand-held CO_2 pressurized sprayer (20 lbs of pressure). Application volume was 1/3 l per pot. The control was sprayed with water only.The fungicide treatments were as follows:

Formulated	oz/A	(g ai/A)	Plant Growth Stage	Spray Schedule
Tilt	4	(50)	Boot and Heading	07/30 & 08/6
Tilt	6	(75)	Boot and Heading	07/30 & 08/6
Tilt	8	(100)	Boot and Heading	07/30 & 08/6
Tilt	8	(100)	Boot	07/30
Tilt	10	(125)	Boot	07/30

Each plot was 5 X 7 ft, with the inner 4 X 6 ft being harvested. The plants were harvested by hand on September 10, 1986. The plants were counted, threshed, and the seed dried at 90 C. The grain was then dehulled, sized and weighed. Wild rice seed greater than 1.245 mm in diameter was used to determine final yields. Treatment means were compared by Duncan's New Multiple Range Test at the$p$=.01 levelof significance.

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

WILD RICE DISEASE RESEARCH-1986

January 23, 1987

James A. Percich, Project Leader
Catherine Huot, Associate Scientist
David Johnson, Research Assistant
Mark Schanke, Undergraduate Student

INTRODUCTION

The 1986 plant pathology wild rice research effort was directed toward the possible biological control of waterplantain, understanding the factors which affect wild rice seed storage and subsequent germination, and continued studies on the possible use of the systemic fungicide propiconazol (Tilt) alone or in combination with the protectant fungicide mancozeb (Dithane M-45) for the control of fungal brown spot (FBS), caused by Bipolaris oryzae. Also, the search and preliminary testing of other new fungicides to control FBS was investigated. A new research project involving the possible use of wild rice tissue tissue culture for FBS resistance screening was initiated.

CHEMICAL CONTROL

A. Tilt Rate Study

Introduction. Propiconazol (Tilt) is a systemic fungicide having both eradicative and protective properties. It has been proposed that this fungicide be registered for use in the management of Bipolaris oryzae (Breda de Haan) Shoem. the causal organism of fungal brown spot of wild rice. Beginning in 1985, a study at the University of Minnesota Experiment Station at Grand Rapids was initiated to determine the effects of differingratesof Tilt on disease development and subsequent plant yield. This study began in 1985 and was completed in 1986.

Experimental Methods. The paddy was prepared by rototilling and amending the soil with 22.5 kg/ha (20 lbs/A) of nitrogen in the form of urea. Volunteer seed was eliminated by fumigation of the soil with methyl-bromide the previous fall. Experimental design was a completely randomized block consisting of six treatments replicated six times. Each treatment was

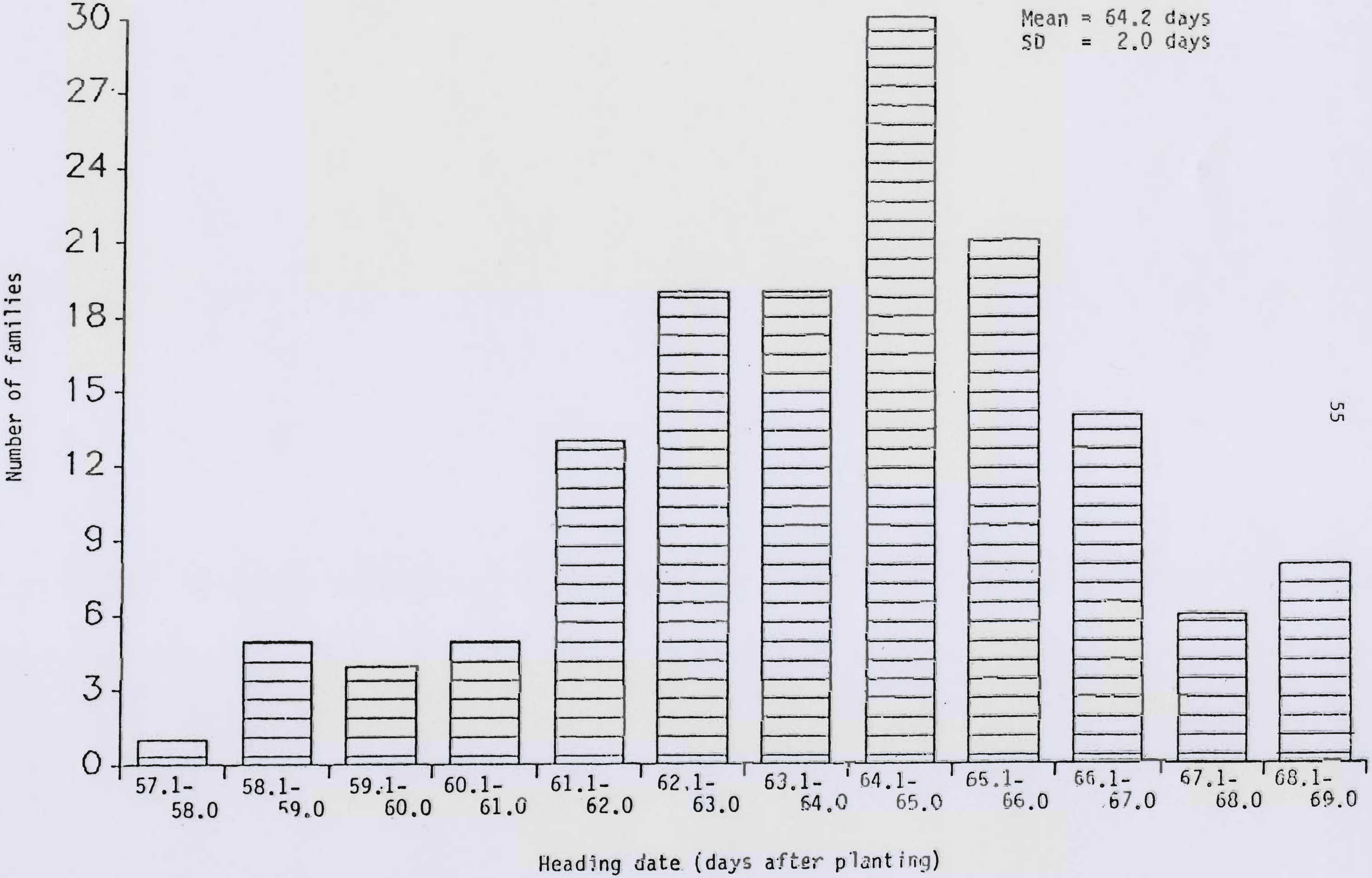


Figure 5. Frequency distribution of half sib family means for heading date (1985).

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Introduction. Propiconazol (Tilt) is a systemic fungicide having both eradicative and protective properties. It has been proposed that this fungicide be registered for use in the management of Bipolaris oryzae (Breda de Haan) Shoem. the causal organism of fungal brown spot of wild rice. Beginning in 1985, a study at the University of Minnesota Experiment Station at Grand Rapids was initiated to determine the effects of differingratesof Tilt on disease development and subsequent plant yield. This study began in 1985 and was completed in 1986.

Experimental Methods. The paddy was prepared by rototilling and amending the soil with 22.5 kg/ha (20 lbs/A) of nitrogen in the form of urea. Volunteer seed was eliminated by fumigation of the soil with methyl-bromide the previous fall. Experimental design was a completely randomized block consisting of six treatments replicated six times. Each treatment was planted in a 1.5 X 2.1 m (5 X 7 ft) blocks. The wild rice cultivar K-2 was used.

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

Wildrice plants were inoculated on the July 30 and August 6 beginning at the boot stage of plant development. The inoculation process was as follows: Approximately 1 liter of the dried inoculum was mixed with 3 liter of water immediately prior to inoculation. The resulting spore suspension was sieved through a 300 micron (U.S. Standard Sieve Series No. 50 W.S. Tyler Co., Mentor, Ohio) screen. This procedure was repeated 4 times. Each plot was inoculatedusing a backpack sprayer (Hudson Stainless steel Suprema 67367, H.D. Hudson Mfg. Co., Chicago, IL). Immediately following inoculation, plants were misted every 15 minutes for 2 minutes up until the fungicide was applied. Fungicides were applied with a hand-held CO_2 pressurized sprayer (20 lbs of pressure). Application volume was 1/3 l per pot. The control was sprayed with water only.The fungicide treatments were as follows:

Formulated	oz/A	(g ai/A)	Plant Growth Stage	Spray Schedule
Tilt	4	(50)	Boot and Heading	07/30 & 08/6
Tilt	6	(75)	Boot and Heading	07/30 & 08/6
Tilt	8	(100)	Boot and Heading	07/30 & 08/6
Tilt	8	(100)	Boot	07/30
Tilt	10	(125)	Boot	07/30

Each plot was 5 X 7 ft, with the inner 4 X 6 ft being harvested. The plants were harvested by hand on September 10, 1986. The plants were counted, threshed, and the seed dried at 90 C. The grain was then dehulled, sized and weighed. Wild rice seed greater than 1.245 mm in diameter was used to determine final yields. Treatment means were compared by Duncan's New Multiple Range Test at the$p$=.01 levelof significance.

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

Results and Discussion

In 1986 all propiconazol (Tilt™) treatments resulted in significantly (P=.01) higher yields than the untreated control (Table 1). Plants treated with the fungicide at a rate of 8 oz /A at boot and heading resulted in a higher yield than any other chemical treatments. Yields were significantly increased with increasing rates of propiconazol when applied at either boot and/or boot and heading stages of plant development Table 1). One application of the fungicide at 8 oz /A resulted in a significantly higher yield when compared with either the 4 or 6 oz /A rates applied at both boot and heading (Table 1).

Table 1. The effect of propiconazol (Tilt™) rate on the yield of wild rice cultivar K-2 inoculated with **Bipolaris oryzae**, the causal organism of fungal brown spot in 1985 and 1986

Rate oz/A	Stage of plant development	Yield lb/A 1985	Yield lb/A 1986
4	boot and heading	281 a*	370 b*
6	boot and heading	278 a	444 d
8	boot	359 b	523 e
8	boot and heading	448 c	544 f
10	boot	293 a	392 c
Control		317 a	264 a

* Means followed by the same letter are not significantly different at the p=.10 and p=.01 in 1985 and 1986, respectively according to Duncan's new multiple mange test.

The 1985 Tilt Rate Study also showed that the maximum significant yields were obtained with either one or two applications of the fungicide at 8 oz per acre.

In both 1985 and 1986 a decrease in yield was observed in teatments receiving a single application of Tilt™ at 10 oz /A during the boot stage stage of plant development. Phytotoxicity was expressed as leaf tissue necrosis at the site of fungicide contact.

