DEVELOPMENT OF HARD WHITE WINTER WHEATS FOR A HARD RED WINTER WHEAT REGION

by

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INTRODUCTION

High grain yield and desirable grain quality are major selection criteria for improvement of wheat (Triticum aestivum L.). The major quality considerations for hard winter wheats are functional quality for milling and baking and adequate protein for baking and nutrition (Jackel, 1979; Johnson and Mattern, 1978). Conceptual quality in terms of grain color also is important. Hard white winter wheat is grown to a very limited extent in the U.S. (Briggle et al., 1982), but its purported advantages suggest that it may have a place in the hard red winter wheat area, the major wheat area in the U.S. (Paulsen and Heyne, 1981; Paulsen et al., 1983).

Improvement of wheat quality is hindered by the inverse relationship between grain yield and protein concentration (McNeal and Davis, 1954; Pushman and Bingham, 1976) and the strong environmental influence on grain protein (Miezan et al., 1977). Although new high-yielding wheat cultivars frequently have low grain protein concentration (Terman, 1979), development of high yielding and high protein white wheat cultivars appears to be plausible (Corpuz et al., 1983).

Preharvest sprouting, especially under adverse conditions, is characteristic of white wheat and greatly lowers its yield, test weight, and functional quality (Bhatt et al., 1981; Lorenz et al., 1983). Successful production of hard white winter wheat requires that it be cultivated where weather conditions are unlikely to induce preharvest sprouting or that cultivars with resistance to the problem be developed (Nielsen et al., 1984). The range of preharvest sprouting in white wheat genotypes indicates that breeding for resistance is feasible (McCrate et al., 1981).

Objectives of studies reported here were to (1) develop hard white winter wheat experimental lines that combine desirable traits--yield, functional quality, and preharvest sprouting resistance--in single genotypes and (2) compare ability of the experimental lines to compete with popular cultivars in the major U.S. hard red winter wheat regions. Seven parental combinations were used and progeny were compared with standard hard red winter wheat cultivars at three locations for two years.

MATERIALS AND METHODS

Forty-four hard white winter wheat experimental genotypes from seven parental combinations (Table 1) were compared with check genotypes 'Newton', 'Plainsman V' and 'KS75216' during the 1981-82 and 1982-83 crop seasons. Newton, a popular Kansas hard red winter wheat cultivar, has medium maturity, good baking quality, and resistance to sprouting. KS75216, an experimental hard white winter wheat, is similar to Newton in most agronomic traits and quality attributes except for its susceptibility to preharvest sprouting in adverse weather (Paulsen et al., 1983). The parentage of Newton and KS75216 is 'Pitic 62'//II53-526 ('Chris' Sib)/'Sonora 64'/3/Sonora 64/'Klein Rendidor'/4/'Scout' (Heyne and Niblett, 1978). Plainsman V, a hard red winter wheat cultivar, is early maturing, high in grain protein level, and resistant to sprouting. It is a privately developed cultivar protected under Title V of the Plant Variety Protection Act. Plainsman V was used as the major donor parent for high grain protein and sprouting resistance. KS75216 and 'Timwin' were the only white wheat genotypes in the crossing block; other white wheat segregates

Table 1. Pedigrees of hard white winter wheat genotypes grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83.

Pedigree	Abbreviation	Number of lines
Plainsman V/KS73159	PV/KS73159	2
KS75216/Plainsman V	KS75216/PV	23
Plainsman V/KS75216	PV/KS75216	7
Timwin/Bezostaia	Tw/Bez	5
Plainsman V/3/Sturdy//Atlas 50/Kaw	PV/3/Sdy//A/K	1
Plainsman V//Caprock/Purdue HP	PV//Crc/PHP	2
Plainsman V/Newton	PV/Nwt	4

from red wheat parents were possible because of the trigenic inheritance of seed coat color (Nielsson-Ehle, 1914). Selection for hard white winter wheat genotypes occurred in early segregating generations and the populations were raised to advanced generations for homozygosity.

The experimental and check genotypes were evaluated in randomized complete block designs with three replications at Manhattan, Powhattan, and Hutchinson, Kansas during 1981-82 and 1982-83. Plot dimension, at all locations, was 0.5 m x 5 m; each plot contained three rows 17 cm apart. Seeds (25 g) were weighed for each plot and planted with a precision disc-type drill. The soil types were Wymore silty clay loam, Grundy silty clay loam, and Clark Ost complex at Manhattan, Powhattan, and Hutchinson, respectively. Seed bed preparation, seeding date, fertilizer application, and pest control followed locally recommended practices (Wilkins et al., 1978).

