WILD RICE BREEDING

Raymond A. Porter, Henry J. Schumer, and Bruce J. MacGregor[1]
North Central Experiment Station, Grand Rapids, MN

Activities in 1992 included variety trials, a pistillate fertility trial, population improvement, and other breeding activities. Bruce MacGregor was added to the project in August of 1992, and a search for a postdoctoral associate to initiate work on molecular genetic mapping resulted in the addition of Dr. Alan Grombacher in January of 1993.

A new shattering-resistant cultivar, Franklin' (formerly K2(2)C4), has been developed by project personnel. It was released in 1992 on the basis of variety trial results from 1990-92. It was named in honor of Franklin Kosbau and carries the following description: "Medium height, medium to early maturity. More shattering resistant than K2 or other currently grown varieties, especially retaining more seed when harvest is delayed."

Variety Trials

We conducted variety trials in 3 locations in 1992--Grand Rapids, Gully (Gunvalson-Imle farm), and Waskish (Rennemo farm). A fourth trial was planted at the Vomela farm site, but was presumed destroyed by crayfish--no plants emerged after flooding.

Methods. Gully and Waskish trials were planted in the fall of 1991. Twenty entries were planted in 6 replicates at each location (see Table 1 for description of entries). Plots were four 10-foot rows with 15 in. between rows and 30 in. between plots. In June, volunteer plants growing between rows were thinned out. The density of volunteers was estimated to be 0.5 plants/ft^2 before removal. Since these were on-farm trials, the water and fertility management were consistent with each grower's normal practices.

Prior to the onset of seed shattering, plastic troughs were placed between the center two rows to catch shattered seed. Estimates of shattering losses per acre were based on the area of these troughs, which was about 13% of the harvested area of the plot. Seeds were collected from the troughs and plots rated for lodging immediately prior to harvest. Only plots with at least 2 plants/ft^2 were harvested (96 of 120 plots at Gully and 106 of 120 plots at Waskish). The earliest 8 entries were harvested first, then the remainder a week later. Lodging had become severe by the second harvest at Waskish, but the binder was able to harvest the center two rows. The center two rows were harvested with a two-row grain binder and threshed with a Vogel thresher. Also at the second harvest, the border rows from the plots of the first harvest were harvested and threshed to estimate their yield under greater shattering pressure. Most of the stem debris was removed from the threshed samples using a shaker-sieve seed cleaner. Final sample included seeds and other material which passed through a 9/64 by 3/4 inch slotted sieve, but not through a 1/14 by 1/2 inch sieve. Fresh samples were weighed, then dried and weighed again to determine dry weight and percent moisture;

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[1] Research Associate, Research Plot Coordinator, and Junior Scientist

yields were adjusted to 40% moisture. In the case of samples from border rows, delayed yield estimates were reduced by 21% to adjust for the border row effect.

Table 1 Description of variety trial entries

Entry	Description
FSSR-C6	Frost-selected shattering resistance population (6 cycles of selection)
K2 (Godward)	Developed by Kosbau brothers; from T. Godward's farm, rotated to new paddies
K2 (Vomela)	Developed by Kosbau brothers; from Vomela farm seed field
K2(1)C5	K2-derived population "1" selected 5 cycles for shattering resistance
K2(2)C3 Pi	K2-derived population "2" selected 3 cycles for shattering resistance, then selected for pistillate plants; this F_2 population should have 25% pistillate plants
Franklin	K2-derived population "2" selected 4 cycles for shattering resistance; released by Minnesota Agricultural Experiment Station in fall of 1992; previously K2(2)C4
NACH-B(Man.)	Netum-derived, selected by A. Hedstrom (Manomin Development Co.) for bottlebrush, shattering resistance
NR(Manomin)	Netum-derived, selected by A. Hedstrom for red flower, shattering resistance
NW(Manomin)	Netum-derived, selected by A. Hedstrom for white flower, shattering resistance
Voyager (Imle)	Selected for earliness, shattering resistance. Released by U of M in 1983
M1(Manomin)	Developed by Manomin
M3(Manomin)	Developed by Manomin; usually contains less than 10% pistillate plants
Petrowske(CW)	Selected by K. Petrowske for healthy, vigorous bottlebrush plants; reselected by Clearwater farm for shattering resistance
Petrowske(G-I)	Selected by K. Petrowske for healthy, vigorous bottlebrush plants; reselected by Gunvalson-Imle farm for bottlebrush, shattering resistance
PM3 x FSSR-C4	F_2 of Pistillate M3 crossed to FSSR-C4; 25% pistillate plants expected
PM3 x K2(1)C4	F_2 of Pistillate M3 crossed to K2(1)C4; 25% pistillate plants expected
PM3 x K2(2)C3	F_2 of Pistillate M3 crossed to K2(2)C3; 25% pistillate plants expected
PM3 x SS-C2	F_2 of Pistillate M3 crossed to SS-C2; 25% pistillate plants expected
SS-C4 (short)	Selected for sturdy stem, 4 cycles; short plants, last 2 cycles only
SS-C4 (tall)	Selected for sturdy stem, 4 cycles; tall plants, last 2 cycles only
PM3-P	Pistillate M3 continuously selected for pistillate plant type, which reaches a maximum frequency of 50%; released as germplasm by U of M in 1988