Table 2. Fungal brown spot disease severity ratings on wild rice cultivar K-2 inoculated with **Bipolaris oryzae** and then treated with Tilt at several different rates in 1986

Rate oz/A	Stage of plant development	Disease severity ratings (%) 7/30	8/6	8/20	8/27	9/9
4	Boot & heading	0	5#1, 3#2, 2#2/[a] 6#3, 4#2, 2#2/ 7#1, 5#2, 5#3	8#1, 6#2, 4#3/ 12#1, 8#2, 2#3/ 14#1, 10#2, 10#3	2/2/2[b]	2/4/2
6	Boot & heading	0	20#1, 5#2, 10#3/ 15#1, 6#2, 4#3/ 20#1, 15#2, 2#3	30#1, 15#2,20#3/ 30#1, 12#2, 8#3/ 30#1, 25#2, 4#3	3/3/3	4/5/20
8	Boot & heading	0	4#1, 5#2, 2#3/	6#1, 8#2/ 4#1, 16#2/ 2#1	1/1/15	2/2/20
8	Boot	0	10#1, 5#2, 2#3/ 8#1, 2#2, 1#3/ 2#2	15#1, 8#2, 4#3/ 16#1, 3#2, 5#3/ 2#1, 6#2	2/2/10	3/3/25
10	Boot	0	15#1, 1#2/ 2#1, 10#3/ 5#1, 20#3	20#1, 4#2/ 4#1, 20#3 10#1, 20#3	2/2/2	2/3/25
Control		0	12#1, 6#2/ 15#1, 3#2, 15#3/ 20#1, 5#3, 8#5	16#1, 12#2 18#1, 6#2, 20#4 25#1, 30#3, 16#5	2/4/6	5/10/60

a = <1 % total leaf area infected for the flag/second/third top most leaves.
b = Percent leaf area infected for the flag/second/third top most leaves.

Disease ratings in 1986 were lowest for the plants receiving one or two 8 oz /A applications of Tilt at boot and boot and heading, respectively (Table 2). The trace levels of disease (<1%) recorded on July 30 and August 6 for plants 6 for plants receiving two 8 oz ai/A applications, have been shown not to cause detectable reductions in yield (Kohls and Percich, 1984a.; Kohls and Percich, 1984b.). The 4, 6, 10 oz ai./A rates on 27 August had mean disease readings of 2.1, 2.0, and 2.1% for the flag, 2nd and 3rd topmost leaves, respectively. When these disease levels are present in unprotected plants during the milk stage of plant development, significant reductions in yield can occur (Kohls and Percich, 1984a.; Kohls and Percich 1984b.). Furthermore the lower disease ratings recorded for the plants receiving two 8oz ai/A applications of propiconazol corresponded to the higher yields observed for these treatments when compared with the others (Tables 1 and 2). However, it should be noted that the disease ratings were low for plants receiving only one application of the fungicide at the 10 oz /A rate at the boot stage of development. The yield from this treatment did not reflect the low disease ratings. This may have been due to the observed phytotoxic effects of the fungicide. The leaves of such treated plants became discolored and ultimately necrotic at the site of chemical contact. These symptoms are typical of chemical spray injury. As mentioned, disease ratings for the remaining treatments were moderate. It should be noted that disease initiating from the milk stage of plant development on, has no effect on the final yield. Thus, high disease ratings at the end of the season do not reflect the yield reductions that would have resulted if the disease was present at such levels earlier in the season. The results of this study after two years indicated that the best control FBS could be obtained with Tilt at 8 oz /A during both boot and heading.

Literature Cited

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

Kohls, C.L. and J.A. Percich. 1984b. Fungicide spray scheduling to control fungal brown spot of wild rice (Zizania Palustris). Rice Technical Report No. 16.

B. Propiconazol (Tilt™) Mancozeb (Dithane M-45™) Study

Introduction.

Mancozeb (Dithane M-45, Rohm and Haas Co., Philadelphia, PA) is currently the only fungicide registered for use on cultivated wild rice in Minnesota to control fungal brown spot (FBS) caused by Bipolaris oryzae (Breda de Haan) Shoem. Dithane M-45 is a protective fungicide with a recommended rate of 2.0 lb/A at a spray application interval of 7 to 10 days. Propiconazol Tilt (Ciba Geigy Corp., Greensboro, NC) is is a systemic fungicide having both eradicative and protective properties. During the 1984 growing season an emergency use permit (section 18) was submitted to the Minnesota Department of Agriculture and the Environmental Protection Agency for the use of Tilt on cultivated wild rice to control FBS. The purpose of this study was to evaluate the use of Tilt and Dithane M-45 in sequential application combinations for control of fungal brown spot. This study began in 1984 and was completed in 1986.

Experimental methods. In 1986 wild rice seed, cultivar K2, was planted on 3 June into 1.5 X 2.1 m (5 X 7) plots. The paddy was previously prepared by rototilling and amending the soil with nitrogen at the rate of 22.5 kg/ha (20 lbs/A). A second application of nitrogen at a rate of 8 kg/ha (7 lbs/A) was applied at the early grain elongation stage of plant development. Volunteer seed had been previously eliminated in the Fall by methyl bromide fumigation 1986, as in both 1984 and 1985, the experimental design was a completely design consisting often treatements and six blocks.

The fungicides were applied with a hand-held, CO_2 pressurized canister sprayer. The application volumes for both fungicides was 0.3 liters (0.09 gal/plot). Dithane M-45 was applied at the recommended rate of 2.25 kg/ha (2 lb/A) and Tilt at the rate of 0.1 kg/ha (8 oz/A) in 1986.

The treatments, fungicide application schedule and inoculation schedule are are described in Tables 2 and 3. Treatments were coded with three letter descriptors which indicate the pattern of fungicide use. The letter 'M' indicates an application of Dithane M-45 whereas, P' refers to an application of Tilt. Control treatment descriptors begin with a 'C' whereas inoculated treatment descriptors contain an'I'. The second and third letters of the descriptor indicate whether the treatment was an individual fungicide used twice - both letters the same, a single fungicide used once - the last letter an 'I', or the two fungicides used in sequence - an 'M' and 'P'. The following is a listing of all treatments:

Treatment	Description
CMM	Control (non-inoculated), 5 applications of Dithane
CPM	Control (non-inoculated), 1 application of Tilt at boot followed by 2 applications of Dithane
CPP	Control (non-inoculated), 2 applications of Tilt one at boot and the other at heading.
CMP	Control (non-inoculated), 2 applications of Dithane followed by 1 application of Tilt at heading.
I	Inoculated only, no fungicide sprays
IPP	Inoculated, two applications of Tilt, one at boot and

Treatment	Description
	the other at heading.
IPI	Inoculated, one application of Tilt at boot
IPM	Inoculated, one application of Tilt at boot followed by one application of Dithane at heading.
MIP	Inoculated, one application of Dithane at boot followed by one application of Tilt at heading.
IMP	Inoculated, one application of Dithane at late boot

In both 1985 and 1986 an unprotected control (I) was added (Table 2). This was done to determine if Tilt did infact increase yields compared to unprotected disease controls. Treatments that were inoculated received two applications of inoculum, respectively, in 1985 and 1986. The procedure for inoculum increase and application was the same as that described for the Tilt Rate Study.

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

Table 3. Fungicide application and inoculation (I) schedule for the comparison of propiconzal (Tilt[TM]) and mancozeb (Dithane M-45[TM]) for the control of fungal brown spot on wild rice cultivar K-2

Date	Non-inoculated				Inoculated					
	CMM	CPP	CPM	CMP	I	IPP	IPI	IPM	MIP	IMP
July 30					I	I	I	I	I	I
July 31	M	P	P	M		P	P	P	M	
August 6					I	I	I	I	I	I
August 7	M			M						M
August 14	M	P	M	P		P		M	P	P
August 21	M		M							
August 28	M									

I = Inoculation with <u>Bipolaris oryzae</u>
M = Mancozeb (Dithane M-45) application
P = Propiconazol (Tilt) application

Panicles in 1984, 1985, and 1986 were harvested from the inner 1.22 by 1.83 m (4 x 6 ft) area of each plot by hand. Plant material was counted, threshed and dried at 60 C. Grain was then de-hulled, graded and weighed. Wild rice seed greater than 1.26 mm in diameter (grade # 3) was used to determine final yields. Treatment means were compared by Duncan's New Multiple Range Test.

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

Results and Discussion. The effects of Tilt and Dithane M-45 on the yield of wild rice cultivar K-2 when infected with **B. oryzae**, the causal organ of fungal brown spot (FBS) are summerized in Table 4.

There were significant differences between many of the treatments in 1986. All the treatments, except for IPM, which were not artifically inoculated with B. oryzae had significantly higher yields than any treatment which were inoculated (Table 4). The CMP treatment resulted in the highest yields during all three years. The CMM and the IPM treatments resulted in high yields and were not significantly different from each other regardless of the year tested. The IPM did as well as the uninoculated CMM, perhaps due to the fact that propiconazol prevented growth, developmemt, and sporulation of the fungus within the infected plant tissue. All the inoculated and fungicide treated plants had significantly higher yields than those plants which were inoculated but received no fungicides (Table4).

The possibility that propiconazol alone may cause yield reductions was also investigated. The IPP treatment, receiving two fungicide applications resulted in a yield of only 321 lb/A in 1986. This would seem to indicate that propiconazol may have had some yielding depressing effect in both 1984 and 1986even though no phytotoxic symptoms were observed in either year. The IPI treatment also resulted in less yield than expected in all three years when compared with the other propiconazol teatments receiving only one application of the fungicide. This may have been due to the constant pathogen pressure applied to particular treatment. It should be noted, however, that the CPP treatment was included in the experiment to determine if propiconazol when applied twice to uninoculated plants at a rate of 8 oz/A would result in any phytotoxic effects. It appears that there may have been some yield depression in this teatment when compared with the CMP treatment (Table 4).

In 1985, no signifucant differences amoung treatments were found (Table 4). Due to poor seed germination (<5%), seedlings had to hand transplanted into all treatment plots. This resulted in non-uniformity with respect to plant stage of development and the time of fungicide application. Since, all the plants in each plot did not reach nearly the same stage of plant

Table 4. The effects of mancozeb (Dithane M-45) and propiconazol (Tilt) on the yield of inoculated and non-inoculated wild rice cultivar K-2 during 1984, 1985, and 1986 at the University of Minnesota North Central Experiment Station at Grand Rapids, Minnesota

Treatment	Yield lb/A		
1984, 1985, and 1986	1984	1985	1986
CMP	805 a*	405 a*	558 a*
CMM	749 b	380 a	499 b
IPM	737 b	387 a	482 b
CPP	691 c	401 a	444 c
CPM	669 c	313 a	425 c
IMP	635 d	382 a	384 d
MIP	623 d	372 a	386 d
IPP	590 e	301 a	321 e
IPI	545 f	337 a	349 de
I		348 a	253 f

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

development at the time of fungicide application disease control and thus yields were affected.

