WILD RICE PRODUCTION RESEARCH - 1989

E.A. Oelke, M.J. McClellan and J.W. Leif[1]
Department of Agronomy and Plant Genetics

The 1989 growing season generally was cooler than in 1988, especially during April and May at all 3 locations (Table 1). However, the total number of growing degree days (GDD) during April through August was higher than the long term (50 years) average at all 3 locations but lower than in 1988. Thus, the 1989 growing season can still be classified relatively warm.

Table 1. Growing degree days[a] comparisons for 1988, 1989 and normal.

Month	Aitkin			Grand Rapids			Crookston		
	1988	1989	Normal	1988	1989	Normal	1988	1989	Normal
	GDD								
April	120	94	114	99	83	107	166	136	132
May	642	424	414	620	454	381	702	574	438
June	792	658	677	826	654	634	954	741	710
July	943	928	871	970	953	817	1034	1069	900
August	816	830	785	810	811	733	980	965	850
Total	3313	2934	2861	3325	2955	2672	3836	3485	3030

[a] $\frac{\text{Maximum temp.} + \text{Minimum temp.}}{2}$ - 40°F; data from Ian A. Barrie, Soil Science Dept., Univ. of Minn.

Total precipitation was greater than in 1988 with the greatest increase at Crookston (Table 2). However, July was very dry at Aitkin and Crookston, while at Grand Rapids July was wetter than in 1988 but still drier than the long term average. Leaf diseases were not as severe as in some years, perhaps because of the drier July.

[1]Professor, Senior Research Plot Technician, and Graduate Research Assistant, respectively.

Table 2. Precipitation comparisons for 1988, 1989 and normal.

Month	Aitkin			Grand Rapids			Crookston		
	1988	1989	Normal	1988	1989	Normal	1988	1989	Normal
	inches								
April	0.15	2.32	2.27	0.40	2.32	1.99	0.00	0.39	1.39
May	3.16	3.90	3.39	1.18	3.19	3.16	1.61	4.56	2.20
June	3.19	5.66	3.83	3.06	4.64	3.79	1.52	2.71	3.61
July	3.96	0.62	4.79	1.66	2.74	4.12	1.84	0.56	3.17
August	7.08	6.27	4.19	10.03	4.54	3.38	1.56	3.76	3.04
Total	17.54	18.77	18.47	16.33	17.43	16.44	6.53	11.98	13.41

Total wild rice production in Minnesota was nearly the same as 1988, while the California production was up slightly from 1988 (Table 3). For the last 3 years, the total production from Minnesota and California ranged from 7.5 to 8.4 million pounds of processed wild rice. Production is expected to be stable for the next few years.

Table 3. Minnesota and California paddy wild rice production[a] (1000 processed pounds).

Year	Production		Year	Production	
	Minnesota	California		Minnesota	California
1968	36	0	1979	2155	200
69	160	0	80	2320	400
70	364	0	81	2274	500
71	608	0	82	2697	880
72	1496	0	83	3200	2500
73	1200	0	84	3600	3800
74	1036	0	85	4200	7900
75	1233	0	86	5100	9000
76	1809	0	87	4200	4200
77	1031	0	88	4000	3500
78	1761	100	89	3978	4000

[a]1968-1982 Minnesota values from Winchell and Dahl and 1983-1989 from Minnesota Department of Agriculture; California values from Marcum, Cooperative Extension Service, University of California.

The value of the wild rice crop to the Minnesota producers has increased from $0.12 million in 1968 to a high of $13.26 million in 1986 (Table 4). Because of the lower wholesale price and the decrease in production, the value dropped to $7.16 million in 1989. The wholesale price has increased slightly from the low of 1987.

