PROGRESS REPORT

of

1976

WILD RICE RESEARCH

Minnesota Agricultural Experiment Station
University of Minnesota, St. Paul, Minnesota 55108

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Contents

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

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Wild Rice Cultural Research - 1976

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Water Depth

The objective of the 1976 water depth experiment was to determine if the presently used nonshattering varieties respond similarly to water depth. The varieties K2, M1 and Johnson were planted on May 13 in 15 x 96 ft. strips. Each strip was divided into eight 12 x 15 ft. blocks for plant sampling and yield determinations. Water depth was 0 inches (soil saturated) on one end of each strip and 24 inches on the other. Water was added daily to maintain a near constant water depth. All varieties were harvested on September 2. The information on plant population, maturity and yield for the three varieties is given in table 1.

Table 1. Plant population, maturity and yield as influenced by water depth - Grand Rapids - 1976

Water depth (in.)	Plants per 10 sq. ft.	Panicles per plant on 7/2	Panicles per plant on 8/5	Grain	
				Moisture %*	Yield lb/A**
			K2 variety		
2	2.6	0.3	2.7	39	83
6	1.5	-	2.3	41	290
10	4.3	2.9	3.0	42	564
14	4.9	-	2.0	42	575
17	3.6	-	4.0	41	487
20	2.6	-	1.0	42	305
24	0.2	-	-	43	26
			M1 variety		
2	3.8	2.5	1.0	37	77
6	2.7	2.0	1.5	40	266
10	4.4	2.0	3.7	43	384
14	7.7	1.7	4.0	42	440
17	7.1	4.0	4.7	43	464
20	6.2	-	3.3	43	392
24	2.9	-	-	43	262
			Johnson variety		
2	5.3	-	1.0	39	66
6	1.7	-	3.0	40	78
10	9.0	0.2	2.0	42	408
14	16.7	0.2	2.7	42	559
17	17.9	0.6	3.5	43	571
20	19.3	0.4	2.3	44	582
24	2.0	-	-	45	143

* Moisture at harvest
** 2% moisture; unprocessed

Generally, the highest yields in 1976 were obtained in slightly deeper water than during the previous three years. The optimum water depth for maximum yield was 10-14 inches during those years while this year it was 14-17 inches. However, as was true in the three previous years, there was considerable lodging at the 17 in. depth. Flowering again was earlier in the 17 in. depth than in shallower or deeper depths. However, the grain from the plants growing in shallow water (2 in. deep) had the lowest percent of moisture at harvest indicating more mature grain than at deeper depths. The trend of increased moisture in the grain at harvest the deeper the water is clearly evident for the later maturing Johnson variety.

There was some varietal difference in their response to water depth. The yield of the K2 variety declined sooner from deeper water than M1 or Johnson. Thus, K2 may not do as well in deep water as the other two varieties. It appears, however, that all three varieties produce well in water kept 14 inches deep. Good weed control is obtained, no lodging occurs and plant population is nearly maximum for all varieties at this depth.

Herbicides

Some herbicides not previously tried on wild rice were included in this year's herbicide trials. These were 2,4-DP, silvex in a different formulation (Kuron), dicamba (Banvel), bentazon (Basagran), bromoxynil (Buctril) and Dow 233. These along with 2,4-D and MCPA were applied to wild rice at two different growth stages at Grand Rapids and to water plantain at one stage of growth at Aitkin in a Kosbau Bros. field. Table 2 gives the results from the herbicides applied on 6-24 when wild rice was in the mid-to-late tillering stage.

Table 2. Herbicides applied to wild rice in the mid-to-late tillering stage - Grand Rapids - 1976

Herbicide	Rate* lb/A	Wild rice injury** 6-29	8-5	Yield*** lb/A
2,4-D amine	1/4	1	1	1714
	1/2	2	1	1180
	3/4	2	1	1146
	1	3	1	1148
	1 1/4	4	1	1214
MCPA	1/4	3	1	1469
	3/4	3	1	1426
	1 1/4	3	1	1143
2,4-DP	1/4	1	1	1361
	1/2	4	1	1114
	1	5	1	1020
Silvex (Kuron)	1/4	1	1	1392
	3/4	2	1	1476
	1 1/4	3	1	1442

Continued

Table 2. continued

Herbicide	Rate* lb/A	Wild rice injury** 6-29	8-5	Yield*** lb/A
Dicamba	1/4	1	1	1727
(Banvel)	1/2	2	1	1464
	1	3	1	1250
Dicamba +	1/16 + 3/16	1	1	1322
2,4-D	1/8 + 3/8	3	1	1076
Bifenox	1/2	1/2	1	1724
(Modown)	1	1	1	1193
	2	2	1	1544
Bentazon	1/2	1	1	1602
(Basagran)	1	3	1	1313
	1 1/2	3	1	1238
	2	3	1	1348
Dow 233	1/2	2	1	1478
	1	4	1	1213
	1 1/2	6	2	902
Bromoxynil	1/4	2	1	1342
	1/2	2	2	1168
	1	2	1	1330
Control	-	1	1	1526
			$LSD_{.05}$	218

* Rate based on acid equivalent or active ingredient; not formulation
** 1 = no injury; 10 = complete kill
*** 40% moisture

Generally the injury to wild rice plants in the later tillering stage from 2,4-D amine and MCPA was less than in previous years particularly at the higher rates. MCPA gave less yield reduction than 2,4-D at the 3/4 lb/A rate. Silvex (Kuron) appeared the best of the additional herbicides tried in terms of wild rice injury.

Not all of the herbicides applied at the late tillering stage were applied at the elongation stage. Table 3 gives the herbicides applied and the results.

Table 3. Herbicides applied to wild rice in the elongation stage - Grand Rapids - 1976

Herbicide	Rate* lb/A	Wild rice injury** 7-7	Wild rice injury** 8-5	Yield*** lb/A
2,4-D amine	1/4	1	1	1158
	1/2	2	1	1207
	3/4	4	2	861
	1	6	4	838
	1 1/4	6	6	791
MCPA	1/4	2	1	1158
	3/4	5	4	751
	1 1/4	7	6	670
2,4-DP	1/4	1	1	1300
	1/2	3	1	1212
	1	7	7	613
Silvex (Kuron)	1/4	1	1	1493
	3/4	3	1	1350
	1 1/4	6	1	1092
Dicamba + 2,4-D	1/16 + 3/16	2	2	1107
	1/8 + 3/8	5	1	957
Bentazon (Basagran)	1/2	1	1	1305
	1	3	1	1118
	1 1/2	3	1	1144
	2	4	1	663
Dow 233	1/2	2	1	1184
	1	3	1	1177
	1 1/2	5	1	1127
Control	-	1	1	1152
			LSD $_{.05}$	289

* Rate based on acid equivalent or active ingredient; not formulation
** 1 = no injury; 10 = complete injury
*** 40% moisture

MCPA and 2,4-D injured wild rice considerably at the higher rates but no yield reductions were obtained at the 1/4 and 1/2 lb per acre rate. Silvex, even though some injury occurred early to wild rice, did not significantly reduce yields even at the high rate of 1 1/4 lb per acre. Bentazon and Dow 233 also appeared better than 2,4-D or MCPA. However, bentazon caused severe burning of the wild rice leaves shortly after application. From these tests on wild rice silvex (Kuron) is a promising herbicide that should be tested again for possible use.

A trial using 12 herbicides was conducted in a Kosbau Bros. field heavily infested with water plantain. The herbicides were applied on 6-10 when the water plantain which came from rootstocks was just beginning to flower. The water plantain which came from seeds was in the floating leaf stage. The wild rice was in the late aerial leaf stage, about 7 inches tall. The herbicides applied and the results are given in table 4.

Table 4. Herbicides applied on 6-10 to water plantain in the very early flowering stage and to wild rice in the late aerial leaf stage - Kosbau, Aitkin - 1976

Herbicide	Rate* lb/A	Water plantain injury**		Wild rice injury**		Plant height (cm) 8-15	Dry wt./ plant (gm)
		6-16	7-7	6-16	7-7		
2,4-D amine	1/4	3	6	2	2	160	32
	1/2	4	9	1	3	166	37
	1	6	9	3	3	142	49
MCPA	1/2	6	10	3	4	133	26
	1	6	10	3	5	127	19
2,4-DP	1/4	2	2	3	1	125	10
	1/2	4	5	3	3	133	19
	1	5	10	4	5	140	30
Silvex (Kuron)	1/4	3	4	2	1	140	15
	1/2	3	6	2	3	130	19
	1	4	8	2	4	128	31
Dicamba (Banvel)	1/4	2	2	3	1	117	10
	1/2	2	2	2	1	123	11
	1	2	2	2	1	147	19
Dicamba + 2,4-D	1/16 + 3/16	3	6	2	1	133	25
	1/8 + 3/8	4	9	3	3	135	27
Bifenox (Mowdown)	1/2	1	1	2	1	137	28
	1	2	1	2	1	143	19
	3	2	1	2	1	147	16
Bentazon (Basagran)	1/2	5	5	4	2	150	31
	1	5	5	5	3	145	23
	1 1/2	5	7	5	4	150	28
Dow 233	1/2	3	2	2	1	125	12
	1	4	5	2	3	105	19
	1 1/2	6	8	4	5	110	17

Continued

Table 4. continued

Herbicide	Rate* lb/A	Water plantain injury** 6-16	7-7	Wild rice injury** 6-16	7-7	Plant height (cm) 8-15	Dry wt./ plant (gm)
Bromoxynil	1/4	1	1	4	1	141	15
	1/2	2	1	5	1	137	17
	1	2	1	5	1	123	11
Endothall	1	10	10	9	8	95	12
	2	10	10	9	10	85	15
	3	10	10	9	10	100	13
Propanil	2	5	3	4	1	118	19
	3	7	5	6	1	130	21
	4	8	5	6	1	135	22
Control	-	1	1	1	1	114	22
					LSD .05	24	22

* Rate based on acid equivalent or active ingredient; not formulation
** 1 = no injury; 10 = complete kill

All except the herbicides dicamba, bifenox and bromoxynil controlled water plantain adequately at some or all of the rates. From this trial and the ones at Grand Rapids it appears that 2,4-D amine, MCPA and silvex at the 1/4 to 1/2 lb per acre rate would be useful to reduce the competition of water plantain in wild rice without injuring wild rice too severely. The slight injury to wild rice may be compensated for by an increase in yield due to less water plantain. More extensive field trials will be conducted with these three herbicides in 1977.

Three granular herbicides were applied directly to the flood water confined in small rings in a Kosbau Bros. field near Aitkin. They were applied when wild rice was in the floating leaf stage and water plantain 3 to 5 inches above the water. The three herbicides were endothall (Hydrothol 191), bifenox, (Modown) and simetryn. Bifenox did not injure wild rice but didn't control water plantain either. Endothall and simetryn controlled water plantain but severely injured wild rice. These three granular herbicides probably are not suitable for weed control in wild rice.

Volunteer Wild Rice Control

Numerous experiments were conducted in 1976 to determine if volunteer plants could be eliminated in the spring in sufficient time to allow for reseeding of a new variety. Three chemicals were tested for this purpose. One was molinate, a barnyardgrass herbicide used in California, another was sodium azide which is phytotoxic to imbibing and germinating seeds and the third was EPTC, a grass herbicide used in several crops.

Sodium azide was applied to soil before flooding and after flooding at Grand Rapids and on peat soil near Aitkin. Tables 5, 6, and 7 give the results from these experiments.

Table 5. Sodium azide applied before and after flooding and its effect on controlling volunteer plants - Grand Rapids - 1976

Rate of Na azide lb/A*	Before flooding: Percent control	Before flooding: Plants in reseeded area	After flooding: Percent control 1**	After flooding: Percent control 2***	After flooding: Plants in reseeded area 1	After flooding: Plants in reseeded area 2
5	0	24	0	0	23	22
10	0	18	0	55	27	17
20	11	18	8	85	28	21
30	29	20	8	-	31	21
50	29	18	24	95	26	10
Control	0	20	0	0	28	23

* Rate based on active ingredient; not formulation (15% granular)
** Applied into water immediately after flooding
*** Applied into water when volunteer plants were 3 in. tall

Table 6. Number of plants established after treating peat soil with 5 different rates of sodium azide before flooding - Aitkin - 1976

Rate lb/A*	No. of plants per 2 sq. ft.**
5	16
10	15
20	15
30	21
50	9
Control	23

* Rate based on active ingredient; not formulation (15% granular)
** Plots reseeded 14 days after treatment

Table 7. Volunteer control after applying sodium azide into flood water in a peat field - Aitkin - 1976

Rate lb/A*	No. of plants in 2.5 sq. ft.	Plant height on 5-18 (cm)	No. of plants in area reseeded, 2.5 sq. ft.**
5	30	20***	15
10	10	12	4
20	13	7	9
30	0	7	0
50	7	6	3
Control	25	26	13

* Rate based on active ingredient; not formulation (15% granular); treated on 4-28
** Reseeded on 5-7
*** Height of volunteer plants

We obtained about a 25 to 30 percent control of volunteer plants when sodium azide (Table 5) was applied to clay loam soils before or immediately after flooding at Grand Rapids. However, a 95 percent control was obtained when sodium azide was applied to flood water after the volunteer plants were 3 in. tall. Small areas, encircled with hardware cloth, were reseeded 2 weeks after treatment with sodium azide. In all cases, we had good stands in the reseeded areas except when 50 lb per acre was applied when the volunteer plants were 3 in. tall. Good stands except at the 50 lb per acre rate from reseeding were also obtained when sodium azide was applied onto peat soils before flooding (Table 6). No volunteer plants grew even in the control, therefore no estimate of volunteer control could be obtained from this experiment. However, when sodium azide was applied into flood water confined by rings before volunteer plants were visible, good control of volunteer plants was obtained at the higher 2 rates (Table 7). This trial was in a peat field near Aitkin. The number of plants established from reseeding, in this case, decreased considerably with an increase in the amount of sodium azide. It may be that in peat soils reseeding would have to be delayed more than 2 weeks. Sodium azide might have some possibility in controlling volunteer plants in the spring. It will be tested considerably more in 1977.

Table 8. Molinate and EPTC applied before and after flooding and its effect on controlling volunteer plants

Rate of molinate lb/A*	Before flooding		After flooding***	
	Percent control	Plants in reseeded area	Percent control	Plants in reseeded area
		Molinate		
1	0	27**	12	21**
3	22	27	10	15
6	61	17	40	13
Control	0	28	0	23

Continued

Table 8. continued

Rate molinate lb/A*	Before flooding		After flooding***	
	Percent control	Plants in reseeded area	Percent control	Plants in reseeded area
		EPTC		
1	14	25**	39	20**
3	7	26	22	21
6	21	23	61	19
Control	0	28	0	21

* Rate based on active ingredient; not formulation
** Includes volunteer plants and plants from reseeding
*** Reseeded 7 days after treatment

Molinate and EPTC were applied to clay loam soil before and after flooding at Grand Rapids. Half of each plot was reseeded 7 days after the chemicals were applied. Applying granular molinate at the rate of 6 lb per acre active ingredient before flooding killed 61 percent of the plants and those plants that were not killed were distorted and delayed in maturity (Table 8). EPTC before flooding was not as effective as molinate. However, it was more effective when applied to the flood water than molinate. Reseeding 7 days after applying molinate or EPTC appears feasible, however, in some treatments the plants from reseeding were shorter than the controls. Therefore, a trial was conducted in boxes at St. Paul where 2 or 4 lb per acre of molinate were applied to the soil, the boxes flooded and then a small area reseeded the same day, 7 days later and 21 days later. Some of the seed used for reseeding was treated with 1,8-naphthalic anhydride (Protect). Table 9 gives the results.

Table 9. Delaying reseeding and treating seed with Protect to prevent injury to wild rice - St. Paul - 1976

Date of reseeding	Untreated		Treated with Protect	
	No. of plants*	Height (cm)*	No. of plants*	Height (cm)*
		2 lb/A molinate**		
8-3	1	3	3	13
8-11	6	28	5	30
8-23	5	20	5	15
		4 lb/A molinate**		
8-3	2	7	1	5
8-11	6	17	1	13
8-23	7	23	5	18
		Control		
8-3	6	65	4	58
8-11	6	50	3	45
8-23	7	22	4	15

* All plants counted and measured at the same time
** Molinate applied before flooding on 8-3; active ingredient; granular

It appears that Protect is not very effective in reducing injury from molinate. In fact, fewer plants became established and they generally were shorter than plants from untreated seed. It is also apparent that delaying reseeding up to 3 weeks may be desirable since the number of plants and height of these plants were similar to the control for 8-23 date but not for the first 2 dates. The rate of molinate to control volunteer plants and the time of reseeding will be investigated on larger areas next year.

An experiment conducted last year was repeated at Grand Rapids in 1976. A small area was seeded and flooded on April 23. When the wild rice plants were in the early aerial leaf stage, May 23, the area was drained and divided into 10 x 10 ft plots. Three days later 3 rates of glyphosate, 2 rates of paraquat and 2 rates of 2,4-D ester were applied. Five days later the area was reflooded and small wire rings of hardware cloth were placed in each plot. These were reseeded with 100 seeds of wild rice. Table 10 shows the percent volunteer control and the number of plants that became established in the small rings from the reseeding.

Table 10. Reduction of volunteer plants with glyphosate, 2,4-D and paraquat after drainage when volunteer plants were in 3 to 4 leaf stage

Chemical	Rate* lb/A	Volunteer control (%)	Number of plants in reseeded rings**
Glyphosate	1/2	77	10
	1	85	10
	1 1/2	92	15
	2	95	12
Paraquat	1	96	15
	1 1/2	90	11
2,4-D	1	88	15
	2	98	18
Control	-	0	10

* Rate based on acid equivalent; not formulation
** 100 seeds per ring seeded into water 5 days after chemical treatment

The results were similar to last year. Glyphosate was erratic in controlling volunteer plants but control generally increased with increased rates. At least 1 1/2 lb. per acre is required for good control. There appeared to be no residue problem for reseeding since there were as many plants in the wire rings from reseeding as in the control areas with no glyphosate. Paraquat and 2,4-D gave good control of volunteer plants at both rates. Again there appeared to be no problem in reseeding. The procedure used in this experiment would have possibilities but would require draining the fields in the spring which may not be practical. Applying these chemicals directly into flood water was tried but herbicide residue is more of a problem with this method. Diquat was used in place of paraquat for flood water treatment. Also waiting until there is sufficient growth of the volunteer plants may delay reseeding too long.

Mechanical destruction of volunteer plants was also investigated in a peat field near Aitkin. A garden rake was used to uproot the volunteer plants and stir up the peat soil. This was done on May 14, 18 and 27. On May 14 the volunteer plants were 3 to 4 in. tall with no leaves floating. On May 18 they were in the floating leaf stage and on May 27 in the aerial leaf stage. Table 11 shows the number of plants which survived or came from newly germinated seeds.

Table 11. Number of volunteer plants remaining in 16 sq. ft. after using garden rake to uproot volunteer seedlings at three different dates - Aitkin - 1976

Raking date*	Number of volunteer plants in 16 sq. ft.
5-14	36
5-18	19
5-27	4
Control	27

* Field flooded on 4-15; no plants visible on 4-28

It appears that growers would have to wait until all of the seed has germinated in the spring and developed a small seedling before they could completely destroy mechanically all volunteer plants in the spring. A considerable number of plants were again present on June 29 for the May 14 and 18 treatments, but only a few for the May 27 treatment.

To find out how long plants continue to come up in a peat field, two metal rings were placed in the same field where the raking experiment was conducted. All plants were pulled out periodically until no more emerged. Table 12 shows the pulling dates and the number of plants removed at each date.

Table 12. Length of time volunteer plants continue to emerge from peat soil after flooding - Aitkin - 1976

Date plants pulled*	No. of plants removed**	Percent of total
5-14	263	32
5-18	189	23
5-25	198	25
5-27	61	8
6-2	73	9
6-9	15	2
6-16	10	1
Total	809	

* Fields flooded 4-15; no plants visible on 4-28
** From 40 sq. ft.

The field was initially flooded on April 28. The first plants appeared on May 11 and on May 27, 88 percent of the plants that were to emerge had done so by this date. On June 2, 97 percent of the plants had emerged. Thus, it appears that emergence takes place over a period of about 4 weeks in the spring in fields that have been in wild rice for several years. Any mechanical destruction would have to be done after most of the plants had emerged from the soil.

Deep plowing in the fall to bury the seed more than 6 inches deep may be a possible way to eliminate volunteer plants the following spring. One grower did this last fall and we will make some observations on volunteer growth in the plowed area next spring. From our previous experiments seedlings will not emerge when the seed is covered with more than 4 inches of soil.

Vapam which was applied in the fall of 1975 at the rate of 50 and 100 gallons per acre reduced the volunteer population 25 and 50% respectively in a peat soil near Aitkin. The control needs to be considerably higher to warrant Vapam use to kill wild rice seeds in the soil. Vapam costs $5.00 per gallon.

Seed Quality of Grain Harvested on Several Dates in 1975

The seed quality of the seed of the Johnson, K2 and M1 varieties harvested on several dates in 1975 was determined by a germination test periodically during winter storage in water at 35° F. Seed was also planted in the spring at St. Paul to determine stand establishment, plant height and yield. The results are given in Table 13.

Table 13. Seed germination and seedling vigor of seed from several harvest dates in 1975 - St. Paul - 1976

1975 Harvest date	1975 % dark kernels	Germination percentage 12-10	1-21	2-11	4-20	6-21	No. of established plants from 45 seeds	Plant height* (cm)	Yield/ row (gm)
				K2 Variety					
8-27	9	6	6	15	15	9	1	38	6
9-2	16	6	14	13	32	5	4	51	9
9-8	32	8	28	14	34	24	7	51	12
9-12	36	16	29	19	32	24	8	52	17
9-16	40	18	54	52	45	37	14	50	20
9-22	62	26	40	49	29	27	12	51	20
				M1 Variety					
8-27	8	4	4	11	6	1	1	33	3
9-2	9	9	14	9	16	4	3	48	10
9-8	25	13	31	30	27	24	9	52	11
9-12	35	11	34	30	32	25	8	52	17
9-16	40	25	36	46	63	59	16	54	20
9-22	57	24	37	22	42	10	6	49	10
				Johnson Variety					
9-2	13	4	18	9	12	12	4	59	8
9-8	18	10	28	44	40	44	7	55	12
9-12	29	22	44	52	40	20	10	49	25
9-16	34	18	58	66	77	72	12	49	21
9-22	36	22	41	42	54	34	10	51	21

* 61 days after planting

Germination of the seed was the highest for all three varieties from the second to last harvest date. This was also true for the number of plants which became established from 45 seeds. Therefore, yields tended to increase also up to this date. Thus, seed quality increased with harvest date except for the last date. It is difficult to explain the decrease in seed quality for the last date except that drying out of the seeds may have reduced the vigor especially for the earlier maturing M1 and K2 varieties.

Seed Dormancy

Preliminary studies by Ken Albrecht, graduate student, indicate that abscisic acid (ABA) may be at least partially responsible for the dormancy of wild rice seeds. ABA is a growth inhibiting hormone.

ABA levels were measured in fresh seeds, seeds stored at 38° F. in water for 1 month, and seeds stored at 38° F. in water for 9 months. Levels of free and total ABA were lower in seeds that were stored for 9 months (non-dormant) than in fresh seeds or seeds stored for 1 month (dormant) (Table 14).

Table 14. Abscisic acid (ABA) in freshly harvested seeds, seeds stored for 1 and 9 months

Kind of ABA	Freshly harvested seeds	Seeds stored in water for 1 mo.	Seeds stored in water for 9 mo.
		ng/gm	
Free	600	881	212
Bound	1119	855	1014
Free + bound	1719	1736	1225

As a follow-up to this study the effects of ABA on seed germination and seedling growth were studied. Non-dormant wild rice seeds were soaked for 1 week in solutions of ABA ranging from 0 to 1.5×10^{-4} M. After 7 days measurements were taken and seeds were transferred to water. Seven days later more measurements were taken.

Table 15. Influence of Abscisic acid (ABA) on seedling growth of wild rice

ABA concentrations*	After 7 days: Percent germ.	After 7 days: Shoot length (cm)	After 14 days: Percent germ.	After 14 days: Shoot length (cm)	Percent plants with roots
1.5×10^{-4}M	0	0	0	0	0
7.6×10^{-5}M	0	0	0	0	0
3.8×10^{-5}M	0	0	0	0	0
7.6×10^{-6}M	8	.9	8	2.1	1
3.8×10^{-6}M	17	1.0	25	2.5	2
7.6×10^{-7}M	21	1.2	36	4.0	13
3.8×10^{-7}M	20	1.3	40	3.5	11
Water	34	1.6	50	4.3	27

* Molar; top is high and bottom is low

Germination was inhibited by ABA concentrations greater than 3.8 X 10^{-5}M. Germination and seedling growth increased as concentrations of ABA decreased from 3.8 X 10^{-5}M. The concentration of 3.8 X 10^{-5}M which inhibits germination and growth is similar to that found in freshly harvested dormant seed.

Alternate Crops

An alternate crop plot was established in cooperation with Dr. Roy Thompson in Clearwater County. The crops included wheat, barley, oats, millet, buckwheat, mustard, rape, pinto beans and navy beans. All crops were planted on June 2. Good stands of mustard, rape, pinto beans and navy beans were obtained. However, only poor to fair stands of wheat, barley, oats, millet and buckwheat were obtained. Part of this was due to the dry conditions causing germination problems. As a result of the poor stands the yields of these crops were low. Also weeds, particularly, lambsquarters, were severe in wheat, oats, barley, millet and buckwheat. These probably could have been controlled with herbicides, but because of susceptible crops in the same plot no herbicides were used. The plots were hand weeded once, early. Table 16 gives the yield of the various crops.

Table 16. Yield of alternate crops on fallow wild rice field in Clearwater Co.; planted on 6-2 and harvested on 9-19

Crop and variety	Yield lb/A		Plant density
	Fertilized*	Unfertilized	
Wheat			
Era	333	186	Fair
1809	165	121	Low
Barley			
Larker	480	430	Fair
Oats			
Froker	82	64	Low
Wright	141	195	Low
Millet			
Snowbird	85	138	Fair
Buckwheat			
Common	100	65	Fair
Mustard			
Yellow	1062	1186	Good
Rape			
Oilseed	833	1015	Good
Pinto beans			
UI 114	1966	1826	Good
Navy beans			
Seafarer	2406	2458	Good

* Fertilized with 150 lb/A of 34-0-0, 400 lb/A of 0-12-25 and 30 lb/A $CuSo_4$

The existing plants of all the crops grew well. Most likely all crops would have yielded well if the proper plant population could have been established. Some visual response to fertilizer was evident but only slight yield increases for wheat, millet, mustard and rape were obtained.

Most of the crops had sufficient time to mature this year even though they were planted late. Millet, rape and pinto beans were partially immature at harvest. Mustard might be a good possibility as an alternate crop. It can be planted late if the fields are wet in the spring and harvested early enough to reshape fields if desired. Navy beans are also a possibility but they require special planting and harvesting equipment.