Disease severity ratings in 1986 varied depending upon the treatment (Table 5). The non-inoculated controls (CMM, CPP, and CPM) had only trace amounts of disease (<1%) through 8 August. By 9 September all the control treatments had <1% total disease on all three leaves examined. The treatment consisting only of inoculated plants (I), but not having fungicides, had the mostsevere disease ratings on 8 August. All the inoculated and fungicide treated plants had less disease than the inoculated (I) treatment (Table 5). The high disease ratings in all inoculated treatments on 9 September had very little effect on yield since the plants were protected during the critical fertilization to 1/4 grain filling stages of plant development. The disease severity ratings for 1984 and 1985 were very similar to the 1986 results.

In summary, after three years of small replicated plot studies under controlled and sustained epidemic conditions at the Univ. of Minn. North Central Experiment Station at Grand Rapids, the control of fungal brown spot of cultivated wild rice in Minnesota can best be achieved by any ofthe following strategies:

1. Dithane M-45 at a rate of 2 lb/A on a 7 to 10 day interval at first sign of disease and continued through the 1/4 grain fill stage of plant development. Depending upon initial onset of disease, three or four applications may be necessary.

2. **Given State of Minnesota and EPA approval for the use of Tilt on cultivated wildricein Minnesota** three approaches appeartobe effective:

    a. Tilt, alone at the rate of 8 oz /A applied at boot or at both boot and heading on a 14 day schedual.

    b. One application of Dithane M-45 at 2 lb/A at boot followed 7 days later by a single application of Tilt at 8 oz per acre.

    c. Tilt at 8 oz /A applied at boot followed 14 days later by either 1 or 2 application(s) of Dithane M-45 at 2 lb per acre.

After 3 years of small plot study, the most effective strategy to control FBS of cultivated wild rice appears to be 2b (CMP), above if no disease is presentwhen the spray program is initiated. However,if a trace amountof diseaseispresentbefore initiation of spray program the (IPM)or2a above, resulted in significant FBS control. The use of Dithane M-45 on a 7 day scheduale before disease onset beginning at boot and continuing to 1/4 grain fill resulted in as good control as the IPM treatment. Again, the useof propiconazol (Tilt) on cultivated wild rice in Minnesota at the present time has not been approved by the Environmental Protection Agency at the present time.

Future

Large field testing of Tilt under normal cultural practices should be performed before growers (If and when Tilt is approved by EPA) attempt to use the chemical. Cultural practices such as plant density and nutrition are a must if Tilt is to perform effectively. Also, equally important is the amount of disease present before application, the stage of plant development at the time of spraying, and the proper application and placement of the fungicide.

Please note: The final label rates for Tilt on wild rice are not known.

C. **Systhane™ And Iprodione (Rovral™) Study**

Introduction. Systhane and Rovral are eradicant and protectant fungicides, respectively that have been reported to have activity against the Bipolaris genus. An experimental material similar to Systhane was tested on wild rice in both the greenhouse and field in 1979 and 1980 for FBS control. The chemical performed well resulting in significant disease control and increased yield. The materal was, like Systhane, was produced by Rohm & Haas Company. Rovral is a product of Rhone-Poulenc Inc. and has not been evaluated on wild rice previously. Rovral is currently labeled for use on almonds, lettuce, stone fruits, and others.

Experimental Methods. All experimental methods concerning experimental design, inoculation schedule, host plant, location, cultural practices, etc. were the same as previously described in the Dithane M-45 and Tilt Study.

Rovral was applied at rates of 1.12 (1) and 0.56 kg ai./ha (0.5 lb ai./ha) on 7 day schedules beginning on 30 July during the boot stage of plant development.

Systhane was applied on a 10 day schedule at a rate of 70.7 g ai./ha (2 oz ai./A) at boot (7/31/86) and again at heading (8/11/86).

Results. The following table summerizes the effects of Systhane and Rovral on the yield of wild rice when compared with the Tilt and Dithane.

Table 6. The effects of Rovral and Sythane on the yield of wild rice cultivar K-2 inoculated with **Bipolaris oryzae** when compared with various Dithane M-45 and Tilt treatments in 1986

Treatment	Yield in pounds per acre
CMP	558 a*
CMM	499 b
IPM	482 b
SYSTHANE	446 c
ROVRAL (1 LB/A)	445 c
CPP	444 c
CPM	425 c
ROVRAL (0.5 LB/A)	400 d
MIP	386 d
IMP	384 d
IPI	349 de
IPP	321 e
I	253 f

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

Rovral at the 1 lb/A and Systhane significantly increased yields when compared with the inoculated but untreated (I) control (Table 6) but were not not significantly different from each other. Rovral at 0.5 lb/A did not perform as well as the 1.0 lb/A, but did result in a significant yield when compared with all the inoculated treatments, excluding the IPM treatment (Table 6).

Plants treated with Rovral at either rate or with Systhane had low disease severity ratings by the end of the season when compared with the untreated but inoculated control (Table 7).

Table 7. Fungal brown spot disease severity ratings on wild rice cultivar K-2 inoculated with __Bipolaris oryzae__ and then treated with either Rovral or Systhane in 1986

Treatment	Disease Severity Ratings (%) On The Flag/2nd/3rd Leaves				
	7/30/86	8/6/86	8/20/86	8/27/86	9/9/86
Rovral (0.5 lb/A)	0	0	tr/tr/tr	<1/<1/1.5	1/1/2
Rovral (1.0 lb/A)	0	tr/tr/tr	<1/<1/<1	2/2/3	5/3/4
Systhane	0	tr/tr/tr	tr/tr/tr	<1/<1/<1	2/3/2
Control-inoculated	0	tr/tr/tr	1/1/1	2/4/6	5/10/60

It should be noted that disease severity ratings are somewhat subjective. However, they can be important guides to the progressive development of epidemics and can serve as a real time indication of the current statis of the disease in a given population,

The preliminary study of both Systhane and Rovral indicated that the fungicides should be evaluated again for their ability to control fungal brown spot of wild rice.

BIOLOGICAL CONTROL OF COMMON WATERPLANTAIN (__Alisma triviale__)

Introduction. Common waterplantain is the most destructive weed present in cultivated wild rice fields (Oelke, 1982). One plant per square foot from rootstocks can result in a yield reduction of 43% (Oelke, 1982; Ransom and Oelke, 1982). Currently effective weed control is usually the result of both cultural and chemical methods.

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

Experimental Methods. The experimental methods are the same as were previously outlined in the Minnesota Wild Rice Research - 1985 report (pp. 44-45).

Results. Three bacteria (**Erwinia**, **Pseudomonas**, and **Xanthomonas** spp.) and four fungi (**Alternaria**, **Epicoccum**, **Rhizopus**, and **Septoria** spp.) have been isolated from common waterplantain during various stages of plant development and at several different locations (Huot and Percich, 1986).

A fungus belonging to the genus **Septoria** appears to be the most promising biocontrol agent isolated thus far. This microorganism was isolated consistaently throughout the growing season by all the techniques utilized. This indicates that the fungus is a resident of the leaf flora. **Septoria** spp. are known to be pathogenic and produce symptoms similar to those that are observed on common waterplantain (Agrios, 1978).

Field and greenhouse studies will continue to determine pathogencity of several isolates of the **Septoria** spp. isolated from naturally infected waterplantain.

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Table 5. The incidence and severity of fungal brown spot, caused by ***Bipolaris oryzae*** on inoculated and non-inoculated wild rice cultivar K-2 when treated with various combinations of Dithane M-45 and Tilt in 1986 at Grand Rapids, Minnesota

Treatment	Mean Disease severity ratings				
	7/30	8/6	8/20	8/27	9/9
CMP	0	0/0/tr	0/0/0	tr/tr/tr[a]	<1/<1/<1[b]
CPP	0	0/0/0	tr/tr/tr	<1/<1/<1	<1/<1/<1
CPM	0	0/0/0	0/0/0	tr/tr/tr	<1/<1/<1
CMP	0	0/0/0	3#1/10#1/1#1[c]	1/2/1	2/3/3
I	0	tr/0/tr	8#1/7#2/5#1, 4#2	2/3/3	4/5/10
IPP	0	tr/tr/0	10#1/6#1/6#1, 5#2	1/2/2	2/3/5
IPI	0	0/0/tr	6#1, 2#2/10#1, 5#2,3#1	3/4/5	3/6/10
IPM	0	tr/tr/tr	4#1, 2#2/5#1/6#1, 2#3	2/3/3	5/10/15
MIP	0	tr/tr/tr	5#2, 6#3/10#1/6#1	3/4/6	5/10/10
IMP	0	tr/tr/tr	4#1/2#1, 3#2/5#1,5#2	2/4/3	10/15/20

a = tr/tr/tr, trace nos. (<2) of lesions on the Flag/second/third top most leaves.
b = <1, less than 1% of the leaf infected.
c = Size and nos. of lesions of a given size (see Figure 1).

RESISTANCE SCREENING

A. Disease Nursery.

There exists a need for a disease nursery that is generally representative of the wild rice growing areas in Minnesota where a long term cooperative plant breeder and pathologist research effort can be developed. Such an effort is expensive and quick results would probably be unlikely. Although there have been several attempts to screen plants in the laboratory and field to identify sources of disease resistance in the past, no continuing and nursery has been developed to date.

B. Wild Rice Tissue Culture.

By the late 1970's plant tissue culture had begun to make important contributions to the improvement of agricultural plants. The earliest advances were made with dicotyledonous plants like carrot and tobacco. More recently some of the techniques have been used successfully in nonocotyledonous plants such as corn and rice. The ability to grow and manipulate cells of these crop plants in culture has resulted in significant advances in the areas of plant physiology, genetics, and breeding. We have initiated a project to evaluate tissue culture techniques for for improvement of disease resistance in wild rice. Although tissue culture is not a substitute for conventional resistance breeding and selection, it does offer some advantages:

1. <u>In vitro selection.</u> Large numbers of cells can be grown and tested in a small space; up to 20 million can be contained in a single five gram callus. In systems where a toxin is produced by the pathogen, it may be possible to screen cell cultures with the toxin and regenerate whole plants from resistant cells.