Table 4. Processed wild rice harvested and value from cultivated fields in Minnesota

Year	Production	Price	Value
	1,000 lb	$/lb	$ Millions
1968	36	3.30	0.12
1969	160	2.55	0.41
1970	364	2.80	1.02
1971	608	2.70	1.64
1972	1,496	2.30	3.44
1973	1,200	2.05	2.46
1974	1,036	2.37	2.46
1975	1,233	2.50	3.08
1976	1,809	2.70	4.88
1977	1,031	4.35	4.48
1978	1,761	5.10	8.98
1979	2,155	5.01	10.80
1980	2,320	4.47	10.37
1981	2,274	3.79	8.62
1982	2,697	3.41	9.20
1983	3,200	3.35	10.72
1984	3,600	3.30	11.88
1985	4,200	2.97	12.47
1986	5,100	2.60	13.26
1987	4,200	1.50	6.30
1988	4,000	1.65	6.60
1989	3,978	1.80 (est.)	7.16

Research

The 1989 research focused on weed control, residue removal-nitrogen fertilization-disease incidence interactions, shading effects on wild rice yield, and effects of drying wild rice seed before storage on seed viability and storeability. The research was conducted on University plot land at Grand Rapids and at St. Paul and on the research area near Aitkin.

Weed Control Research

Control of Giant Burreed Grown Under Flooded Conditions

Field experiments were conducted in 1988 and 1989 to determine the effects of glyphosate, surfactant, and ammonium sulfate concentrations on control of giant burreed when grown under flooded conditions. The chemicals were applied with a ropewick applicator. In 1988, giant burreed corms were planted in 2 rows spaced 10 inches apart (corm density = 3 per 10 ft^2) in the center of each plot. In 1989 plants emerging

from the previous year's infestation were used (corm density = 25 per 10 ft^2). Plots were 4 ft by 10 ft in both years. Water depth was maintained at 10 inches throughout the growing season. Treatments were applied on June 17, 1988 and June 14, 1989 to 20-inch tall giant burreed in the manner outlined in the non-flooded experiments in the 1988 Minnesota Wild Rice Research Report. In 1989, the center 2 x 10 ft area of each plot was treated. Treatments were replicated three times.

Visual weed control ratings were taken 30 and 60 days after treatment. The ratings were a combination of population reduction and leaf necrosis. Giant burreed vegetation and corms were not harvested due to encroachment of rhizomes from adjacent control plots at the end of each growing season.

In 1988, giant burreed control 60 days after treatment was highest with 30% glyphosate and decreased as surfactant concentration increased (Table 5). Glyphosate applied at 5% did not significantly reduce giant burreed population. Some leaf tissue necrosis was observed at 0.3, 0.6, and 1.2% surfactant concentrations 3 to 5 days after treatment. Ammonium sulfate did not increase glyphosate toxicity to giant burreed (data not presented).

Table 5. Effects of glyphosate concentration and surfactant concentration on giant burreed visual injury when applied through a ropewick in flooded conditions.[a]

Concentration		Visual Injury[b]			
		1988		1989	
Glyphosate	Surfactant	30 DAT	60 DAT	30 DAT	60 DAT
(%)	(%)	%			
0	0	0	0	0	0
	0.15	0	0	0	0
	0.30	0	0	0	0
	0.60	0	0	0	0
	1.20	0	0	0	0
5	0	10	10	5	0
	0.15	5	5	0	0
	0.30	0	0	0	0
	0.60	0	0	0	0
	1.20	0	0	0	0
30	0	90	85	15	0
	0.15	90	85	10	0
	0.30	80	75	10	0
	0.60	60	50	0	0
	1.20	40	35	5	0
LSD .05		17	14	NS[c]	NS

[a]Means are averages across ammonium sulfate concentrations.
[b]Injury ratings: 0 = no injury, 100 = complete kill.
[c]Non-significant difference.

In 1989, the ratings were not statistically different but they were in 1988 (Table 5). In 1989, the giant burreed population was much higher than in 1988, since it was a second year stand. The higher giant burreed population in 1989 could have decreased the amount of glyphosate applied to any one shoot thus contributing to the poor control in 1989.

Decreased control of perennial species by glyphosate with high surfactant concentrations has been shown by other reserachers. In 1989 there was some evidence of this when using glyphosate with high concentrations of surfactant for control of giant burreed. The presence of leaf necrosis at the higher surfactant concentrations and reduced control at those concentrations suggests that leaf tissue damage may, in part, be responsible for decreased glyphosate translocation out of the treated leaves, thus giving decreased giant burreed control. Based on 3 years of study, adding a surfactant (X-77) or ammonium sulfate to enhance glyphosate (Rodeo^{R}) activity on giant burreed is not cost effective. In fact in some years, glyphosate activity can be reduced at high concentrations of surfactant.