Acknowledgement

The help of Mike McClellan, plot technician, during the year was greatly appreciated. He was particularly helpful in designing and building a small back-pack plot sprayer that was very useful in flooded conditions. Also appreciated was the help of Ken Albrecht, graduate student and Steve Durham, part-time student helper.

WILD RICE FERTILIZATION RESEARCH - 1976

A PROGRESS REPORT
January 3, 1977

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Research was continued during 1976 on fertilization, nutrient requirement and water quality. Nitrogen rate studies were conducted on mineral soil at Grand Rapids with two varieties in second production year, and with three varieties in first production year. Three fertilization experiments were established on peat with a 2nd year stand in Aitkin county to study NPK rates and to explore effectiveness of foliar fertilization. A strip-trial on peat with potassium was conducted in Clearwater county. Plant samples were collected and analyzed to learn more about nutrient requirement of the plant. Soil temperature, redox potential and quality of paddy water were monitored during growing season to obtain information on the environment in which wild rice grows.

A. NITROGEN RATE AND VARIETY STUDIES ON MINERAL SOIL

Two experiments were conducted on mineral soil at the North Central Experiment Station, Grand Rapids. Experiment 1 was established in spring of 1976 with three varieties: early maturing K2 and M3 and the late maturing "Johnson". Experiment 2 had been established in spring of 1975 with K2 and "Johnson" varieties and was in second production year.

FIRST YEAR STAND

The experimental paddy was in fallow during 1975 and was fumigated with methyl bromide in fall 1975. Four rates of nitrogen were used: 0, 20, 40, 80 lb/acre. Urea (46-0-0) was applied with a 3-foot Gandy spreader on April 28 and incorporated into the soil by rototilling. Phosphorus and potassium were not applied because high availability of these nutrient elements was indicated by soil tests (4/8/76: pH 5.8; P 88; K 245). Three varieties, the early maturing K2 and M3 and late maturing "Johnson" wild rice were grown. Each variety occupied a 48 x 72 ft. area. Varieties were separated by 10 foot wide alleys. "Johnson" variety was placed between the two earlier maturing varieties to minimize cross-pollination. Individual plots were 12 x 12 ft. Each N treatment was replicated 6 times. Wild rice was seeded on April 28 and rototilled into the soil. Water level in the paddy was maintained at about 8-12 inches. Plant population in this experiment was 5-7 plants per square foot. Malathion (1.5 lb/A) was sprayed on May 28 to control midge. Copper sulfate (15 lb/A) was applied to control algae. Dithane and malathion were used to control disease and rice worm. Although the paddy had been covered with netting, blackbirds caused grain losses in some areas. Ten plants were selected at random from each plot at jointing and 5 plants per plot at late flowering for weight measurements and plant analysis. A 4 x 4 ft. square area from each plot was hand-harvested for yield determination. The K2 and M3 varieties were harvested on August 24 and the "Johnson" on September 1.

Wild rice responded well to nitrogen treatments and exhibited height and color differences, particularly at jointing and boot stages. Plants in N0 plots were short, light green in color with yellow lower leaves. Plants in N40 and N80 plots were taller and had dark green color. At flowering, plants lodged in the N80 plots.

Yield of grain was not affected by different rates of nitrogen (table 1). Nitrogen concentration in second leaf at jointing of the K2 variety was increased from 3.56% in plants from N0 treatment to 4.55% in those from N80 plots (table 2). Nitrogen concentration and uptake in different plant parts are given in tables 3 and 4. These values were affected by N rates in a few instances.

Table 1. Effect of nitrogen application on the yield of three wild rice varieties - 1976, Grand Rapids, 1st year stand.

Variety	N rate, lb/Acre				Average (variety)
	0	20	40	80	
	Grain yield, lb/Acre				
K2	808[1)]	901	1046	862	904
M3	996	1052	932	766	937
"Johnson"	741	839	782	817	795
Average (rate)	848	931	920	815	

[1)] 7% moisture; 76% ave. Grain recovery
Significance NS (not significant)

Table 2. Effect of Nitrogen application on N concentration in 2nd leaf at jointing,
Grand Rapids - 1976, 1st year stand.

Variety	N Rate, lb/Acre				Significance
	0	20	40	80	
	N% in Dry Matter				
K2	3.56[1)]	3.75	3.76	4.55	+
M3	3.56	3.60	3.95	3.91	NS
"Johnson"	3.04	3.82	3.00	3.75	NS

1) Average of 20 plants
+ = Significance at the 10% level.

Table 3. Effect of Nitrogen application on N concentration of different plant parts at late flowering.
Grand Rapids - 1976, 1st year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves
		N% in Dry Matter		
K2	0	1.41[1)]	0.60	1.90
	20	1.63	0.76	1.75
	40	1.47	0.62	2.08
	80	1.96	0.76	2.17
Significance		+	NS	NS
M3	0	1.59	0.72	2.03
	20	1.59	0.70	2.24
	40	1.62	0.76	2.38
	80	1.61	0.74	2.44
Significance		NS	NS	NS
"Johnson"	0	1.50	0.67	1.85
	20	1.51	0.71	1.92
	40	1.40	0.59	1.77
	80	1.58	0.75	1.88
Significance		NS	NS	NS

1) Average of 10 plants.

Table 4. Effect of Nitrogen application on total uptake of N by wild rice at late flowering.
Grand Rapids - 1976, 1st year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves	Total
		N in milligrams per plant			
K2	0	43[1)]	60	56	158
	20	59	88	71	218
	40	54	90	94	237
	80	64	88	101	253
Significance		NS	NS	NS	NS
M3	0	63	86	82	230
	20	59	98	101	258
	40	45	74	103	221
	80	64	109	142	315
Significance		NS	NS	*	NS
"Johnson"	0	63	124	106	294
	20	64	122	119	305
	40	71	134	144	348
	80	88	159	145	392
Significance		NS	*	*	NS

1) Average of 10 plants.
NS = Not Significant; * = Significant at the 5% level.

SECOND YEAR STAND

The nitrogen rate-variety experiment, established in spring of 1975 was continued. Three rates of nitrogen were used: 0, 40, 80 lb/acre. Urea was applied on April 28 and incorporated into the soil. Straw was disked and rototilled into the soil. A split-plot design was used in this experiment with the varieties, K2 and "Johnson", as main plots and N rates as sub-plots. Individual plots were 10 ft. wide and 12 ft. long. Nitrogen treatments were replicated 6 times with 3-foot wide alleys separating replications. Water level and pest control measures were the same as used in 1st year paddy.

Redox potential (Eh) of flooded paddy soil was determined by placing platinum electrodes into the root zone. Following readings were obtained during the season:

Date	Eh, millivolts
5/21	+ 190
6/02	- 100
7/16	- 190
7/22	- 190
8/04	- 200
8/12	- 205.

During June - August Eh ranged from -100 to -205 mv indicating a strongly reduced condition in the mineral soil.

The stand was not thinned and plant population was 8 - 9 plants per square foot. At jointing and boot stages striking differences in plant height and color were observed. Plants in NO plots were shorter and lighter in color than those in plots receiving N80 treatment; plants in N40 plots were intermediate in color and height. In August, heavy lodging occurred in the plots receiving 80 lb/acre of N.

Grain yields (at 7% moisture) varied from 659 to 1231 pounds per acre (Table 5). The earlier maturing K2 outyielded the "Johnson" variety by nearly 330 lb/acre. Yield of wild rice was not affected significantly by the rate of nitrogen. It appeared, however, that the 80 pound N rate had a more adverse effect on the "Johnson" variety, probably due to greater vegetative growth (Table 7) and more severe lodging than on the K2 yield. Nitrogen concentration in second leaf at jointing was increased from 3.27 to 3.88 % by the application of 40 lb N/acre (Table 6). At late flowering, a single plant contained from 294 - 367 milligrams of N. Fertilization, generally had little or no effect on N concentration of different plant parts (Table 8) or the N uptake by wild rice at this stage of plant development.

Table 5. Effect of Nitrogen application on the yield of two wild rice varieties.
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate, lb/Acre 0	40	80
	Grain Yield, lb/Acre		
K2	989[1)]	1101	1231
"Johnson"	787	892	659

1) 7% moisture; Ave. Grain Recovery 79%

(a)

Variety	Grain Yield, lb/Acre
K2	1107
"Johnson"	779
Significance	*
Blsd (.05)	263

(b)

N Rate, lb/Acre	
0	888
40	997
80	945
Significance	NS

Table 6. Effect of Nitrogen application on N concentration in 2nd leaf of two varieties at jointing,
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate, lb/Acre 0	40	80	Average (Variety)
	N % in Dry Matter			
K2	3.24[1)]	4.11	3.71	3.69
"Johnson"	3.30	3.65	3.96	3.63
Average (Rate)	3.27	3.88	3.84	

1) Average of 60 plants
Significance *
BLSD (0.05) 0.44

Table 7. Effect of Nitrogen application on plant weight of two varieties at jointing.
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate 0	N Rate 40	N Rate 80	Average (Variety)
	Dry Matter, grams per plant			
K2	3.87[1)]	3.42	3.73	3.67
"Johnson"	3.75	3.47	4.25	3.82
Average (Rate)	3.81	3.45	3.99	

1) Average of 60 plants.
Significance (Rate) *
BLSD (0.05) 0.53

Table 8. Effect of Nitrogen application on N concentration of different plant parts at late flowering,
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves
		N % in Dry Matter		
K2	0	1.71[1)]	1.00	2.39
	40	1.98	0.93	2.56
	80	1.74	0.88	2.44
"Johnson"	0	1.88	0.95	2.30
	40	1.88	1.04	2.50
	80	1.72	0.91	2.46

1) Average of 30 plants.

		Panicles	Stems	Leaves
Significance		+	NS	NS

Table 9. Effect of Nitrogen application on total uptake of N by wild rice at late flowering,
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves	Total
		N in milligrams per plant			
K2	0	69[1)]	121	104	294
	40	76	113	121	310
	80	80	140	144	364
"Johnson"	0	79	139	109	327
	40	82	152	133	367
	80	58	114	122	294

1) Average of 30 plants.
Significance NS.

B. FERTILIZATION STUDIES ON PEAT

Since the great majority of paddies in Minnesota are on organic soils it is important that soil fertility and fertilization problems are investigated on organic soils. In the past our effort in the soil fertility area has been handicapped by the lack of an experimental site on peat. In fall of 1975 a suitable area of nearly 2 acres in size was located in one of Kosbau Bros. paddies in Aitkin county. A good first year stand of K2 variety was present. Soil samples were collected and depth of peat was measured in October of 1975. Soil characteristics for areas eventually occupied by experiments are given in Table 10.

Experiments were staked out and fertilizer materials were applied by hand on April 3. Fertilizer was not incorporated into the soil. Within a week the area was flooded. Rice was thinned once by airboat on May 26 when plants were in floating leaf-aerial leaf stage. Copper sulfate (20 lb/A) was applied on June 30 to control algae. Plant population, at early tillering stage, was 3 - 4 plants per square foot. Redox potential (Eh) on June 22 was -227 mv. indicating a strongly reduced condition. Paddy was sprayed with chemicals to control blight and rice worm, Helminthosporium was not evident, there was no lodging and no damage caused either by rice worm or blackbirds. By July 14 the paddy had been drained. Experimental areas were harvested on August 18. A 4 x 4 ft. area was hand-harvested from each plot for yield measurement.

Table 10. Depth of peat and soil test values of experimental areas Kosbau Bros., Aitkin County.

Area	Depth of Peat Inches	Soil test results for 0-6 inch depth		
		pH	Extractable P pp2m	Exchangeable K pp2m
Foliar Fertilization 175-225 ft.	7-8	4.6	17	40
NK Experiment 250-350 ft.	8-11	4.6	14	50
NP Experiment 400-500 ft.	18-21-11	4.4	7-15	60

NP RATE TRIAL

The NP experiment was located in an area within the paddy were the peat layer was thickest, ranging from 18-21 inches on north side and decreasing to 11 inches on south side (table 10). Water depth in this portion of paddy was greatest and wild rice yielded more than in the two other experimental areas. Extractable P was 7-15 pp2m indicating low to medium phosphorus level. Three nitrogen rates were used: 0, 40, 80 lb/acre with urea as N source. Concentrated superphosphate (0-46-0) was used to supply phosphorus at three rates: 0, 40, 80 lb P_2O_5/acre. All plots received 60 lb K_2O/acre. Fertilizer treatments were replicated 6 times. Size of individual plot was 12 x 12 ft.

Wild rice yield (table 11) ranged from 1110 to 1171 pounds per acre. Nitrogen and phosphorus treatments had no effect on the grain yield.

Nitrogen concentration in 2nd leaf at jointing ranged from 3.44-4.05% and was increased by application of N in combination of 40 lb P_2O_5 per acre. Total N uptake by the plant at jointing ranged from 82-114 mgm per plant and was increased significantly either by the N80 treatment alone or by N40 treatment in combination with phosphorus. Phosphorus concentration in 2nd leaf at jointing ranged from 0.52-0.58% P but was not affected by applications of either element. Total phosphorus uptake by the plant was not related to fertilizer treatments. A plant, on the average, had taken up 22 mgm P by jointing and 88 mgm by late flowering.

No visual differences in plants related to P treatments were observed during growing season. At the boot to heading-out stages plants in the NO treatment plots were slightly shorter and lighter in color than those receiving N application.

Table 11. Effect of nitrogen and phosphorus application on grain yield of wild rice 1976, Kosbau Bros., Aitkin County.

P rate P_2O_5, lb/acre	N rate, lb/acre 0	40	80	Ave.
	Grain yield, lb/acre			
0	1059[1)]	1061	1171	1097
40	1098	1064	1132	1098
80	1030	1084	1110	1075
Ave.	1062	1070	1138	

1) 7% moisture; 79% Ave. Grain recovery
Significance NS

NK RATE TRIAL

Exchangeable potassium in the plot area ranged from 30-70 pp2m considered to be a relatively low level. Depth of peat ranged from 8-11 inches. Nitrogen treatments consisted of 0, 40, 120 lb N/acre. Potassium was applied at rates of 0, 60 and 200 lb K_2O per acre. Urea and muriate of potash (0-0-60) were the fertilizer materials used in this experiment. All plots received 40 lb P_2O_5/acre. Fertilizer was applied by hand on April 3 but was not incorporated into the soil.

Plants, at jointing and boot stages, showed striking response to nitrogen treatments. Plants in NO treatment plots exhibited typical nitrogen deficiency symptoms: plants were slightly shorter and lighter in color than those observed in plots receiving N applications. Lower leaves were yellow with dead tissue at tips; some of these leaves had yellow margins (slightly resembling the marginal scorch observed in K deficient corn leaves). Response of wild rice to K treatments was not detected by visual observation.

Yield of wild rice, in this experiment ranged from 737 to 931 lb/acre (table 12). Nitrogen,applied at a rate of 120 lb/acre, increased the grain yield by 133 pounds per acre. On the other hand, potassium treatments (60 and 200 lb K_2O/acre) had no effect on the yield.

Weight and several chemical characteristics of plants collected at jointing and late flowering were affected by NK treatments. Most effective, however, appeared to be nitrogen treatments, particularly when applied at the high rate (120 lb/acre).

Dry matter at jointing ranged from 4 to 5 grams per plant and the increase was mainly due to N. At late flowering, an average plant weighed from 18 to 26 grams and the increase again was related mainly to N treatments.

At jointing, N concentration of the 2nd leaf was increased from 3.33% to 4.17% by the application of 120 lb N/acre (table 13). Average potassium concentration in 2nd leaf at jointing was 3.80% (table 14). Application of 60 lb K_2O/acre in combination with 40 lb N/acre increased concentration in 2nd leaf from 3.65 to 4.10%.

Total N uptake by wild rice was increased by the use of high rate of N. At jointing, a plant had taken up 100 to 160 milligrams of N. The same relationship between N uptake and nitrogen rate was found at late flowering (table 15). On the average, 237 grams of N had been taken up by wild rice. Total N uptake by plant was increased from 199 to 313 milligrams by the use of 120 lb N/acre.

Total K uptake by the plant also showed significant increases. However, such increases in K uptake resulted more from the increased dry matter production caused by N application than from K treatments. An average plant contained 125 grams of K at jointing and 237 grams at late flowering.

Table 12. Effect of nitrogen and potassium application on grain yield of wild rice - 1976,
Kosbau Bros.

K rate	N rate, lb/acre			
K_2O, lb/acre	0	40	120	Ave.
	Grain yield*, lb/acre			
0	778	801	909	829
60	737	827	931	832
200	795	811	869	825
Ave.	770	813	903	

* 7% moisture; 79 ave. grain recovery
Significance +
BLSD (0.10) 133

Table 13. Effect of NK application on N concentration in 2nd leaf at jointing,
Kosbau Bros. - 1976.

K rate K_2O, lb/acre	N rate, lb/acre 0	40	120	Average (K rate)
	N% in dry matter			
0	3.47[1)]	3.49	3.33	3.43
60	3.34	3.43	4.12	3.63
200	3.28	3.65	4.17	3.87
Average (N rate)	3.36	3.52	3.87	

1) Average of 60 plants
Significance *
BLSD (0.05) 0.70

Table 14. Effect of NK application on K concentration in 2nd leaf at jointing,
Kosbau Bros. - 1976.

K rate K_2O, lb/acre	N rate, lb/acre 0	40	120	Average (K rate)
	K% in dry matter			
0	3.49[1)]	3.65	3.83	3.66
60	3.77	4.10	3.83	3.90
200	3.79	3.95	3.81	3.85
Average (N rate)	3.68	3.90	3.82	

1) Average of 60 plants
Significance +
BLSD (0.10) 0.37

Table 15. Effect of NK application on N uptake by wild rice at late flowering,
Kosbau Bros. - 1976.

K rate K_2O, lb/acre	N rate, lb/acre 0	40	120	Average (K rate)
	N in milligrams per plant			
0	207[1)]	190	294	230
60	204	205	324	244
200	187	203	322	237
Average (N rate)	199	199	313	

1) Average of 30 plants
Signiicance *
BLSD (0.05) 85

FOLIAR FERTILIZATION

Growers' interest was aroused by the publicity given, last winter, to work by Dr. John Hanway at Iowa State University (J. J. Hanway, Foliar Fertilization of Soybeans, 28th Annual Fertilizer & Ag. Chemicals Dealers Conference, Des Moines, Iowa, 1976). Yields, on some fields, had been increased by 10 to 20 bushels per acre by applying a specially formulated fertilizer solution on foliage during the seed-filling period. The keys to the new technique appeared to be time of application and the ratio of specific nutrients of the solution. Understanding what happens within the soybean plant during its development was helpful in this research.

During the seed filling period, sugars produced in the leaves are moved to the seeds. This normal occurrence shortchanges the root's food supply, then (a) root growth slows down or stops, (b) nodules die, hence a reduced nitrogen supply, (c) nutrient uptake from the soil is reduced, and (d) loss of leaf nutrients as they nourish the seed causes a decline in photosynthesis (sugar manufacture) and further bean growth stops.

Supplying the depleted leaves with the right ratio of nutrients at this strategic time is expected to stop the decline of the soybean plant and can increase yield because it will prevent leaf nutrient depletion and keep leaves and roots active longer. But, excess amounts of fertilizer on the leaves can injure, or "burn" the leaves. So to increase seed yield by use of foliar fertilization, it is essential that the proper kinds and amounts of fertilizer solutions be sprayed on the plants at the proper times.

Numerous soybean leaf spraying trials were conducted in the Midwest during 1976. In some instances yields were increased slightly by foliar fertilization but there were many cases where serious "leaf burn" reduced yields resulting from foliar spraying related either to drought or too high application rate. "Wait and see" is the advice on foliar fertilization of soybeans that most researchers give.

Hanway (Foliar Fertilization of Soybeans, talk given at Soils, Fertilizer and Agricultural Pesticides Shortcourse, Minneapolis, Minn. 12/15/76) feels that there still is much to be learned before foliar fertilization should be generally recommended for farmers. But, he suggests that, because of the potential and the successes that have been obtained research should be continued. Research is needed to determine: (1) The most effective time and rate of application; (2) Forms of nutrients that are effective; (3) The most effective adjuvants; (4) Factors that result in leaf burn; (5) The effects of dew, urease, etc.; (6) Factors that limit yield increase.

Hanway has emphasized that foliar fertilization is in addition to, not a substitute for, for other good crop production and soil fertilization practices. To be successful, foliar treatment should supply all four elements, N. P, K and S, at about the same ratio as found in grain. Spray applications should be made at 2 to 4 times during the seed-filling period and each application should not exceed 20 to 25 lb N/acre.

FORMULATION

An objective of foliar fertilization is to supply four major nutrient elements at a ratio as closely as possible to that found in the seed. The concentrations of NPKS in wild rice grain are:

Nutrient	Green rice	Dehulled rice
	— % in dry matter —	
N	2.04	2.39
P	0.42	0.44
K	0.40	0.30
S	0.15	

So the desired ratio of the four elements, on elemental basis, is 6: 1: 1: 0.58, or on oxide basis 6: 2.3: 1.2: 0.58. Note: with the available fertilizer materials, the actual formulation was 6 - 2.3 - 3.7 - 0.58. It contained 3 times more K than desired. A fertilizer solution, having this formulation and applied at a rate of 250 pounds per acre (26.4 gallons/acre, since the material has specific weight of 9.4 lb per gallon) would give: 15+6+9+1.3S pounds per acre of plant nutrients at each spraying. Table 16 shows the formulation, materials used and the cost of foliar fertilization.

Table 16. Formulation for a 6-2,3-3.7-0.5S fertilizer solution

Material	Pounds per ton	Cost per pound	Cost per ton	Nutrient element	lb per ton	%
Urea (46-0-0)	260	6¢	$15.60	N	120	6
Potassium polyphosphate (0-26-25)	177	12.4	21.95	P_2O_5	46	2.3
				K_2O	44	
Potassium sulfate (0-0-50-17S)	58	6.4	3.71	K_2O	29	3.7
				S	10	0.5
Water	1505					

Total 2000* $41.26
Add dealer service charge (25%) 10.32

Approximate cost to grower $51.58

At 250 lb/acre: 0.125 tons x $51.58 — $6.45/acre
Aerial application ($3.00 + 26.4 gal. x 25¢) — 9.60/acre
Total cost per application — $16.05/acre

2 applications — $32.10
3 applications — $48.15

*Plus Tween 80 surfactant (adjuvant)

Potassium polyphosphate was supplied by the TVA, and Dr. Harvey Meredith (TVA) provided necessary information for calculating formulation and costs. Soil application of 40+40+60 lb/acre of N, P_2O_5 and K_2O, at 1976 prices, would cost $18.20 per acre.

In spring of 1976, a foliar fertilization trial was established with 2nd year stand of K2 variety on peat, Kosbau Bros. paddies, Aitkin county in an area adjoining the NK and NP experiments. Depth of peat was 7-8 inches. Soil test results (Table 10) indicated medium extractable P and low exchangeable K levels. Soil applications of fertilizer (40+40+60) were made by hand on April 3 but fertilizer materials were not incorporated into the soil. The paddy was flooded on April 4. Rice was thinned once with an airboat at floating leaf-aerial leaf stage. At 2nd aerial leaf stage the plant population was 4 plants per square foot. To control algae, 20 lbs per acre of copper sulfate were applied at boot stage. Pesticides were applied to control Helminthosporium and rice worm. Fertilizer solution was sprayed on 12 x 12 ft. plots with an electric cordless garden sprayer at a rate of 400 milliliters per plot. Foliar applications were made on the following dates:

1st spraying, 6/30 - at boot stage,
2nd spraying, 7/20 - mid-flowering,
3rd spraying, 8/06 - early grain formation.

No "leaf burn" damage was observed in this trial. Plots were harvested on August 18. Two 4 x 4 ft. areas were hand harvested from each plot. One replication, however, was not harvested because of extremely poor stand and growth due to low water level and weeds.

Table 17. Effect of foliar and soil application of fertilizer on the grain yield of wild rice - 1976, Kosbau Bros., Aitkin County.

Foliar Application					Soil Application		
Number	Total plant nutrients applied lbs/Acre				None	40+40+60	Average (Foliar)
	N	P_2O_5	K_2O	S			
					Grain yield[1], lb/acre		
None	None				658[2]	717	688
1x	15 +	6 +	9 +	1.3	---	734	734
2x	30 +	12 +	18 +	2.6	---	867	867
3x	45 +	18 +	27 +	3.9	781	791	786
Average (soil)					720	777	

1) 7% moisture; 2) Ave. of 3 replications; Significance NS; C.V. % 16.7

Wild rice yield was increased slightly by foliar fertilization (table 17). The most effective treatment consisted of soil application (40+40+60) and two foliar applications (30+12+18+2.5S) made at boot and early grain formation.

Foliar fertilization of wild rice is not a recommended practice at the present time. With the varieties and production know-how that are available today, nutrient requirements of the plant can be satisfied effectively and economically by conventional soil applications of NPK and N topdressing. But there is potential that should be explored by continued investigation of this new practice. First, the positive trends of wild rice yield obtained in the 1976 trial look promising. Secondly, growers already are applying pesticides and topdress-N by airplane or helicopter. So there is a possibility of combining these operations, thus, making foliar fertilization more economical than it is today.

C. POTASSIUM RATE TRIAL

The role of potassium in wild rice production is subject to frequent inquiry. The possibility that losses caused by lodging or disease may be lessened, as in other crops, by the application of K is most intriguing to growers. Some growers have experimented with different K rates but the results have been inconclusive. In our own experiments, moderately high rates of potassium (200 lb/acre K_2O) have not produced any striking results. In 1974 on peat, plots receiving 200 lb/acre K_2O combined with 0-40 lb/acre N, had healthier plants and less lodging than plots receiving 0 or 40 lb/acre K_2O treatments. This, however, was not true for the 120+40+200 treatment. Since it is possible that rather large amounts of K are required for the nutrient to become beneficial to the crop, it was decided to include in this study some exceptionally high rates. Two trials were established on growers paddies. The cooperators applied fertilizer in 40-60 ft. wide strips in fall of 1974. In 1976 one of these trials was discontinued. The remaining trial was located in paddy No. 2W owned by the Clearwater Rice, Inc. in Clearwater county. The paddy had a good stand of "Johnson" wild rice (1972 seeding). Muriate of potash (0-0-60) was applied in 40x516 ft. strips in fall of 1974 and then rototilled into the soil. A basic application of 35+12+7 was made by airplane on June 29, 1976. Paddy was treated with insecticide against rice worm but Dithane was not used. The stand was thinned with an airboat. There was very little lodging in the paddy and infection with Helminthosporium was not serious. The yield was determined by harvesting two 4 x 4 square areas from each strip.

Grain yield was variable and did not appear to be affected by fertilization with potassium (table 18). At jointing stage, dry matter weight, K% of 2nd leaf and total K uptake by plant were not affected by K treatments (table 19, 20, 22). At the late flowering stage, however, the extremely high rates of potassium, made in fall of 1974, appeared to result in slight increases of total plant weight (table 19), K concentration in stems and leaves (table 21) and total K uptake by the plant (table 22).