2. <u>Somaclonal variation.</u> Tissue cultured-induced (somaclonal) variation can result in recombination events which are not possible by convential methods. By changing the conditions of the culture, variation can be maximized to create novel genotypes or minimized to obtained many genetically identical plants.

3. <u>Hpaloid cultures.</u> Haploid cultures (Cultures with half the normal number of chromosomes in each cell) can be derived from the reproductive parts of the plant, such as anthers or ovules. Plants regenerated from these cultures would express recessive traits rarely seen in open pollinated plants. Such plants would be extremely useful in breeding and genetic studies.

4. <u>Genetic recombination.</u> Additional novel variation can be obtained through additions, deletions, and rearrangements in the plant's genetic information. <u>In Vitro</u> mutagenesis (using radiation or chemical mutagens) results in random genetic alterations. More directed changes can be accomplished using recombinant DNA techniques such microinjection of DNA, protoplast fusion, and direct gene transfer.

The approaches listed above are already possible in some culture systems. Our immediate concern is the development of the proper cell culture systems and methods of plant regeneration that will enable us to use these techniques. We have initiated callus cultures from immature embryos and are currently experimenting with different culture methods to mazimize cell growth rate and viability. If culture growth rate can be increased slightly, it should be possible to regenerate plants from undifferentiated callus. Methods for transformation and evaluation of regenerants are under consideration.

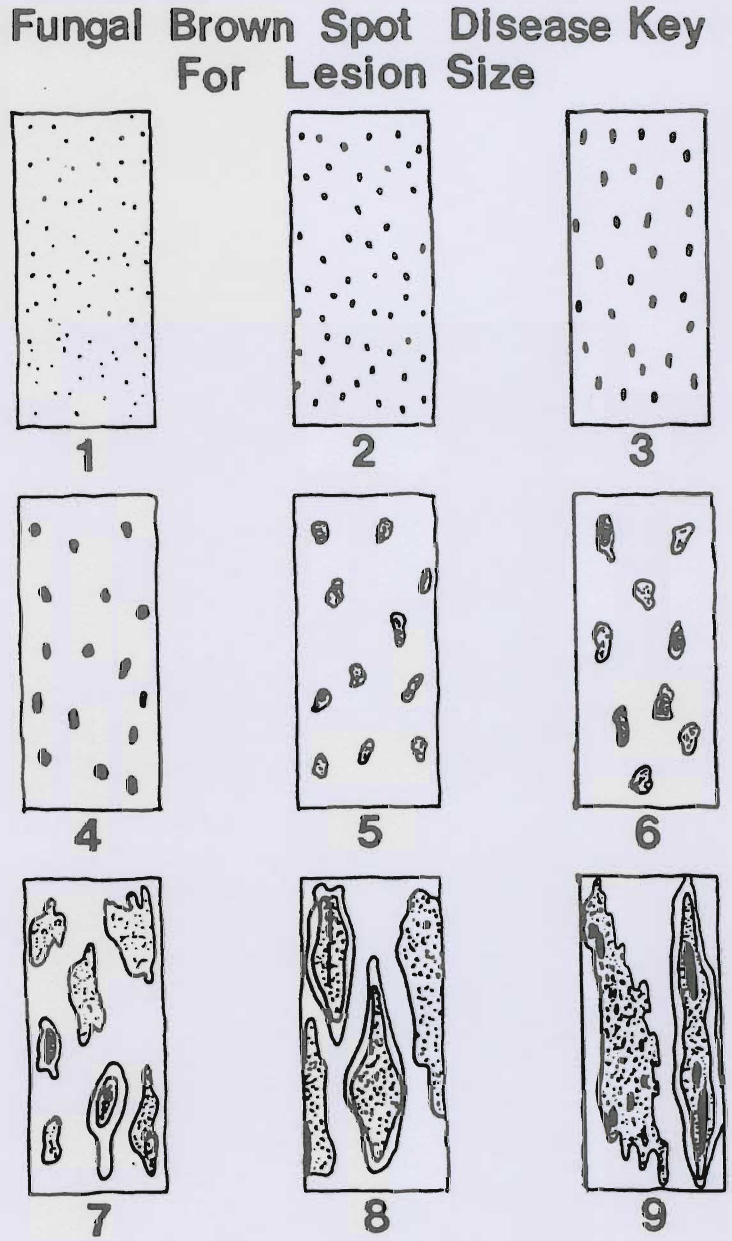

Figure 1 . Fungal brown spot of wild rice key to lesion size. Based on the work of Dr. David Punter, University of Manitoba, Winnepeg, Manitoba, Canada (unpublished). Leaf sections contain lesions coded by a number beneath each leaf. Lesions smaller than 1 are considered to be size 0; those larger than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

WILD RICE HARVEST INVESTIGATIONS RELATING TO COMBINE ADJUSTMENT FOR MAXIMUM HARVEST PROFITABILITY AND METHODS FOR ESTIMATING PERCENT RECOVERY

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

Wild rice harvest research activities in 1986 were directed principally toward:

1) Development of procedures for determining combine adjustment requirements for maximum harvest profitability as influenced by amount and quality of the harvested grain.

2) Evaluation of alternative methods for "quickly" estimating percent recovery of combine harvested wild rice grain, including:
   a) bulk density measurement(s) and
   b) abbreviated sample analysis at the farm.

Procedures for Determining Optimum Combine Adjustment

Proper (optimum) combine adjustment in wild rice harvest calls for a tenuous compromise between trying to maximize possible yield (minimize grain loss) and trying to maximize the quality of the net yield. One area of compromise, for example, is the performance of the cleaning-separating system. Here the desire to minimize loss of grain from the sieve by reducing fan speed and/or increasing sieve openings must be balanced with the desire to minimize the amount of non-grain material going into the grain tank. A method has been developed to determine relationships between the magnitude of the net green yield (NGY) and, based on its percent recovery, the resulting net processed yield (NPY). From this relationship, the cost of processing an incremental increase in NGY can be compared to the value of the incremental increase in NPY. Based on such an analysis, a decision can be made regarding appropriate combine adjustments to achieve a higher or lower NGY.

Procedures, applicable to any combine and set of harvest conditions, were developed and tested in 1986 for determining a relationship between NGY and NPY. Two series of tests (Series A and B) were conducted, each series being performed in a different field, with a different combine and on a different day. A series consisted of several test runs. To produce variations in NGY and percent recovery among test runs, a different combination of fan speed and sieve setting was used for each run. Test runs consisted of a complete round (two end-to-end trips) in the field. Harvested distances for individual runs were 2427 ft and 2170 ft for Series A and B, respectively. After each test run, the NGY in the grain tank was transferred to a weigh-wagon and weighed. During each run, a sample was obtained of the

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Published as paper No. 15,294 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station on research conducted under Minnesota Agricultural Experiment Station Project No. 12-026.

material coming into the grain tank. This sample was subsampled for laboratory analysis to determine percent recovery, moisture content and kernel size distribution.

The results for percent recovery (at zero moisture content) vs. NGY for both test series are shown in Figure 1. The shape of the curves in Figure 1 confirms what is known; i.e., as the combine is adjusted to increase the NGY, the percent recovery is decreased.

Results for NPY vs. NGY for both series are shown in Figure 2. These results were obtained by multiplying the NGY for each run by the decimal equivalent of the corresponding percent recovery value. Again, as expected, the tests show that as NGY increases in response to combine adjustment, NPY also increases, although at a decreasing rate.

Curves like those in Figure 2 form the basis for determining, with a given set of crop conditions and a given combine, the effect of specific combine adjustments on profitability. At time of harvest, cost per acre for processing the current year's crop is the only cost that the grower can control. Information of the type depicted in Figure 2 can be used to determine the economic effect of adjusting the combine to change NGY from one level to another and the desirability of making such an adjustment. Such a determination also requires pricing information on a) the processing charge per pound of processed wild rice and b) the value per pound of processed wild rice. The following two examples, using specific values, illustrate a procedure for defining the effect of combine adjustments on profitability.

For the first example, let"s consider the curve for Series A in Figure 2 and determine the appropriateness of making combine adjustments to increase NGY from 860 lb/ac to 960 lb/ac. From the curve, the NPY for these two values of NGY are 342 and 348 lb/ac, respectively. For illustration, let's assume that the cost of processing and the value of the processed wild rice are $.15/lb and $1.75/lb, respectively. In this example, the 100 lb/ac incremental change in NGY results in an added $15/ac ($.15/lb x 100 lb/ac) processing cost and the 6 lb/ac (348 minus 342 lb/ac) incremental change in NPY results in an added crop value of $10.50/ac ($1.75/lb x 6 lb/ac). In this example, the increased crop value of $10.50/ac does not justify the added processing cost of $15/ac. Therefore, increasing NGY from 860 to 960 lb/ac would not be recommended. The results in this example suggest that consideration should be given to adjusting the combine so as to increase percent recovery even though a reduction in NGY would be anticipated.

For the second example, let's consider the curve for Series B in Figure 2 and determine the appropriateness of making combine adjustments to increase NGY from 1000 lb/ac to 1100 lb/ac. From the curve, the NPY for these two values of NGY are 480 and 502 lb/ac, respectively. For illustration let's assume that the cost of processing and the value of the processed wild rice are the same as those used in the first example, $.15/lb and $1.75/lb, respectively. In this example, the 100 lb/ac incremental change in NGY also results in an added $15/ac ($.15/lb x 100 lb/ac) processing cost and the 22 lb/ac (502 minus 480 lb/ac) incremental change in net processed yield results in an added crop value of $38.50/ac ($1.75/lb x 22 lb/ac). The increased crop value of $38.50/ac does justify the added processing cost of $15/ac. Therefore, increasing NGY from 1000 to 1100 lb/ac would be recommended even though a reduction in percent recovery would be anticipated.

It is considered that for these profitability evaluations, the differences in hauling costs will have only minor influences. Therefore, the hauling costs have not been calculated in the above examples.

These two examples, although not stated, considered that the sale value of the processed wild rice is independent of the kernel distribution. For each run, the sample of grain was also analysed to determine the influence of the change in NGY on kernel size distribution. The samples were sorted by length and diameter into seven grade groups. The grades within each group were based on the grades specified by the International Wild Rice Association in May 1984. A copy of these grade specifications is attached to this report as Appendix 1. The grade groups used in this analysis were

- length 1 and 2 with diameter of T and O,
- length 1 and 2 with diameter of P and I,
- length 1 and 2 with diameter of N and G,
- length 1 and 2 with diameter of S,
- length 3 with all diameters,
- length 4 and 5 with all diameters and
- length 6 and 7 with all diameters.