The variety trial at Grand Rapids was conducted similarly, with the following exceptions. Twenty entries were planted in six reps, but three entries were discarded because of poor germination. Sixteen of the seventeen entries corresponded to the entries at the other two locations (Table 1). Plots were planted and flooded on May 14, 1992. Each plot consisted of four 10-foot rows with 12 in. between rows and 24 in. between plots. Preplant fertilizer was applied as a blend of N-P-K-S-B at the rate of 50-0-40-20-3 lb/A. In addition, urea was topdressed once at early flowering at a rate of 30 lb/A of N. The date on which 50% of mainstems had emerged was noted for each plot. The average date was then used to determine the relative maturity of entries for harvest decisions at all three locations. The date of appearance of the first head in a plot, as well as 10% flowering date were also noted. The difference between 50% heading date and first head appearance date was calculated and analyzed as flowering range. Plant height and length of seed bearing portion of normal panicle types were also measured. In addition to estimating shattering in the manner described above, seed tensile strength was measured--the in-line force required to break the seed free from the panicle. Five mature seeds were measured on each of five tagged plants per plot. Panicles had been tagged at head emergence in order to compare plants of the same maturity.

Maturity of all plantings was probably delayed by cool weather. Even so, entries were not as mature at harvest as in past years, as evidenced by higher grain moisture and lower shattering losses (see Table 2). We presented yield and shattering data from the first harvest to the Crop Variety Review Committee in support of the final release of 'Franklin'. We harvested the first entries slightly early (see first group, Table 1) in order to have time to analyze data, present it to the committee, and release Franklin before the seed increase was harvested on September 8.

Results and Discussion. Table 2 shows the yield and shattering averages for each location, as well as the means across all three locations for yield, shattering, grain moisture at harvest, and lodging. Means reported were adjusted in the analysis to account for missing plots. The first 8 entries listed were all harvested on the first date, and had lower shattering losses than the later ones. This makes comparisons between entries with different harvest dates for shattering resistance inadvisable, at least for this year's data. Furthermore, shattering comparisons between entries within the first harvest group should be avoided, since differences were usually less than the LSD, and since shattering at the optimum harvest date may not reflect relative losses at a later harvest date, as we will show below. Voyager should have been harvested in the early group at all 3 locations, but was missed in the first harvest at Waskish and Gully, which increased its overall shattering loss.

Yields at Grand Rapids were highest (over 2000 lb/A on the average), followed by Gully and Waskish. Some factors which may have been responsible for the higher yield at Grand Rapids are: bird netting, soil fumigation (eliminating weed problems), better plot establishment resulting in higher plant populations, longer period of flooded growth (paddy was not drained until about 1-2 weeks prior to harvest), and less lodging, especially among the later entries.

M1 and M3 had high shattering losses and lower yields at all locations. The highest yielding entry was NACH-B, which outyielded even the elite experimental populations in the same maturity group. In fact, it was the highest yielding entry overall. Most of the other entries (including later-maturing ones) were grouped between 1200 and 1500 lb/A. Franklin fell into this group, showing it to be respectable in yield, but not the highest. However, we did not expect it to yield the highest under conditions of low shattering losses. Rather, it was selected to retain more seed through a later period of seed maturity, outyielding other varieties when shattering losses are high.

Lodging was high at Waskish, especially among the later entries, averaging 2.5 overall (on a 1-5 scale) compared to 1.7 for Gully and 1.4 for Grand Rapids. PM3 x K2(1)C4 lodged the most (2.8), possibly related to a greater plant height (see Table 3). The short and tall versions of the SS-C4 population had been selected for stem sturdiness for 4 cycles, but were still in the middle range of lodging overall, with SS-C4 (short) having a slight advantage. The least lodged entry was FSSR-C6, which made sense considering how it was selected. Plants were tagged as they emerged from the boot but selection was not applied for seed retention until at or after frost. By that time, many plants which were prone to lodging had already gone down, since they were well past maturity, leaving only standing plants to select from. Since plants were color coded with tags for flowering date, unconscious selection for late maturity was presumably avoided.