Table 23 shows K test results of samples collected from the fertilizer strips (0-6 inch depth) at the end of 1975 and 1976 growing seasons. Exchangeable potassium in the root zone was increased only slightly by the application of 840-1260 lb K_2O/acre. Generally, in this trial, high to extremely high rates of potassium fertilizer had little or no effect on disease resistance, lodging and yield.

Table 18. Residual effect of K application on grain yield of wild rice on peat,
1976 - Clearwater Rice, Inc.

Treatment [1] K_2O, lb/acre	Grain Yield lb/Acre
0	720[2]
42	633
210	543
420	768
630	867
840	753
1050	1032
1260	771

1) All strips received a basic treatment of 35+12+7 applied by plane on June 29.

2) 7% Moisture.

Table 19. Effect of K application on dry matter of wild rice,
1976 - Clearwater Rice, Inc.

Strip No.	Treatment K_2O, lb/Acre	Dry matter: At jointing	Dry matter: At late flower
		Grams per plant	
1	0	9[1]	25[2]
2	42	11	22
3	210	13	24
4	420	12	23
5	630	6	23
6	840	9	25
7	1050	13	33
8	1260	8	31

1) Average of 10 plants; 2) Average of 5 plants

Table 20. Effect of K application on K concentration of wild rice tissue at jointing stage - 1976. Clearwater Rice, Inc.

Strip No.	Treatment K_2O, lb/Acre	2nd leaf	Whole plant
		K% in dry matter	
1	0	3.45[1)]	5.00[1)]
2	42	3.79	3.90
3	210	3.97	4.63
4	420	3.37	4.87
5	630	4.29	5.12
6	840	3.97	5.21
7	1050	3.81	4.88
8	1260	3.73	5.96

1) Average of 10 plants

Table 21. Effect of K application on K concentration of wild rice tissue at late flowering - 1976. Clearwater Rice, Inc.

Strip No.	Treatment	Stems	Leaves	Flower parts
		K% in dry matter		
1	0	3.36[1)]	2.58	1.47
2	42	3.98	2.84	1.38
3	210	4.15	2.51	1.21
4	420	3.41	2.63	1.44
5	630	4.62	3.52	1.54
6	840	4.81	3.39	1.53
7	1050	4.86	3.18	1.86
8	1260	5.02	3.46	1.73

1) Average of 5 plants

Table 22. Effect of K application on K uptake by wild rice, 1976 - Clearwater Rice, Inc.

Strip No.	Treatment K_2O, lb/Acre	Stage of development: Jointing	Late flowering
		— K uptake, milligrams per plant —	
1	0	425[1)]	728[2)]
2	42	440	738
3	210	615	796
4	420	549	665
5	630	324	908
6	840	487	998
7	1050	630	1268
8	1260	486	1274

1)Average of 10 plants

2)Average of 5 plants

Table 23. Effect of K application to peat on soil test levels, Clearwater Rice, Inc.

Treatment* K_2O, lb/Acre	Sampling date: 9/11/75	8/31/76
	Exchangeable K, pp2m	
0	60	50
42	50	50
210	30	40
420	30	50
630	50	70
840	110	60
1050	100	90
1260	110	70

* Applied as 0-0-60 in fall 1974 and rototilled into the soil.

D. WEATHER AND PLANT DEVELOPMENT

The growing season of 1976 was an unusally warm and dry one. When compared to the normal (for a period 1931-60) all months from April through August in 1976 were warmer and consequently had a greater number of Growing-Degree-Days (see table 24 and Fig. 1). This warmer weather, coupled with increased solar radiation, allowed wild rice growth and development to advance about 2 weeks ahead of the usual pattern. Air temperature data for the Aitkin and Clearwater (Fosston) areas were taken at the nearest available weather station. These data may differ somewhat from actual temperature conditions in the peat bog area (bogs are usually cooler than upland areas) but they are indicative of the same "warmer than normal" trend.

The temperature and GDD data indicate that April, 1976 was much warmer than usual and started the growing season early. Upon seedling emergence, in mid-May, development was consistently ahead of the usual schedule. When compared to 1974, which had very close to normal temperature, 1976 wild rice development stages were always advanced by 2 weeks or more. The jointing stage occurred in mid-June rather than in mid-July and final harvest was in early September rather than mid-September (see Fig. 2). Regardless of planting date, however, the actual number of days from the floating leaf stage to maturity is rather constant and, at Grand Rapids, may vary from 90 to 110 days.

This early plant development during 1976 was also aided by increased solar radiation. Cloud cover was reduced and consequently radiation was increased by approximately 20%.

All of these factors leading to advanced plant development were beneficial in that they reduced the amount of late season cool weather and eliminated chances of frost injury.

Table 24. Average air temperature as measured at three U.S. weather stations.[1]

Station, Year	Month					5 Month Average	GDD T_b=40
	April	May	June	July	August		
	average air temperature, °F						
Fosston, Polk Co.							
Normal[2]	41.0	54.6	63.6	69.4	67.5	59.2	2954.5
1974	41.0	50.5	63.4	71.6	62.8	57.9	2743.9
1975	34.8	55.7	61.9	70.5	64.6	57.5	2851.8
1976	46.6	54.9	66.8	68.8	70.9	61.6	3314.6
Grand Rapids, N.C. School							
Normal	39.9	52.7	62.0	67.4	65.1	57.4	2681.2
1974	41.6	49.4	62.7	70.7	62.8	57.4	2669.5
1975	34.7	57.0	62.2	71.5	65.2	58.1	2950.7
1976	47.1	54.4	66.1	68.2	67.4	60.6	3166.0
Aitkin							
1974	42.9	49.8	63.1	71.1	63.3	58.0	2770.2
1975	39.0M	59.4M	64.4M	72.1	66.2M	60.2	3140.7
1976	47.5	54.8	66.8	69.3M	68.1	61.3	3267.2

1) Source: Climatological Data, Minnesota, Vol. 80, 81, 82 (1974-76), U.S. Dept. of Commerce.

2) Normals for the period 1931-60.

3) M = less than 10 days record missing.

GDD, T_b = 40°F.

Fig. 1. CUMULATIVE GROWING DEGREE DAYS, GRAND RAPIDS

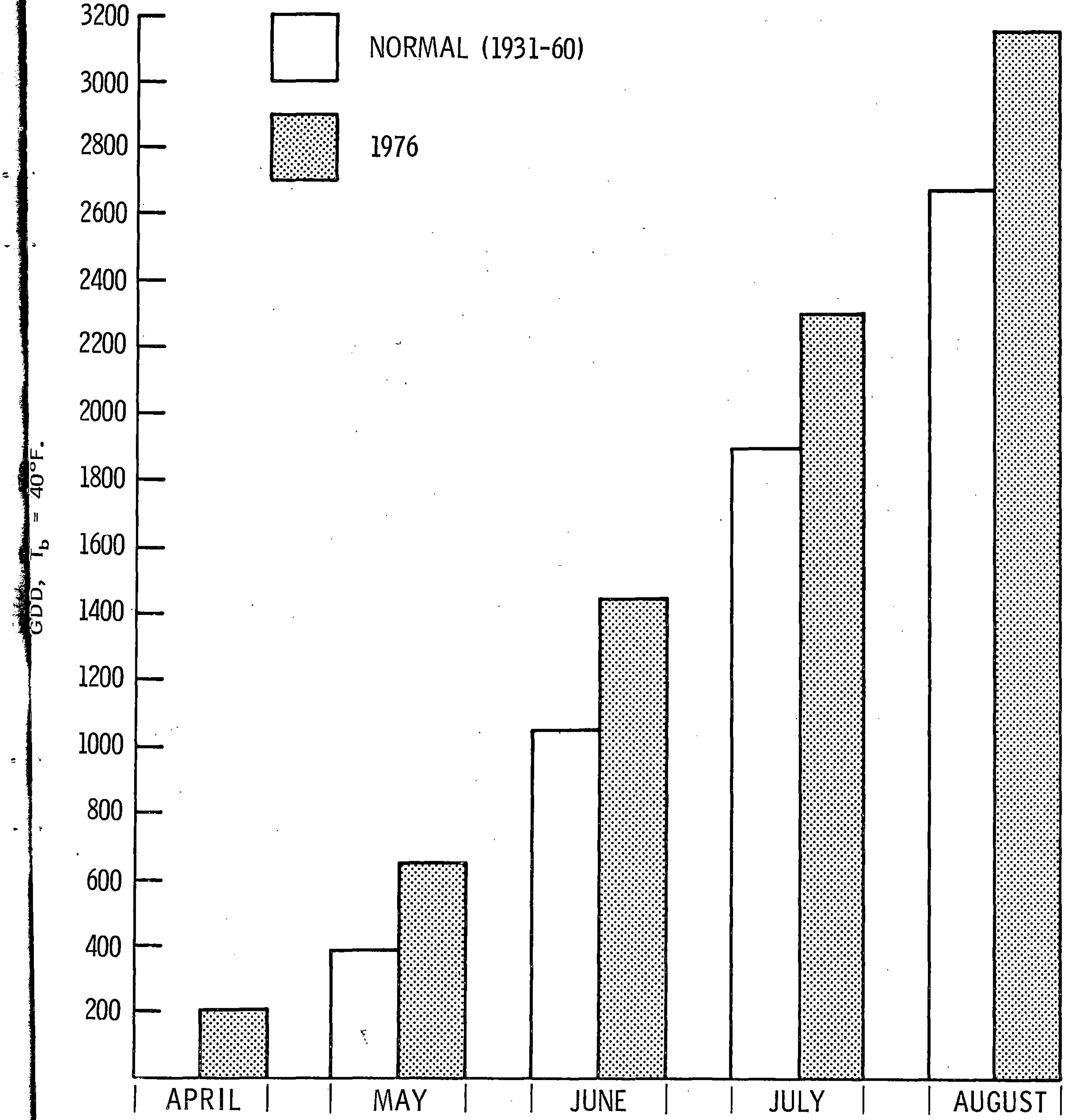


Fig. 2. DEVELOPMENT OF WILD RICE AT GRAND RAPIDS - 1974, 1975, 1976
JOHNSON VARIETY

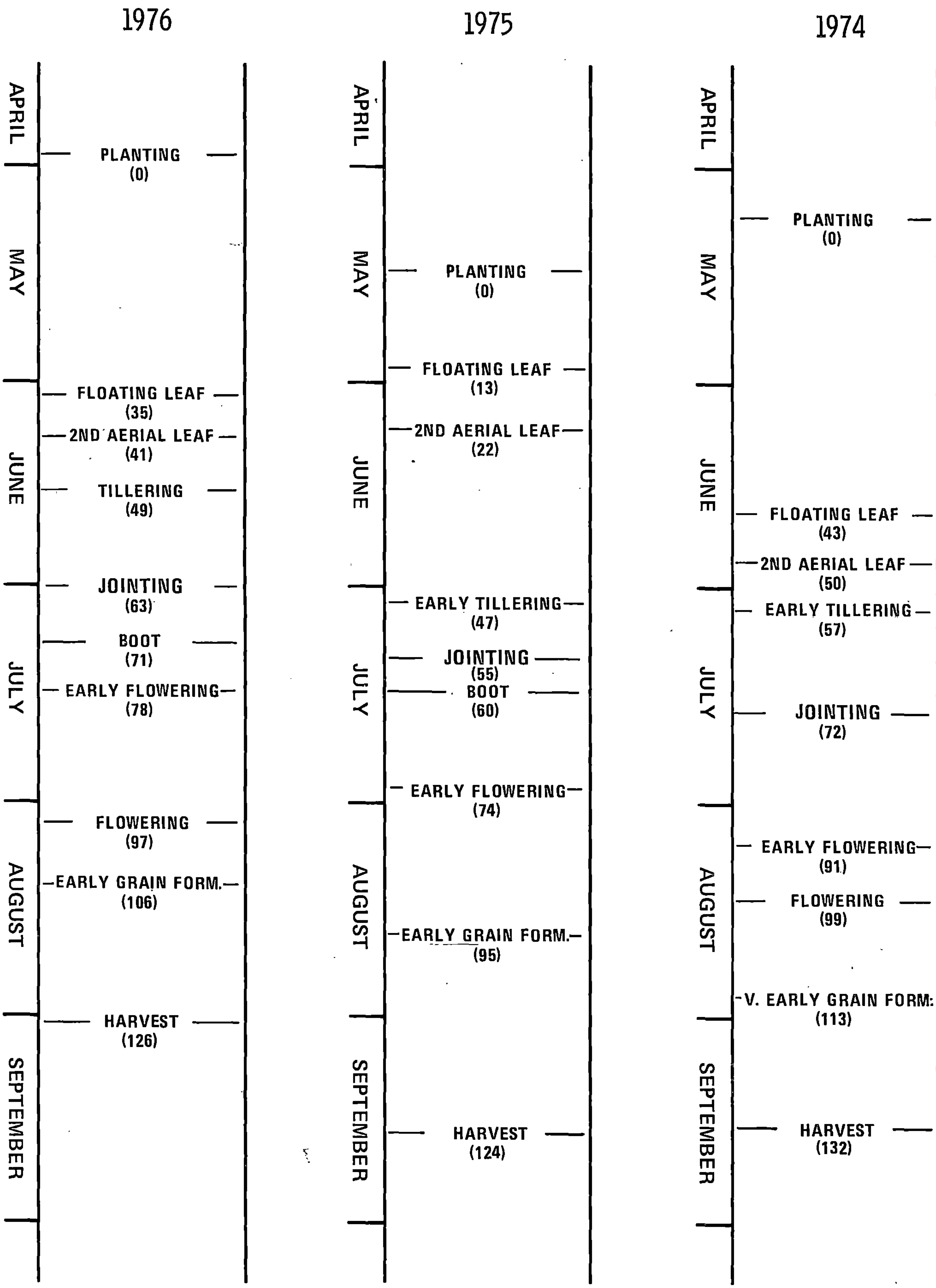
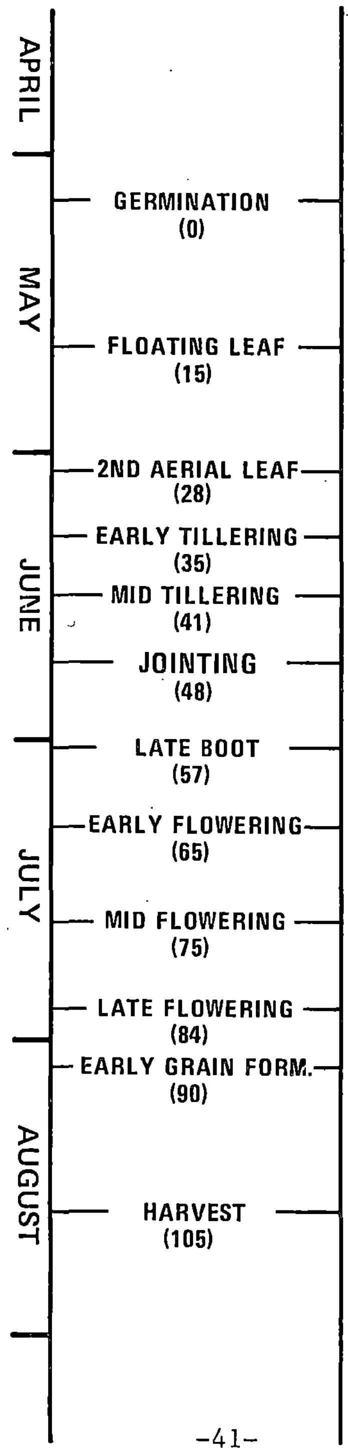


Fig. 3.
WILD RICE DEVELOPMENT
KOSBAU BROS. AITKIN CO.; 1976
K2 VARIETY
(April 3, 1976 - frost @ 3" depth)



TEMPERATURE MEASUREMENTS - 1976

Soil temperatures were taken during the growing season at Grand Rapids and at a commercial grower's paddy in Aitkin county. Air and water temperatures were also measured at the Aitkin county site. The soil temperature at Grand Rapids was measured by a stainless steel probe, inserted horizontally at about the 6 inch depth and connected to a thermometer measuring maximum, minimum and current soil temperatures (in °F.). This thermometer was read and reset daily. The soil, air and water temperatures at the Aitkin county site were measured by a 3 point, automatic sensing and recording thermograph (Weathermaster Corp. #T603). One probe was inserted into the soil at a 6 inch depth, one probe was placed in the water horizontally at a depth 6 inches from the water surface, and one probe was placed 3 feet above the water surface. Selected data for the two sites are reported at 5 day intervals (see Fig. 4-6).

The soil temperature for the Grand Rapids mineral soil (Fig. 4) was found to fluctuate much more than in the peat soil at the Aitkin county site (Fig. 5). The mineral soil temperature often varied by as much as 10°F in a single day, whereas the peat soil never varied by more than 3°F in a single day. However, both soils followed the same general heating and cooling trends. Both soils reached their maximum temperatures during the second week of June with the mineral soil reaching a high of 79°F and the peat soil reaching 70°F. After reaching these peaks both soils fluctuated within 60° and 70°F until harvest, with the peat soil being slightly cooler than the mineral soil.

The air and water temperatures at the Aitkin county site (Fig. 6) showed much greater fluctuations than the soil temperature. The water temperature closely followed the daily air temperature fluctuations. The mean water temperature was always slightly higher than the mean air temperature. The soil temperature was much more stable than air and water temperatures and stayed within the 60° and 70° range after it had reached its maximum.

Fig. 4. SOIL TEMPERATURE, 1976, GRAND RAPIDS - SOILS PADDY

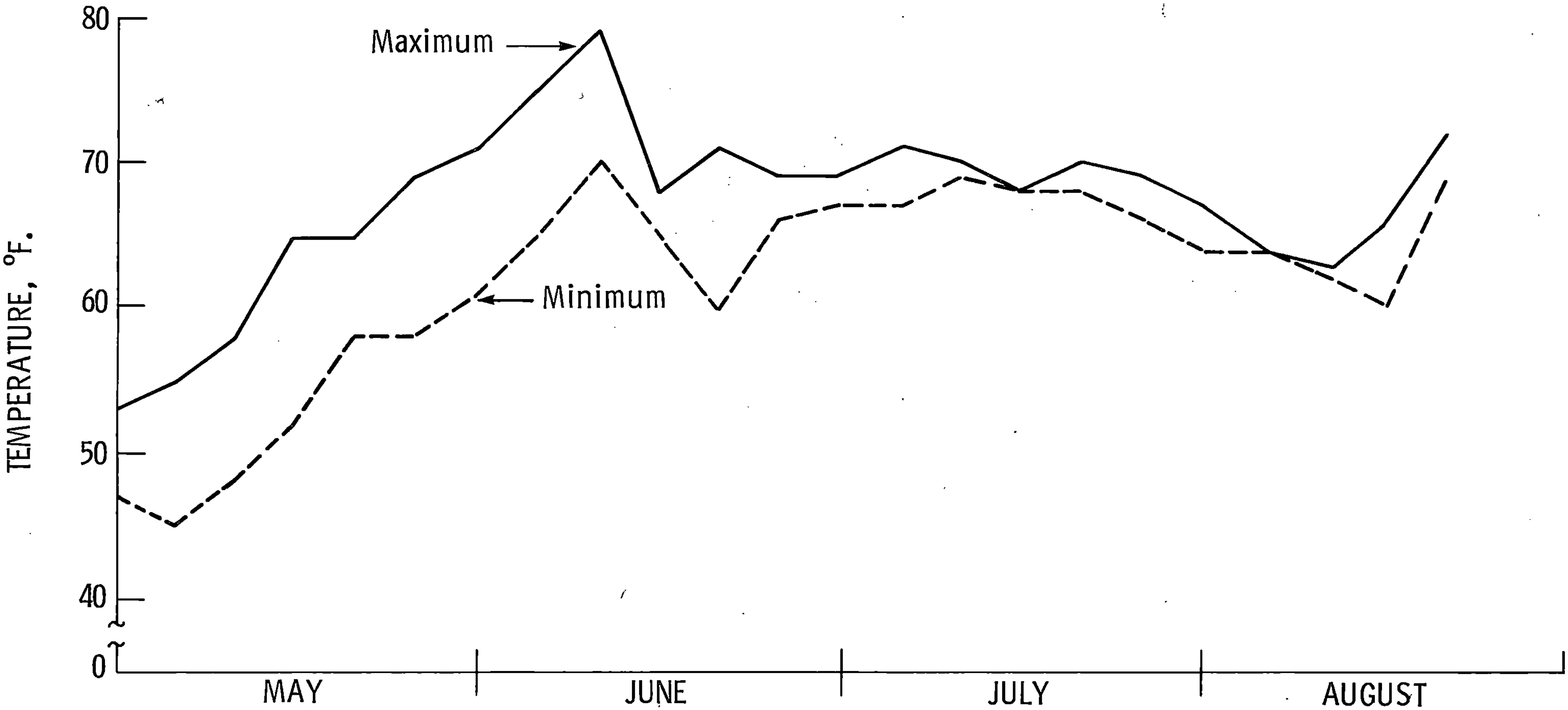


Fig. 5. SOIL TEMPERATURE, 1976, KOSBAU BROS., AITKIN COUNTY

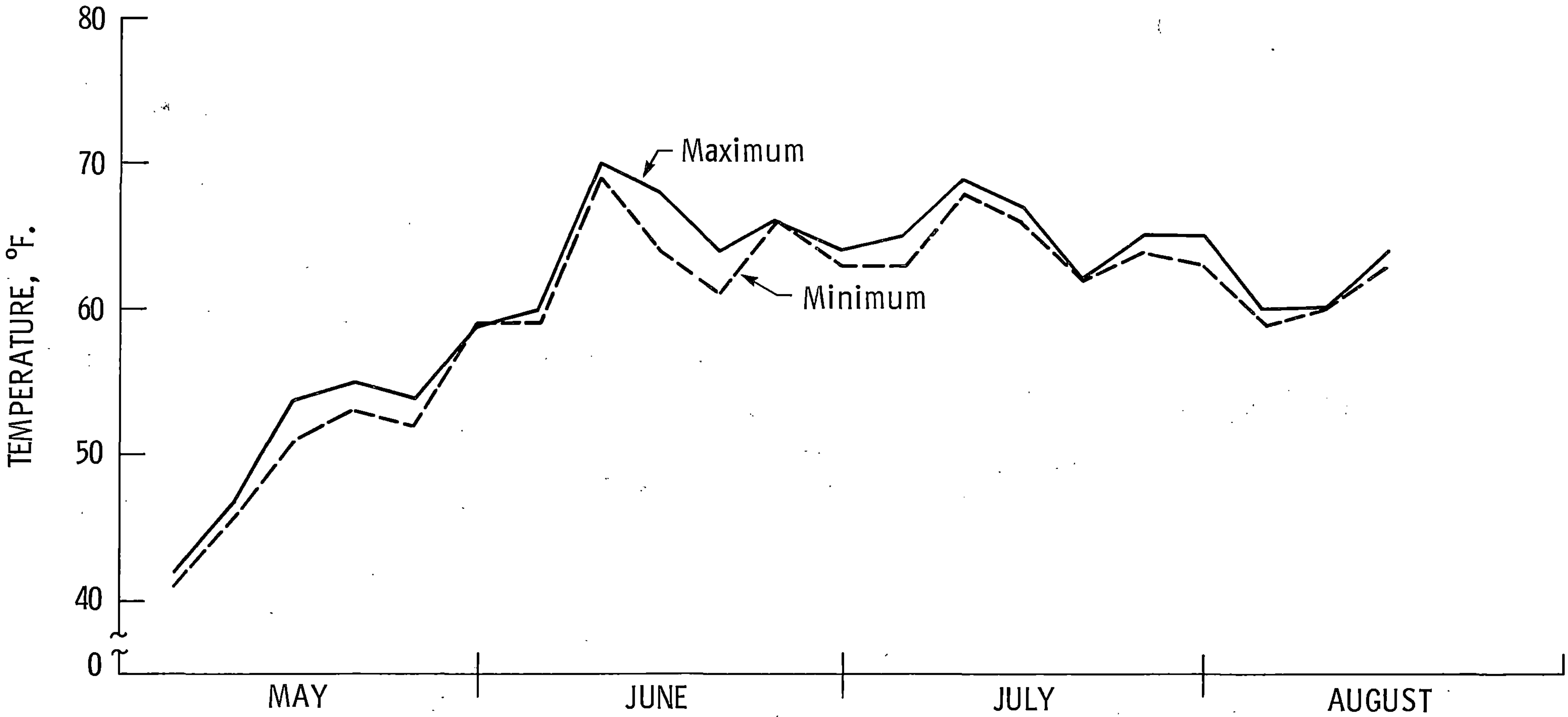
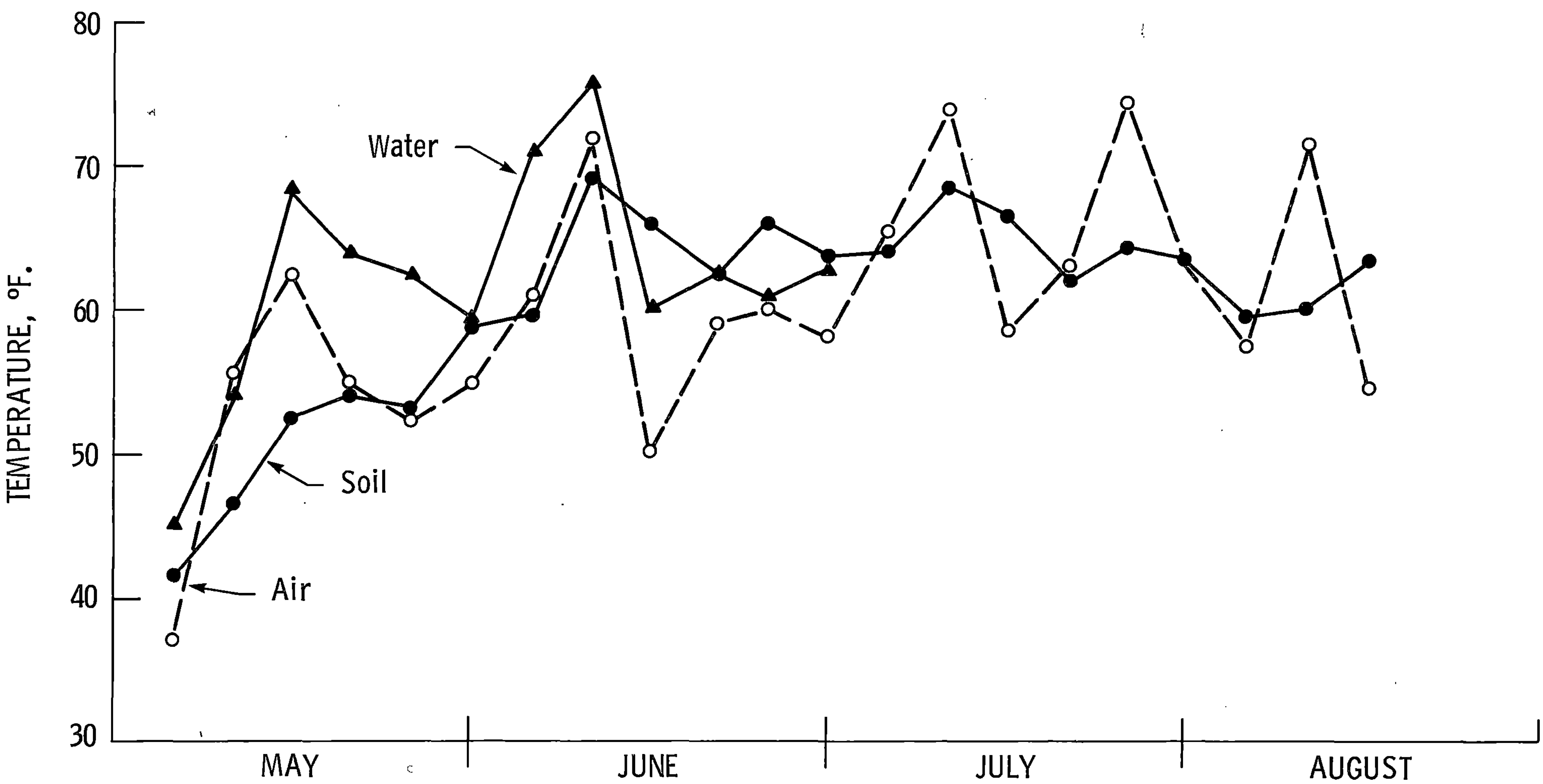


Fig. 6. MEAN AIR, WATER, SOIL TEMPERATURES, KOSBAU BROS., 1976



E. CHEMICAL CHARACTERISTICS OF PADDY WATER

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

Water samples were collected from four paddies during 1976 growing season. Two of the paddies located on the Grand Rapids Experiment Station were used for nitrogen rate studies on mineral soil. Source of water is the Prairie River. The third sampling site was a paddy on peat in Aitkin county in which 3 fertilization trials were conducted. Paddies, at this location, derived water from the Little Willow River via a diversion ditch. Water passed through two other production paddies before entering the research paddy. Water level in the paddy dropped from June 15 on due to evaporation and by July 14 the remaining water had been drained off. The fourth paddy on peat in Clearwater county was the site of a potassium rate strip-trial. Water from Clearwater River reaches this paddy via Ruffy Brook. Chemical determinations were made by the Research Analytical Laboratory, University of Minnesota. Information on sampling dates and the chemical composition of water are given in table 25.