The results from this sorting by grade groups is shown in Figures 3 and 4 for Series A and B, respectively. These graphs show the kernel size distribution vs. NGY. To further refine the profitability analysis in the two examples above, the value of the grain in each of the grade groups could be calculated and totaled for each NGY level considered.

Another method of assessing the preferred adjustment of net green yield is to take data similar to that of Figure 2 and calculate for each NGY level: 1) the crop value, 2) the processing costs and 3) the resulting difference. Considering that the cost of processing and the value of the processed wild rice are the same as those used in the two earlier examples, $.15 and $1.75/lb, respectively, the difference between the values and the processing costs are shown plotted in Figure 5. The operation point for maximum profitability is where the crop value minus processing cost is a maximum. Other values for processing costs and crop value can be used to determine the influence of these parameters on the optimum NGY.

These results, in Figure 5, are applicable only for the specific harvest studied and for the prices used in these sample analyses. Other examples could be considered with different parameter values of: 1) combine performance curves of percent recovery vs. NGY, 2) levels of NGY, 3) processing costs and 4) crop values.

Alternative Methods for "Quickly" Estimating Percent Recovery

Two methods for quickly estimating percent recovery have been evaluated. The objective is to develop a procedure which can be accomplished quickly on the farm so as to be useful in making combine adjustments.

The first method relates to measurement of bulk density. Many wild rice growers use a form of bulk density (weight per unit of volume) measurement for estimating percent recovery. Some growers have been using the weight of an unspecifiaed but fixed volume of rice to make this estimate of percent recovery. Even though the volume is not specified in this method, the procedure serves well for those with considerable experience in relating weight of the wild rice to the actual percent recovery of the harvested yield. We all use the bulk density concept when we use the hand method and bounce a handful of wild rice to make an evaluation for the grain being "heavy".

In view of this past association of bulk density with percent recovery, measurements were made of bulk density and percent recovery for several samples of wild rice from different fields, different combines and different wild rice growing areas. This study was conducted to evaluate the precision with which bulk density will estimate of percent recovery.

The bulk denisty (lb/cu ft) was determined by weighing the wild rice contained in a 0.5 cu ft bucket struck level. The actual percent recovery for each sample was determined by laboratory analysis. Three different methods of filling the bucket container were used and evaluated. These methods were loose-fill, jostle-fill and pack-fill. The results of this study are shown in Figures 6, 7 and 8 in the portions of the figures labeled "wet basis". The label "wet basis" is indicated because the bulk density values and percent recovery were calculated on basis of the wet in-field condition of the wild rice. It is realized that the effect on bulk density from the addition of moisture to a sample is opposite to the effect on percent recovery. An increase in moisture content increases bulk density but decreases percent recovery. Conversely, a loss of moisture decreases bulk density but increases percent recovery. Because of this opposite effect, it was judged that the bulk densities and percent recovery should be evaluated on the dry basis. These values on dry basis are also plotted in Figures 6, 7 and 8 and labeled "dry basis". The bulk density, on the dry basis, is the weight of dry matter in a cu ft of green wild rice grain. The percent recovery on the dry basis, is the ratio expressed in percent of the weight of dry matter, in the wild rice kernels to the weight of dry matter in green wild rice (including hulls and straw pieces).

The data in Figures 6, 7 and 8 indicate that: 1) percent recovery is correlated to bulk density, 2) the method of fill has little influence on the precision of predicting percent recovery for the data calculated on the wet basis, 3) the data for loose-fill method has a narrower spread than the other two fill methods for the data calculated on the dry basis, 4) for any of the methods the band width is 2 to 3 percentage points in percent recovery.

The second method was an abbreviated sample analysis at the farm involving oven heating, dehulling, fanning, weighing and calculating. The steps employed were to heat a small sample in an oven at 217° F for two hours, dehull in a small dehuller and fan to separate the hulls. This method deviates from the routine laboratory method because in this abbreviated method the samples are not dried for an extended period of time after fanning, to remove the moisture. Therefore, the value calculated by this method is expected to be higher than the zero moisture percent recovery. The comparison graph for this method is shown in Figure 9.

This method, with appropriate refinement, shows good potential as a predictor of percent recovery within two to three hours. This method does require the use of a relatively precise balance for weighing the samples, a small dehuller, an oven and a means for fanning.

Other methods were explored briefly for their effectiveness in predicting percent recovery. One method was the evaluation of the sinker volume from a sample of wild rice submerged in water. The preliminary results to date for this method with the procedures used were not conclusive.

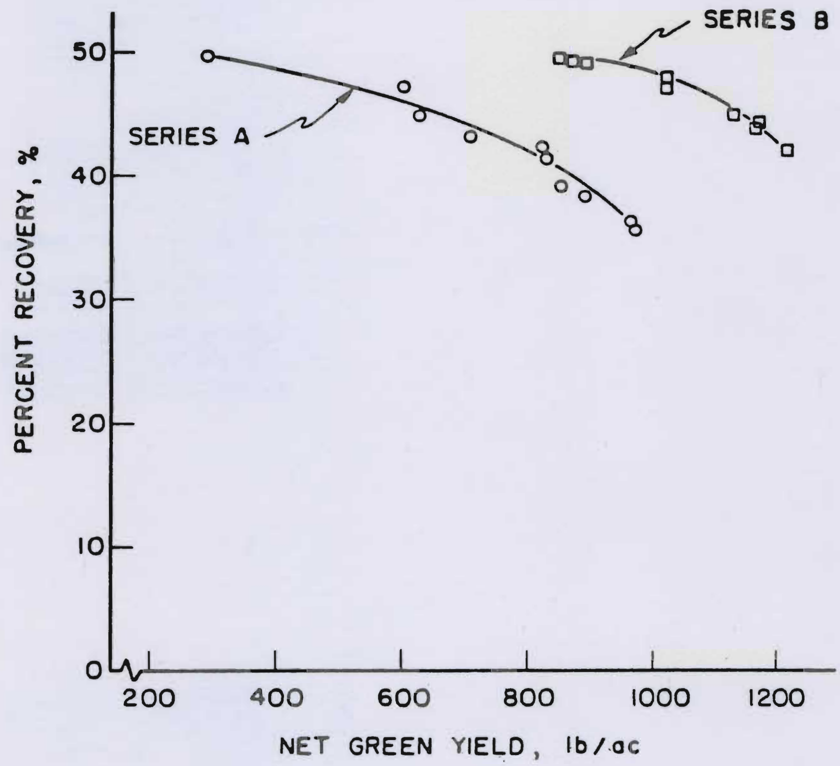

Fig. 1 Percent recovery vs. net green yield.

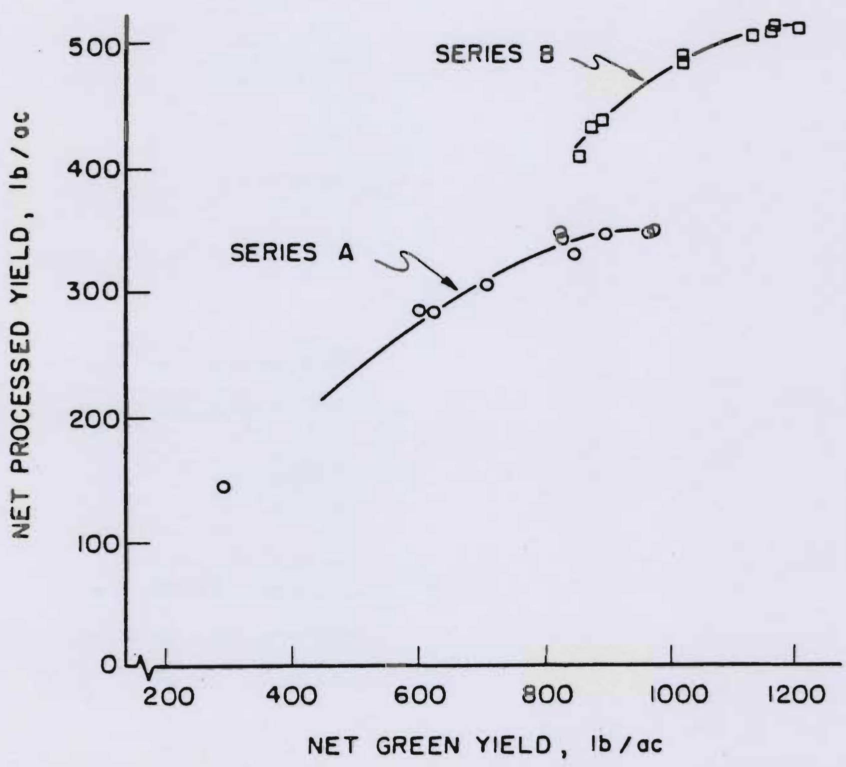

Fig. 2 Net processed yield vs. net green yield.

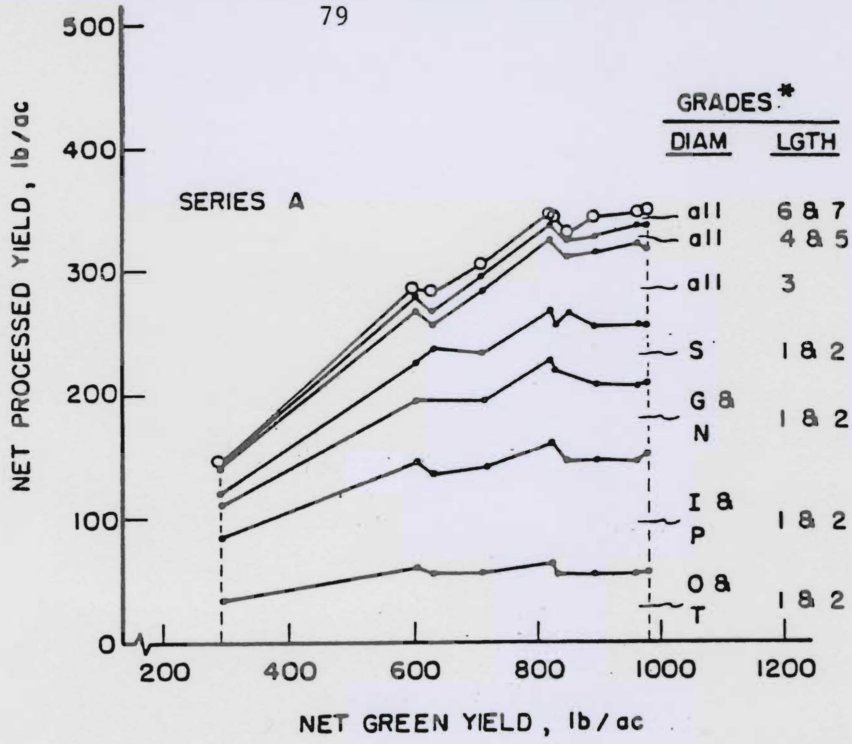

Fig. 3 Net processed yield by grade vs. net green yield for Series A.