Table 2 Yield, shattering, and moisture of grain from variety trials at 3 locations

Entry	Adjusted Yield (Shattering)			Mean over 3 locations			
	G. Rapids	Gully	Waskish	Yield	Shat.	Moist.	Lodg.
	---lb/A[a] (%[b])---			lb/A[a]	%[b]	%[c]	score[d]
FSSR-C6	1722 (5)	1091 (13)	808 (16)	1209	11	42	1.1
K2 (Godward)		1537 (17)	1020 (22)				
K2 (Vomela)	2257 (7)	1198 (17)	823 (23)	1424	16	37	1.3
K2(1)C5	1984 (6)	1148 (15)	982 (22)	1373	14	40	1.7
K2(2)C3 Pi	2317 (4)						
Franklin	1882 (7)	1266 (16)	1051 (16)	1402	13	39	1.3
NACH-B(Man.)	2169 (6)	1508 (16)	1436 (14)	1702	12	39	1.7
NR(Manomin)	1957 (7)	1450 (14)	1189 (16)	1526	12	40	1.8
NW(Manomin)	2222 (5)	1190 (16)	1044 (18)	1487	13	43	1.9
Voyager (Imle)	2024 (4)	954 (41)	639 (46)	1208	30	37	2.3
M1(Manomin)	1753 (20)	762 (42)	513 (51)	1006	38	38	2.3
M3(Manomin)	1455 (31)	439 (51)	331 (66)	746	49	39	2.2
Petrowske(CW)		917 (37)	684 (55)				
Petrowske(G-I)	2174 (17)	1183 (35)	934 (38)	1425	30	36	2.1
PM3 x FSSR-C4		1065 (24)	728 (28)				
PM3 x K2(1)C4	2345 (11)	1275 (27)	684 (41)	1436	26	37	2.8
PM3 x K2(2)C3		1188 (26)	815 (39)				
PM3 x SS-C2	2062 (9)	1484 (22)	998 (26)	1514	19	37	1.9
SS-C4 (short)	1967 (14)	1460 (20)	926 (26)	1451	20	39	1.8
SS-C4 (tall)	2338 (11)	1212 (21)	806 (28)	1450	20	35	2.1
PM3-P	2075 (9)	1285 (16)	761 (28)	1374	18	39	2.0
Trial mean	2041 (10)	1181 (24)	859 (31)	1358	21	39	1.9
LSD(5%)	432 (5)	314 (7)	223 (9)	198	4	3	0.4

[a] Adjusted to 40% moisture. [b] Seed shattering expressed as a percentage of harvested plus shattered grain. [c] Moisture on a fresh-weight basis. [d] 1 to 5 scale where 1 = all stems upright, 5 = all stems lodged.

Table 3 shows other characteristics of the entries in the Grand Rapids variety trial. Entries were not greatly different for flowering date, perhaps because the earlier entrie were delayed by the cool weather. The flowering range (from first head to 50% heading) was somewhat related to maturity--the correlation between the two was 0.65 ($r^2 = 0.42$). The later flowering entries tended to have a greater flowering range. However more than half the flowering range variability among entries was not explained by its positive correlation with maturity. The presence of both higher- and lower-range entries among the early group means that there is probably genetic variability for selection of a narrower-range variety independent of flowering date itself. The range of seed maturity at harvest is probably a reflection of this flowering range, as well as the lack of flowering synchrony among tillers of the same plant.

Table 3 Maturity, size, and seed retention traits of Grand Rapids variety trial entries

Entry	50% flowering days[a]	flowering range days[b]	Height in[c]	Panicle length in[d]	Shatt. loss %[e]	Tensile strength grams[f]
FSSR-C6	80	9.7	72.1	6.6	5	119
K2 (Vomela)	80	7.7	73.4	6.4	7	113
K2(1)C5	81	8.7	74.0	6.1	6	130
K2(2)C3 Pi	81	9.5	72.9	6.9	4	143
Franklin	79	9.2	74.4	6.7	7	127
NACH-B(Man.)	81	8.3	71.1	7.2	6	123
NR(Manomin)	81	8.0	72.4	7.6	7	98
NW(Manomin)	81	8.3	70.6	7.0	5	105
Voyager (Imle)	80	8.8	69.9	7.2	4	98
M1(Manomin)	83	9.2	72.2	7.2	20	71
M3(Manomin)	81	8.7	70.7	7.2	31	82
Petrowske(G-I)	82	8.2	71.8	7.2	17	109
PM3 x K2(1)C4	82	8.0	75.4	7.3	11	103
PM3 x SS-C2	83	9.2	77.0	7.0	9	94
SS-C4 (short)	84	10.2	73.9	7.3	14	93
SS-C4 (tall)	84	10.0	79.1	7.1	11	110
PM3-P	88	10.8	68.6	7.5	9	110
Trial mean	82	9.0	72.9	7.0	10	108
LSD(5%)	2	ns	4.0	0.7	5	31

[a] Time from flooding until 50% of mainstems show male branches. [b] Time from appearance of first hea in plot until 50% flowering. [c] Height to tip of panicle of the tallest tiller of a plant. [d] Length of seed bearing portion of normal, monoecious panicle. [e] Seed shattering expressed as a percentage of harvested plus shattered grain (Waskish and Gully data averaged). [f] Force necessary to remove seed from panicle, mean of 5 plants, 5 seeds per panicle