Basic Studies on Glyphosate Absorption and Translocation in Giant Burreed

Glyphosate is a non-selective herbicide that translocates to the roots and meristematic tissues of perennial weeds. Translocation of glyphosate to root buds is important for bud kill and long term control of perennial weeds. The concentration of glyphosate applied with ropewick applicators is relatively high and can cause localized leaf necrosis which could cause poor translocation of glyphosate away from the site of application. The objectives of this research were to study the effects of glyphosate and surfactant concentrations on glyphosate absorption and translocation and to study the effects of glyphosate and surfactant on giant burreed leaf tissue integrity.

Laboratory experiments

General procedures. Giant burreed plants were grown from corms with 1 viable bud. Individual corms were planted in 1-liter pots filled with sterilized potting soil (silt loam:sand:manure:peat, 1/1/1/1 v/v/v/v) and grown in a glasshouse during December through March. Glasshouse air temperature was maintained at 77 $\pm$ 5 F. Natural sunlight was supplemented with fluorescent light for a total day length of 12 h. Uniform 6 week old plants were transferred to a growth chamber with 12 h light (450 $\mu E \cdot m^{-2} \cdot s^{-1}$) at 77 F, 12 h darkness at 68 F and 70% relative humidity. Plants were kept in the growth chamber for 2 weeks before treatments were applied. Plants were grown under continuous flooded conditions in both the glasshouse and growth chamber by submerging the 1-liter pots in 3-liter pots filled with water. This was done to provide an optimum growth environment for giant burreed.

^{14}C-glyphosate absorption and translocation. Methyl-labeled ^{14}C-glyphosate (specific activity 52 mCi/mmol) was mixed with commercial formulation of glyphosate, surfactant, and distilled water to give solutions containing glyphosate at concentrations of 5 or 30% (v/v) with either 0, 0.15, 0.6, or 1.2% (v/v) surfactant. A total of 0.2 μCi ^{14}C-glyphosate (in 4 μl of solution) was applied with a microsyringe onto the fourth fully expanded leaf of 8 week old giant burreed plants which had developed rhizomes. The four μl of each solution was applied as 20 0.2- μl droplets spaced 0.5 cm apart in four rows parallel to the midrib (two rows/side). The treated area was midway between the leaf base and leaf tip. The treatments were applied to the abaxial surface of the leaf to simulate ropewick applicator placement.

Three days after treatment, plants were divided into the treated leaf, untreated leaves, developing corm, and roots plus rhizomes. The treated leaf was washed twice with 1.5

ml volumes of distilled water to remove the unabsorbed ^{14}C-glyphosate from the leaf surface. The leaf washes were combined, added to 15 ml of a scintillation solution and radioassayed using standard liquid scintillation spectrometry techniques. Following the aqueous wash, ^{14}C-glyphosate remaining in the epicuticular wax was removed with two 2.5- ml chloroform washes. Chloroform washes were combined and evaporated to dryness in air. Scintillation solution was added and radioactivity was quantified. All plant parts were dried at 60 C for 7 days, weighed, ground (except for treated leaf which was not ground), and a 250 mg sub-sample was combusted in a sample oxidizer. The CO_2 evolved was trapped in 21 ml of a 2:1 (v/v) mixture of liquid scintillation solution and a CO_2 absorbent. Radioactivity from the oxidations was quantified by liquid scintillation spectrometry.

The experimental design was a randomized complete block with 4 replicates. Data were subjected to analysis of variance and means were compared using a Fisher's protected LSD test. The experiment was repeated in time and the data are the means of two experiments.

Electrolyte leakage. Glyphosate at 0, 5, or 30% (v/v) was applied in combination with surfactant at 0, 0.15, 0.6, or 1.2% (v/v) to 1.5 inch giant burreed leaf sections. Sixteen µl of solution were applied to the abaxial surface of each section as 80 0.2-µl droplets spaced 0.08 inch apart in 4 rows parallel to the midrib (two rows/side). The leaf sections were placed on moist filter paper in a petri dish and incubated for 24 h in a growth chamber.