* Grades as specified by the International Wild Rice Association, May 1984. See Appendix 1.

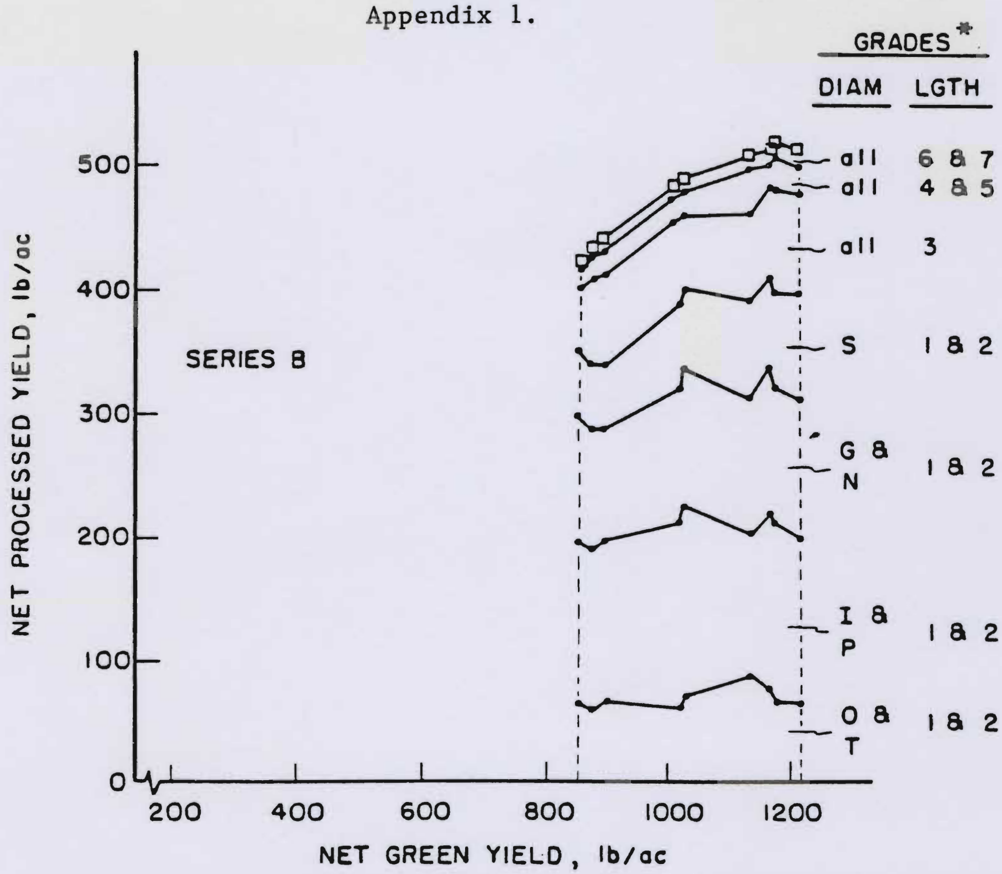

Fig. 4 Net processed yield by grade vs. net green yield for Series B.

* Grades as specified by the International Wild Rice Association, May 1984. See Appendix 1.

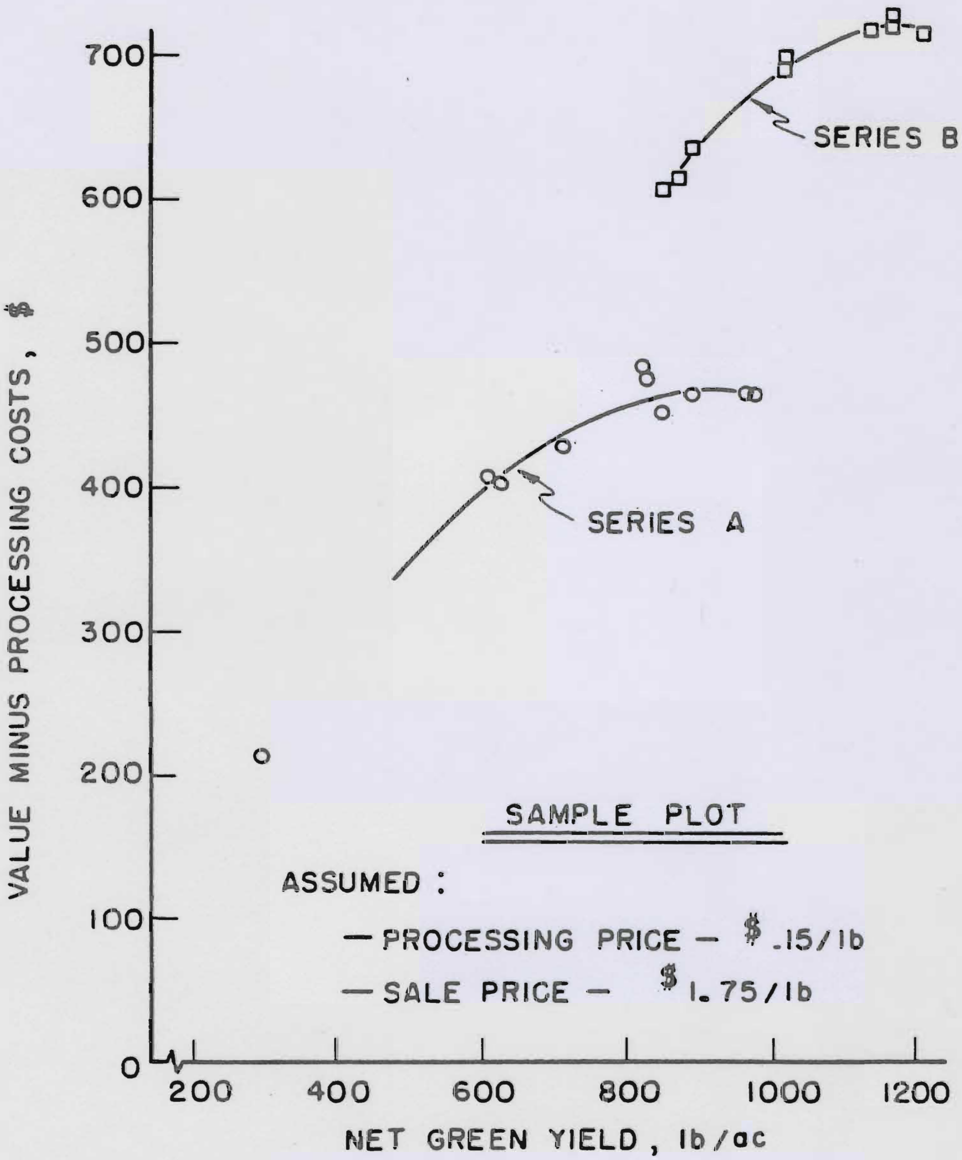

Fig. 5 Value minus processing cost vs. net green yield.

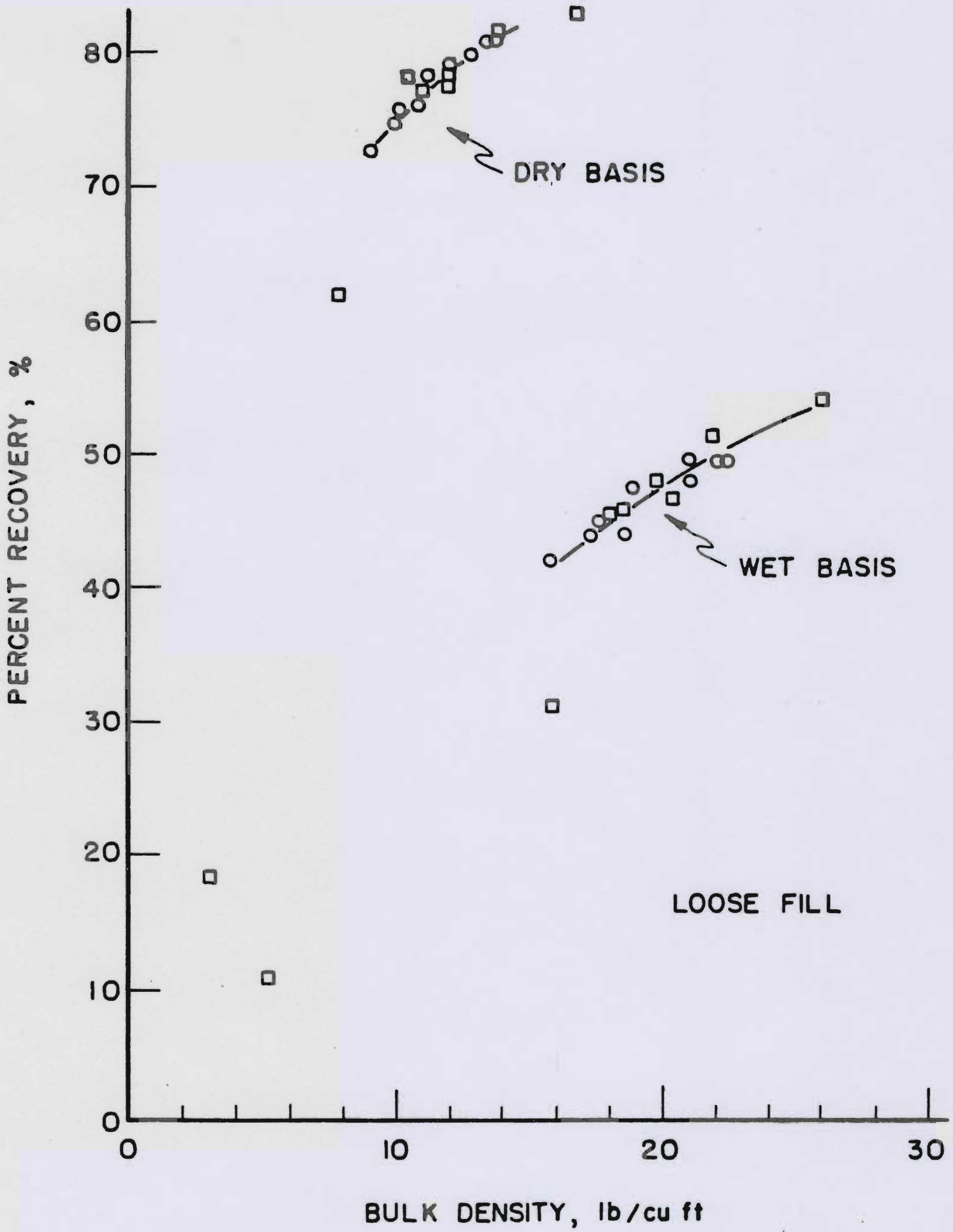

Fig. 6 Percent recovery vs. bulk density by loose-fill method.