The tallest entry was SS-C4 (tall), which had been selected only 2 generations for tall plants. The short version of this population was more than 5 inches shorter than its tall counterpart, but was still slightly above the mean. Voyager was also short, as expected. Pistillate M3 was short and had a delayed maturity, probably due to the high frequency of transplants necessary to fill in the plots of this variety in particular. PM3 x K2(1)C4 and PM3 x SS-C4 were 4.1 inches and 4.4 inches taller than the mean of their respective parents, possibly an indication of remnant hybrid vigor still present in the F_2 generation. However, there were no significant increases in yield associated with these or the other hybrids, PM3 x FSSR-C4 and PM3 x K2(2)C3.

Although Franklin was not the highest yielding entry in this year's tests, its seed retention strength as measured by the force gauge was high. Only K2(1)C5 and K2(2)C3 Pi (a pistillate version of Franklin). NACH-B was also high in tensile strength. The correlation of tensile strength with actual shattering loss at Grand Rapids was -0.66 (r^2 = 0.43)--higher tensile strength entries tended to be less shattering. However, 57% of the variability was not explained by this relationship, probably because of the low shattering pressure of the early-harvested entries.

Table 4 shows the comparison between the optimum harvest (center rows) and delayed harvest (border rows) for the first harvest at Waskish and Gully. Although the delayed harvest was represented by border rows, we made every effort to adjust the yields to reflect the effect of more space available for border rows. Regardless, we expect the performance of border rows to represent the *relative* performance of the entries, had the harvest of the center rows been delayed. FSSR-C6 yielded lowest in the group at optimum harvest, but best when harvest was delayed. The performance of Franklin relative to the other entries, especially NACH-B, changed dramatically. Although NACH-B, NR, and K2 (Godward) were higher at the first harvest, Franklin was higher at the second. Actually, Franklin maintained its yield level while the others dropped below it. This reaffirms that the primary advantage of this variety is its longer and greater seed retention, for which it was selected--not higher yield capacity, which was not the focus of selection. Nevertheless, there is room for yield improvement in Franklin. The high yield of NACH-B (although this is only one year's data), puts the onus on the breeding project to develop a variety that has both higher yield and greater shattering resistance.

Based on this data, as well as data from 1990 trials at Aitkin and Grand Rapids, we recommend that Franklin be utilized in a way that takes advantage of its longer seed retention, perhaps freeing growers to harvest other paddies with more shatter-prone varieties. We further recommend that Franklin seed be obtained from a reliable, preferably certified, source (i.e., from paddies free of volunteer plants), and that it be put into paddies in a production system of at least 1 year out of production (2 if possible) for every 2 years in production. Following these recommendations should maintain the integrity and continued shattering resistance of the variety, and may even improve its shattering resistance.

Table 4 Yield and shattering of medium-early entries at optimum harvest date and one week later (average of Waskish and Gully variety trials)

Entry	Yield at optimum harv. lb/A[a]	Shattering at optimum harv. %[b]	Adjusted yield at delayed harv. lb/A[c]
FSSR-C6	958	14	1047
K2 (Godward)	1264	19	845
K2 (Vomela)	1003	20	733
K2(1)C5	1074	19	773
Franklin	1167	16	999
NACH-B(Man.)	1470	15	888
NR(Manomin)	1303	15	789
NW(Manomin)	1117	17	665
Mean	1170	17	842
LSD(5%)	200	4	167

[a] Adjusted to 40% moisture. [b] Seed shattering expressed as a percentage of harvested plus shattered grain. [c] Yield of border rows divided by a correction factor of 1.27; adjusted to 40% moisture

Pistillate Fertility Trial (in collaboration with Dr. Paul Bloom)

As a follow-up to recent research on the pistillate head type, we conducted a nitrogen fertilizer response experiment using different levels of urea topdress on populations wi... varying proportions of pistillate plants. The experiment's objectives were to 1) determine whether and to what extent pistillate and normal plants responded to increased nitrogen by filling more grain per head, and 2) determine the effect of increasing topdress nitrogen on overall yield, shattering, lodging, and nitrogen status of the plants.

Methods. Six populations (see Table 5 for descriptions) were spring-planted in 3 replicates, with 4 sub-plots of each variety planted adjacent to each other in each rep. These four sub-plots were treated in an identical fashion until separated into 4 topdress treatments: 0, 30, 60, and 90 lb/A of N as urea. The design of the experiment was split-plot with entries as whole plots and topdress treatments as subplots. Each subplot consisted of four 10-foot rows, with 12 inches between rows within plots and 24 inches between adjacent plots. After plants had reached the aerial leaf stage, plots were thinned and transplanted as needed to obtain relatively uniform stands (PM3 x K2(1)C4 had a slightly lower population than the others). Topdress treatments began at the late boot stage and were split into applications of 30 lb/A at each of 3 times (see Table 6).