At the end of the incubation period visual injury ratings were taken on each leaf section. The leaf sections were cut into 1-cm sections, washed with deionized water to remove any unabsorbed herbicide or surfactant, and assayed for electrolyte leakage.

The experimental design was a randomized complete block with 6 replicates. Data were subjected to analysis of variance and means were compared using a Fisher's protected LSD test. The experiment was repeated in time and the data are the means of two experiments.

Results. ^{14}C-glyphosate recovery was 97%, and was not influenced by treatments. Increasing glyphosate concentration from 5% to 30% increased ^{14}C-glyphosate absorption into the plant by 61% and increased translocation into the roots and rhizomes by 41% (Table 6). The increase in translocation would explain the decrease in giant burreed corm and rhizome viability with 30% glyphosate in the 1987 field experiment as reported in the 1988 Minnesota Wild Rice Research Report. The increase in absorption with the increase in concentration is consistent with other research showing that glyphosate uptake is a concentration dependent process.

Retention of ^{14}C-glyphosate in epicuticular waxes was minimal and was not influenced by glyphosate concentration or surfactant concentration (Tables 6 and 7). This suggests epicuticular waxes were not a major barrier to glyphosate entry into giant burreed leaves.

Table 6. Effect of glyphosate concentration on the distribution of ^{14}C-radioactivity in giant burreed 3 days after treatment with ^{14}C-glyphosate.[a]

	Glyphosate[b]					
Glyphosate conc.	Absorbed	Epicuticular waxes	Treated leaf	Untreated leaf	Corm	Roots and rhizomes
(%)	(%)					
5	32.3	0.3	17.7	6.1	1.4	6.8
30	52.5	0.3	31.2	8.0	3.4	9.6
LSD .05	6.5	NS[c]	6.4	NS	0.8	2.4

[a]Means are averages across surfactant concentrations.
[b]Percent of the total ^{14}C-radioactivity recovered.
[c]Non-significant difference.

The addition of surfactant increased absorption of ^{14}C-glyphosate into the plant about two-fold (Table 7). Severe leaf necrosis at the point of application was observed with 0.6% or 1.2% surfactant, regardless of glyphosate concentration. Translocation of ^{14}C-glyphosate into the roots and rhizomes was reduced when surfactant concentration was increased from 0% to 1.2%.

Table 7. Effect of surfactant concentration on leaf injury and distribution of ^{14}C-radioactivity in giant burreed 3 days after treatment with ^{14}C-glyphosate.[a]

		Glyphosate[b]					
Surfactant conc.	Injury[c]	Absorbed	Epicuticular waxes	Treated leaf	Untreated leaf	Corm	Roots and rhizomes
(%)		(%)					
0.0	0.0	24.7	0.2	12.5	3.2	1.6	7.2
0.15	0.2	43.5	0.3	26.1	5.1	3.1	8.9
0.6	4.6	50.2	0.3	30.2	10.6	2.8	6.3
1.2	4.7	51.2	0.3	33.0	10.5	3.1	4.3
LSD .05	0.6	9.3	NS[d]	9.1	4.9	1.1	2.8

[a]Means are averages across glyphosate concentrations.
[b]Percent of the total ^{14}C-radioactivity recovered.
[c]0 = no injury, 5 = severe leaf necrosis at point of droplet application.
[d]Non-significant difference.

Severe leaf necrosis at the point of treatment application was observed with surfactant at 0.6% or 1.2%, regardless of glyphosate concentration. Surfactant concentration did not influence leaf membrane integrity, as measured by electrolyte leakage, except when glyphosate was applied at 30% (Table 8). Electrolyte leakage was higher with

glyphosate applied at 30% than when applied at 0% or 5%. With 30% glyphosate, increasing surfactant concentration from 0% to 1.2% increased electrolyte leakage. These data suggest the combination of high glyphosate concentration and high surfactant concentration disrupted giant burreed leaf tissue and caused decreased translocation away from the site of glyphosate application. Localized necrosis did not correspond to leaf membrane disruption (Table 8), suggesting that high glyphosate and surfactant concentrations disrupt cells in the mesophyll or phloem. Since glyphosate has phloem mobility, disruption of phloem cells and cells associated with the phloem, may have caused decreased glyphosate translocation. Further experiments are necessary, however, to confirm this hypothesis.