Plant characteristics, preharvest sprouting, grain yield and grain quality attributes were studied. Plant height was measured from the soil surface to the apex of spikes of the main stems. Days to anthesis occurred when anthers extruded from florets on half of the spikes. Days to physiological maturity occurred when three-fourths of the peduncles turned yellow. Days to anthesis and maturity are reported in Julian days.

A 2.5-m^2 area in each plot was mechanically harvested both years. A 100-kernel sample and 0.946-L sample were weighed to determine kernel weight and test weight, respectively. Kernel number per spike was counted on twenty-six randomly harvested spikes threshed by a head thresher.

Seven randomly harvested spikes from each plot were treated in a rain simulator one week or six weeks after harvest (McMaster and Derera, 1976). Five cm of simulated rain at 20 C were applied to the spikes for two h and the interior of the rain simulator was maintained at 100% relative humidity for 48 h. The treated spikes were dried at 40 C, manually threshed, and the percentage of sprouted kernels was measured. Kernels were considered sprouted when the pericarp over the embryo was ruptured.

Grain α-amylase activity was estimated by a colorimetric method using Phadebus dye-bound starch substrate (Mathewson and Pomeranz, 1977). Relative starch viscosity, a measurement of liquifying grain enzyme activity, was determined by a falling number procedure (Anonymous, 1972). Falling number is the time in seconds for a plunger to stir for 60 s and traverse a viscous medium of 7 g flour and 25 ml water at 100 C.

Grain protein was determined on 10 g of whole wheat flour by infrared reflectance calibrated against the standard kjeldahl method. SDS-sedimentation, an indicator of protein functional quality, was measured on 6 g of whole wheat flour (Axford et al., 1979). Ash content was determined gravimetrically after incinerating 2 g whole wheat flour at 200 C for 2 h and 500 C for 6 h.

Functional quality was evaluated in terms of dough mixing time, loaf volume, and loaf weight. The balance of the grain of each genotype from all replications and locations was bulked and milled to assess breadmaking quality (Junge and Hoseney, 1981). Mixing time used a 10-g mixograph procedure (Finney and Shogren, 1972). Loaf volume and loaf weight were assessed by the procedure of Junge and Hoseney (1981). Optimally developed doughs were fermented for 180 min, punched at 105 and 155 min, and proofed for 55 min.

Loaves were baked at 218 C for 24 min and their quality was judged by visual ratings of bread appearance, crumb structure, and texture.

Weather during the 1981-82 and 1982-83 seasons was characterized by excellent conditions for seeding both years. Winter temperatures were moderate during 1981-82, but were below normal during much of 1982-83. Spring precipitation generally was abundant both years. Low temperatures during spring 1983 delayed crop development. Moisture and temperature conditions were favorable for crop ripening and harvesting both years.

Analysis of variance procedures of the Statistical Analysis System (SAS, 1982) were used to analyze data. All tests were analyzed as completely random designs.

RESULTS

Mean plant characteristics and their ranges of experimental lines from each parental combination and the check cultivars are presented in Table 2. Days to anthesis, days to maturity, and plant height ranged widely in some combinations, but means were generally similar to values for Newton. Genotypes from the cross KS75216/Plainsman V flowered earliest both years and reached physiological maturity earliest in 1981-82. Those from the cross Plainsman V/KS73159 flowered latest both years and reached physiological maturity latest in 1981-82. That cross also produced the tallest lines, whereas the lines from the cross Plainsman V/3/Sturdy//Atlas 50/Kaw was shortest both years.

Grain yields of most experimental lines--45% in 1982 and 93% in 1983--were similar to those of Newton (Table 3). Highest yields

Table 2. Range and mean plant characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Kansas during 1981-82 and 1982-83.