Two weeks after the final application, leaf greenness was measured with a SPAD 502 chlorophyll meter. Ten pistillate and ten normal flag leaves were measured per plot. Shattered seed was collected in troughs as in the variety trials. Lodging was rated prior to harvest. Plots were harvested by hand, keeping pistillate heads and normal heads apart for separate threshing and weighing. The remaining portion of the plants was harvested with the binder, added to the threshings, dried, and weighed. This variable (non-grain dry matter) was added to shattered grain and harvested grain dry weights to compute total above-ground biomass. Harvested seed and shattered seed estimates were combined to calculate potential yield, all three of which were reported on a 40% moisture basis. Harvest index was calculated by dividing harvested grain by total biomass (dry weights). Number of stems harvested was used to calculate stem density and yield per head of each panicle type.

Table 5 Description of fertility trial entries

Entry	Description
PM3 x K2(1)C4	F_2 of population hybrid between Pistillate M3 and K2(1)C4; 25% pistillate plant frequency expected
PM3-P	Pistillate M3 germplasm selected continuously for pistillate; 50% pistillate frequency expected
PM3-N	Pistillate M3 selected continuously for pistillate, then one generation for nonpistillate plants; 25% pistillate frequency expected
PM3 x LaRonge	F_6 of Pistillate M3 crossed to a population from LaRonge, Saskatchewan, then reselected for pistillate from F_2 through F_6 generation; 50% pistillate expected
PM3 x SS-C2	F_2 of population hybrid between Pistillate M3 and SS-C2; 25% pistillate plant frequency expected
M3 (Manomin)	Developed by Manomin Dev. Co.; usually contains less than 10% pistillate plants

Table 6 Topdress application schedule for fertility trial

Application time	0 lb/A plots	30 lb/A plots	60 lb/A plots	90 lb/A plots
	b/A applied			
late boot	0	0	30	30
early flowering	0	30	0	30
mid flowering	0	0	30	30

Results and Discussion. Tables 7 and 8 shows the means for each entry across topdresses and reps, and for each topdress treatment averaged across entries and reps. Each contrast listed at the bottom of the table reports the difference between the averages of one set of treatments and another set, along with the statistical significance of each contrast. Discussion of the various treatments will focus on these contrasts.

The most noticeable difference between groups of varieties was between the rest of the varieties and M3 (Table 7). The potential yield of M3 was 650 lb/A less than the others. Shattering was 18% greater, contributing to an even greater difference in harvested yield--1000 lb/A. M3 biomass was less, but not significantly less than the others, in spite of having more stems per ft^2 and greater SPAD readings. Harvest index and hea yield were 10% less and 0.9 g less than the other entries. First, the others contained 18-42% pistillate stems (see Table 8), and second, M3 shattered a great deal more tha the others. Unfortunately, the relative contribution of these two factors to the loss yield could not be determined on the basis of these data.

Table 7 Average yield, lodging, and SPAD readings for fertility trial entries and topdress treatments, and contrast differences between groups of treatments

Treatment/contrast	Pot'l yield lb/A[a]	Harv. yield lb/A[a]	Seed shatt. %[b]	Bio-mass lb/A[c]	Harv. index %[d]	Stem density ft^{-2}	Head yld. g[e]	Lodg-ing score[f]	SPAI rdg. units
	treatment means								
entry									
PM3 x K2(1)C4	2739	2487	9.3	4809	31.2	7.6	2.0	1.7	44
PM3-P	3099	2814	9.5	5731	29.3	9.5	1.8	1.7	41
PM3-N	2646	2455	7.3	5021	29.3	8.8	1.7	1.2	43
PM3 x LaRonge	3016	2796	8.1	5646	29.4	8.3	2.1	1.7	44
PM3 x SS-C2	2928	2672	8.9	5387	29.7	8.7	1.9	1.4	43
M3 (Manomin)	2229	1640	27.0	5030	19.4	9.7	1.1	1.3	40
topdress									
0	2493	2217	12.2	4761	27.6	8.3	1.7	1.7	40
30	2743	2433	12.5	5065	28.5	8.4	1.8	1.4	43
60	2847	2552	10.9	5575	27.6	8.9	1.8	1.4	43
90	3022	2707	11.1	5682	28.4	9.5	1.8	1.4	45
	contrast differences								
entry contrast									
the rest vs. M3	657 **	1004 **	-18.4 **	289	10.4 **	-1.1 *	0.9 **	0.2	3
50% vs. 25%P	286 *	267 *	0.4	617 *	-0.7	0.5	0.1	0.3	-1
PM3 P vs. N	453 *	359	2.2	711 *	0.0	0.7	0.1	0.5 *	-2
Hybrid vs. nonhyb.	187	125	1.8	77	1.1	-0.7	0.2	0.4	0
topdress contrast									
nitrogen (linear)	529 **	490 **	-1.1	921 **	0.8	1.2 **	0.1	-0.3 *	4