Table 8. Effect of glyphosate concentration and surfactant concentration on injury and electrolyte leakage of giant burreed leaf sections.

Glyphosate conc.	Surfactant conc.	Injury[a]	Electrolyte leakage
(%)	(%)	(%)	(%)
0	0.0	0	14.1
	0.15	0	10.4
	0.6	86	11.9
	1.2	92	11.6
5	0.0	0	13.8
	0.15	0	14.2
	0.6	88	14.9
	1.2	96	15.8
30	0.0	0	25.1
	0.15	0	28.9
	0.6	90	28.7
	1.2	94	34.1
LSD .05		12	6.6

[a]0 = no injury, 100 = severe leaf necrosis at point of droplet application.

Screening Herbicides for Wild Rice Injury and Giant Burreed Control

Two broadleaf herbicides, acifluorfen (Blazer) and bromoxynil (Buctril), which showed some promise in a 1987 trial, were evaluated again in 1989 on a mixed stand of wild rice and giant burreed at Grand Rapids. Wild rice was seeded in the spring into a giant burreed stand established the previous year. Plots were 4 x 10 feet in size.

The experimental design was a randomized complete block with three replications. The herbicides were applied at two dates with a hand CO_2 sprayer at 25 psi at a total volume of 30 gal/A. The first application was on June 28 when wild rice had 2-4 aerial leaves and giant burreed was 24-30 inches tall. The second application was on July 6 when wild rice had 4-6 aerial leaves and giant burreed was 30-36 inches tall. Table 9 gives the injury ratings, plant height and dry weight (panicle weight) of wild rice and above ground plant dry weight of giant burreed.

Table 9. Influence of two herbicides applied to wild rice and giant burreed at two dates and several rates, Grand Rapids - 1989.

Treatment	Rate	Wild Rice			Giant Burreed		
		Injury rating[a] 8 days	Plant height	Panicle dry wt	Injury rating[a] 8 days	Plant height	Plant dry wt
	lb/A a.i.		inches	lb/A		inches	lb/A
herbicides applied 6/28[b]							
Blazer + crop oil	.25 + 1 qt	1.0	43	224	4.5	45	700
	.50 + 1 qt	1.2	44	274	6.0	45	534
	.75 + 1 qt	1.5	46	377	5.2	43	562
Blazer + surfactant (X-77)	.25 + 1%	1.0	47	256	4.2	46	562
	.50 + 1%	1.0	43	270	6.8	46	622
	.75 + 1%	1.2	43	267	5.5	46	672
Buctril	.125	1.0	45	235	5.2	45	512
	.25	1.0	47	170	5.2	47	718
	.375	1.2	44	295	6.2	45	789
Untreated	0	1.0	43	300	1.0	46	918
herbicides applied 7/6[c]							
Blazer + crop oil	.25 + 1 qt	1.0	47	305	4.8	43	779
	.50 + 1 qt	1.5	44	195	6.8	43	715
	.75 + 1 qt	1.2	43	295	5.8	45	455
Blazer + surfactant (X-77)	.25 + 1%	1.0	45	220	4.8	47	562
	.50 + 1%	1.0	45	220	7.0	48	455
	.75 + 1%	1.2	42	256	5.8	45	338
Buctril	.125	1.0	42	288	6.0	45	573
	.250	1.0	39	153	5.5	41	359
	.375	1.0	41	210	7.2	45	619
Untreated	0	1.0	43	139	1.0	44	676
LSD .05		---	8.0	148	---	---	346

[a]1 = no injury, 10 = complete kill.
[b]Wild rice had 2-4 aerial leaves and giant burreed was 24-30 inches tall with 4-5 leaves.
[c]Wild rice had 4-6 aerial leaves and giant burreed was 30-36 inches tall with 5-7 leaves.