The alkalinity of water is its capacity to neutralize acid. The results, in this report, indicate alkalinity obtained by titration with a combination of indicators having an endpoint of pH 5.0. In most natural waters, the alkalinity is practically all produced by dissolved carbonate and bicarbonate ions. Some organic acids also may contribute to titratable alkalinity. The values for alkalinity follow closely to those of hardness. Water samples from the Kosbau paddy showed the lowest alkalinity levels and those from Clearwater the highest with the Grand Rapids paddy water having intermediate values.

The hardness is calculated by mutiplying Ca and Mg concentrations by factors, adding up and is expressed as $CaCO_3$, mg/liter. Water from Clearwater paddy is very hard with values ranging from 201 to 364. Water in Grand Rapids paddies is moderately hard (53-98 mg/L) while the Kosbau paddy has soft water with hardness values ranging from 26 to 62.

Chemical characteristics of water from 1st and 2nd year paddies at Grand Rapids were nearly the same. Total N, generally, did not exceed the 2 ppm level and total P concentration ranged from 0.13 to less than 0.01 ppm. Potassium concentration during most of the growing season was less than 2 ppm. Water contained less than 2 ppm sulfate-S or less than 6 ppm of sulfate (SO_4).

Water from paddy on peat located in Aitkin county, contained about 1.9 ppm total N and 0.73 ppm P at the end of April. Levels of these two chemical elements in water increased as the season progressed due to evaporation and release from the soil. Maximum levels of 4.97 ppm of total N and 2.75 ppm P were reached during June. Potassium levels also were exceptionally high in the water of this paddy. However, the water did not contain appreciable amounts of sulfate.

Water from the paddy on peat in Clearwater county contained 1.88 to 3.55 ppm total N, but the total P concentration was less than 0.7 ppm. May sampling showed 12.1 ppm K but by August the concentration had decreased to 3.3 ppm. Sulfate level in samples from this paddy varied considerably. The highest concentration of 13.6 ppm sulfate-S was measured on May 11, equivalent to 40 ppm of sulfate (SO_4).

ACKNOWLEDGMENTS

Grateful acknowledgments are made to following cooperators and University personnel for their valuable assistance during 1976 in obtaining information reported here: Messrs. Franklin and Harold Kosbau, Aitkin county; Messrs. Donald Barron and Ray Skoe, Clearwater Rice, Inc.; Dr. Wm. Matalamaki and the Staff, North Central Experiment Station, Grand Rapids; Drs. E. A. Oelke and M. F. Kernkamp, Messrs. Owney Koski and Henry Schumer, University of Minnesota; CENEX Co-op Oil Association, Gully.

Table 25. Chemical composition of water collected from wild rice paddies during the 1976 growing season.

Sample No.	Sampling Date	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Grand Rapids, 1st year paddy												
3.	4/28	50	58	.76	.20	.27	.61	< .01*	< 2.0#	16.5	4.0	1.5
9.	5/21	69	75	1.00	.10	< .01	.08	.02	< 2.0	20.6	5.8	2.0
15.	6/3	78	81	.53	.07	.07	.05	.01	< 2.0	22.5	6.1	2.3
17.	6/9	84	87	1.07	.19	< .01	.08	< .01	< 2.0	24.5	6.3	2.1
24.	6/16	68	73	.73	.10	.05	.05	< .01	< 2.0	20.6	5.3	1.6
28.	6/22	70	73	.58	.04	< .01	.02	< .01	< 2.0	20.0	5.6	1.5
32.	6/30	46	53	.90	.07	< .01	.04	< .01	< 2.0	15.1	3.6	.4
35.	7/8	73	81	1.61	.19	< .01	.13	.05	< 2.0	22.7	5.8	1.4
39.	7/15	78	76	1.60	.21	< .01	.16	.04	< 2.0	20.9	5.7	1.3
43.	7/22	79	77	1.99	.18	< .01	.21	.02	< 2.0	21.4	5.8	1.4
47.	7/27	83	80	1.33	.08	.01	.12	.03	< 2.0	22.7	5.6	1.8
49.	8/3	91	87	1.48	.33	< .01	.10	.04	< 2.0	24.0	6.5	1.5
53.	8/12	104	98	1.70	.26	< .01	.06	.01	< 2.0	25.8	8.1	2.0
Location: Grand Rapids, 2nd year paddy												
4.	4/28	50	57	.84	.10	.19	.37	< .01	< 2.0	16.3	4.0	1.6
10.	5/21	72	77	.96	.07	< .01	.06	.01	< 2.0	21.7	5.6	1.8
16.	6/3	86	86	.62	.08	< .01	.06	.01	< 2.0	24.1	6.2	2.7
18.	6.9	84	81	1.09	.22	< .01	.14	.03	< 2.0	22.1	6.3	2.2
23.	6/16	65	71	.73	.14	.05	.06	< .01	< 2.0	19.7	5.3	1.4
27.	6/22	72	71	1.31	.06	< .01	.13	.13	< 2.0	19.6	5.3	1.4
31.	6/30	48	55	1.00	.08	< .01	.06	.01	< 2.0	15.9	3.8	< .1
36.	7/8	66	75	.93	.07	< .01	.03	.01	< 2.0	21.7	5.0	1.1
40.	7/15	78	72	1.46	.13	< .01	.10	.02	< 2.0	20.1	5.2	2.1
44.	7/22	73	65	2.12	.11	< .01	.17	.05	< 2.0	18.4	4.7	2.6
48.	7/27	71	67	.88	.07	< .01	.06	.02	< 2.0	19.6	4.5	2.0
50.	8/3	78	72	1.77	.32	< .01	.18	.13	< 2.0	20.2	5.2	4.2
54.	8/12	93	81	1.10	.29	< .01	.13	.13	< 2.0	23.3	5.6	6.0

* < = less than; # 2.0 ppm sulfate-S x 3 = 6.0 ppm sulfate (SO_4).

Table 25. Chemical composition of water collected from wild rice paddies during the 1976 growing season (continued).

Sample No.	Sampling Date	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Kosbau Bros., Aitkin County												
5.	4/29	32	47	1.90	.20	< .01*	.73	.35	< 2.0#	12.3	3.9	15.7
11.	5/20	48	62	1.53	.30	< .01	1.04	1.01	< 2.0	15.6	5.5	17.9
14.	6/2	38	53	4.97	.58	< .01	1.63	1.63	< 2.0	13.0	4.9	21.4
20.	6/9	25	48	2.59	.63	.01	2.75	2.75	< 2.0	9.9	5.7	28.5
22.	6/15	10	28	4.32	.61	< .01	2.31	1.97	< 2.0	4.1	4.2	19.7
26.	6/22	13	26	4.45	.38	< .01	1.45	1.22	< 2.0	2.3	4.8	11.2
30.	6/30	18	29	2.78	.31	< .01	1.08	.86	< 2.0	4.0	4.7	6.6
38.*	7/14	50	52	3.45	.29	< .01	.35	.22	< 2.0	11.4	5.8	5.0
Location: Clearwater Rice, Inc., West 2 paddy												
7.	5/11	192	206	2.05	.08	< .01	.12	.03	13.6	55.1	16.5	12.1
33.	7/8	175	201	1.88	.12	< .01	.67	.63	< 2.0	44.5	21.9	9.6
52.	8/11	333	364	3.55	1.55	< .01	.65	.43	9.1	95.2	30.6	3.3

* < = less than; # 2.0 ppm sulfate-S x 3 = 6.0 ppm sulfate (SO_4).

The fourth full year of research was completed during 1976. Research continues to focus upon development of varieties that are early maturing and more resistant to shattering and diseases. This report describes the progress made in varietal development and in other related areas during 1976.

A. Varietal Development and Testing

1. Objective

Develop early maturing types having shattering resistance. Growers have continued to indicate that harvesting late, in September, increases their chances from losses due to frost, cold weather, winds, and disease. Late harvesting also places the completion of post harvest tillage and paddy maintenance in jeopardy.

The amount of actual losses that are expected in late maturing varieties from frost, cold weather, winds and disease are difficult to estimate because of the relatively short period that wild rice has been grown using modern production practices. Data of temperature in paddies would be useful in showing the frost date that a variety should avoid. Unfortunately, long term weather data is only available from official weather stations and not from paddies. Experienced weather scientists have said that substantially lower temperatures would be expected in the paddies than the official readings that are normally taken at higher elevations and from enclosed structures.

This year during August the official air temperatures at Aitkin and in a paddy near Aitkin were compared. The official reading was usually 6-8 degrees higher than the reading in the paddy. In an effort to see the frequency of potentially damaging frosts, the official low temperatures recorded over the past 19 years in the wild rice growing region are shown in Figure 1. The Figure indicates that in Wild Rice growing areas frost damage would be expected 30 percent of the time if harvested on September 1 and 50 percent of the time if harvested on September 15.

Besides reducing losses from frost and cold weather, early varieties should avoid a good share of the losses incurred from strong wind storms. Figure 2 indicates that harvesting in August would avoid approximately one third of the severe winds that would be encountered by those harvested September 10.

It is suspected that yield reduced by disease occurs to some degree every year and was a major concern to growers in the central growing area in 1973. Early shattering types grown in 1973 avoided that major epidemic by maturing before the effects of the late season blight and therefore appears to hold potential as a means of control. Early varieties would also allow the potential use of Diathane M-45, a chemical protectant, in the northern growing areas. Besides reducing disease, Diathane M-45 apparently delays maturity. Its use on presently grown full season varieties, therefore, is prevented because it increases the chances too much for losses from frost.

Results

An experimental line, Exp 1, has been developed from a cross between an early maturing but shattering Canadian ecotype and a relatively late maturing, but shattering resistant selection attained from Green Giant (apparently tracing back to the "Johnson nonshattering" selection). Exp 1 is the result of 4 cycles of selection for earliness and shattering resistance. Exp 2 is of identical background except it has approximately 3-5% shattering while Exp 1 has 1% and K2 was observed to have 4%.

Table 1 gives the yield results from 1975 in which Exp 1 was 13 days earlier in heading and slightly higher yielding than any of the shattering-resistant varieties grown. Table 2 gives the results obtained in 1976 in two tests conducted at Grand Rapids and one at Excelsior. The unusual environment experienced this year resulted in all entries maturing earlier than is normal. At Grand Rapids in test 1, Exp 1 headed approximately 14 days earlier and was harvested 17 days earlier than K2. The yield of Exp 1 is markedly reduced from the 1975 level and significantly lower than K2. One explanation of this is that a substantial but undetermined amount of loss in the earlier entries, Exp 1, Exp 2 and Man Exp 1 was caused by blackbirds before protective nets were in place. Exp 1 and Man Exp were also perhaps harvested before they had accumulated maximum yields as indicated by their moisture percentages being higher than K2. This year was particularly favorable for the later full season varieties in developing more harvested panicles in comparison to last year, while Exp 1 was only slightly changed.

Exp 2 was among the entries tested at Grand Rapids in Test 2. It was again approximately two weeks earlier at heading and harvest, but was the lowest yielding in the test. Because of the variation of varieties among replications, there were no statistical differences among varieties. At Excelsior, all yields were depressed. Exp 2, however, was 9 days earlier than K2 and slightly higher yielding.

The results of these tests suggest that there must be a high variety-environment interaction. Full season varieties should produce maximum yields in years having high heat units being present, and frost and disease being absent. In order to hedge against high losses, it seems advisable to have acreages of each full and short season varieties.

An increase of seed of Exp 1 and Exp 2 is being made on two 2A and one 4A paddies, respectively. An additional increase is anticipated in 1978 of one of the lines on 84A to meet a possible release date of fall, 1978. Yield tests with Exp 1, Exp 2 and the commonly used varieties were fall planted in Aitkin, Clearwater and Itasca counties. In addition yield tests will be spring planted in Itasca county (Grand Rapids) and Carver county (Excelsior).

2. Objective

Develop high yielding early maturing shattering resistant varieties.

Results

Nine lines developed from backcrossing Exp 1 to the early Canadian types and lines developed by Dr. Don Woods at the University of Manitoba were placed in a preliminary yield test at Grand Rapids. Seed increase for advance testing will be done on the most promising lines.

3. Objective

Develop high yielding lines with superior shattering resistance.

Results

a. An experimental population, Exp 3, was developed from three cycles of mass selections from Exp 1. Selections were made in the Greenhouse by using a meter that measures tensile strength of the seed attachment. Approximately 235 lines have been developed and others are being developed from the population and will be field evaluated in 1977 for yield, earliness and shattering resistance.

b. Shattering resistance selections from lakes, Accessions 1 and 17, were maintained and crossed with Exp 3. The progenies from these crosses will be evaluated and selections will be made for superior shattering resistance.

4. Objective

Develop early shattering resistant plants that have reduced plant height.

Results

Thirty eight plants were selected from Exp 1 and Exp 2 that were approximately two thirds as tall as the normal Exp 1 plants and had the other desired characters. They have been intermated in the greenhouse and reselection will be done during 1977 for dwarf plants.

5. Objective

Develop populations of plants having Leaf Blight (*Helminthosporium*) resistance (in cooperation with M.F. Kernkamp).

Results

a. The second cycle of ear-to-row selection was completed at Grand Rapids were inoculated with a combination of *Helminthosporium oryzae* and *H. sativum*. Using the ear-to-row procedure, each line was kept separately and planted in three replications. Evaluation was based upon the average performance of the line in all replications. There were approximately 60 plants in each of 76 lines evaluated. The 76 lines originated from 35 genetic sources selected in 1976 tests as having some resistance. Table 3 gives the comparison of Helminthosporium resistance of the 76 lines. Basing selection upon lesion coverage of flag leaves at harvest, 19 lines were superior to K2, 55 were not different and two were inferior to K2. Table 4 gives the lesion index and lesion size at harvest, flowering, and tillering of the 19 superior lines. Only one selection, 761035, was superior in lesion index at all three times.

b. The modified mass selection procedure developed by Gardner in corn breeding is also being used for selection resistance to plants artificially inoculated with both *H. oryzae* and *sativum*. Genetic material used as the source populations were the Gene Pool 1975 (GP75-DMS) and bulk of seed from the 76 entries used in the ear-to-row procedure described in part (a)(ER76-DMS). In the GP75-DMS population approximately 3000 plants were observed and 30 superior plants were selected. In the ER76-DMS population approximately 5800 plants were observed and 14 superior plants were selected.

c. Plants from 18 lake collections made during 1975 were grown in 5 replications and inoculated as in parts (a) and (b). Lesion Index and Size data were obtained and are given in Table 5. Two accessions, Ac 120 and Ac 123, were superior to K2 and were selected for further study.

d. At Rosemount, efforts were made to conduct the second cycle of ear-to-row selection for resistance to *H. oryzae* at one location and to *H. sativum* at another. In selection for *H. oryzae* resistance, complications developed because fumigation efforts failed to kill seed in the soil produced in the first cycle of selection in 1975. Because of the many volunteer plants, correct identification could not be made of the planted selections therefore the second cycle was not conducted as planned. However, meaningful differences in the flag-leaf lesion coverage among plants were observed. The modified mass selection procedure was used and 30 plants having an average lesion index of 1.5 were selected from the approximately 3840 plants having an average lesion index of approximately five.

An inadequate disease level developed in the population of plants inoculated with _H. sativum_. This failure of disease was probably due to the high temperatures and low humidity during much of the summer. Seed was harvested from each of the 23 lines to conduct the second cycle during 1977.

B. Other Related Activities

1. Objective

Maintenance of germ plasm pool.

Results

A germ plasm pool of 51 accessions were intermated in 1974 and the number was increased to 71 accessions in 1975. This past year 18 additional ones were incorporated. Among the notes taken on the entries were heading date, height, growth habit, disease resistance, tiller number, 100 kernel weight, length and width of the flag leaf, and length, width, and depth of the seed.

2. Objective

Test the DPX3778 chemical on wild rice to determine if treated plants are functionally male sterile.

Results

As reported in the Progress Report of 1975, a preliminary test suggested that 16 lbs/A of DPX3778 might be required for effective pollen control rather than the 2 lbs/A that has been used in corn. A greenhouse study using four rates of the chemical and a field study using two rates with one, two, and three applications were completed. From these studies, it was found that while DPX3778 did at times control pollen shedding, it was unreliable. It was concluded that the chemical would not be useful in making controlled crosses in wild rice.

3. Objective

Test Mesurol on wild rice to determine if treatment reduced losses from blackbirds.

Results

A one acre research paddy was sprayed with 2 lbs/A of Mesurol plus Triton CS on 7/23 and 8/13 and an adjacent paddy was left untreated. Seventy-seven samples were taken from exposed plants and also from bird excluded plants in each of the paddies. The results of the test are reported in Table 6. Significant losses were detected that could be attributed to blackbirds and also possibly from shattering. The Mesurol treated plot, however, did not have less losses than the nontreated check plot. The results from this one test are not conclusive; however they indicate that Mesurol may not be effective in reducing losses from blackbirds in relatively small test plots.

4. Objective

Determine the amount of natural selfing that occurs in wild rice and determine the number of guard rows required to reduce the crossing in adjacent plots.

Results

The tests were run and seed harvested. In this coming year genetic markers will be evaluated in the progenies and the amount of crossing that had occurred will be determined.

5. Objectives

a. Study the inheritance of rough awn character to be a genetic marker.

b. Study progenies from crosses made between wild rice from Minnesota and Virginia, Texas and the St. Lawrence River.

Results

Crosses have been made and progenies will be studied during 1977. Useful progress was made during 1976 that will ultimately bring benefit to the wild rice growers and to the industry.

We were fortunate to have been cohost to Dr. Dave Punter on sabbatic leave from the University of Manitoba, who pursued an interest of improving screening techniques. Among his contributions were: standardized a system on taking notes on amount of lesion coverage (lesion index and lesion size), initiated a detached leaf test for disease resistance, and conducted a study on the relationship between lesion index and yield.

We were also fortunate to have Dr. Don Woods from the University of Manitoba to be here and cooperate in genetic and pollen travel studies. The genetic material that he contributed to the breeding program was deeply appreciated and holds promise of contributing to the genetic improvement of wild rice.

Gary Linkert and Mark Weinberger, full time employees and Jack Boyan and Lonny Buss, undergraduate students, continued to provide excellent dedicated efforts in our goal of developing superior varieties.

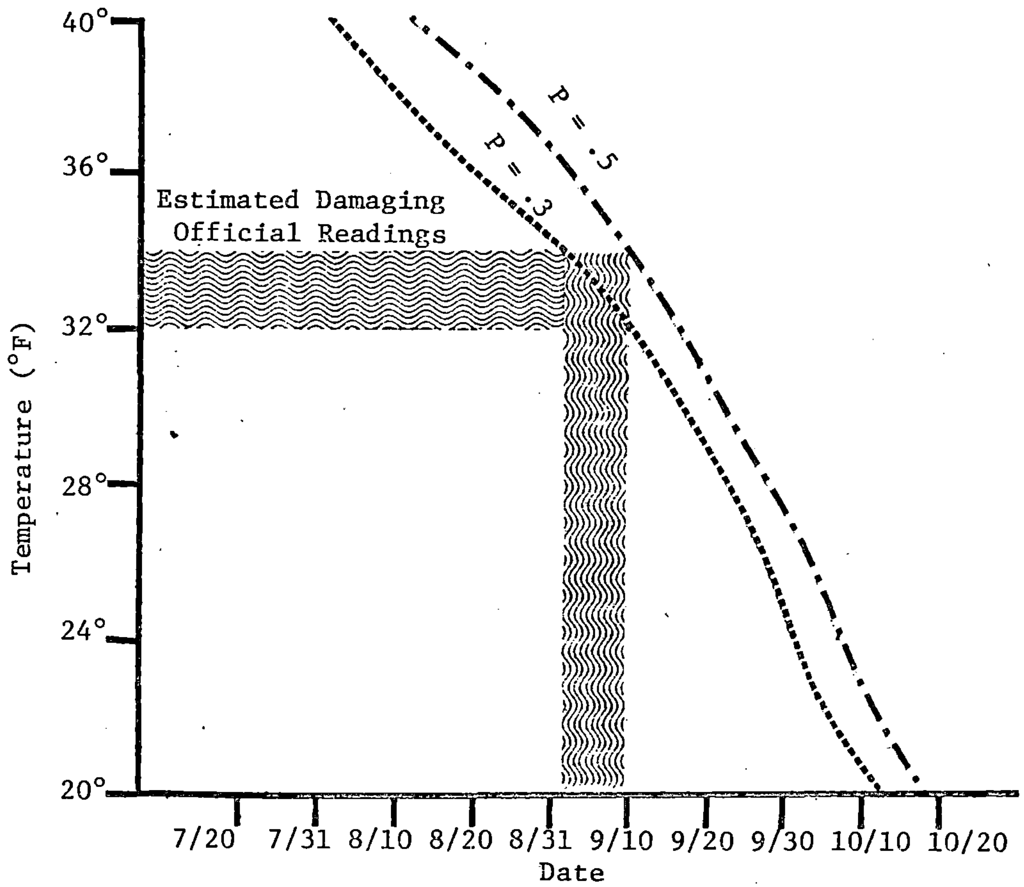


Figure 1. The relationship between Fall Dates and minimum temperatures with probabilities of .3 and .5 at Foston, Pine River Dam, Bemidji and Red Lake Falls.

Source: Climate of Minnesota. Technical Bulletin 243.

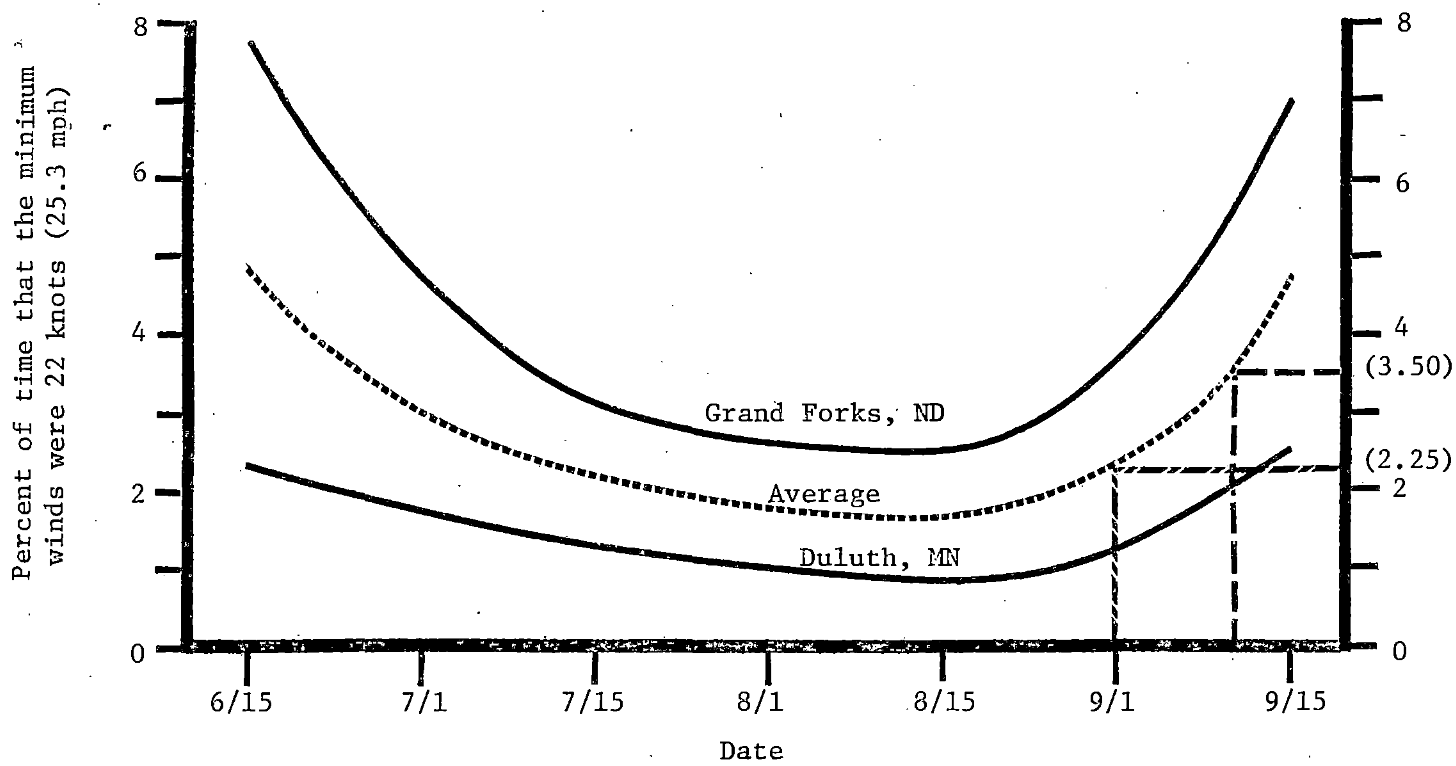


Figure 2. Percent of time that steady minimum winds of 22 knots (25.3 mph) were experienced during June 15-Sept. 15 over a 19-year period (1948-1966).