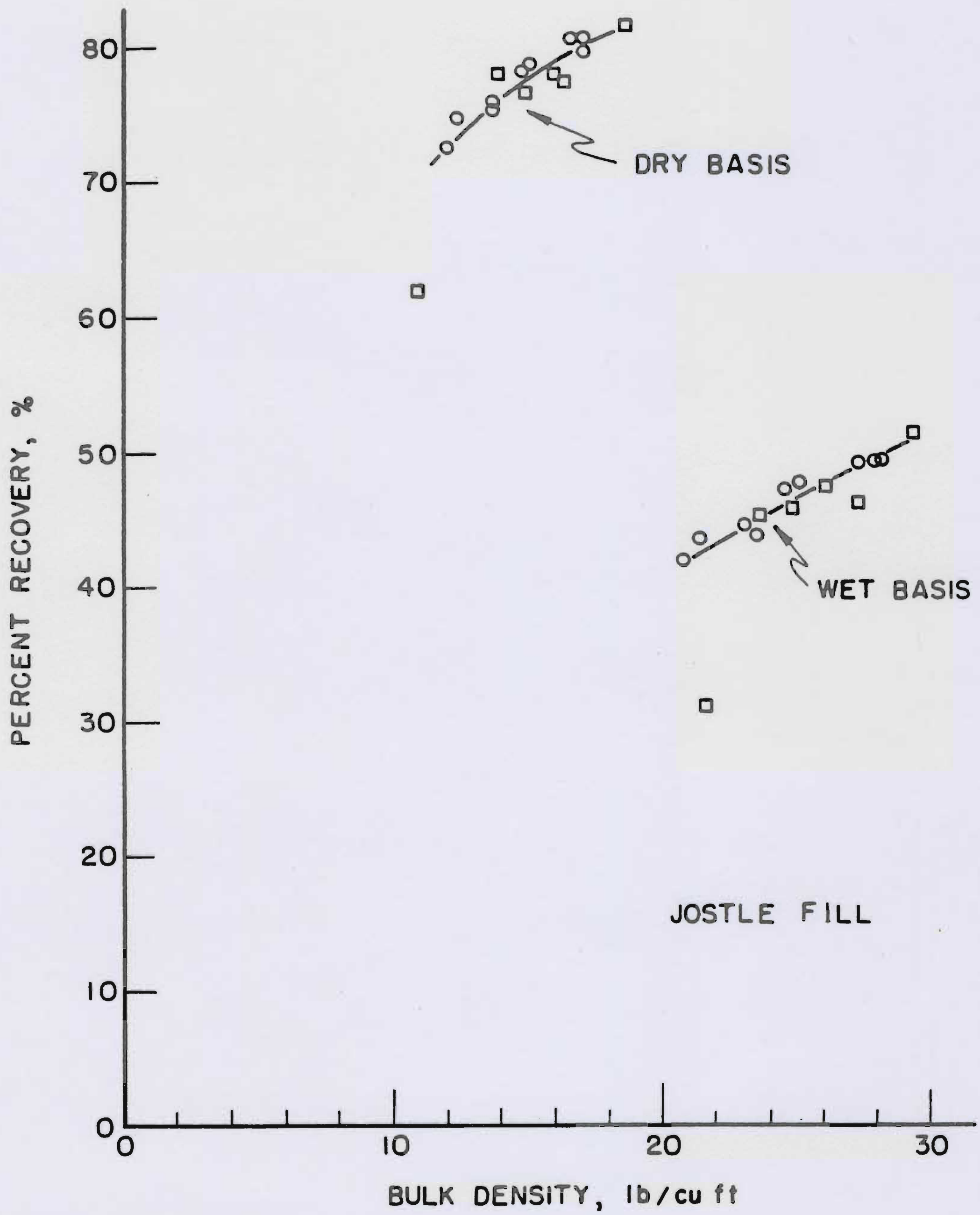

Fig. 7 Percent recovery vs. bulk density by jostle-fill method.

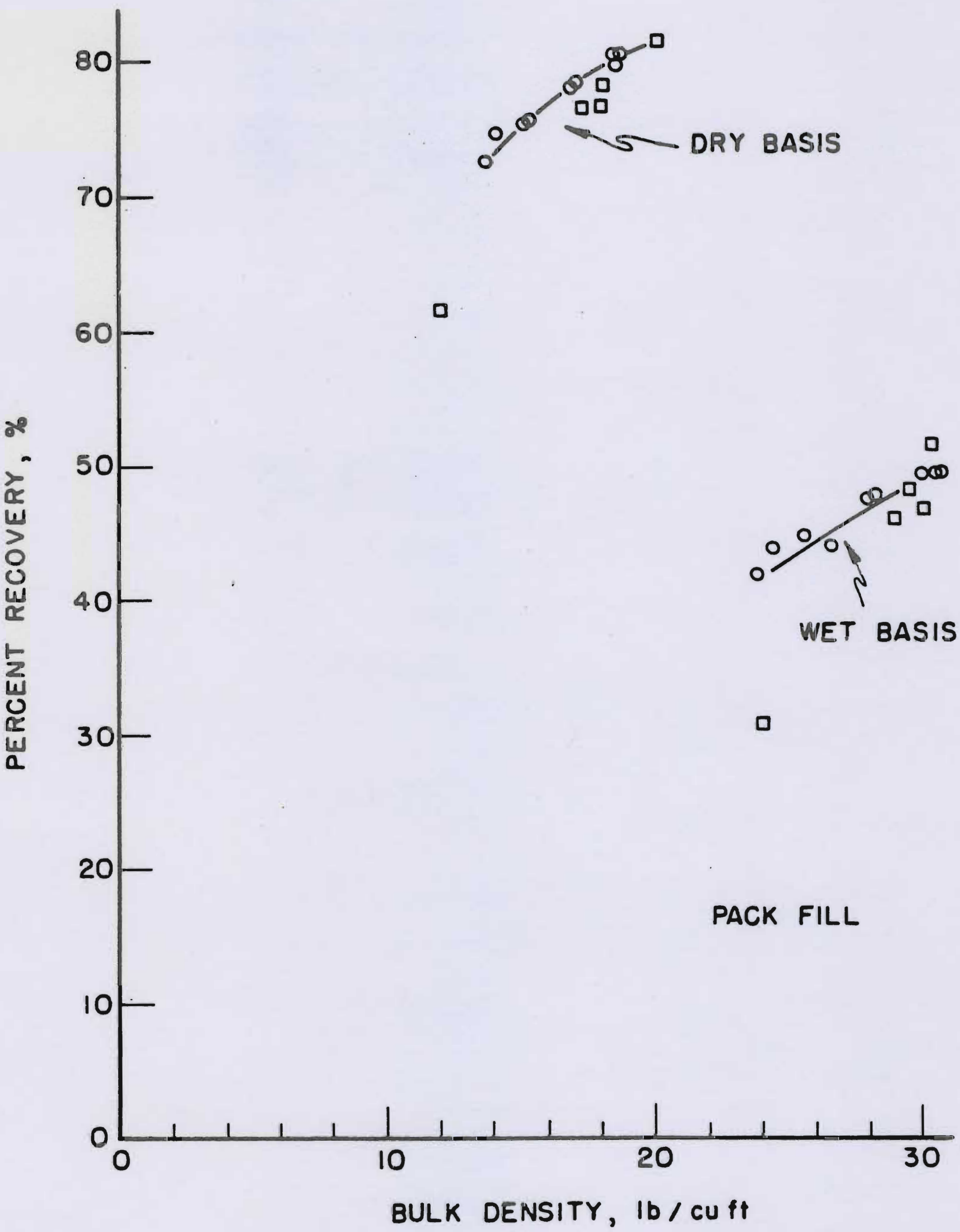

Fig. 8 Percent recovery vs. bulk density by pack-fill method.

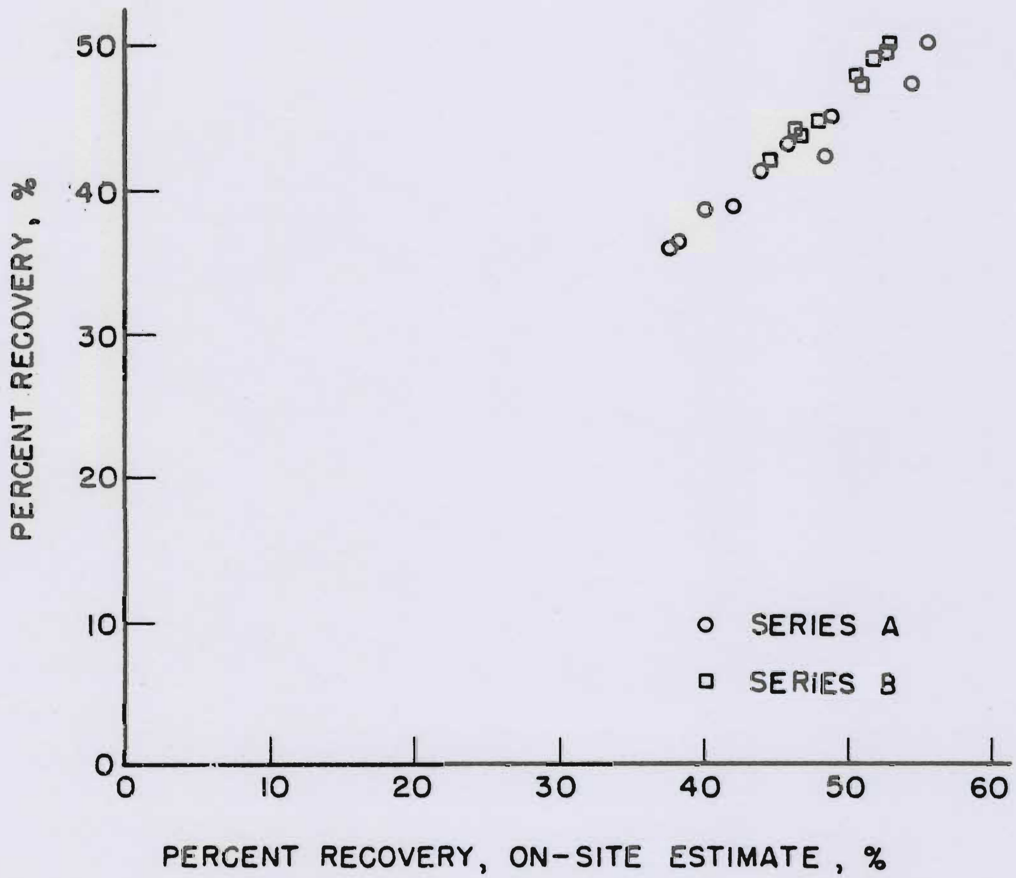

Fig. 9 Percent recovery vs. on-site estimate of recovery by abbreviated analysis at the farm.