Wild rice stands were relatively thin with only 6 to 12 panicles produced per ft^2. The severe competition from giant burreed even in the plots with some giant burreed control reduced the tillering of the wild rice. The wild rice which was present was not severely injured from either herbicide, thus panicle dry weight per acre was not significantly different from the untreated control for either application date (Table 9). The herbicides, however, did reduce the total above ground plant dry weight of giant burreed. On the first treatment date among the Blazer treatments, the lowest giant burreed plant dry weight was obtained by applying 0.5 lb/A of Blazer plus 1 qt crop oil. Applying Buctril

at 0.125 lb/A reduced giant burreed growth more than the higher two rates at the first date. On the second application date neither compound significantly (5% level) reduced above ground plant dry weight; however, there was a trend for plant dry weight to be reduced as Blazer rates increased regardless which additive was used. This was not evident when Buctril was used.

Blazer, which looked promising in the 1987 experiments, looked promising again when applied early, in 1989, especially since it didn't injure wild rice. A more extensive trial with Blazer will be conducted in 1990.

Rate and Method of Nitrogen Fertilizer Application and Residue Removal on Third Year Peat Fields

This experiment is a continuation of the experiment started in the fall of 1986 utilizing six 2-acre peat paddies on the Vomela Farm. In the fall of 1987 the residue left after harvest was removed with a dump-rake from three of the paddies. In the fall of 1988, in the same three paddies, the residue was removed with a specially designed flail chopper which was constructed by Dr. Cletus Schertz of the Agricultural Engineering Department. The fall nitrogen treatments were the same as described in the 1988 Minnesota Wild Rice Research Report. Four nitrogen treatments were applied to each 2-acre paddy in the fall of 1988. Nitrogen, 30 or 60 lb/A, was applied by injection or broadcast. The broadcast treatments were incorporated with a rotovator. In the spring of 1989 all of the paddies were flooded. Dithane M-45 was applied twice on half of all paddies for fungal brown spot control and malathion was applied once to both halves of all paddies for wild rice worm control. The paddies were harvested on August 17 with a combine harvesting a 16-foot wide strip approximately 200 feet long from each treatment.

The 1989 N fertility treatments were visually not as evident as in the first year (1987) of the experiment. In 1988 and 1989 the 60 lb/A rate of N was not greener early in the season than the 30 lb/A rate of N as was evident in 1987. There was very little lodging in 1989 compared to 1987 and 1988 when lodging was severe especially in the high rates of nitrogen. Fungal brown spot began to appear on July 5 in 1989.

Grain yield was considerably better in 1989 than in to 1987 and 1988. On the average for 1989 the 60 lb/A N rate produced slightly more dehulled grain, however, the difference was not statistically different (Table 10). The injected application method produced 35 lb/A more dehulled grain than the broadcast-rotovator incorporated application method (Table 10). On the average, the halves of the paddies that were treated 2 times with Dithane M-45 produced 44 lb/A more dehulled grain and the percent recovery was slightly higher (1.8%) in the fungicide treated part of the paddies. The paddies from which the residue was removed produced 20 lb/A more dehulled grain.

Table 10. Overall averages of green and dehulled grain yield, grain moisture, and percent recovery in response to nitrogen and fungicide application and residue removal at Aitkin-1989.

Treatment	Grain moisture	Green grain	Percent recovery	Dehulled grain
	%	lb/A	%	lb/A
		No fungicide		
Residue removed	39.0[a]	825[a]	41.4	344[a]
Residue left on	38.2	739	42.3	313
30 lb/A N	38.7	766	42.6[a]	327
60 lb/A N	38.5	798	41.1	329
N injected	38.3	850[a]	42.5	361[a]
N incorporated	38.9	715	41.2	296
		Fungicide		
Residue removed	37.9[a]	850	44.1	377
Residue left on	38.5	850	43.1	368
30 lb/A N	38.1	833	43.7	366
60 lb/A N	38.3	868	43.5	378
N injected	38.0	846	43.9	374
N incorporated	38.4	855	43.3	370
		Combined fungicide & no fungicide		
Residue removed	38.4	838	42.8	360[a]
Residue left on	38.4	794	42.7	340
30 lb/A N	38.4	799	43.2[a]	347
60 lb/A N	38.4	833	42.3	354
N injected	38.1	847[a]	43.2[a]	368[a]
N incorporated	38.6	785	42.3	333
Fungicide	38.2	850	43.6	372[a]
No Fungicide	38.6	782	41.8	328

[a] The two means are significantly different from each other at the 20% level or below.