Source: Air Weather Service of U.S.A.F.

Table 1. Wild Rice Yield Test[1/], Grand Rapids, 1975.

	Entry	Heading Date	Harvest Date	Yield lbs/A Dry Wt.	Yield lbs/A At 45% Moisture	% Moisture At Harvest	Plants per sq. ft.	Panicles per sq. ft.	Height in.
1.	Exp 1	7/19	9/4	1120	2037	31	2.7	11.3	76
2.	M1	8/2	9/12	1007	1832	39	2.2	8.5	75
3.	M3	8/1	9/12	918	1668	38	1.8	8.1	69
4.	M3N	8/3	9/16	914	1662	34	1.4	7.7	68
5.	K2	8/1	9/12	878	1596	40	1.5	6.5	76
6.	Johnson	8/5	9/17	733	1334	40	1.4	5.7	78
7.	M3P	8/5	9/16	582	1059	35	0.9	5.1	65
8.	Clearwater	8/4	9/17	512	932	44	1.0	4.3	77
	LSD .05	2	1	322	585	--	.5	2.4	6

1/ Mean of 3 replications, planted May 28, 1975.

Table 2. Wild Rice Yield Test [1/], Grand Rapids and Excelsior, 1976.

	Date		Yield lbs/A		% Moisture	Number per sq. ft.		Height
Entry	Heading	Harvest	Dry Wt.	Adjusted [2/]	at Harvest	Plants	Panicles	(inches)
				(Grand Rapids, Test 1) [3/]				
Exp 1	6-23	8-5	698.9	1270.9	32	3.3	16.8	80
Exp 2	6-24	8-7	932.8	1696.4	28	2.7	13.8	79
Johnson	7-7	8-20	1490.7	2710.9	28	3.4	12.5	87
K2	7-10	8-22	1619.6	2945.4	21	1.8	10.8	87
M1	7-9	8-18	1376.9	2503.6	30	2.6	9.3	87
M3	7-4	8-18	1696.5	3083.6	29	3.0	16.7	85
Man Exp	6-29	8-12	663.4	1205.4	57	2.8	15.6	83
LSD .05	4	4	511.3	929.6		NS	NS	6
				(Grand Rapids, Test 2)				
Exp 2	6-23	8-7	1092	1985.4	32	2.5	17.2	81
Johnson	7-8	8-22	1967	3576.4	21	2.7	13.3	90
K2	7-8	8-22	2009	3652.7	24	2.4	12.2	83
M1	7-7	8-20	1787	3249.0	16	3.1	11.8	82
M3	7-5	8-22	2236	4065.4	20	3.1	14.3	83
LSD .05	4	5	NS	NS		NS	2.2	NS
				(Excelsior) [4/]				
Exp 2	6-30	8-2	797.8	1450.9	32	2.4	15.5	70
Johnson	7-12	-	-	-	-	1.5	-	78
K2	7-9	8-13	606.7	1103.6	25	1.5	12.2	75
M1	7-9	8-9	574.9	1045.4	33	1.8	12.8	74
M3	7-8	8-13	652.2	1185.4	44	1.6	14.5	74
LSD .05	2	1	NS	NS	NS	NS	NS	4

[1/] Mean of 3 replications.

[2/] Adjusted to 45% moisture.

[3/] Planted on 4/15.

[4/] Planted on 5/6.

Table 3. Average lesion index values of 76 lines selected in the first Cycle of Ear-to-row selection, Grand Rapids, 1976.

	Average Lesion Index Values[1/] for Selected Lines			Total Number
	Below 5.8[2/]	5.8 to 7.6[3/]	Above 7.6[4/]	of Lines
Number of lines	19	55	2	76

1/ Index values are percent flag leaf coverage by lesions on a plot basis at Harvest time (8-25-76) and averaged over three replications, 1 = 0% coverage, 9 = 50% coverage.

2/ Significantly more resistant (P = .05) than K2 check.

3/ Not significantly different (P = .05) than K2 check.

4/ Significantly less resistant (P = .05) than K2 check.

Table 4. Average Lesion Index and Lesion Size Values at three stages of growth of the 19 Superior Lines [1] and K2 Check Variety, Grand Rapids, 1976.

Identification		Harvest Index [2]	Harvest Size [3]	Flowering Index	Flowering Size	Tillering Index	Tillering Size
1. K2 check		6.7	4.3	4.3	4.0	3.3	4.3
2. 761001	AC 69	5.0	4.8	3.3	4.0	4.3	3.7
3. 761004	AC 69	5.0	4.8	3.3	3.7	4.7	3.3
4. 761067	M 1	5.2	4.7	3.7	4.0	4.7	4.3
5. 761002	Exp 1	5.3	4.3	4.0	3.7	3.7	4.0
6. 761006	K 2	5.3	4.7	4.3	4.0	4.7	4.0
7. 761027	Ac 59	5.5	5.0	3.7	4.0	4.3	4.7
8. 761044	Ac 5	5.5	4.8	3.3	3.7	3.3	3.3
9. 761054	Ac 80	5.5	4.7	3.7	4.0	4.3	3.7
10. 761057	K 1	5.5	4.5	4.0	4.3	4.0	4.7
11. 761058	K 2	5.5	4.3	4.0	4.0	3.3	3.3
12. 761079	M 1	5.5	5.0	3.7	4.0	4.3	4.0
13. 761022	Ac 72	5.5	4.3	3.3	4.0	4.0	3.3
14. 761073	M 1	5.7	4.0	3.3	4.0	4.3	4.0
15. 761061	Ac 86	5.7	4.8	3.3	4.7	3.3	3.7
16. 761055	Ac 80	5.7	4.5	4.0	3.7	4.3	4.3
17. 761035	K 2	5.7	4.5	3.3	3.3	3.0	3.7
18. 761030	Ac 59	5.7	5.0	3.7	4.0	5.0	4.7
19. 761005	Ac 40	5.7	4.7	3.7	3.3	3.7	4.0
20. 761035	K 2	5.7	4.5	3.3	3.7	3.7	3.7
LSD .05		0.9	0.6	0.8	0.8	1.2	1.0

[1] Nineteen of the 76 lines in the Second Cycle of Ear-to-Row Selection that were significantly more resistant (P = .05) than K 2 based upon Lesion Index at Harvest over 3 Replications.

[2] Index based on percent coverage by lesions; 1 = 0%, 3 = .75%, 5 = 3%, 7 = 12%, 9 = 50%.

[3] Size based on lesion size; 1 = pin point lesions, 5 = lesions of 1" or longer.

Table 5. Observations[1/] on 18 Lake Collections of 1975 and K2, Grand Rapids, 1976.

Entry	Accession	Origin	Headed[2/]	Height (inches)	Leaf Disease Reading[3/] Index	Size	Growth Habit[4/]
1	921	K2	40.6	73	2.8	3.4	2.6
2	922	K2	38.6	81	3.4	3.8	2.3
3	109	Minnewawa Lake, Aitkin	34.6	90	3.6	3.8	3.3
4	110	Flowage Lake, Aitkin	39.4	87	4.0	3.2	2.6
5	111	Ottertail R. No. of Frazee, Becker	42.4	86	2.8	3.2	2.3
6	112	Boy R. to Inguadona, Cass	42.8	70	2.6	2.8	1.6
7	113	Big Rice Lake, Cass	41.6	79	2.4	2.4	2.0
8	114	Norway Lake and River, Cass	42.0	98	3.0	3.6	2.3
9	115	Hattie Lake and River, Cass	32.2	79	3.8	3.2	3.0
10	116	Emily Lake, Crow Wing	42.6	85	2.6	2.8	3.3
11	117	Dahler Lake, Crow Wing	39.8	86	2.6	3.4	3.3
12	118	Twin Island Lake, Crow Wing	41.0	91	4.0	2.8	3.0
13	119	Rice Lake (Edison School) Crow Wing	42.2	87	2.8	3.4	3.0
14	120	Shakopee Lake, Mille Lacs	36.6	75	2.2	2.8	4.0
15	121	Rice Lake (Frazee), Becker	46.8	100	2.4	3.6	3.1
16	122	Rice Lake (Richville), Ottertail	41.2	92	2.8	3.0	3.0
17	123	Ottertail River, Ottertail	46.0	89	2.0	2.8	2.6
18	124	Cullen Lake, Crow Wing	40.6	81	2.8	2.8	2.0
19	125	State of Idaho	34.4	92	4.4	4.2	2.5
20	126	Masque, Canada	24.8	64	3.2	3.4	1.3
		LSD .05	4.6	6	.9	.7	-

1/ All values are means of 5 replications except for growth habit which is of 3 replications.

2/ Days from June 1.

3/ Readings made when plants were flowering; Index is percent coverage by lesions, 1 = 0%, 3 = .75%, 5 = 3%, 7 =12%, 9 = 50%; Size is using scale 0 = pin point lesions, 5 = lesions of 1" or longer.

4/ Rating of 1 = erect and 5 = prostrate.

Table 6. Comparison of Seed Weight per Panicle of Wild Rice in Mesurol Treated and Untreated Research Paddies, Grand Rapids, 1976.

Treatment	None	Mesurol[1/]	Mean
Exposed to Birds	3.18	2.90	3.04
Excluded from Birds[2/]	4.08	4.56	4.32*
Mean	3.63	3.73	

1/ Mesurol treated on 7/23 and 8/13 at two lbs per acre + Tritan C57.

2/ Excluded by bagging heads

* Significantly different at P = .05.

Tests to Control Helminthosporium Blight of Wild Rice with Fungicides

M. F. Kernkamp, W. C. Woodruff, L. J. Nickelson

Tests were continued to determine the efficacy of controlling Helminthosporium blight of wild rice. Large scale airplane application experiments in 1974 and 1975 indicated that four applications of Dithane M-45 at the rate of 2 lbs/a in 5 gal. of water plus 1.6 oz. of the spreader sticker Triton CS7 gave the best results. In 1976 field tests were established in commercial paddies at Aitkin, Palisade, Clearbrook and Gully, Minnesota.

The tests comprised 4 replicates with Dithane M-45 and a check plot randomized in each. All plots were 120 ft. wide and ranged in length from 158 to 437 ft. depending on location. Fungicide applications were made on July 1, 11, 19 and 24 at Aitkin. They were made July 1, 12, 18 and 27 at Palisade; at Clearbrook and Gully Dithane M-45 was applied July 10, 16, 22 and 28. A helicopter was used at Aitkin and Palisade and a winged airplane was used at Clearbrook and Gully.

At each location the crop was heading when fungicide applications were started. In each test the last application was made at least 26 days before harvest to comply with EPA specifications.

Initiation and development of blight were observed during the entire growing season. By mid-June there was general distribution of blight throughout the test fields. Prevalence ranged from 30 to 100 per cent of the plants with lesions. Severity remained very low throughout the summer. On August 10-11, detailed notes were recorded on severity and lesion size in all of the test plots. This was two to three weeks before harvest. Severity of blight was less than 5 per cent of the foliage covered with lesions. However, in each replicate in all the tests there was about twice as much blight in the check plots as in the Dithane M-45 plots.

Yields from the tests were harvested by taking one 15-foot combined cut lengthwise through the center of each plot. Green weights were recorded and tabulated in Table 1-4. Samples were taken also for analysis of dry weight, moisture and hulls and trash. Dithane M-45 residue analyses were made on the samples from all plots.

In each test the Dithane M-45 treated plots yielded more than the checks. Fields at Aitkin, Palisade, Clearbrook and Gully were 137, 63, 84 and 27 lbs/a over the checks, respectively. Percentage increases in yield were 9.4, 8.9, 12.9 and 5.7 respectively. The average yield from sprayed plots of all 4 tests was 77 lbs/a over the non-sprayed for an average increase of 9.2%.

The differences between treatments and no treatment were not statistically significant. However, the increases in yield suggest that it is economically feasible to decrease loss in yield by spraying with 4 applications of Dithane M-45. The results at Aitkin, Palisade and Clearbrook were particularly gratifying.

Another test was made at the North Central Experiment Station, Grand Rapids, MN, in which Bravo 6 F was included. The plots were 36 ft x 50 ft, replicated 4 times with Dithane M-45, Bravo and a check randomized in each replicate. The chemicals were applied with a 30 gal. sprayer at 200 psi. Applications were started July 8, 1976, and continued at weekly intervals until 4 applications were made. Dithane M-45 was applied at 2 lbs/a in 45 gal. of water plus 1.6 oz. Triton CS7 spreader sticker. Bravo 6 F was applied at 5 lbs. active ingredient per acre in 45 gal. of water. The control was sprayed with 1.6 oz. Triton CS7 spreader sticker in 45 gal. of water.

Table 1. Pounds of wild rice per acre from Dithane M-45 tests, Aitkin, MN, 1976

Replicate	Dithane M-45	Check
I	1617	1354
II	1890	1449
III	1564	1480
IV	1302	1543
Mean	1593	1456

Table 2. Pounds of wild rice per acre from Dithane M-45 test, Palisade, MN, 1976

Replicate	Dithane M-45	Check
I	745	805
II	765	673
III	811	745
IV	732	580
Mean	763	700

Table 3. Pounds of wild rice per acre from Dithane M-45 test, Clearbrook, MN 1976

Replicate	Dithane M-45	Check
I	813	542
II	672	585
III	727	744
IV	725	732
Mean	734	650

Table 4. Pounds of wild rice per acre from Dithane M-45 test, Gully, MN, 1976

Replicate	Dithane M-45	Check
I	492	459
II	501	558
III	589	527
IV	413	342
Mean	498	471

Table 5. Pounds of wild rice per acre from Dithane M-45 tests at Aitkin, Palisade, Clearbrook, and Gully, MN, 1976

Location	Dithane[a] M-45	Check	Dithane M-45 over check	% Increase over check
Aitkin	1593	1456	137	9.4
Palisade	763	700	63	8.9
Clearbrook	734	650	84	12.9
Gully	498	471	27	5.7
Mean	896	819	77	9.2

[a] Each figure is an average of four replications.

This nursery was inoculated 3 times with a mixture of 5 cultures each of *H. sativum* and *H. oryzae*. The first inoculation was made one day prior to the first spray. The second and third inoculations were made approximately one week and two weeks later, respectively.

At the time of the first spray there was virtually 100% prevalence of blight throughout the nursery. Blight continued to develop but the severity never exceeded 5%. Detailed disease ratings two weeks before harvest demonstrated distinctly less blight in the sprayed plots compared to non-sprayed. The Bravo 6 F plots had less blight than the Dithane M-45 plots.

At harvest yields were recorded from a 10 ft. strip cut through the length of each plot. The results clearly demonstrate an increase of 168 and 266 lbs/a from the Dithane M-45 and Bravo 6 F treatments, respectively, representing increases of 13.4 and 21.9%.

Analyses for Dithane M-45 residues were made on green seed and semi-processed seed from all plots in all 5 tests. The results of the Dithane M-45 analyses are in Table 6. It is clear that the residues on semi-processed seed were all far below the tolerance of 5 ppm. The high residues on the Aitkin and Palisade green seed can probably be accounted for by absence of rainfall between the last application and harvest. This is of no consequence anyway, since all seed is processed before it gets into commerce.

Since the State Department of Natural Resources and other governmental agencies are concerned about Dithane M-45 residues in runoff water, residue analyses were made on water samples from the test at Palisade. Absolutely no residue was found in water samples. All of the residue results agree

Table 6. Dithane M-45 residues on green and semi-processed wild rice in PPM

Test	Semi-processed seed	Green Seed	Check
Aitkin	0.5[a]	18.4	2.7
Palisade	0.6	23.3	1.9
Clearbrook	0.0	0.7	0.4
Gully	0.0	0.8	0.2
Grand Rapids	0.1	3.4	0.0

[a] Each figure is an average of four replications.

with the results of 1974 and 1975 with the exceptions of green seed at Aitkin and Palisade.

We think the increased yields are good enough to recommend that growers can use Dithane M-45 in reducing losses from Helminthosporium blight. The results are not statistically significant, but the cost of application is low, approximately $16.00 per acre for 4 applications. With green wild rice selling at 70 cents per pound, only an increase of 23 pounds per acre will defray the cost of chemical sprays.

For several reasons it is highly desirable that these tests be repeated in 1977. Obviously, a test of this kind must be repeated to be of scientific and practical value. There was no epidemic in 1976. The question of how Dithane M-45 would perform in a moderate to severe epidemic is not answered.

The encouraging results with Bravo 6 F dictate that further tests with it should be made.

Development of Disease-Resistant Lines

Approximately 21,000 individual plants of wild rice were inoculated with a mixture of 10 cultures of Helminthosporium oryzae and sativum. The nurseries were planted at Grand Rapids and Rosemount, MN. Notes were taken on their reaction to blight one to three times during the growing season. Of the 21,000 plants 137 had significantly less blight than the most susceptible checks.

This is encouraging, although, none of those plants is highly resistant. Seed of these plants will be planted next year and their progenies will be examined for blight reaction. Also, these plants will be used as parental material for crossing with each other and other desirable plants.

Other Disease Studies

A fungus similar to the stem rot pathogen was found on white water lily. It infected wild rice. This is significant because the white water lily can serve as an overwintering host, it can perpetuate the life of the fungus, and it can serve as a source of primary inoculum in the growing seasons.

Results of studies on the survival of the stem rot organism indicate that it can live over winter only if imbedded in host tissue. Sclerotia free in the soil apparently cannot survive. If this is true, the results emphasize the need of destroying as much straw and stubble as possible to reduce the chances of survival of the pathogen in the fields.

A second bacterial disease was observed in the field, and it apparently is different from the bacterial streak that was reported last year. No work has been done on it up to this time. If it is different, another disease will have to be considered in commercial production of wild rice.

Experiments on Control of Wild Rice Insects

A. G. Peterson, J. E. Sargent, and D. M. Noetzel

We continued observations and experiments on the biology, evaluation of injury, and control of both the rice stalk borer (Chilo plejadellus) and the riceworm (Apamea apamiformis) during 1976. Light traps were operated daily at the Manomin Development Corporation north of Gun Lake in Aitkin County and at the Grand Rapids Experiment Station in order to determine flight periods and relative abundance of both stalk borer and riceworm adults. Light traps were operated every 6th day at Clearbrook, White Elk Lake, and at the Jacobson paddies located west of McGregor and south of Highway 210.

An insecticide experiment on one of the Manomin paddies was designed to compare several materials for control of the rice stalk borer and to provide an evaluation of injury. All the plots in this experiment were treated with malathion on Aug. 3 to control riceworms. A second experiment at Grand Rapids was designed to compare several materials for control of both stalk borers and riceworms and to evaluate the effects of both species on yields.

In order to evaluate further the effects of stalk borers on yields we collected heads from borer-infested stalks and heads from healthy stalks. Our samples were necessarily limited in size this year because of the low infestation of stalk borers. Heads were threshed separately to obtain average weights per head. We counted kernels of each head so that we could calculate the average weight per kernel as a measure of plumpness. (In 1975 there was some evidence that some kernels were not as well filled on borer-infested plants as on healthy plants.)

We placed riceworm larvae on bagged heads of wild rice at Grand Rapids at rates of 0, 1, 2 and 4 larvae per head with 20 replications in order to evaluate injury. Larvae were nearly all 3rd instar when they were placed in the bags Aug. 4 to 6. One of us (J.E.S.) made preliminary observations on the effect of methiocarb on riceworms.

The rice stalk borer.

Overwintered stalk borer larvae collected in May, 1976, were heavily parasitized by the braconid wasp, Chelonus knabi. 79% of the larvae were parasitized at Aitkin, 32% at Grand Rapids and 34% at Clearbrook. Although sanitation of ditch banks and rotovation of paddies, as well as the parasites, probably helped to reduce the infestation, adults were still numerous during June. Adults first emerged about June 4 (2 weeks earlier than in 1975), and light trap catches indicated a peak of abundance June 11-14. A second peak about June 22 followed a cool period which either interrupted emergence or reduced flight activity. Maximum light trap catches included 110 at Aitkin June 14, 195 at Aitkin June 22, 81 at Grand Rapids June 11, and 60 at Clearbrook on July 3. Egg masses were present on floating leaves from June 10 to July 10. Adult Chelonus wasps were actively ovipositing in stalk borer eggs at Aitkin during mid-June. Stalk borer oviposition was generally less than expected, and infestations were much lower than in 1975. Paddies at Clearbrook had only 1 to 2% of the stalks infested, and we found only 6% infestation in the experiments at Aitkin and Grand Rapids.

Chlordimeform (Galecron) applied July 1 and 9 at Aitkin and July 2 and 8 at Grand Rapids gave the best stalk borer control of any material we have tested (Tables 1 and 2). It has been reported to control rice stalk borers in Europe without harming fish, and it did not kill lady beetles in our experiments. Unfortunately, there is some question of carcinogenicity in mice, and the manufacturers withdrew all uses of chlordimeform until further tests can be made. At Aitkin both Bacillus thuringiensis (Dipel) and Dimilin were significantly less effective against stalk borers than chlordimeform but significantly better than diazinon or the untreated check (Table 1). At Grand Rapids only chlordimeform was significantly better than the check (Table 2). Only 6% of the stalks were infested in the checks, and the differences in yields were not significant at either location.

Table 1. Control of the rice stalk borer. Manomin Development Corporation. Aitkin, Minn., 1976. Insecticides were applied July 1 and July 9.

Treatment	Rate/A.	% Stalks infested	Yield/12 sq.yd.
B. thuringiensis	1.0 lb.	2.5[1]	621 gms.
Dimilin	0.5	2.0[1]	601
Diazinon	0.5	4.2	434
Chlordimeform	1.0	0.5[1]	520
Check	-	5.8	527

[1]Significantly lower than check at the 5% level.

Table 2. Control of the rice stalk borer. Grand Rapids, Minn., 1976. Insecticides were applied July 2 and July 8.

Treatment	Rate/A.	% Stalks infested	Yield/12 sq.yd.
B. thuringiensis	1.0 lb.	2.9	1,323
Dimilin	0.25	5.4	1,416
Chlordimeform	1.0	0.8[1]	1,529
Check	-	5.5	1,365

[1]Significantly lower than check at the 5% level.

Comparison of yields from heads of borer-infested and healthy stalks indicated that stalk borers may cause a slight loss in yield and a slight reduction in kernel weight (Table 3). According to these results a 100% infestation of stalk borers might be expected to result in a 6% loss in yield. The corresponding figures for yield losses in borer-infested stalks in 1975 were 5% for Grand Rapids and 9% for Clearbrook (Table 4). All of our evidence indicates that the rice stalk borer has relatively little effect on yields of wild rice. Probably the larger stalks of wild rice, as compared to those of white rice, make the wild rice tolerant to injury by the stalk borer.

Table 3. Yields of rice from borer-infested and healthy stalks. Aitkin, 1976.

	No. of heads	Kernels/head	Wt./head	Wt./kernel
Borer-infested	57	185.8	2.363 gm.	0.0127 gm.
Healthy	204	174.9	2.535	0.0145
Decrease in borer-infested			6%	12%

Table 4. Yields of rice from borer-infested and healthy stalks, 1975, in gms/head.

	Grand Rapids	Clearbrook
Borer-infested	2.017	1.815
Healthy	2.126	1.996
Decrease	5%	9%

We believe that rotovation of paddies soon after harvest and cleaning up ditch banks, together with natural control by parasites, will make the use of insecticides unnecessary for control of the stalk borer.

The riceworm.

First emergence of riceworm adults on June 24 coincided with the first heading of wild rice and the first blossoming of common milkweed, and all were about 2 weeks earlier than in 1975. However, the main flight period of riceworm moths occurred from July 3 to July 22 which was not much earlier than usual. Light trap collections indicated that riceworm adults were less numerous than in 1975 at all locations. On Aug. 1 we recommended that growers apply malathion to control riceworms where the worms exceeded 20 per 100 heads. Most of the eggs had hatched by this time, and the riceworms were in about the same stages of development as they were on Aug. 1, 1975. The wild rice, on the other hand, was 2 weeks closer to maturity than it was in 1975. The early maturity of the wild rice resulted in much less damage from riceworms. This observation was substantiated in our experiment in which we placed 0, 1, 2 and 4 riceworms per head on bagged heads Aug. 4 to 6. Some of the young 3rd instar riceworms apparently were not able to feed on the developing kernels, and very few of the larvae reached the 6th instar by harvest time on Aug. 23. The result was much less injury than we expected. It was certainly not typical of the damage usually caused by riceworms. The correlation of -0.35 between numbers of riceworms per head and yields was statistically significant but indicated a surprisingly low degree of association. We suspect that the early-maturing variety Exp. 1 developed by Agronomy and Plant Genetics may have less injury from riceworms than later varieties, and we are anxious to test this new variety under field conditions.

None of the materials applied to control the stalk borer at Aitkin and Grand Rapids in early July had any effect on oviposition by riceworm adults or on subsequent populations of riceworms. In the Aitkin experiment, an application of malathion by air to all the plots on Aug. 3 gave excellent control of riceworms. Bacillus thuringiensis (Dipel), Dimilin, and malathion were compared for control of riceworms in the plots at Grand Rapids. Malathion was more effective than either of the other materials (Table 5). Populations of riceworms were rather low and variable in the plots, and control did not result in any significant differences in yields.

Table 5. Control of riceworms. Grand Rapids, 1976. Insecticides were applied on Aug. 5.

Treatment	Rate/A. lbs.	Average riceworms per 50 heads July 26	Aug. 6	Aug. 13	Yield in gms/12 sq.yd.
B. thuringiensis	1.0	9.0	13.8	9.3[1]	1,323
Dimilin	0.25	4.5	6.3[1]	1.5[1]	1,416
Malathion	1.0	10.0	0.8[1]	0.5[1]	1,284
Check	-	9.0	13.3	17.3	1,365

[1]Significantly lower than check at 5% level.

Preliminary observations in the Manomin and Jacobson paddies in Aitkin County indicate that methiocarb, which is being tested as a blackbird repellent, controlled riceworms almost as effectively as malathion (Table 6).

Table 6. Effect of methiocarb on riceworms. Aitkin, 1976.

	Riceworms per 50 heads Manomin	Jacobson
Before treatment July 29	27	39
After treatment Aug. 1	7	1

Studies in the Control of Blackbird Damage to Cultivated Wild Rice: 1976 Research Report. D. W. Moulton[1], K. C. Carr[2], R. S. Wetzel[2], M. W. Weller[1]

Research on the control of blackbird damage to cultivated wild rice crops in 1976 centered around testing the carbamate insecticide methiocarb [3, 5- dimethyl-4-(methylthio) phenol methylcarbamate]. Of over 700 compounds tested, methiocarb is the most promising candidate chemical bird repellent yet found (Schafer and Brunton, 1971). This report describes the results of the 1976 methiocarb field trial in northern Minnesota, and the results of some feeding trials with caged red-winged blackbirds.