*, ** Contrast significant at the 0.05 and 0.01 level, respectively. [a] Adjusted to 40% moisture; potenti yield is harvested yield plus estimated shattered seed losses. [b] Shattering loss expressed as a percentage of potential yield. [c] Biomass includes total above-ground biomass, including shattered se expressed on a dry weight basis. [d] Harvest index is harvested yield as a percentage of total biomass. [e] Seed yield per panicle, dry weight. [f] 1 to 5 scale where 1 = all stems upright, 5 = all stems lodged. [g] Mean of 10 pistillate and 10 normal flag leaves' SPAD readings in [relative] SPAD units, weighted proportionally to the number of stems of each type in the plot

The second contrast was between the two entries with 50% pistillate plants (PM3-P PM3 x LaRonge) and those with 25% pistillate plants. Entries had been categorized 50% or 25% pistillate based on previous data; pistillate plant counts were not made i this experiment. However, since pistillate plants generally emerged later, they produ fewer tillers (unpublished data, 1991). This is probably why there were less than 50 pistillate *stems* in the entries which should have had 50% pistillate *plants*. Entries with 50% pistillate outyielded those with 25% by more than 250 lb/A and produced over 600 lb/A more dry matter. However, there were no significant differences in seed shattering, harvest index, stem density, head yield, or lodging. Table 8 also shows that there are significant differences in yield of pistillate and normal fractions of each plot. Pistillate stems yielded 650 lb/A more in the 50% pistillate entries, but normal stems 386 lb/A less, since the percentage of pistillate heads was 17% greater (and normal heads 17% less) in the 50% entries. The 50% entries were not significantly different from 25% entries for yield per pistillate plant or yield per normal plant. The 50% entries had a slightly higher P/N head yield ratio, but the difference was not significant.

PM3-P generally compared favorably with PM3-N, but the former was significantly greater (at the 5% level) only for potential yield (450 lb/A higher), and biomass (700 lb/A more dry matter); PM3-P yielded 430 lb/A more pistillate seed and 70 lb/A less normal seed, but these differences were not significant. PM3-N had a significantly higher SPAD reading (by 2 units) and lower lodging (by 1/2 unit).

Table 8 Pistillate and normal yield and panicle frequency for fertility trial entries and topdress treatments, and contrast differences between groups of treatments

Treatment/contrast	P fraction yield lb/A[a]	N fraction yield lb/A[a]	P head yield g[b]	N head yield g[b]	P/N head yield ratio %[c]	P head frequency %[d]
entry	treatment means					
PM3 x K2(1)C4	687	1800	2.6	1.9	134	23
PM3-P	1295	1518	2.5	1.5	167	34
PM3-N	864	1591	2.7	1.5	190	23
PM3 x LaRonge	1489	1306	2.6	1.7	149	42
PM3 x SS-C2	668	2004	2.6	1.8	147	18
topdress						
0	856	1541	2.5	1.6	164	27
30	1073	1584	2.7	1.7	156	31
60	1002	1681	2.7	1.7	161	27
90	1071	1769	2.5	1.7	149	28
entry contrast	contrast differences					
50% vs. 25%P	653 **	-386 **	-0.1	-0.1	1	17 **
PM3 P vs. N	432	-73	-0.2	0.0	-23	11
Hybrid vs. nonhyb.	-186	311 *	-0.1	0.4 *	-49 *	-2
topdress contrast						
nitrogen (linear)	214	227 *	0.0	0.1	-15	1

*, ** Contrast significant at the 0.05 and 0.01 level, respectively. [a] Adjusted to 40% moisture; yields of pistillate panicles (P) and normal panicles (N) harvested separately; their sum is total harvested yield (see previous table). [b] Seed yield per panicle, dry weight. [c] Ratio of P head yield to N head yield. [d] Frequency of pistillate panicles (not plants)

Hybrid 25% pistillate entries (F_2's of PM3 x K2(1)C4 and PM3 x SS-C2) were not m different from nonhybrid 25% entry (PM3-N), except that the hybrids produced over lb/A more grain from normal plants and 0.4 g more seeds per normal panicles th t nonhybrids. More grain from normal panicles resulted in a significantly lower P/ a since hybrids produced more grains per normal head while maintaining a similar yiel the pistillate heads.

The linear contrast for nitrogen topdress shows whether there was a significant linea response to increasing levels of nitrogen. Potential yield, harvested yield, biomass, stem density, SPAD readings, and normal fraction yield all increased significantly as topdressed nitrogen increased. Pistillate fraction yield increased (though without statistical significance) by over 200 lb/A, but the primary increase seemed to be due the first 30 lb/A of nitrogen. Pistillate yield *per panicle* did not increase on the avera probably due to the fact that increased nitrogen meant an increase in number of panicles harvested. The later panicles would likely have produced less grain, compensating for any increase in head yield of the other panicles.