APPENDIX 1

May/1984

INTERNATIONAL WILD RICE ASSOCIATION

GRADES[1]- LENGTH & DIAMETER

Screens	Diameter Measure[2]	Grade							
425	425 & above	T	X	X	X	X	X		
400	400	O	X	X	X	X	X		
375	375	P	X	X	X	X	X		
350	350	I	X	X	X	X	X		
325	325	N	X	X	X	X	X		
300	300	G	X	X	X	X	X		
	Below 300	S		X	X	X	X		
	Grade:		1 (Long	2 Gr)	3 (Med)	4 (Short	5 Gr)	6 (Small	7 Broken)

Length Measure:[3] 30 26 20 12 10 8 6

Riddle:[4] #1 (at 20) 000 (at 12)

[1]Although there is a potential of 49 grades the smaller lengths cannot be used.

[2]Measurements expressed in 64th of an inch (ex. 425 = 4¼/64ths).

[3]Measurements expressed in 64th of an inch (ex. 32 = 32/64ths).

[4]<u>Measurement of Riddle</u>

#1 - 20/64ths

#000 - 12/64ths

<u>Equation: Fraction of inch to 64ths of an inch:</u>

1 = 64
1/2 = 32
1/3 = 21-1/3
1/4 = 16
1/5 = 12-4/5

Wild Rice: Competition Between Minnesota and California

by

Ronald N. Nelson and Reynold P. Dahl*

Agricultural and Applied Economics

Production of cultivated wild rice in Minnesota has increased at an impressive rate; more than doubling from an estimated 2.8 million processed pounds in 1982 to 6.0 million processed pounds in 1986. But, production in California has increased even more rapidly from 0.8 million processed pounds in 1982 to 10.4 million processed pounds in 1986. California production in the latter year exceeded that in Minnesota by an estimated 4.4 million pounds (Table 1).

Wild rice is an attractive alternative crop for California rice farmers since they are able to use their existing rice land and equipment with little additional investment. Expansion of wild rice production in the Sacramento Valley is largely dependent on the price relationship between wild rice and rice. When rice prices fell to low levels from 1982 to 1984, wild rice prices were relatively favorable and California wild rice production increased rapidly.

The consumer demand for wild rice has increased substantially in recent years. Wild rice production increased by 83 percent between 1982 and 1984. The market absorbed these large production increases of over two million processed pounds per year with only a small downward adjustment in wholesale prices.

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* Ronald N. Nelson is Executive Director, Minnesota Paddy Wild Rice Research and Promotion Council and a former research assistant; and Reynold P. Dahl is professor, Department of Agricultural and Applied Economics.

Table 1. Wild Rice Production and Wholesale Prices, 1968-1986.[1]

Year	Total Lake	MN CULT	CALIF CULT	Grand Total	Wholesale[2] Price $/lb.
	(Millions of Processed lbs.)				
1968	0.66	0.04	---	0.7	$3.27
1969	0.4	0.2	---	0.6	2.66
1970	0.6	0.4	---	0.9	2.88
1971	0.8	0.6	---	1.4	2.71
1972	1.2	1.5	---	2.7	2.34
1973	0.7	1.2	---	1.9	2.11
1974	0.5	1.0	---	1.5	2.37
1975	0.3	1.2	---	1.5	2.51
1976	1.5	1.8	---	3.3	2.68
1977	1.4	1.0	0.01	2.4	4.25
1978	0.5	1.8	0.03	2.3	5.15
1979	0.7	2.2	0.07	3.0	5.01
1980	2.1	2.3	0.2	4.7	4.47
1981	1.1	2.3	0.5	3.9	3.79
1982	0.9	2.8	0.8	4.5	3.40
1983	0.9	3.2	1.4	5.5	3.35
1984	1.3	3.6	3.7	8.6	3.30
1985	0.5	5.1	8.3	13.9	2.97
1986 prelim.	0.5	6.0	10.4	16.9	2.60

[1] Source: Winchell, E.H. and Dahl, R.P. Wild Rice: Production Prices and Marketing, University of Minnesota Agricultural Experiment Station, Misc. Pub. 29-1984.

Nelson, R.N. and Dahl, R.P. The Wild Rice Industry: Economic Analysis of Rapid Growth and Implications for Minnesota, Univ. of Minn. Dept. of Agric. and Applied Economics, Staff Paper P86-25, July 1986.

[2] Wholesale prices obtained from large industrial buyers of wild rice.

But, in 1985, wholesale prices fell by more than 10 percent in response to a 60 percent increase in production over 1984. This resulted in a significant carryover of wild rice stocks, estimated at 3 million pounds, or about 20 percent of the 1985 crop year production. Production expanded again in 1986, and wholesale prices fell to a level comparable to prices in the mid-1970's. (Table 1)

Wild Rice Production Costs in Minnesota and California

An analysis of wild rice production costs in Minnesota and California is useful in assessing the level of production costs that can be expected. Wild rice crop budgets for Minnesota and California under 1985 prices and costs are shown in Table 2. The prices and crop inputs specified were estimated by formula and/or by survey information collected from the industry in 1985. The indicated yields are representative of what growers might reasonably expect under normal weather conditions, application of good farming practices, and the use of recommended agricultural technologies for wild rice. The budgets do not reflect any particular grower operation in the wild rice industry, and they are not presented as a standard to be met, maintained, or exceeded.

A comparison of these two crop budgets shows the advantageous position of California growers. While cash production costs in California range between $95 to $192 per acre higher than in Minnesota, and typical wild rice producer prices can be about $1.00 per pound less than in Minnesota, these disadvantages are offset by a nearly three-fold higher yield and a greater yield of processed wild rice per pound of unprocessed wild rice in California. Therefore, returns over cash costs on a processed basis in California amount to nearly $400 more per acre ($689.76 for California as compared to $294.29 for Minnesota) than (second year) net returns for Minnesota. This differential falls to $368.92 for returns over total costs (Cash costs + non-cash costs). This advantage may be best appreciated when comparing the total cost of producing a pound of processed wild rice. For California, this cost is $.99 per processed pound. In Minnesota total production cost per

Table 2. Wild Rice Budgets, 1985.*

	MINNESOTA**		CALIFORNIA	
Gross Returns/Acre	188 LBS @ $3.00 = $564.00		576 LBS @ $2.00 = $1,152.00 [1,200 LBS @ $0.80 = $ 960.00]	
Cost/Acre	Total Costs	Cash Costs	Total Costs	Cash Costs
Field Preparation	$ 31.76	$ 18.26	$ 39.41	$ 12.00
Planting Costs	154.20	154.20	308.00	308.00
Growing Costs	70.95	70.95	99.71	99.71
Harvest Costs	151.88	115.91	55.83	7.72
Other Costs	50.62	8.38	68.46	34.81
TOTAL (Year 1)	$456.68	$367.71	$571.39	$462.24
(Year 2)	$352.31	$269.71	$571.39	$462.24
(Year 3)	$400.23	$314.71	$571.39	$462.24

	MINNESOTA			CALIFORNIA	
	YR 1	YR 2	YR 3		
Returns Over Total Costs	$107.32	$211.69	$163.77	$580.61	[$388.61]
Returns Over Cash Costs	196.29	294.29	249.29	689.76	[497.76]
Total Costs/Pound	$ 2.43	$ 1.87	$ 2.13	$ .99	[$ 0.48]
Cash Costs/Pound	1.96	1.43	1.67	.80	[0.39]

* All returns and costs based on processed wild rice, except bracketed values for California represent returns and costs for unprocessed wild rice.

** Costs in year one includes costs of seeding. Production in years two and three comes from volunteer seed. California growers re-seed every year.

processed pound is $2.43 for the first year's production from a newly seeded field. In years two and three, when production comes from volunteer seed, total production cost is $1.87 and $2.13, respectively.

Reasons for Differentials in Returns

Yields and producer prices differ markedly between Minnesota and California. Over the ten years since substantial production began, California growers have increased yields to almost three times Minnesota yields. Calculated yield estimates for California in 1982 crop year were nearly 700 unprocessed pounds per acre. By the 1985 crop year, these had grown to 1,200 unprocessed pounds per acre. Some of the better Minnesota yields are now approaching 1,000 unprocessed pounds per acre.

Three primary reasons account for this striking differential. First, the dry California climate prevents the development of yield-reducing fungi, particularly the brown spot fungus, that have retarded the increase in Minnesota yields since the early years of cultivated production. Second, California growers have an ability to plant dense stands of wild rice to increase yield. This is related to the climatic advantage, in that denser stands in Minnesota are conducive to a greater incidence of fungal disease. Third, California growers can annually select wild rice varieties with the highest potential yields. In the Sacramento Valley, each field must be seeded annually. Although this is a primary cost input for California growers, contributing 49 percent of total cash costs as shown in Table 2, this cost is overcome by the ability to select the best yielding variety available each growing season. In Minnesota, wild rice fields will reseed themselves after the first year. As much as 1,000 pounds of seed per acre can shatter to the ground prior to harvest, cutting significantly into returns and creating dense stands in the subsequent growing seasons. These dense plant populations must be thinned to achieve optimal yields.

Producer price is the second component of grower returns. In general, Minnesota producers receive higher prices for processed wild rice than California growers. In the 1985/86 marketing year, Minnesota growers received prices ranging from $2.45 to $3.10 per processed pound while California growers received prices ranging $2.00 to $2.75 per processed pound. This price differential is partially attributed to transportation costs since much unprocessed California wild rice is purchased by Minnesota marketers and transported back to Minnesota for processing.

Conclusions

If Minnesota is to remain competitive with California in wild rice production, growers will have to increase yields and become more efficient. It will be of crucial interest to the entire wild rice industry to follow what happens to wild rice production in California in 1987 in response to price reductions in the past year and the increase in wild rice stocks. The big challenge confronting the young wild rice industry, as in many other specialty crops, is to gear production expansion to the growth in consumer demand.