RESEARCH OBJECTIVES

1) Determine losses of wild rice due to direct consumption and indirect losses due to blackbird feeding activity (shattering).

2) Determine the effectiveness of methiocarb in protecting wild rice from blackbird damage under field and cage conditions.

3) Band and color-mark blackbirds to determine if local birds are mainly involved in damage and where these birds winter.

4) Determine the effect of methiocarb on wild riceworm (*Apamea apamiformis*) populations.

5) Collect samples of rice, mud, water, and straw to be used for residue testing if required. Determine methiocarb residues on green and processed rice.

STUDY AREA

The field trial was conducted in the Aitkin-Palisade area on M3 seed-rice paddies owned by the Manomin Wild Rice Co. and the Jacobson Bros. The caged-blackbird feeding trials were conducted in St. Paul.

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METHODS AND MATERIALS

Field Trial- Methiocarb (75 percent wettable powder provided by Chemagro, Division of Mobay Chemical Corp.) was applied to the Manomin paddy at the rate of 1.5 lb. (active) in 10 gal. of water/ac by helicopter (Paul Dagnon, Apple Valley, MN). Triton CS7 was used as the binder. Other chemical treatments (dithane and malathion) were the same for both paddies. Methiocarb was applied on 30 July and again on 14 August. Five open and five exclosed plots (1.5 m^2) were randomly located in both the treatment and control paddies (Fig. 1). The 8-ft^3 exclosures (5 in each paddy) were covered with plastic mesh to protect the plots from bird damage. Ten waxed-paper cups (17 cm deep, 9 cm mouth diam.) on wood stakes were randomly placed in each of the 20 plots. The cups were an attempt to estimate shattering loss due to blackbird activity. At harvest (23 August) the cups were collected and the number of rice grains in each recorded. All the rice in the 1.5 m^2 plots was collected, threshed, oven dried at 60°C for 1 week, and weighed (unhulled) to the nearest 0.5 gm. Yield samples were used to estimate blackbird damage in the two paddies. An elevated platform was constructed so blackbird feeding activity could be observed. A 3 lb/ac treatment was applied to 8 ac of a 12 ac paddy (Jacobson) by fixed-wing aircraft (Steve Kurtz, Aitkin, MN) on 30 July (15 gal water/ac) and again on 13 August (10 gal water/ac). Samples of rice, mud, water and straw were collected at weekly intervals (both treatment levels) and frozen for possible residue testing. Samples of green and processed rice (1.5 lb/ac level only) were sent to the Denver Wildlife Research Center (J. F. Besser, E. W. Schafer) to be tested for methiocarb residue.

Feeding Trials (Oct.-Nov. 1976)- Male red-winged blackbirds were held in cages indoors under 24 hr light/day. They were fed dried, unhulled wild rice and water, both ad libitum. Cages 2 and 3 held the same birds (3 in each cage) throughout the feeding trials. Cage 1 held 3 birds during Trial 1 but only 1 of these survived for Trial 2. Cage 1 held a new group of 3 birds (previously unexposed to methiocarb) during Trial 3 and they remained there for Trials 4 and 5. The trials consisted of offering the birds a choice between untreated rice and rice treated with various concentrations of methiocarb solutions (0.06, 0.1 and 0.5 percent active). These levels were chosen on the basis of work by Schafer and Brunton (1971) and Rogers (1974). In some trials the solutions were sprayed (plant mist bottle) onto the rice and in some the rice was soaked. Some trials incorporated a time period when only treated rice was offered. Measurements of rice consumed were to the nearest 0.1 gm. A sample of rice soaked in a 0.1 percent methiocarb solution was sent to the Denver Wildlife Research Center for residue testing.

RESULTS

Field Trial- The results of the shattering experiment (cups) are in Table 1. In the treated paddy (1.5 lb/ac), the mean number of shattered grains/plot (10-cup total) was 67.8 in the open plots (exposed to bird damage) and 78.6 in the exclosed plots (protected from bird damage). In the control paddy (0 lb/ac), the mean number of shattered grains/plot was 87 in the open plots and 80.4 in the exclosed plots. Open plot #5 in the control paddy (Co5) was omitted from these and all subsequent calculations because the observation platform was located too close to plot Co5 and the presence of the observer prevented birds from feeding in that plot. An analysis of variance was performed on the data of Table 1. No statistically significant ($\underline{P}<0.5$) shattering loss can be attributed to blackbird activity on the basis of this experiment. M3 is a shatter-resistant strain. An analysis of variance of the yield samples (Table 2) compared the protected (exclosed) and unprotected (open) plots within paddies. We compare the yield difference between open and exclosed plots within the treated paddy with that difference within the control paddy. In the control paddy, the mean dry weight/open plot was 73 gm compared to a mean of 151.4 gm for the exclosed plots. The open plots yielded 51.8 percent less rice than the exclosed plots. In the treatment paddy, the mean dry weight/open plot was 91.8 gm compared to a mean of 104.9 gm for the exclosed plots, a loss in yield of 12.5 percent. The yield loss for the control paddy open plots is significantly greater ($0.025 > \underline{P} > 0.01$) than the yield loss for the treatment paddy open plots. The yield difference is probably due to the blackbird-repelling property of methiocarb.

The data for blackbird-feeding activity (Table 3) in the two paddies tend to support this hypothesis. Perhaps the most striking feature of these data is the number of days during which there was no blackbird feeding activity; there were 14 such days in the treated paddy compared to 4 in the control paddy.

Feeding Trials- Trial 1 (Table 4) offered the birds a choice between untreated rice and rice sprayed with a 0.06 percent solution of methiocarb. The trial was terminated after 28 hr since the treated rice did not appear to repel the birds. A subsequent trial (3) using the same treated rice indicated that a repellent effect may have been observed had Trial 1 been continued for a longer period.

Trial 2 (Table 5) offered the birds a choice between untreated rice and rice soaked in a 0.1 percent solution of methiocarb. The trial continued for 3 days, and there is little doubt that the birds avoided the treated rice in favor of the untreated alternative. The amount of untreated rice eaten by the birds was 87.9 percent of their total consumption (Table 6). This is a very highly significant ($\underline{P} < 0.001$) departure from the expected 50 percent for birds showing no avoidance of treated rice.

Trial 3 (Table 7) provided some useful information even though it did not lend itself to statistical analysis. This trial offered the birds a choice between untreated rice and the same treated rice used in Trial 1 (0.06 percent). During the first 24 hr the new group of birds (not previously exposed to methiocarb) in cage 1 showed no aversion to the treated rice. This result is similar to that of Trial 1. However, after the first 24 hr an aversion to the treated rice appears to have developed in the new birds. The birds in cages 2 and 3 (exposed to 0.1 percent in Trial 2) showed an immediate aversion to the treated rice. When the untreated rice was withdrawn the birds ate the treated rice in quantities approximating their normal total consumption of rice for the same time period. The aversion to the 0.06 percent rice was not strong enough to prevent the birds from eating the treated rice in the absence of an alternative food source.

Trial 4 (Table 8) showed this to be true also for rice treated with the 0.1 percent solution (both sprayed and soaked). When only treated rice was offered, the birds ate it in amounts approximating their normal total consumption for the time period involved (24 hr).

Trial 5 (Table 9) offered the birds only rice soaked in a 0.5 percent solution of methiocarb. The birds showed a very strong aversion to this rice. In fact, the birds entered the initial stages of starvation, as evidenced by their green (bile pigments) droppings, rather than eat the treated rice. An analysis of variance was performed on the combined data of Trials 4 and 5 (Table 10). The mean consumption/cage/day (3 days) during Trial 4 was 30.9 gm compared to 4.6 gm/cage (1 day) in Trial 5. The difference between these means is very highly significant ($\underline{P} < 0.001$).

<u>Birds Banded</u>.- In 1976, a total of 440 blackbirds were banded: 211 red-winged blackbirds (including 29 nestlings); 112 yellow-headed blackbirds (including 2 nestlings); 86 common grackles; 30 bobolinks; and 1 brown-headed cowbird. Band returns may eventually provide information on where blackbirds from the upper Midwest spend the winter. The yellow-headed blackbird leaves its breeding areas before wild rice begins to ripen and is therefore not part of the rice-damage problem. Colored streamers were placed on 46 adult male yellow-headed blackbirds and 10 adult male and 2 nestling red-winged blackbirds.

<u>Effect of Methiocarb on Wild Riceworm Populations</u> - Pre- and posttreatment counts of wild riceworms in the experimental paddies were made by J. E. Sargent for both treatment levels (1.5 and 3.0 lb/ac). These data will be reported by A. G. Peterson.

<u>Residue Data</u> - Thin-layer chromatography (accurate to within ± 10 percent) gave the following posttreatment residues for rice collected after the second methiocarb application (1.5 lb/ac) at Manomin: day 1 = 100 ppm, day 7 = 43 ppm, day 14 = 7-9 ppm, processed rice had no detectable (<2ppm) residue. There was no appreciable posttreatment rainfall. The rice soaked in a 0.1 percent solution of methiocarb (feeding Trials 2 and 4) had about 169 ppm residue.

CONCLUSIONS

Blackbirds do not ingest the hull of the wild rice grain. This is probably also true of other small grains which are protected by a hull. This being the case, there is some question as to whether the birds will ingest enough methiocarb to produce the physiological effects that would lead to a conditioned aversive response. In the studies of Schafer and Brunton (1971), where hulled white rice was treated, and Rogers (1974), where the methiocarb was mixed into a mash, a conditioned aversion to the effects of the chemical (nausea and regurgitation, immobilization, or death) did develop. The present study represents a more realistic model for ripening wild rice. The following conclusions seem justified: 1) the birds detected the methiocarb at all treatment levels; 2) the birds avoided the treated rice at all levels when an alternative food was offered; 3) avoidance at the 0.06 percent level was stronger and more rapid in birds previously exposed to a higher level (0.1 percent); 4) the birds ate the rice at the 0.06 and 0.1 percent levels in the absence of an alternative food; 5) the birds refused to eat the rice at the 0.5 percent level even in the absence of an alternative food. These experiments do not define the mode of action of methiocarb. However, they indicate that the response is probably a conditioned aversion to the toxic effects of the chemical which the birds associate with the taste rather than a simple taste aversion. The conditioned aversive response produced by punishment (illness) for eating toxic food is a much more powerful behavioral response than a simple taste aversion produced by bad-tasting but non-toxic food (Alcock 1970a, b).

The field trial indicated that the two, 1.5 lb/ac - applications of methiocarb did afford considerable protection from blackbird damage. The fact that the yield data were consistent with the blackbird feeding-activity data tends to strengthen this conclusion.

PROPOSED RESEARCH-1977

The same regulations governing the experimental use of methiocarb in 1976 will likely pertain in 1977, i.e. only seed-rice paddies $\leq$ 10 ac can be treated. Therefore, the 1976 experiment on the Manomin paddies will be repeated in 1977 with the control and treatment paddies reversed. If the yield and blackbird-feeding results are also reversed, the hypothesis that methiocarb protects wild rice from blackbird damage will be strengthened. The treatment level should probably be kept at 1.5 lb/ac so the results from the 2 years will be comparable. In addition, 1 ac of rice will be available for study at the North Central Experiment Station in Grand Rapids in 1977. This paddy will be divided and half treated with methiocarb (perhaps at a rate of 1.0 lb/ac active) and the other half left untreated. The experimental design will probably be similar to that used on the Manomin paddies. The Grand Rapids paddy will be separated from the other experimental paddies and should be subject to heavy blackbird pressure. The need to observe blackbird activity on two widely separated areas in 1977 may necessitate the hiring of a part-time field assistant.

It may be desirable to run additional feeding trials in the fall of 1977. If this is done, birds should be housed individually so as to avoid dominance hierarchy (peck order) problems which are unavoidable when groups of birds are used as the experimental units.

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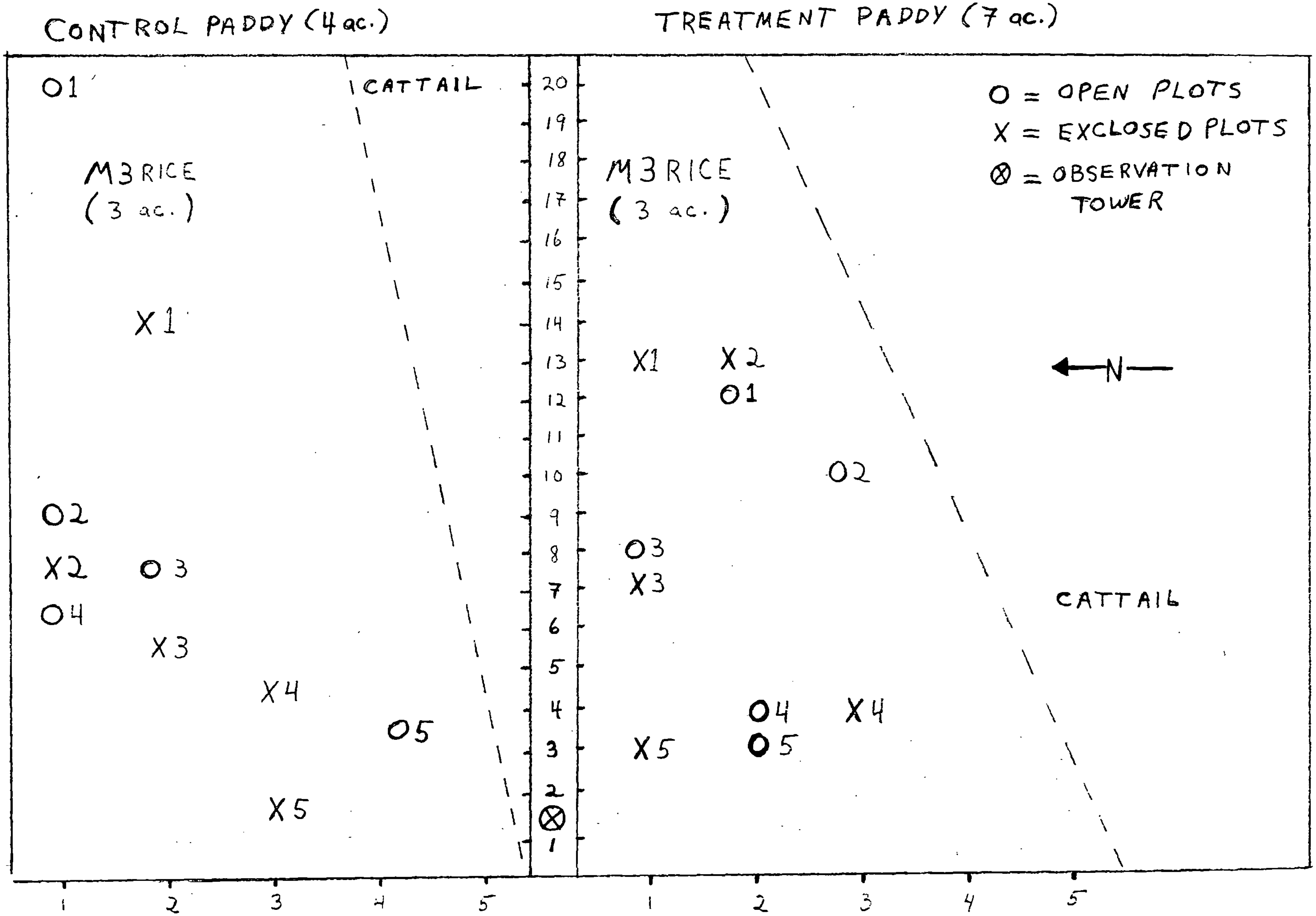


Fig. 1. Experimental seed-rice paddies used for methiocarb field trial, Manomin, 1976.

Table 1. Shattering loss (M3 rice) due to blackbird activity, Manomin, 1976.

TREATMENT PADDY

# grains/	Open Plots T_o1	T_o2	T_o3	T_o4	T_o5	Exclosed Plots T_x1	T_x2	T_x3	T_x4	T_x5
cup 1	8	6	10	13	7	19	16	12	12	4
2	12	7	10	14	6	18	11	8	6	7
3	10	5	11	7	4	10	9	3	13	9
4	8	9	9	13	8	10	12	4	9	20
5	20	3	7	10	5	11	4	3	5	3
6	10	2	5	7	7	8	4	2	2	3
7	1	3	1	4	2	6	14	12	1	6
8	1	5	2	10	17	5	14	4	3	3
9	0	3	1	4	2	12	8	3	3	2
10	7	7	6	7	3	4	11	9	4	12
Totals	77	50	62	89	61	103	103	60	58	69
Means			67.8					78.6		

CONTROL PADDY

# grains/	Open Plots C_o1	C_o2	C_o3	C_o4	C_o5*	Exclosed Plots C_x1	C_x2	C_x3	C_x4	C_x5
cup 1	10	22	8	5	6	6	8	14	9	11
2	6	6	3	14	4	2	6	6	6	5
3	16	8	3	14	4	9	4	10	5	10
4	5	5	9	13	7	10	4	10	8	9
5	4	2	5	7	8	11	12	10	7	9
6	5	6	10	10	1	7	13	11	6	4
7	4	13	6	12	11	4	5	11	9	13
8	4	9	6	19	5	5	13	8	5	19
9	7	6	10	17	2	7	13	7	8	6
10	8	17	6	8	4	8	1	8	6	4
Totals	69	94	66	119	52	69	79	95	69	90
Means			87.0					80.4		

* C_o5 omitted from mean (see text).

Table 2. Methiocarb field trial, Manomin, 1976. Yield samples of dried, unhulled rice weighed to nearest 0.5 gm.

Plot	Control Paddy C_o	Control Paddy C_x	Treatment Paddy T_o	Treatment Paddy T_x
1	97.0	197.5	110.0	118.0
2	66.5	115.0	85.5	139.5
3	65.5	125.5	86.5	68.5
4	63.0	169.5	89.5	82.5
5	168.5*	149.5	87.5	116.0
Totals	292.0	757.0	459.0	524.5
Mean	73.0	151.4	91.8	104.9
% loss	51.8		12.5	

H_o: $\overline{C_x} - \overline{C_o} = \overline{T_x} - \overline{T_o}$ $\underline{t}_{(15)} = 2.897$*

* C_o5 omitted from all computations (see text).

Table 3. Estimated Daily Blackbird Numbers Observed Feeding, Manomin, 1976.

Date	Control Paddy		Treatment Paddy
7/17	0		50
7/26	0		300
7/30	-	Methiocarb	-
7/31	0		0
8/1	15		0
8/2	500	Malathion	0
8/3	500		0
8/4	36		0
8/5	36		0
8/7	0		60
8/8	0		100
8/9	2300		300?
8/10	300		0
8/11	300		0
8/12	200		0
8/13	150		0
8/14	200	Methiocarb	0
8/15	0		100
8/16	24		0
8/17	300		0
8/18	300		100?
8/19	100		200
8/20	40		40
8/21	500		24
8/23	500	Harvest	0
Totals	6301		924
# of zero - activity days	4		14

? = uncertain that birds actually fed

Table 4. Feeding Trial 1. Rice sprayed with a 0.06 percent methiocarb solution.

Date	Time	Cage 1(3 birds)		Cage 2(3 birds)		Cage 3(3 birds)	
		U[1]	T	U	T	U	T
10-15	8:00am	- - - - - S T A R T - - - - -					
10-15	12:00am	194/200[2]	197/200	200/200	200/200	199/200	200/200
10-15	4:00pm	98/200	198/200	200/200	200/200	200/200	200/200
10-16	12:00am	9/20[3]	12.1/20	17.1/20	16.6/20	16.9/20	6.3/20

1 U = untreated; T = treated

2 grains eaten / grains offered

3 gm eaten / gm offered

Table 5. Feeding Trial 2. Rice soaked in a 0.1 percent methiocarb solution.

Date	Time	Cage 1(1 bird) U	Cage 1(1 bird) T	Cage 1(1 bird) TOT	Cage 2(3 birds) U	Cage 2(3 birds) T	Cage 2(3 birds) TOT	Cage 3(3 birds) U	Cage 3(3 birds) T	Cage 3(3 birds) TOT
10-19	8:00am			- - - - - - - S T A R T - - - - - - -						
10-19	4:30pm	4.9/20[1]	1.2/20	6.1	12.8/20	6.1/20	18.9	10.5/20	1.9/20	12.4
10-20	8:00am	5.9/20	0.1/20	6.0	13.3/20	3.3/20	16.6	10.5/20	0.2/20	10.7
24-hour TOTALS		10.8	1.3	12.1	26.1	9.4	35.5	21.0	2.1	23.1
10-20	4:30pm	6.3/20	0/20	6.3	16.1/20	2.3/20	18.4	12.8/20	0.1/20	12.9
Switch cups										
10-21	8:00am	5.3/20	0.6/20	5.9	12.8/20	3.7/20	16.5	7.3/20	3.3/20	10.6
24-hour TOTALS		11.6	0.6	12.2	28.9	6.0	34.9	20.1	3.4	23.5
10-21	4:30pm	3.9/20	0.1/20	4.0	14.1/20	0.5/20	14.6	8.6/20	2.9/20	11.5
10-22	8:00am	6.5/20	0/20	6.5	16.9/20	0.7/20	17.6	10.5/20	2.3/20	12.8
24-hour TOTALS		10.4	0.1	10.5	31	1.2	32.3	19.1	5.2	24.3
10-22	12:00am		0.5/40			2.7/40			1.5/40	
10-22	4:30pm		1.1/40			5.9/40			3.6/40	
			1.6			8.6			5.1	
10-23	1:00pm	10/20	0.1/20		25.9/30	4.3/20		17.1/20	6.0/20	

[1] gm eaten / gm offered

Table 6. Untreated rice consumed as percent of total consumed in Trial 2.

	Cage 1	Cage 2	Cage 3	Row Means
Day 1	0.893	0.735	0.909	0.846
Day 2	0.951	0.828	0.855	0.878
Day 3	0.990	0.963	0.786	0.913
Column Means	0.945	0.842	0.850	

Ho: $\frac{\Sigma\hat{p}}{9} = 0.50$ $\frac{\Sigma\hat{p}}{9} = 0.879$

$\underline{t}(4) = 12.74^{**}$

Table 7. Feeding Trial 3. Rice sprayed with a 0.06 percent methiocarb solution.

Date	Time	Cage 1(3 birds)*			Cage 2(3 birds)			Cage 3(3 birds)		
		U	T	TOT	U	T	TOT	U	T	TOT
10-27	8:30am			- - - - - - S T A R T - - - - - -						
10-27	4:30pm	8/20[1]	7.2/20	15.2	11.8/20	1.2/20	13.0	7.9/20	5/20	12.9
Switch cups										
10-28	8:30am	9.8/20	8.8/20	18.6	15.8/20	2.0/20	17.8	11/20	3.6/20	14.6
24-hour TOTALS		17.8	16.0	33.8	27.6	3.2	30.8	18.9	8.6	27.5
- - - -										
Switch cups										
10-28	4:30pm	8.4/20	2.7/20	11.1	13/20	0.5/20	13.5	9/20	5.7/20	14.7
Switch cups										
10-29	8:00pm	20.7/40	10.8/30	31.5	30.3/50	2.1/30	32.4	22.1/40	6/30	28.1
32-hour TOTALS		29.1	13.5	42.6	43.3	2.6	45.9	31.1	11.7	42.8
- - - -										
11-1	4:30pm			- - - - - - S T A R T - - - - - -						
11-2	8:30am	15.8/30				18.8/30			19.5/30	

* Three new birds not previously exposed to methiocarb.

[1] gm eaten / gm offered

Table 8. Feeding Trial 4. Rice sprayed with a 0.1 percent methiocarb solution.

Date	Time	Cage 1(3 birds) U	Cage 1 T	Cage 1 TOT	Cage 2(3 birds) U	Cage 2 T	Cage 2 TOT	Cage 3(3 birds) U	Cage 3 T	Cage 3 TOT
11-2	8:30am				- - - - - S T A R T - - - - -					
11-2	4:30pm	12.6/20	2.6/20	15.2	13.9/20	2.6/20	16.5	12.1/20	3.3/20	15.4
Switch cups										
11-3	8:30am	15.2/25	2.9/20	18.1	17.9/25	3.1/20	21	16.2/20	5.8/20	22
24-hour TOTALS		27.8	5.5	33.3	31.8	5.7	37.5	28.3	9.1	37.4
- - -										
11-3	12:30pm		3.2/20			4.2/20			4/20	
11-3	4:30pm		5.5/17.1			6.9/16.9			6/14.2	
11-4	8:30am		16/20			16.6/20			16.5/20	
24-hour TOTALS			24.7			27.7			26.5	
- - -										
11-4	4:30pm		10.4/20			14.1/20			10/20	
Switch to 0.1% soaked										
11-5	8:30am		18.2/25			19.5/25			19/25	
24-hour TOTALS			28.6			33.6			29	

Table 9. Feeding Trial 5. Rice soaked in a 0.5 percent methiocarb solution.

Date	Time	Cage 1(3 birds) U	Cage 1(3 birds) T	Cage 2(3 birds) U	Cage 2(3 birds) T	Cage 3(3 birds) U	Cage 3(3 birds) T
11-8	4:30pm		- - - - - S T A R T - - - - -				
11-9	8:30am	15.6/30	0.8/20	17.9/30	1.2/20	15.5/30	0.4/20
- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
11-9	1:00pm		0.7/20		0.8/20		1.1/20
11-9	4:30pm		0.4/19.3		0.6/19.2		0.1/18.9
11-10	8:30am		2.6/20		3.8/20		3.7/20
24-hour TOTALS			3.7		5.2		4.9
- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
11-10	4:30pm		3.6/17.4		3.0/16.2		1.7/16.3

Table 10. Total daily consumption of rice (gm) during Trials 4 and 5. An analysis of variance was performed on the combined data.

	Cage 1	Cage 2	Cage 3	Row Means
Day 1	33.3	37.5	37.4	36.067
Day 2	24.7	27.7	26.5	26.3
Day 3	28.6	33.6	29.0	30.4
Day 4	3.7	5.2	4.9	4.6
Column Means	22.58	26.0	24.45	

Ho: $\bar{R}_4 = 1/3\ (\bar{R}_1 + \bar{R}_2 + \bar{R}_3)$

$\underline{t}\ (6) = 31.86^{**}$

Harvest Losses and Study of Separation Within the Combine

by

C. E. Schertz and J. J. Boedicker

This research work has looked at the harvest losses with emphasis on the combine discharge losses. Also studies have been made of the separation process within the combine to help provide information useful in reducing the discharge losses.