Figures 1 and 2 show the comparison between 50% and 25% pistillate entries' respc to nitrogen topdressing. The difference between the two types of entries is striking, the contrast between them for *response* to nitrogen, although not presented in Table is significant. *There was a 930 lb/A increase in total yield associated with the additic 90 lb/A of topdressed nitrogen to the 50% pistillate entries.* Over 600 lb/A of that increase came from the pistillate fraction. There was no increase in pistillate yield of 25% entries, although there did seem to be a response of normal plants to the first 3 lb/A of nitrogen (160 lb/A increase). For the 50% entries, there was an initial drop in normal fraction yield in response to the first topdress, followed by an increase with subsequent topdresses. The total dry matter (biomass) increased by 1180 in res n to 90 lb/A of nitrogen. Taking into account that the increase of 930 lb/A grain yie (4 moisture) was equivalent to 560 lb/A (dry weight), the 47% of the increase in total biomass was due to additional grain.

To summarize, we saw that there was an increase in yield associated with additional nitrogen as topdress beginning at the boot stage. The response (averaged across a entries) was associated with significant increases in normal plant yield, biomass, ste density, and chlorophyll content of the flag leaf (which was already higher); yield of pistillate plants increased, but the linear response was not significant. Entries with 5 pistillate plants yielded more and responded better to nitrogen than 25% entries. Hy entries (in the F_2 generation) had higher yielding normal plants than the nonhybrid 2 pistillate entry. Lodging was not a problem in this experiment, and actually decrease slightly. M3 yielded less and shattered more than the other entries.

Cultivar Development and Other Activities

Zizania aquatica x Z. palustris backcrosses. We have backcrossed to several po lations of Z. palustris while selecting nondormant seeds. We now have seed of the BC_3F_1 generation from winter greenhouse crosses, and we are also increasing seec obtain BC_1F_3 seed for further study.

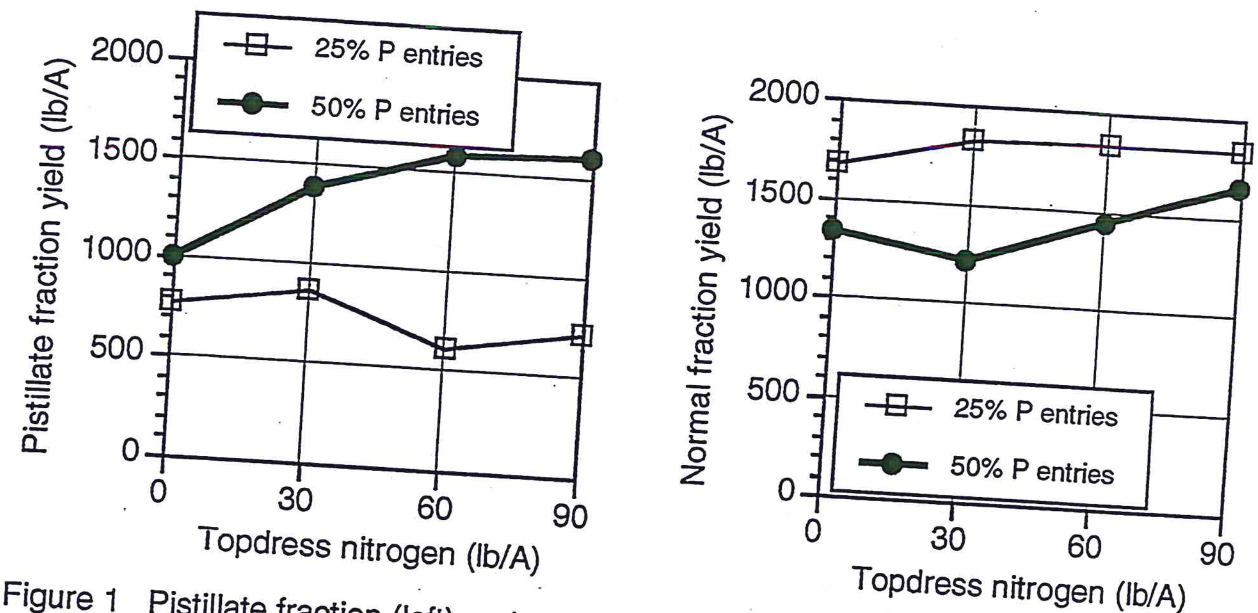

Figure 1 Pistillate fraction (left) and normal fraction (right) yield response to topdressed nitrogen--comparison of average of 25% pistillate entries with 50% pistillate entries.