In summary of this 3-year study, it appears that in a first-year peat paddy 30 lb/A N injected is adequate. Even for second and third year fields, 30 lb/A N injected is adequate based on yield measurements. More efficient use of N was obtained by injecting compared to broadcasting and then rotovating the N into the soil.

Benefits of removing the residue was not evident after one year but some increase in yield was obtained by removing the residue for two years. It is not clear why residue removal increased yields during the second year of removal since fungal brown spot infection in 1989 was similar whether the residue was removed or not. Based on the difficulty and expense of removing the residue it appears that removal would not be

economical unless it could be burned.

Influence of Shade During Grain Fill and on Yield of Wild Rice

A trial was conducted at St. Paul to study the effect of reduced light during grain fill on the yield of wild rice. Growers have experienced lower yields when long periods of cloudy days occur during grain fill. This trial was conducted to see if reduced light during grain fill could result in lower yield. The trial was similar to the one conducted in 1987. The study was conducted utilizing 4 ft x 4 ft boxes that were 1 foot deep. The boxes were lined with black plastic sheeting and filled with 8 inches of greenhouse mix soil. The soil was fertilized with 40 lb/A N (urea) plus 6 lb/A of Fe chelate. Four rows of wild rice were seeded, 1 foot apart, into each box after which the boxes were flooded to the top. After the plants were in the 3- to 4-leaf stage the rows of plants were thinned to one plant every 2 inches. On July 14, when the plants were in late boot to early flowering, black plastic mesh screening that reduced light by 47% was placed over all boxes except the controls. The center two rows were harvested for grain yield and plant measurements. Grain was hand stripped 3 times beginning on August 7 and ending on August 21. There were 8 replicates and the experimental design was a randomized complete block. There were 4 light regimes, one with no shading during grain fill and three with the mesh removed after 2, 4 and 5 weeks.

Plant development was not influenced by reducing the light except for a slight reduction in plant height (Table 11). These results were similar to the 1987 experiment except that no plant height differences were obtained in 1987. Grain yield was reduced as length of shading time increased, again these results are similar to the 1987 results except that 2 weeks of shading reduced yield which wasn't true in 1989. The results from the 1987 and 1989 experiments indicate that yields can be reduced by long periods of reduced sunlight which could be the case during long periods of cloudy weather.

Table 11. The effects of reducing natural light by 47% during grain fill on wild rice yield and plant characteristics.

Weeks of light reduction after flowering	Plant height	Plant number	Dry wt/ plant	Stem/ plant	Grain yield[b]
	cm	no./ft^2	gm	no.	lb/A
0	187	5.7	12.6	2.9	663
2	181	6.1	12.0	2.4	673
4	171	5.0	12.2	2.3	530
5[a]	183	5.5	12.0	2.5	517
LSD .20	9	NS	NS	NS	109

[a]Harvested on this date. [b]40% moisture.

Seed Storage and Handling

A seed storage experiment was initiated in 1987 to determine if wild rice seeds could be stored out of water for extended periods of time and still remain viable. If a period

of dry storage would be possible, it would be easier to store wild rice seed for longer time periods than is possible now using cold water storage. Seeds of the K2 variety were air dried on a laboratory bench at room temperature for 12 days. The room temperature was 70-75°F and relative humidity was 40%. Seed was divided into 36 lots. Twenty-six subsamples of 100 g each were randomly taken from 3 lots each day. Eight of the subsamples were treated with a 50:50 mixture of Captan and Dithane M-45. At each sampling date these 8 plus 16 other subsamples were bottled in small glass bottles. The lids were sealed with silicone. The 8 treated bottles plus 8 untreated bottles were stored at 38°F while 9 untreated ones were stored at 28°F. In addition, 2 other subsamples were taken from the 3 lots sampled each day. One of the subsamples was put directly into water at 38°F while grain moisture was determined on the remaining subsample. Moisture content was determined by drying the subsample for 7 days in a forced air oven at 150°F. The treatments were replicated 3 times.