Crosses	Days to anthesis		Days to physiological maturity		Plant height	
	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83
	Julian days				cm	
PV/KS73159						
Range	139.3-140.0	150.0-150.6	172.0-173.0	180.0-180.3	86.6-94.6	94.6-95.0
Mean	139.6	150.3	172.5	180.1	90.6	94.8
KS75216/PV						
Range	128.0-139.6	143.6-150.0	166.3-171.3	175.0-179.3	75.6-92.3	86.3-99.0
Mean	135.4	146.2	169.6	177.0	84.2	92.2
PV/KS75216						
Range	135.0-139.6	145.6-148.6	169.0-172.3	176.3-179.0	79.3-93.0	89.3-95.3
Mean	137.0	146.9	170.2	177.5	84.9	92.1
Tw/Bez						
Range	139.0-140.0	145.0-150.3	168.6-173.0	177.3-180.3	87.0-91.0	89.3-94.6
Mean	139.5	147.5	171.5	178.3	89.7	91.6
PV/3/Sdy//A/K						
Range	136.6	149.6	170.6	180.3	76.0	88.6
Mean	136.6	149.6	170.6	180.3	76.0	88.6
PV/Crc/PHP						
Range	137.6-138.3	146.0-148.6	170.6	177.3	76.0-86.0	89.3-92.3
Mean	137.9	147.3	170.6	177.3	81.0	90.7
PV/Nwt						
Range	134.3-136.3	145.3-149.3	165.6-170.6	176.6-181.0	70.6-86.6	90.0-93.6
Mean	135.3	146.8	168.7	178.3	79.2	92.2

(continued)

Table 2. Range and mean plant characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Kansas during 1981-82 and 1982-83 (continued).

Crosses	Days to anthesis		Days to physiological maturity		Plant height	
	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83
	Julian days				cm	
Newton	139.0	147.6	171.5	178.3	87.5	95.0
Plainsman V	135.1	147.0	168.6	177.1	76.5	90.5
KS75216	137.8	146.6	171.3	177.8	87.3	93.8
LSD (.05)	1.5	4.8	2.6	3.2	4.0	7.2

Table 3. Range and mean grain yield characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83.

Crosses	Grain yield 1981-82	Grain yield 1982-83	Kernel number per spike 1981-82	Kernel number per spike 1982-83	100-kernel weight 1981-82	100-kernel weight 1982-83	Test weight 1981-82	Test weight 1982-83
	kg ha^{-1}				g		kg m^{-3}	
PV/KS73159								
Range	4288-4780	3398-3611	25-30	30-31	2.9-3.0	3.2-3.4	724-727	765-778
Mean	4534	3505	27	30.5	3.0	3.3	725	771
KS75216/PV								
Range	4161-4991	3277-3605	23-31	27-34	2.5-3.3	3.0-3.6	687-746	745-796
Mean	4601	3441	27	31	3.0	3.3	724	776
PV/KS75216								
Range	4286-5000	3267-3742	25-29	29-34	2.5-3.1	3.0-3.4	691-733	752-775
Mean	4564	3496	27	32	2.8	3.2	719	765
Tw/Bez								
Range	4404-4722	2701-3511	26-30	34-35	2.6-3.2	2.9-3.3	713-723	707-748
Mean	4556	3213	28	35	2.9	3.1	719	728
PV/3/Sdy//A/K								
Range	4130	3158	25	33	2.7	3.0	713	737
Mean	4130	3158	25	33	2.7	3.0	713	737
PV//Crc/PHP								
Range	3843-4696	3218-3315	26-28	34-35	2.7-2.9	2.9-3.2	698-707	749-775
Mean	4269	3266	27	34.5	2.8	3.0	702	762
PV/Nwt								
Range	3889-5016	3170-3605	24-29	31-33	2.8-3.1	3.1-3.3	708-745	761-785
Mean	4581	3330	26	32	2.9	3.2	722	777

(continued)

Table 3. Range and mean grain yield characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83 (continued).

Crosses	Grain yield		Kernel number per spike		100-kernel weight		Test weight	
	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83
	$kg\ ha^{-1}$				g		$kg\ m^{-3}$	
Newton	5020	3501	29	34	2.8	3.1	737	783
Plainsman V	4491	3471	23	31	2.9	3.2	730	790
KS75216	4827	3508	28	33	2.8	3.1	714	760
LSD (.05)	510	327	2	4	0.2	0.3	17	

were from the crosses KS75216/Plainsman V and Plainsman V/KS73159, which also had the highest 100-kernel weights and high test weights both years. Lowest grain yields, kernel number per spike, and 100-kernel weight were usually from the cross Plainsman V/3/Sturdy//Atlas 50/Kaw.

Mean grain ash content, SDS sedimentation value, and grain protein content of experimental lines equalled or exceeded that of Newton (Table 4). The lowest mean ash content occurred in progeny from Plainsman V/Newton in 1981-82 and in progeny from Timwin/Bezostaia in 1982-83. Sedimentation values were lowest in Plainsman V/KS73159 progeny and grain protein concentration was lowest in Timwin/Bezostaia progeny both years. Grain from the experimental line Plainsman V/3/Sturdy//Atlas 50/Kaw had the highest ash, sedimentation and grain protein values both years.