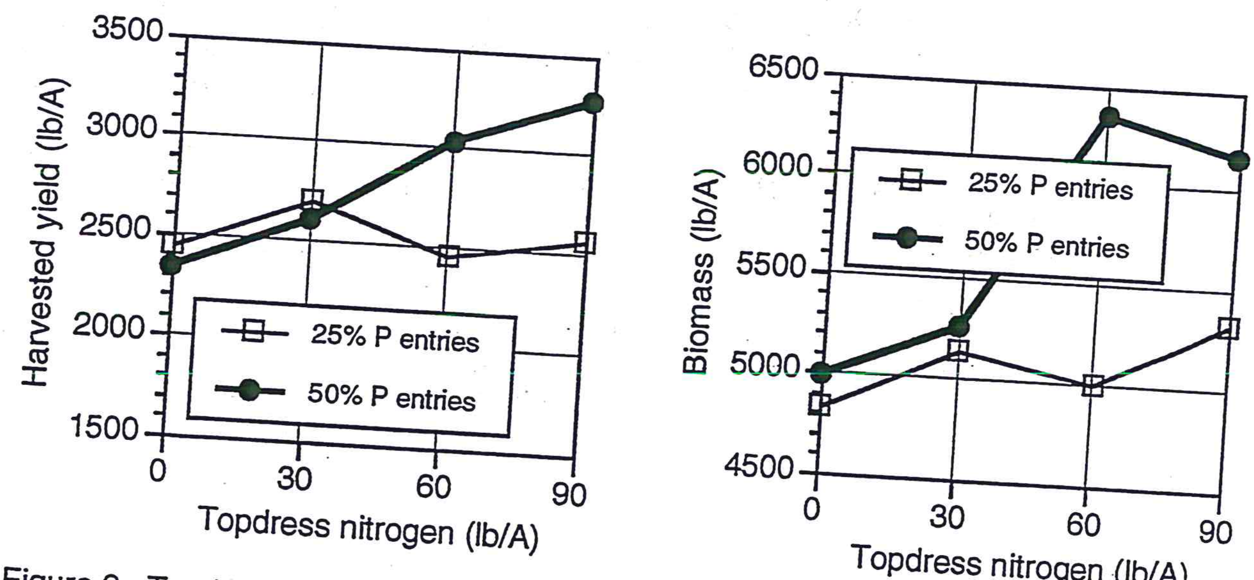

Figure 2 Total harvested yield (left) and biomass dry weight (right) response to topdressed nitrogen--comparison of average of 25% pistillate entries with 50% pistillate entries.

Population improvement. We continued selection for shattering resistance in man populations. We selected the best 10% of plants to obtain seed for the next cy[illegible] selection in 1993 for the following experimental populations: K2(4)C5, (M3 x Netum (Meter x Johnson), FSSR-C7 (known as "Frosty"), Petrowske Bottlebrush, and PM3- In addition, we selected for stem sturdiness to obtain SS-C5, concentrating mainly o the short-plant population. We continued selection for the pistillate trait in PM3-C3, x LaRonge, PM3 x K2(1)C4, PM3 x SS-C2, PM3 x K2(2)C3, K2(2)C3 Pi (F_3 seed obtained), and K2(1)C4 Pi (F_3). We also continued selection for the bottlebrush trai Petrowske Bottlebrush, PB(M)C3, and a Netum population.

We obtained half-sib seed of a number of populations for use in genetic studies next summer, and for evaluation and selection for higher yield and shattering resistance. also obtained seed of outstanding or unusual individual plants. In addition, we have obtained selfed seed from a number of plants of Franklin and a few from other populations, to begin a larger program of inbreeding.

Our selection activities were confined largely to Grand Rapids this year. The populations planted at Aitkin were destroyed, presumably by crayfish. In addition, however, Art Hedstrom allowed us to make selections from his seed field, for which are grateful.

Hybridization. We have crossed NorCal-3 plants to FSSR-C6, SS-C4, K2(1)C6, ar Franklin. We have also crossed two other California populations--a Johnson popula and an unknown population ("Goose Valley")--with PM3 x LaRonge and PB(M)C3 in greenhouse. Our goal is to introgress shattering resistance and high yield from thes populations into Minnesota-adapted populations. We have also crossed 3 Minn[illegible]t lake populations (Dora Lake, White Elk Lake, and Shovel Lake) to Franklin.

Other Activities. Because of the cool weather, fungal brown spot disease severity low, so disease ratings were not useful for evaluation or selection. We are increasin our inbreeding activities (by selfing or sib-mating), both in the field and in the greenhouse, with the goal of obtaining inbred lines for use in new breeding approacl and for developing molecular genetic mapping populations for use by Dr. Alan Grombacher in molecular genetic studies. We are also continuing to develop tester lines for each of two major shattering genes. We hope to be able to tag these gene: with a molecular markers to permit their elimination from breeding populations, and t allow us to select more efficiently for shattering resistance.

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