Every 3 months, 3 replicates of each seed moisture content were removed from dry storage and placed into water at 38°F for another 3 months. Germination was determined after the 3 months of water storage for each treatment. Germination was determined by placing 100 seeds into a petri dish filled with water and kept at 70-74°F. Seeds were determined to be germinated when the coleoptile had grown longer than the length of the seed.

The germination results for the first 9 months of dry storage were given in the 1988 Minnesota Wild Rice Research Report. The summary of the experiment for 21 months of storage is presented in Table 13.

Table 12. Germination percentage after dry storage of seed at 12 moisture levels for 90 days up to 630 days followed by 3 months of storage in water after each 90 day dry storage period, St. Paul.

Drying time	Seed moisture	Months in dry storage							
		3	6	9	12	15	18	21	Average
days	%	Germination percent							
		Stored at 28°F							
0	32	36	12	7	18	2	0	0	11
2	27	58	25	10	9	6	20	0	18
3	23	61	48	29	20	19	9	0	26
4	22	50	65	49	25	37	2	0	33
5	19	52	52	56	38	52	38	0	41
6	19	58	64	59	34	66	30	0	44
7	14	60	68	66	46	53	62	0	51
8	12	67	61	50	24	37	21	1	37
9	11	62	51	46	30	11	2	0	29
10	10	71	46	40	40	22	5	0	30
11	9	52	49	50	47	24	36	0	37
12	9	58	50	51	42	35	48	7	42
	Average	57	49	43	31	30	27	1	34

Table 12 (Continued).

Drying time	Seed moisture	Months in dry storage 3	6	9	12	15	18	21	Average
days	%	Germination percent							
		Stored at 38°F							
0	32	38	62	43	6	1	0	0	21
2	27	49	53	19	1	0	0	0	17
3	23	53	64	37	1	0	0	0	22
4	22	56	59	36	0	0	0	0	21
5	19	53	68	35	1	0	0	0	22
6	19	58	64	59	10	0	0	0	29
7	14	59	60	73	30	29	0	0	36
8	12	65	64	65	18	46	25	1	40
9	11	60	46	27	12	6	1	0	22
10	10	67	49	12	0	1	0	0	18
11	9	58	49	39	21	14	1	0	26
12	9	49	45	52	32	39	6	7	33
	Average	55	57	41	12	11	3	1	26
		Stored at 38°F + fungicide seed treatment							
0	32	43	39	20	0	0	1	0	15
2	27	45	45	33	2	0	0	0	18
3	23	55	45	48	2	0	0	0	21
4	22	58	54	39	4	0	0	0	22
5	19	48	45	46	5	0	0	0	20
6	19	23	45	61	25	12	12	0	26
7	14	60	48	63	38	35	1	0	35
8	12	61	52	52	41	38	18	7	38
9	11	62	57	38	3	10	2	0	25
10	10	50	45	18	0	0	0	0	16
11	9	47	52	36	41	10	2	1	27
12	9	43	43	49	18	33	13	0	28
	Average	50	47	42	15	12	4	1	24

A detailed statistical analysis has not been done at this time, however, the best overall dry storage condition was storing the bottles of seed at a temperature slightly below freezing (Table 13). The average germination of all the treatments for this storage temperature was 34% compared to 26% for 38°F storage temperature when the seed was not treated with fungicides and 24% when the seed was treated with fungicides and also stored at 38°F. Part of the reason for a higher germination average at 28°F is better germination up to 18 months in dry storage compared to storing at the higher temperature. The best seed moisture for the longest period of dry storage appears to be 14-20% moisture range. However, even at 9% seed moisture, 48% germination was obtained after 18 months dry storage at 28°F. At seed moisture percentages above 19,

seed germination declined sooner with length of storage at both storage temperatures then seed moisture percentages below 19. It appears that it would be possible to store seeds at 14-19% moisture out of water up to 18 months at temperatures just below freezing and still obtain fair germination. We are repeating in 1990-92 storing seeds at 28°F at several moisture levels. If the results are similar, it would be easier to store seeds in dry conditions for a period of time compared to keeping them in water. Also length of storage time could be increased.

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