Mean breadmaking quality characteristics of experimental lines and check genotypes were substantially similar (Table 5). Mixing time was shortest for the Plainsman V/3/Sturdy//Atlas 50/Kaw progeny and longest for the Timwin/Bezostaia progeny. Mean loaf volume was greater in all experimental lines than in the Newton check; within the experimental lines it was lowest in KS75216/Plainsman V progeny and highest in Plainsman V/3/Sturdy//Atlas 50/Kaw progeny. Mean loaf weight differed little, being 142 g for the Newton check and KS75216/Plainsman V and Plainsman V/KS75216 progeny and 144.5 for the Plainsman V/KS73159 progeny.

Grain sprouting characteristics in terms of falling number and α-amylase activity were within acceptable limits in all genotypes (Table 6). Progeny of Plainsman V//Caprock/Purdue HP had the

Table 4. Range and mean whole grain quality characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83.

Crosses	Ash content		SDS-sedimentation value		Grain protein	
	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83
	$g\ kg^{-1}$		cm^3		$g\ kg^{-1}$	
PV/KS73159						
Range	16.8-17.6	17.2-17.4	60.5-61.6	76.4-77.6	121-129	115-125
Mean	17.2	17.3	61.0	77.0	125	120
KS75216/PV						
Range	15.4-19.6	15.5-17.1	60.3-76.3	72.3-87.8	114-126	111-123
Mean	16.8	16.2	67.1	80.8	120	117
PV/KS75216						
Range	16.0-17.6	15.6-16.8	63.8-72.5	79.1-90.8	110-128	110-122
Mean	16.8	16.0	68.2	83.6	119	116
Tw/Bez						
Range	15.9-18.4	15.5-16.2	66.1-67.1	77.4-81.8	111-115	111-114
Mean	16.8	15.9	66.0	79.3	113	112
PV/3/Sdy//A/K						
Range	17.5	17.6	77.0	88.1	136	134
Mean	17.5	17.6	77.0	88.1	136	134
PV//Crc/PHP						
Range	16.6-17.2	16.2-16.3	54.5-79.5	69.5-87.2	103-137	111-133
Mean	16.9	16.2	67.0	78.3	120	122
PV/Nwt						
Range	16.0-17.8	15.7-16.5	67.8-74.6	77.6-88.7	116-127	114-119
Mean	16.6	16.0	71.1	84.5	120	116
Newton	15.7	15.6	60.6	79.9	109	108
Plainsman V	17.2	16.6	82.0	89.5	139	131
KS75216	16.9	15.9	55.7	66.5	106	109
LSD (.05)	1.3	0.6	4.6	6.0	6.4	---

Table 5. Range and mean breadmaking quality characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82.

Crosses	Mixing time	Loaf volume	Loaf weight	Quality estimate†
	min:sec	cm^3	g	
PV/KS73159				
Range	3:48-4:12	845-885	144-145	1(OK),1(OK^-)
Mean	4:0	850	144.5	
KS75216/PV				
Range	2:40-7:02	760-912	139-144	7(OK^+),7(OK),9(OK^-)
Mean	4:54	840	142	
PV/KS75216				
Range	3:30-6:18	830-880	141-144	2(OK^+),2(OK),3(OK^-)
Mean	4:42	851	142	
Tw/Bez				
Range	4:0-6:35	750-815	142-145	1(OK^+),4(OK^-)
Mean	5:34	778	143	
PV/3/Sdy//A/K				
Range	3:35	965	144	1(OK^-)
Mean	3:35	965	144	
PV//Crc/PHP				
Range	3:42-5:08	762-988	142-145	2(OK^-)
Mean	4:25	875	143.5	
PV/Nwt				
Range	3:35-6:25	815-912	142-145	3(OK^+),1(OK)
Mean	5:01	861	143	
Newton	5:01	757	142	OK^+
Plainsman V	3:38	929	144	OK^-
KS75216	5:23	790	141	OK^+

†OK=Average performance; OK^+, OK^-=deviation from average performance.

Table 6. Range and mean grain sprouting characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83.