Discharge loss

Discharge losses were measured for one combine while harvesting in one field. To collect the discharge losses, a cloth catcher was inserted beneath the rear of the combine. Separate catching cloths were inserted to collect the straw walker discharge, sieve discharge and the discharge over the rear of the return grain pan. Eight replications 25 ft to 40 ft travel distance) were made of these discharge losses. These were done in conjunction with the net yield determinations made by Dr. Kernkamp on a series of plots for evaluation of disease control. After collection of the discharged material, it was bagged, weighed, dried, reweighed, threshed, sorted, dehulled, resorted, and dried to zero moisture. The weight of dried, dehulled rice was converted to equivalent weight of processed rice (7% Mwb) per acre. The data for these discharge losses are tabulated in Table 1. The losses from the walker and sieve are considered to be high. The loss over the rear of the grain return pan is satisfactory; however, combines have been observed where the build-up of material on the grain return pan was causing loss of rice over the rear of this pan.

Amount of material over walkers

Also, from these collections of the combine discharge, information was determined on the feed rate of the MOG (material other than grain) (straw and chaff). This data, tabulated in Table 1, averaged 8,210 lb MOG per acre. The moisture content of the material going over the walkers was 70% Mwb. Considering a 2 mph travel speed and cutting full width with a 16 ft header, results in 530 lb of MOG per min.

Table 1. Combine discharge losses and MOG feed rate.

Run No.	Net yield processed rice	Combine discharge losses as processed rice at 7% Mwb* — Walker lb/ac	Sieves lb/ac	Pan lb/ac	Total lb/ac	Total % of Net yield	Discharge Material (straw, chaff & rice) lb/ac	Moisture % Mwb
1	327	72.7	11.9	0.4	85.0	26.0	9,100	74
2	304	58.9	13.8	0.3	73.0	24.0	9,520	73
3	311	61.1	10.6	0.3	72.0	23.2	9,740	75
4	352	44.9	10.8	0.5	56.2	16.0	6,280	68
5	306	50.6	11.8	0.3	62.7	20.5	7,770	71
6	265	43.9	16.7	0.3	60.9	23.0	7,070	57
7	240	98.2	12.9	0.3	111.4	46.4	9,560	71
8	370	53.3	19.8	0.2	73.3	19.8	6,660	73
Avg.	309	60.4	13.5	0.3	74.2	24.0	8,210**	70
Percent of net yield		19.5	4.4	.1	24.0		---	--

* The rice was dried, dehulled and weighed. (The dry matter weight was converted to moisture level of 7% Mwb).

** Rate of 530 lb/min considering 2 mph (estimated) travel speed.

Gathering loss

Gathering losses were determined in the same field with the same combine used for the discharge loss measurement. To evaluate the gathering losses, groups of cups (cottage cheese cartons) were placed in the field and the combine operated until the header had traveled over the forwardmost cup. Then the combine was stopped and backed a distance to permit retrieving the cups. The rice in the cups was taken as gathering loss. The results for these tests are tabulated in Table 2.

Table 2. Gathering loss.

Replication No.	Gathering loss lb/ac
1	29
2	31
3	33
4	22
5	38
6	28
Average	30 lb/ac

Preharvest loss

Preharvest loss measurements were made in the same field and near where the combine discharge material was collected. To make the preharvest loss measurenents, a 1' x 1' frame was laid on the ground in the unharvested rice. The rice on the ground within this frame was preharvest loss. The data for these preharvest loss measurements is tabluated in Table 3.

Table 3. Preharvest loss.

Replication No.		Preharvest loss lb/ac
1		126.9
2		87.7
3		152.7
4		80.5
5		168.2
6		270.3
	Average	148 lb/ac

Separation of rice from straw within the combine

Studies have been undertaken to help understand the separation process that occurs within the combine. A procedure has been developed for determining the amount of rice being separated at various positions from cylinder to end of straw walker. A schematic diagram of the procedure is shown in Figure 1. The procedure makes use of a parked combine from which the sieves have been removed. A tray with compartments is place beneath the cylinder concave, beater fingers, and straw walker. A slatted canvas is placed over the tray. The slats on the canvas provided support for the canvas between the sides of the tray. The slatted canvas is somewhat like the shutter system of a camera with a focal plane shutter, it has an opening in it through which the sample falls on the tray. The combine is fed by means of a powered conveyor which is loaded with cut rice to simulate a typical harvest rate. When the combine is operating at steady state conditions, the slatted canvas is pulled rearward at a speed equal to the speed of the material through the combine. This permits the opening (4' by width of machine) in the slatted canvas to move rearward at the rate of material speed through the combine. This correlation of speed is desired so that the sampling (through the opening in the slatted canvas) at all points in the combine is taken from the same straw material throughout the machine. To alter the time of sampling, the length of opening in the slatted canvas is altered.

This procedure, with components as used, provided the opportunity to collect separately: 1) the material coming through the concave, 2) the material coming through the beater fingers, 3) the material coming through each one-foot increment of walker length, and 4) the material coming over the end of the walkers.

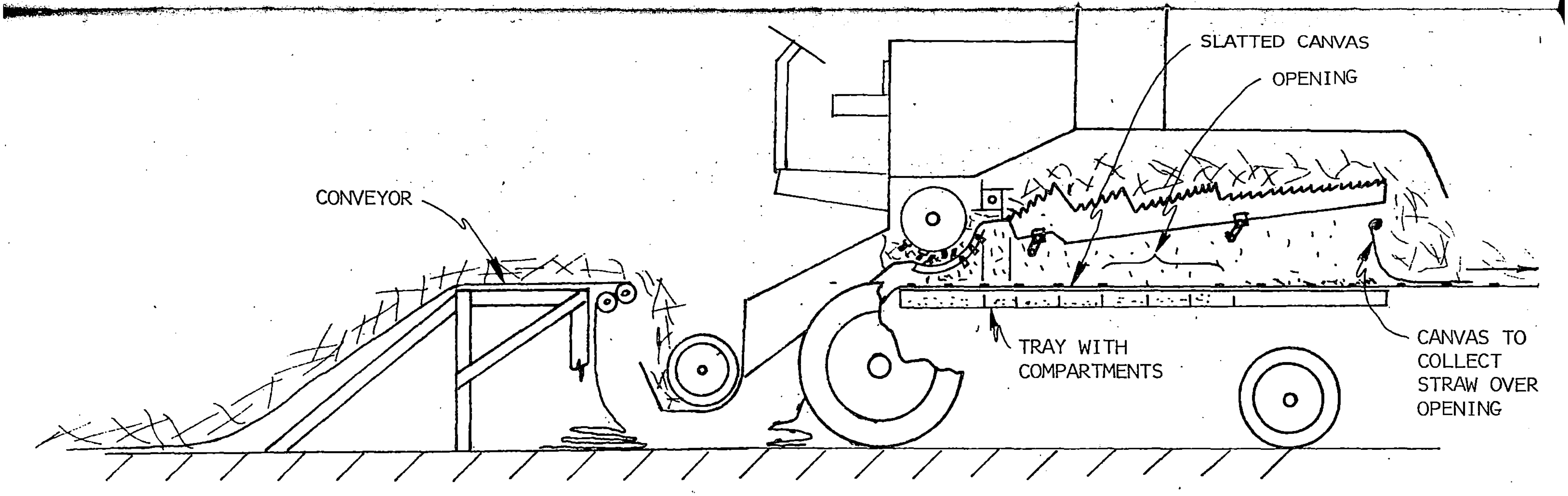
Eight separate runs were made with this procedure. The result was that the first four were used to debug the technique and get partitions and cutoff sheets in their proper places. For the last four runs, realistic data was obtained and are tabulated in Table 4 and 5. Because of the windrowing operation before testing the rice was somewhat drier than for normal harvest operations. The data for the separation through the walkers is shown in graphical form in Figure 2. This data on walker separation when plotted on semi-log paper helps determine the walker half-length. The walker half-length is that length of walker required to separate half (50%) of the rice entering upon the respective segment of the walker. The first third of walker shows a half-length of 1.5 ft and the end third of walker shows a half-length of 4.5 ft. The reasons for the difference in walker half-length characteristics have not been determined.

Table 4. Percent separation at cylinder concave and beater fingers.

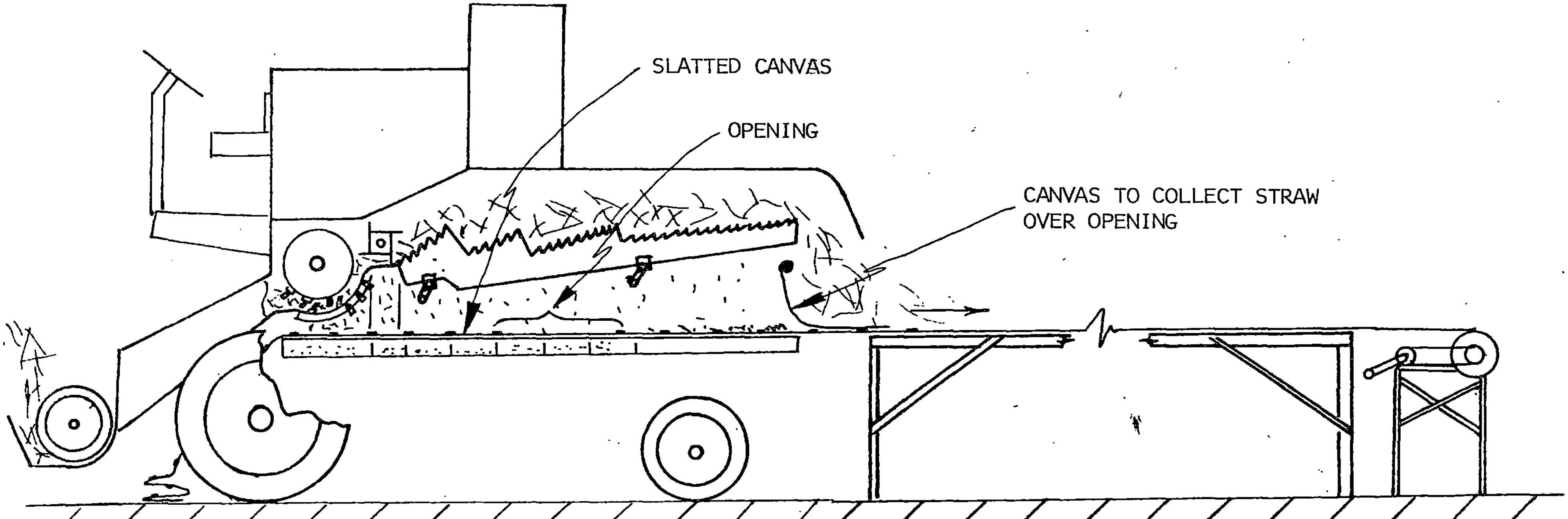
Run No.		Percent separation at cylinder concave	Percent separation at Beater fingers
5		34	25
6		48	23
7		33	23
8		42	27
	Average	39	25

Table 5. Percent, of total coming onto walkers, and not separated at start of indicated increment of walker length.

Run No.	Percent not separated at indicated increment of walker length. 0-1'	1-2'	2-3'	3-4'	4-5'	5-6'	6-7'	Overend
5	100	59	33	19	14	12	10	9
6	100	58	29	17	10	8	8	6
7	100	68	46	33	28	24	21	16
8	100	52	28	18	14	12	10	8
Avg.	100	59	34	22	16	14	12	10



FEEDING OF COMBINE



SAMPLING SEPARATION MATERIAL

Fig. 1. Schematic of combine for separation studies.

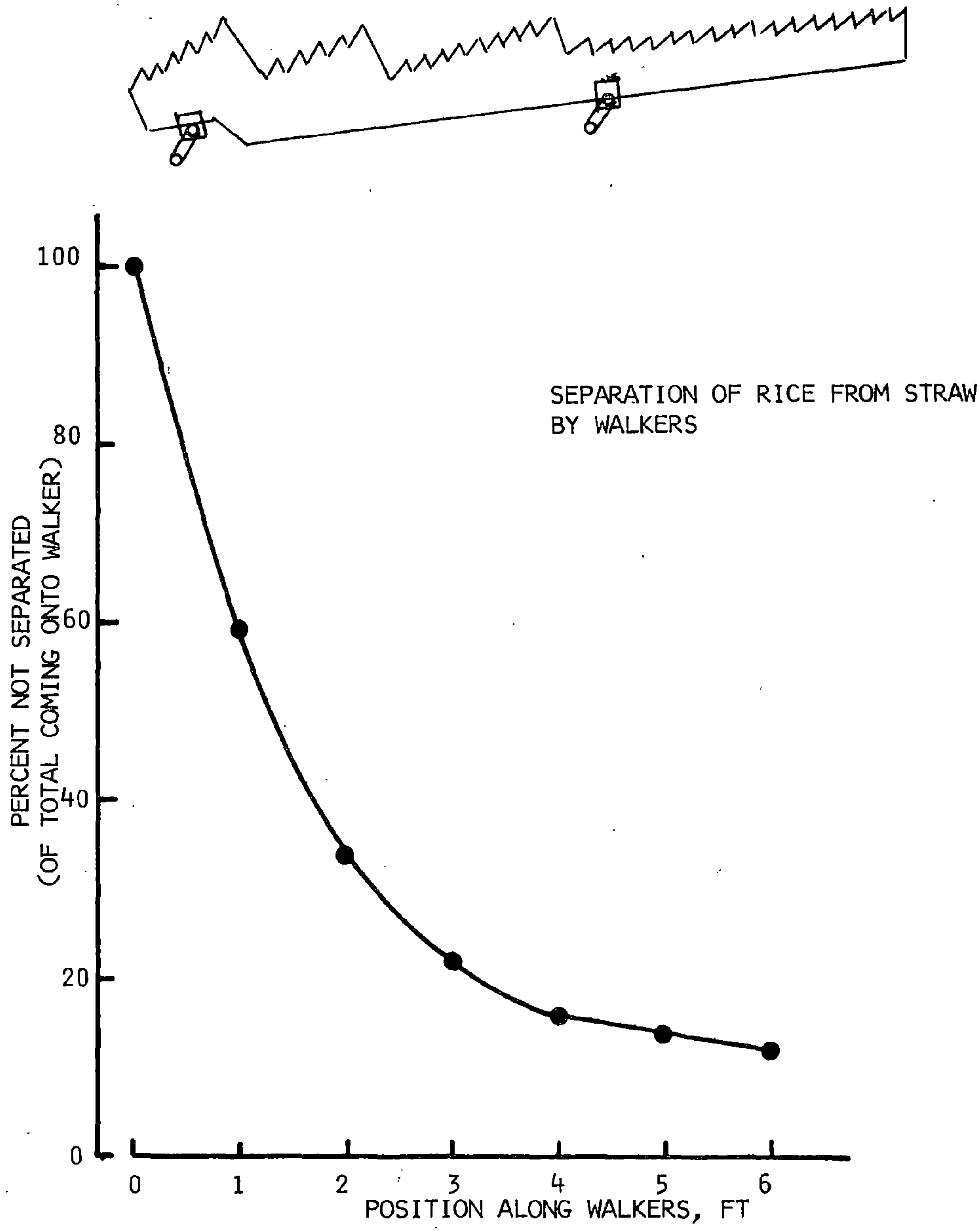


Fig. 2 Separation of material on walkers.

SEPARATION OF IMMATURE KERNELS FROM COMBINED WILD RICE

John Strait, D. W. Nordquist, and J. J. Boedicker

Research on the separation of immature kernels from combined wild rice prior to processing was continued during the past year. Previous reports have described work done in the laboratory and at Kosbau Brothers' Deerwood processing plant on this problem. A laboratory model of a device which is referred to as the air stream separator was constructed and used in laboratory experiments to study a wide range of design criteria applicable to this particular separation process. The laboratory unit was modified and used to produce two experimental lots of material which were processed through the regular processing sequence at the Deerwood plant in the fall of 1975.

Description of 1976 Prototype Separator

A prototype separator, using information obtained from experiments with the above described units, was constructed and used at the Deerwood plant last fall with the 1976 wild rice crop.

Figure 1 is a schematic side view of the separator showing the principal components of the machine and their relative locations. An oscillating feeder receives combined wild rice at the left-hand end as viewed in Figure 1. A backward curved blade fan supplies air to the underneath side of the feeder through a perforated steel sheet which acts as a straightener. The oscillating motion of the feeder along with the air spreads the rice and moves it toward the discharge end. The feeder tends to stratify the kernels with the light ones on top. The rice is discharged from the feeder into an air stream in the collector. A second backward curved blade fan delivers air to the air chamber where it passes through two perforated metal straighteners and then through a group of deflector plates into the collector. The lighter immature kernels are carried a greater distance downstream by the air than are the heavier more mature ones. Three compartments are provided in the collector to divide the rice into heavy, medium, and light fractions. Adjustable dividers and a variable speed drive on the lower fan allow for variation in the proportion of rice collected in each of the three compartments. Cross conveyors deliver the rice from each compartment to inclined conveyors which carry it to hauling units.

Specifications

Some specifications relating to the prototype separator are as follows:

A. Feeder
   1. 32" wide by 72" long
   2. Screen, 12 x 12 mesh, 19 ga. wire
   3. Air straighteners, perforated sheet metal, 1/4" round openings, 35% open area.

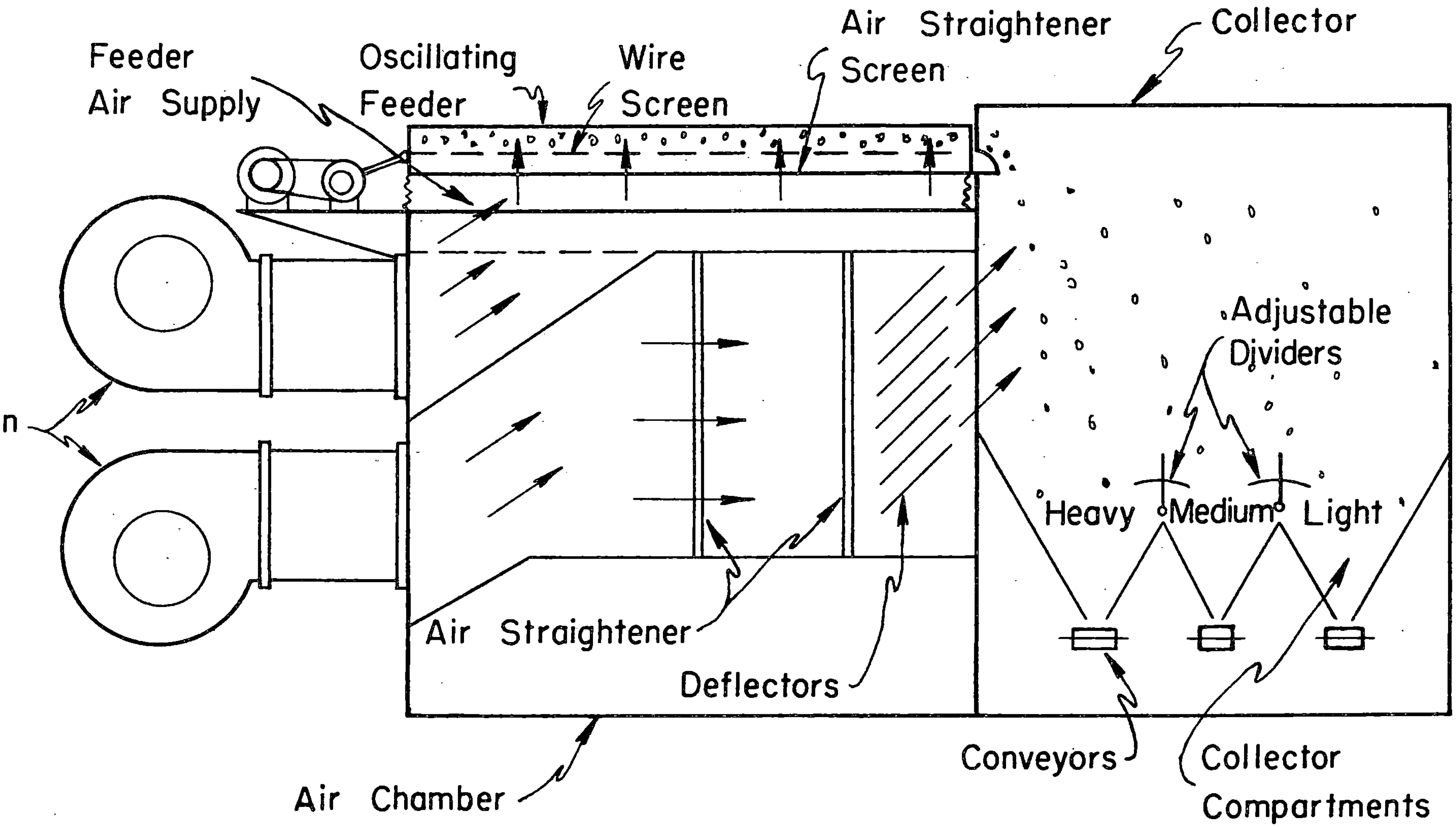


Fig. I. SCHEMATIC OF AIR STREAM SEPARATOR FOR GREEN COMBINED WILD RICE

4. Speed of oscillation, 900 cycles/min., adjustable
5. 5/16" front to back movement.

B. Fans
1. Double width, double inlet, backward curved blade. 20" wheel diameter.
2. Air delivery to collector, approx 10,000 cfm.
3. Air delivery to feeder, approx. 8,000 cfm.
4. Collector fan is equipped with a variable speed drive.

C. Air Chamber
1. 36" wide x 74" long
2. Straighteners, perforated sheet metal 1/4" and 3/16" round openings. 35% open area.
3. Height of air passage at straighteners, 30".
4. Deflectors, 16" wide galvanized iron set at 40° to the horizontal.

D. Collector
1. 36" wide x 83" long
2. Dividers, galvanized iron, adjustable.

E. Conveyors
1. Collector cross conveyors, 12" wide cotton belt.
2. Forage feeder wagon to separator, 16" wide cotton belt.
3. Collector cross conveyors to wagons, 12" wide cotton belt.

F. Approximate overall dimension of the separator, 48" wide x 16' long x 102" high excluding conveyors.

G. Capacity, about 6000 pounds per hour.

<u>Experimental Work Done</u>

Approximately 750,000 pounds of green wild rice were run through the separator during the period of August 20 to September 14. Thirteen experimental runs were completed where performance data and samples for future analysis were collected. Detailed data and samples were collected as material from five of the runs was processed according to the standard procedures used at the Deerwood plant. Plant yield data from all the separation runs were made available for analysis.

As each experimental run progressed, small quantities of rice from each maturity fraction and the unseparated rice were collected at frequent intervals to make up a composite sample representative of the rice entering the separator and of each of the three fractions leaving the separator. Five-quart samples taken from the composite samples were later processed and analyzed in the laboratory.

The laboratory work and analysis of the data has been only partially completed. More results will be available at a later date.

Results

It was found that the separator could operate at a feed rate in excess of the 6000 pounds per hour feed rate for which it was designed. Most of our test runs, however, were made with a feed rate of about 6000 pounds of rice per hour.

Table 1 shows data from six runs selected as representative of the thirteen runs completed. The data show that the moisture content of the rice in the heavy fraction varied from 31.9 to 35.8; the medium ranged from 35.2 to 39.4, while the moisture content of the light material was in excess of 50% for all runs shown except run 7. Run 7 was made with rice that had been fermented 4 days prior to separation during which time the wetter immature kernels had dried to a considerable extent. Also shown are the proportions of the rice as combined which constituted the heavy, medium, and light fractions expressed on both a weight and volume basis. It is significant to note that the light fraction included about 14% by weight and about 26% by volume of the combined rice. The heavy fraction had a density of 2 1/2 to 3 times that of the light material. The yield of finished rice expressed as a percentage of the wet weight of five-quart quantities from each fraction processed in the laboratory is shown in Table 1. The figures under the column headed "Recovered, Lbs." were obtained by multiplying the weight of rice in each fraction as separated by the yield from the 5-quart laboratory samples. It is therefore a calculated recovery figure. The last column shows that up to about 63% of the total finished rice recovered came from the heavy fractions.

Table 2 shows yields obtained and the grade characteristics of the finished rice for the heavy and medium fractions processed according to the regular procedures used at the Deerwood plant. No separate plant processing runs were made with check material comparable to the heavy and medium fractions obtained from any of our test runs. Also, none of the light fractions were processed in the plant. Table 2 shows yield as a percent of the green or wet weight for plant runs with heavy and medium fractions and yields obtained in the laboratory by processing representative five-quart samples from the heavy, medium, and light fractions, and the unseparated check. These yield results are reported under the column headed, "Yield-% of green weight."

Particular attention is directed to the yield of finished rice from the light fraction which averaged about 14%. In our laboratory procedures practically every kernel, regardless of size, was recovered. Had this material been processed in a typical processing plant, it is believed that at least half of this rice would have been aspirated away or otherwise lost. Machine adjustments could be readily made to reduce the proportion of the green rice included in the light fraction. This would result in a reduction in the yield of finished rice from the light fraction. The optimum adjustment of the separator would be largely dictated by economic considerations with respect to plant capacity, operating costs, processing procedures, and product quality.

Differences between plant and laboratory yields for the heavy and medium fractions shown in Table 2 are likely due to the loss of very small diameter kernels in the plant, fermentation losses, and perhaps sampling errors.

Table 3 includes only data from laboratory processed samples. It shows the distribution of finished rice based upon the diameter of the finished kernels in each lot of experimental material.

The last two columns are of particular interest because they show the percent by weight of the finished rice which passed 2 1/2 and 2 slotted sieves. The table shows that approximately 60% of the rice in the light fractions were immature kernels which passed the 2 1/2 sieve. The data also show that the separator does not achieve perfect separation of the immature kernels. A few immature kernels are found in the heavy fraction and a considerable number in the medium fraction. However, in the heavy and medium fractions, immature kernels comprise only 1.3 and 9 percent, respectively, of the finished rice.

Figure 2 is a bar graph showing distribution of finished rice within each fraction for run 7 according to size as determined by sorting with a nest of slotted sieves. For the heavy fraction, 69.8% of the rice was retained on a 3 1/2 sieve and 93.7% on a 3 sieve. For the medium fraction 65.6% of the rice passed a 4 sieve and was retained on a 3 sieve while 85.7% passed a 4 sieve and was retained on a 2 1/2 sieve. In the light fraction 64.5% passed a 2 1/2 sieve and 92% passed a 2 1/2 sieve. The kernel size differential is very apparent upon visual inspection of the rice from each of the three fractions.

Figure 3 is another bar graph made from the results obtained with run 7. Figure 3 shows the distribution of kernels by size within each maturity fraction, but in addition, shows the comparative yield by weight obtained from equal (5 quart) samples of each fraction. The size distribution is the same as shown in Figure 2. Yields of finished rice were about 726 grams, 508 grams, and 84 grams from five quarts of heavy, medium, and light rice respectively. This comparison seems to be very significant since the capacity of the parchers is to a large extent volume limited.

Figure 4 is also drawn from data from run 7. It shows the percent of finished rice in each fraction which passed or was smaller in diameter than the sieve size designated. It is similar in what it shows to Figure 2. It shows that the light fraction contains predominantly small diameter kernels while the heavy fraction consists mainly of large mature kernels.

Figure 5 is drawn from data obtained from run 9 and represents a different view of the performance of the separator. Figures 2, 3, and 4 were primarily concerned with the characteristics of the three maturity fractions resulting from the separation process. Figure 5 shows the percent by weight of the kernels in each size group in rice as combined which the separator sorted into each of the heavy, medium, and light fractions. For example, the unseparated material contained a certain weight of kernels that when processed would have passed the 4 1/2 and been retained on the 4 sieve. Upon separation, the machine sorted 87% of these kernels into the heavy fraction 13% into the medium, and virtually none into the light fraction. Similarly, for the 3 x 2 1/2 size kernels, the separator sorted 28% of those kernels into the heavy fraction, 68% into the medium, and 4% into the light. With respect to the removal of immature kernels it would be desirable to have a higher percentage of those kernels passing a 2 sieve included in the light fraction.

Operation of the Separator

No mechanical problems with the separator were experienced during the separation of approximately 3/4 million pounds of combined wild rice. The conveyors required periodic adjustment to maintain alignment of the belts on the flat pulleys. The conveyor from the feeder wagon to the separator was inclined to an angle of about 26° to the horizontal and some problems were occasionally experienced with roll-back when the system was started up after being shut down for a few hours. There was also a tendency for material to collect on the drive roller which required periodic attention. This conveyor, in effect, limited the overall capacity of the system to about 7000 pounds per hour. The other conveyors functioned well.

There was a tendency for a buildup consisting mainly of trash to occur at certain locations on the feed table screen. A similar tendency was noted on an aluminum trough which was placed over the screen for one test run. This did not appear to have any significant effect on the performance of the separator since the buildup was quite limited.

There was a fair amount of dust and pieces of awns flying around in the vicinity of the separator which required screening of the fan inlet. Even so, fine particles got into the fans and tended to collect on the vertical perforated sheet metal straighteners in the air chamber. The operator should brush or tap the straighteners to remove this material about every 2 to 6 hours of continuous operation depending mainly on wind direction. This requires only a minute or two. A simple manometer measuring static pressure in the air chamber ahead of the straighteners was used to indicate a need for cleaning the straighteners.

It is believed that one man could easily operate the system except for help needed in emptying the wagons.

Summary

To summarize, the following statements can be made as a result of our research work this past year with respect to the development and performance of the separator:

1. The separator appears to be capable of removing immature kernels from green combined rice with a reasonably good level of performance.

2. The separator appears to work equally well with either freshly combined or fermented rice.

3. The machine is simple in operating principle and has an inherently high capacity with relatively low energy consumption.

4. Adjustments on the separator are sufficient to allow the operator a wide choice of grading options with respect to the relative quantities sorted into the three maturity fractions produced.

5. Although it appears to us that it would be economically feasible to separate out the immature kernels to the degree possible in the present machine, the economics of the procedure has not been firmly documented.

6. We are confident that a more precise and complete separation of the immature kernels can be achieved through further research and development work.

Table 1. Separation data from selected test runs, 1976 crop, and calculated yield of finished rice based upon data obtained from five-quart samples processed in the laboratory.

Run No.	Fraction	Date Separated	As Separated					Yield of Finished Rice		
			Weight Lbs.	M.C Wet Basis %	Percent of Total by Weight	Percent of Total by Volume	Relative Density	Percent of Green Weight	Recovered Lbs. (1)	% of Total Rice Recovered
5	Heavy	Aug. 23	4560	33.9	40.7	31.6	1	56.0	2554	47.6
	Medium		5310	38.2	47.3	42.1	0.86	49.6	2634	49.1
	Light		1345	55.9	12.0	26.3	0.36	13.2	178	3.3
	Check			39.0			0.76	47.3		
6	Heavy	Aug. 24	2394	33.4	43.8	34.8	1	56.0	1341	50.6
	Medium		2385	38.5	43.2	40.8	0.85	49.4	1178	44.5
	Light		740	57.2	13.4	24.4	0.44	17.4	129	4.9
	Check			38.7			0.79	47.7		
7	Heavy	Aug. 24	6245	31.9	52.8	42.0	1	56.3	3516	62.9
	Medium		3930	37.1	33.2	30.9	0.85	46.0	1808	32.3
	Light		1660	40.9	14.0	27.1	0.41	16.2	269	4.8
	Check			36.3			0.80	48.6		
9	Heavy	Aug. 26	23620	32.5	50.2	39.4	1	56.6	13369	58.3
	Medium		18430	35.2	32.1	34.7	0.89	49.1	9049	39.5
	Light		5027	53.3	10.7	25.8	0.33	9.9	498	2.2
	Check			36.7			0.75	48.7		
10	Heavy	Sept. 1	11835	35.8	31.1	26.8	1	53.1	6284	38.6
	Medium		19815	37.0	52.0	45.3	0.99	47.1	9333	57.3
	Light		6430	52.0	16.9	27.9	0.52	10.3	662	4.1
	Check			41.6			0.86	43.0		
12	Heavy	Sept. 3	14275	34.2	37.1	28.3	1	55.8	7966	46.0
	Medium		18840	39.4	49.0	45.6	0.82	46.4	8742	50.5
	Light		5325	50.5	13.9	26.1	0.40	11.4	607	3.5
	Check			38.6			0.72	47.1		

(1) Obtained by multiplying weight as separated by yield expressed as a percent of green weight determined from 5-quart samples processed in the laboratory.

Table 2. Characteristics of separated material and yield data obtained from selected separation test runs processed in the Deerwood plant.

Run No.	Fraction	Date Parched	Weight as Separated lbs.	Yield-% of Green Wt.		Total Recovered lbs.	Finished Rice-% of Total Recovered (1)				
				Plant	Lab		A Grade	B Grade	D-1 Grade	D-2 Grade	Rerun
4, 5, 6	Heavy	Aug. 26	13704	56.2	56.0	7702	36.0	44.9	6.4	5.4	7.3
	Medium	Aug. 22	12035	42.6	49.5	5129	14.6	62.4	8.5	7.8	6.7
	Light (2)		3560		15.5						
	Check				47.5						
7	Heavy	Aug. 26	6245	58.0	56.3	3619	38.1	37.7	7.6	8.7	7.9
	Medium	Aug. 27	3930	47.6	46.0	1871	10.7	55.2	12.1	11.4	10.7
	Light		1660		16.2						
	Check				48.6						
8	Heavy	Aug. 25	8095	56.5	56.5	4571	33.5	42.8	7.5	6.5	9.8
	Medium	Sept. 2	7085	47.2	50.9	3343	10.2	60.6	11.2	10.5	7.6
	Light		2275		15.6						
	Check				49.3						
9	Heavy	Sept. 3	23620	54.8	56.6	12950	38.7	40.0	7.5	6.2	7.6
	Medium	Sept. 3	18430	43.9	49.1	8092	8.7	60.6	11.1	11.1	8.6
	Light		5027		9.9						
	Check				48.7						
10-13	Heavy	Sept 12	47760	55.2	55.1	26366	25.0	46.9	11.6	8.2	8.1
	Medium	Sept 11	77360	43.2	48.7	33448	6.6	59.2	12.6	10.5	11.2
	Light		23680		12.7						
	Check				45.8						

(1) A grade retained on 3.75/64 slotted sieve, B grade passed 3.75/64 sieve. D-1 grade rice picked up by 20/64 indent cylinder and passed 10/64 indent. D-2 grade rice picked up by 10/64 indent cylinder and passed 8/64 indent.

(2) No light fractions were pocessed in the plant.

Table 3. Yield and size distribution of wild rice kernels in unseparated check and heavy, medium, and light fractions produced by the air stream separator from combined rice from the 1976 crop. Five quarts of rice from the check and each of the three maturity fractions were processed in the laboratory. The finished rice kernels were separated according to diameter using slotted sieves.

Run No.	Fraction	Sample Weight Grams	Finished Rice Weight, Grams	Finished Rice % Sample Weight	Size Distribution of Finished Rice Kernels-% by Weight: Over 4 1/2	4 1/2 x 4[1]	4 x 3 1/2	3 1/2 x 3	3 x 2 1/2	2 1/2 x 2	Under 2
5	Heavy	1491.0	834.7	56.0	2.8	19.9	47.3	24.1	4.7	1.0	0.2
	Medium	1305.4	647.0	49.6	0.8	8.6	34.6	34.9	14.7	4.7	1.7
	Light	529.8	70.1	13.2	0	0.3	2.1	10.9	28.7	29.6	28.5
	Check	1127.5	533.4	47.3	1.4	13.0	38.5	30.3	10.8	3.9	2.0
6	Heavy	1429.9	800.5	56.0	1.9	16.3	46.0	28.2	6.3	1.1	0.2
	Medium	1216.7	600.7	49.4	0.4	4.7	27.4	40.3	19.1	6.1	2.0
	Light	632.1	109.8	17.4	0	0.1	0.9	9.0	31.4	31.5	27.1
	Check	1124.5	536.5	47.7	0.9	9.2	36.5	33.1	13.2	4.8	2.4
7	Heavy	1290.7	726.4	56.3	2.5	19.9	47.4	23.9	5.0	1.1	0.2
	Medium	1101.7	506.4	46.0	0.3	4.4	26.6	39.0	20.1	6.9	2.6
	Light	531.1	86.2	16.2	0	0.1	0.8	6.9	27.5	33.6	30.9
	Check	1036.7	503.3	48.6	1.8	14.1	38.8	28.2	10.6	4.2	2.2
9	Heavy	1455.2	824.2	56.6	1.8	15.0	47.8	27.9	6.2	1.0	0.2
	Medium	1289.7	632.6	49.1	0.3	3.2	25.8	39.7	22.3	6.7	2.1
	Light	473.1	46.6	9.9	0	0.2	1.1	4.5	23.0	34.8	36.5
	Check	1086.3	529.0	48.7	1.2	9.9	37.4	32.2	13.2	4.2	1.9
10	Heavy	1316.0	698.4	53.1	0.1	5.5	49.0	35.6	8.0	1.5	0.2
	Medium	1300.8	612.8	47.1	0	1.2	24.6	42.1	22.3	7.4	2.3
	Light	686.5	70.4	10.3	0	0	0.7	3.9	23.9	30.9	56.4
	Check	1133.4	487.8	43.0	0.1	3.0	33.2	37.0	17.1	6.7	3.0
12	Heavy	1541.3	858.7	55.8	0.6	10.9	54.3	27.1	5.5	1.2	0.2
	Medium	1260.7	585.5	46.4	0.1	1.6	21.8	39.3	25.2	9.2	2.8
	Light	622.5	71.2	11.4	0	0.1	0.8	3.0	15.7	35.9	44.5
	Check	1117.2	526.7	47.1	0.2	6.9	40.7	32.0	13.0	4.6	2.5

(1) 4 1/2 x 4 means that the kernels passed through a 4.5/64" slotted sieve and were retained on a 4/64" slotted sieve. All sieve sizes refer to 64ths inch.

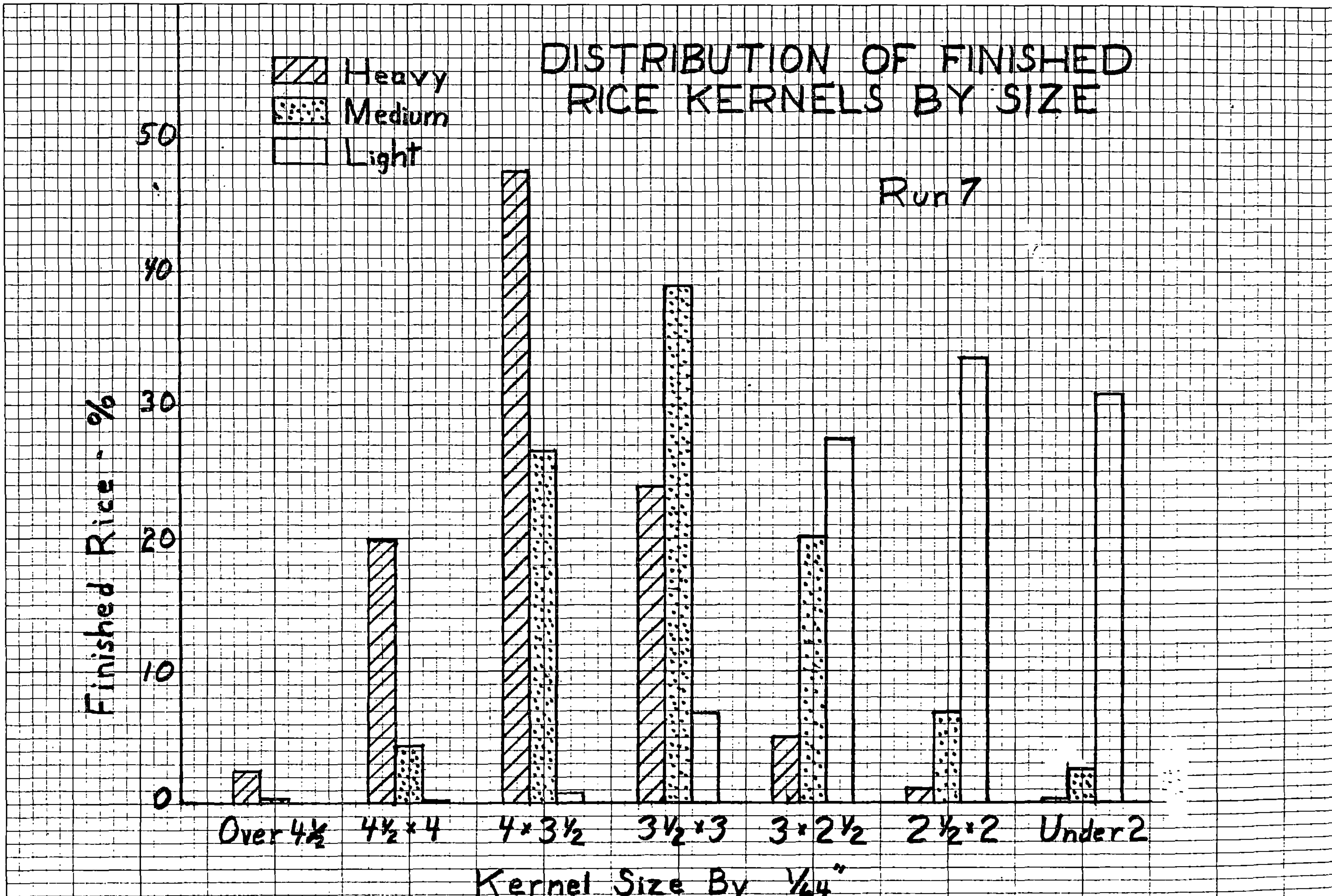

DISTRIBUTION OF FINISHED
RICE KERNELS BY SIZE
Heavy
Medium
Light
Run 7
Finished Rice - %
50
40
30
20
10
0
Over 4½
4½ × 4
4 × 3½
3½ × 3
3 × 2½
2½ × 2
Under 2
Kernel Size By 1/64"

FIGURE 2

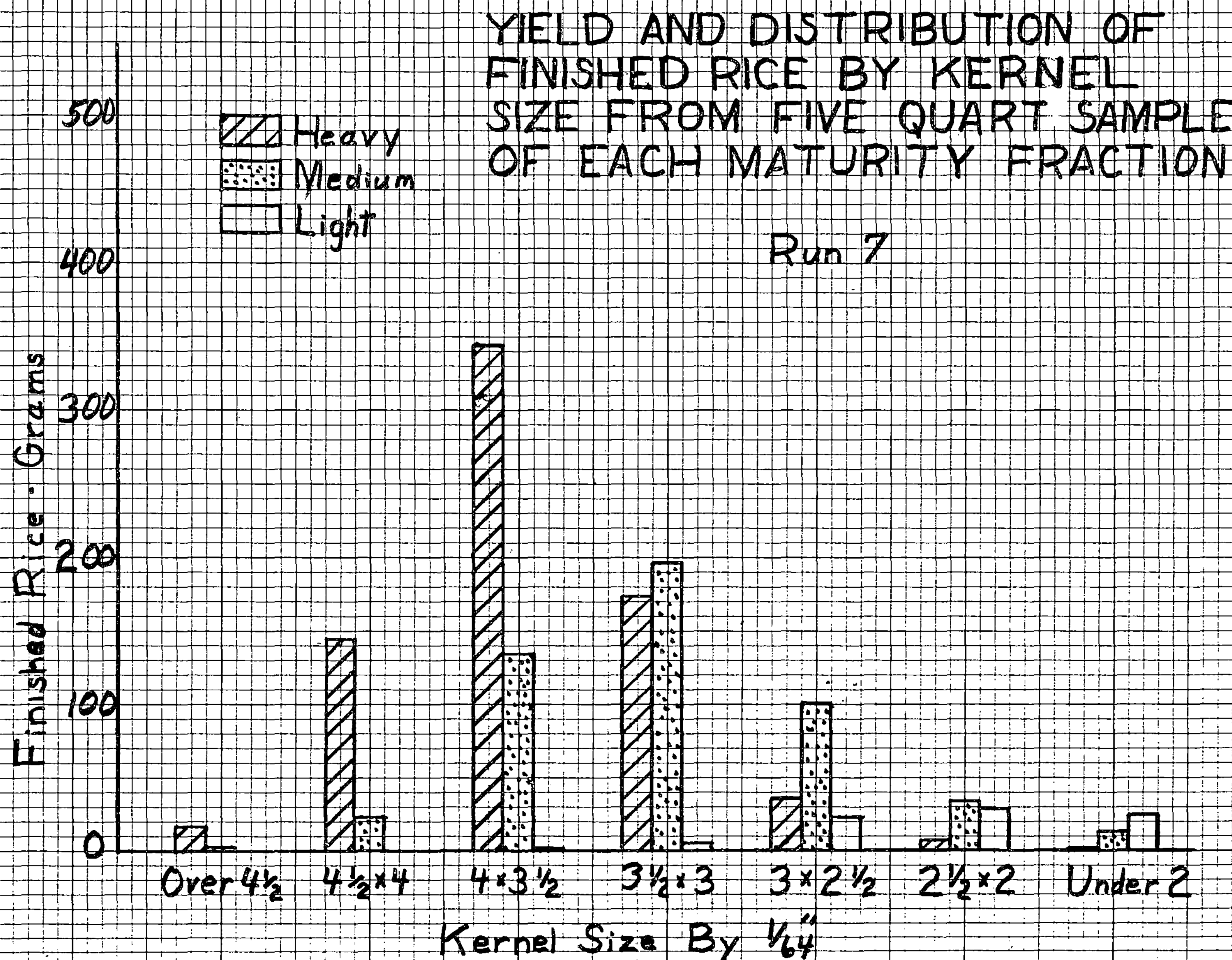

YIELD AND DISTRIBUTION OF
FINISHED RICE BY KERNEL
SIZE FROM FIVE QUART SAMPLE
OF EACH MATURITY FRACTION
Run 7
Heavy
Medium
Light
Finished Rice - Grams
500
400
300
200
100
0
Over 4½
4½×4
4×3½
3½×3
3×2½
2½×2
Under 2
Kernel Size By 1/64"

FIGURE 3

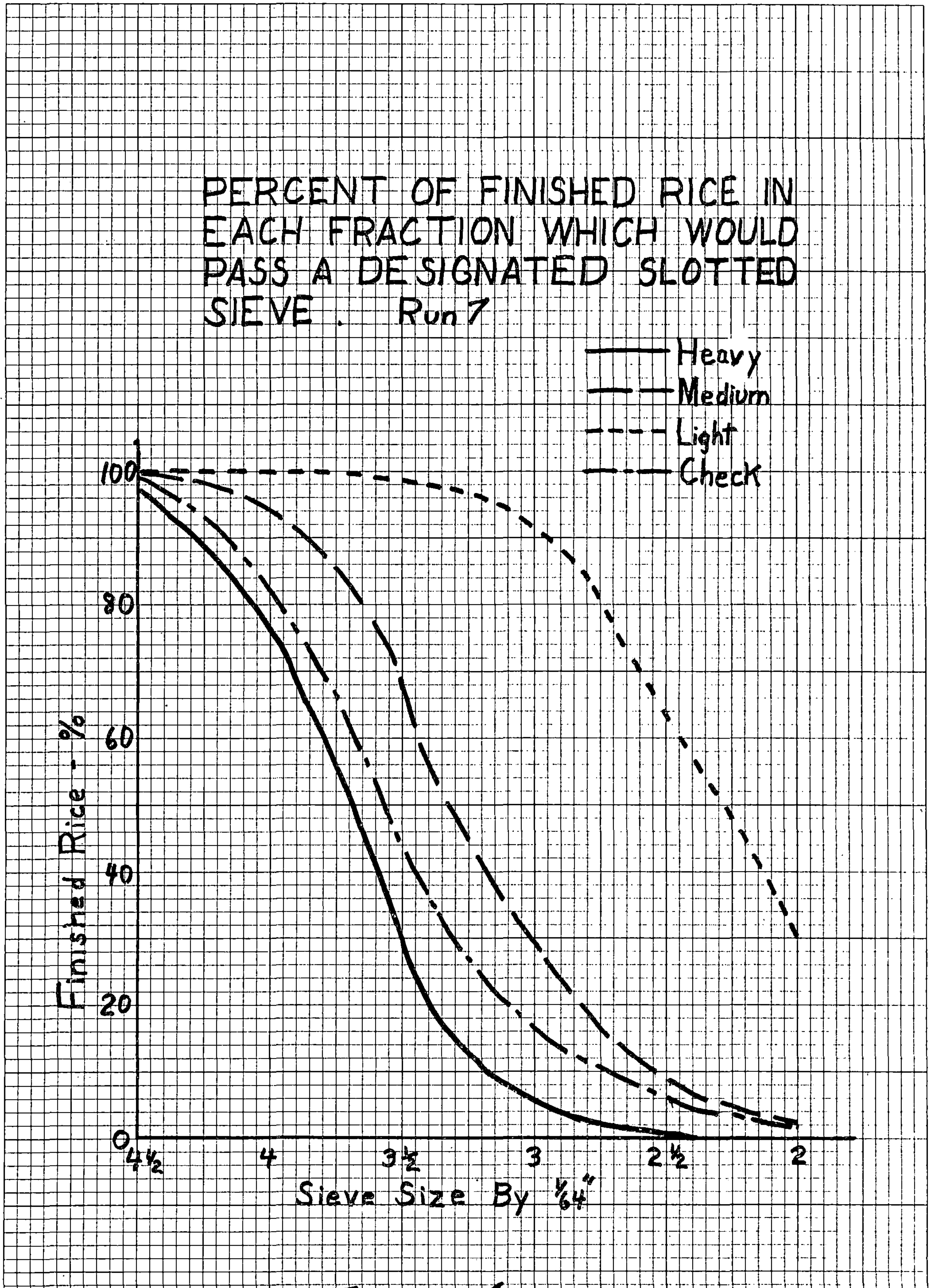

PERCENT OF FINISHED RICE IN EACH FRACTION WHICH WOULD PASS A DESIGNATED SLOTTED SIEVE. Run 7
Heavy
Medium
Light
Check
100
80
60
40
20
0
Finished Rice - %
4½
4
3½
3
2½
2
Sieve Size By 1/64"

FIGURE 4

PERCENT DISTRIBUTION OF THE TOTAL WEIGHT OF KERNELS OF A PARTICULAR SIZE AMONG THE THREE MATURITY FRACTIONS.

Run 9

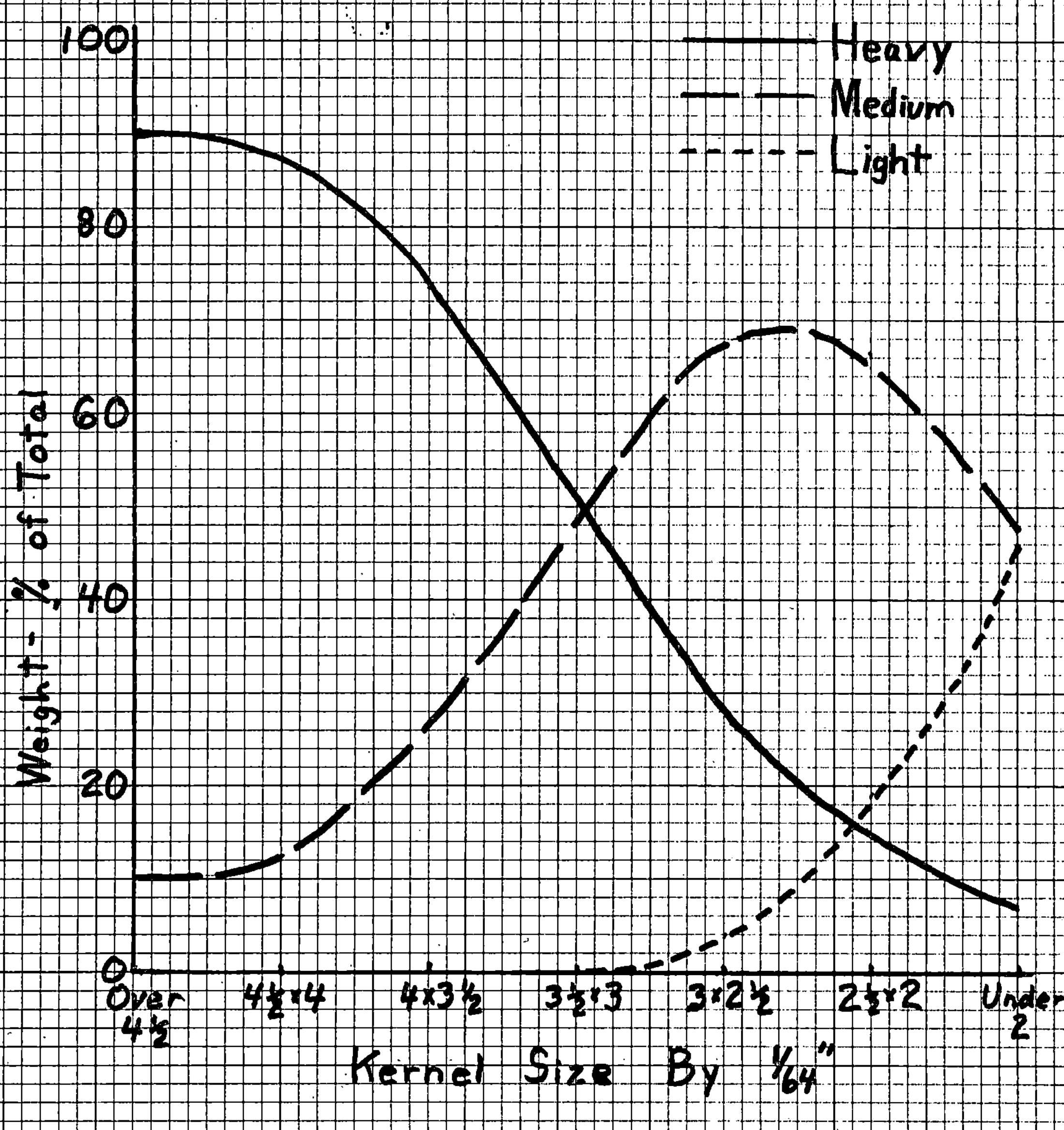


FIGURE 5