	Sprouting (field)				Visual sprouting (rain simulator)			
	Falling number		α-amylase activity		1st week		6th week	
Crosses	1981-82	1981-82	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83
	sec		mDU kg^{-1} S^{-1}		%			
PV/KS73159								
Range	396-472	360-404	3.1-5.5	6.0-8.1	24.8-34.8	16.8-20.4	86.6-88.2	60.9-64.8
Mean	434	382	2.7	7.0	29.8	18.6	87.4	62.8
KS75216/PV								
Range	329-539	349-444	2.6-9.5	5.6-11.6	29.9-61.2	20.4-38.3	94.5-97.5	68.6-86.9
Mean	450	394	4.4	8.6	44.6	28.2	96.3	73.4
PV/KS75216								
Range	366-496	372-442	3.4-6.4	5.9-11.1	32.5-60.0	17.1-32.0	94.6-98.0	63.6-75.2
Mean	449	402	4.4	8.0	41.8	26.1	96.5	69.5
Tw/Bez								
Range	332-436	347-370	4.4-10.4	9.3-22.3	52.9-63.5	28.5-34.6	94.0-99.0	72.8-83.5
Mean	392	360	6.4	13.1	60.0	31.3	97.0	78.5
PV/3/Sdy//A/K								
Range	438	391	4.5	7.7	58.5	28.7	97.4	67.5
Mean	438	391	4.5	7.7	58.5	28.7	97.4	67.5
PV/Crc/PHP								
Range	289-482	304-419	3.2-9.6	5.7-14.2	10.0-66.1	14.1-27.6	91.9-98.6	64.7-75.8
Mean	385	361	6.4	9.9	38.0	20.8	95.2	70.2
PV/Nwt								
Range	393-508	330-401	2.9-7.5	7.9-24.5	27.9-49.7	18.3-31.4	92.4-97.0	72.5-75.4
Mean	431	371	5.3	13.8	42.9	27.7	95.5	74.8

(continued)

Table 6. Range and mean grain sprouting characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83 (continued).

Crosses	Sprouting (field)				Visual sprouting (rain simulator)			
	Falling number		α-amylase activity		1st week		6th week	
	1981-82	1981-82	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83
	sec		mDU kg^{-1} S^{-1}		%			
Newton	476	396	3.2	5.3	2.9	12.3	87.4	66.3
Plainsman V	581	456	2.2	5.6	2.8	5.5	92.0	66.7
KS75216	310	301	10.1	15.8	62.0	34.4	90.0	81.4
LSD (.05)	48	43	0.9	1.0	10.3	3.8	6.6	3.8

lowest mean sprouting susceptibility in terms of α-amylase activity in harvested grain and percentage sprouting in the rain simulator both years. Lines from the cross Timwin/Bezostaia, on the other hand, usually had the lowest sprouting resistance in terms of the same parameters.

DISCUSSION

Development of hard white winter wheats that are equivalent, and in some ways superior, to popular hard red winter wheat cultivars in their major region in the U.S. seems eminently feasible. Plant and grain yield characteristics of the best experimental white wheat lines were similar to those of the most popular hard red winter wheat cultivar, Newton. Low ash content, high grain protein concentration, and high SDS-sedimentation values--indicators of high grain quality (Axford et al., 1979; Jackel, 1979)--were characteristic of most experimental lines. There apparently is no agronomic barrier to high yields of high quality hard white wheat grain in the U.S. "Breadbasket".

The purported functional advantages of white grain over red grain were not considered in the present study. These advantages--higher flour extraction rate, higher flour protein content from closer milling, greater aesthetic appeal of whole-grain products, more valuable bran, and better flour color scores (Paulsen and Heyne, 1981; Paulsen et al., 1983)--are substantial. Any one of them would warrant consideration of white wheats where only red wheats are now grown. The combination of favorable grain yield and functional traits clearly merits regard.

Plainsman V is an effective source of the high protein trait for breeding improved genotypes (Corpuz et al., 1983). Mean grain protein content was higher in all experimental lines having Plainsman V as a parent than in the Newton and KS75216 check genotypes. Mean grain yield, on the other hand, was lower only in progeny from two crosses, Plainsman V/3/Sturdy//Atlas 50/Kaw and Plainsman V//Caprock/Purdue HP. These results were consistent with the general trend of lower yields when wheat grain protein content is increased by breeding (Miezan et al., 1977). The numerous exceptions to this trend observed among the experimental lines, however, show that substantial progress can be made toward increasing grain protein content without sacrificing grain yield.

Preharvest sprouting probably is the major agronomic limitation associated with white wheats (Bhatt et al., 1976, 1981; Derera, 1980; McCrate et al., 1981). The inferior sprouting resistance of white wheats relative to red wheats was more evident in spikes placed in the rain simulator than in field-harvested grain. Field sprouting as measured by mean falling number was more severe only in experimental lines from Timwin/Bezostaia and Plainsman V//Caprock/Purdue HP than in Newton in 1981-82. α-Amylase activity nevertheless was usually higher in the white wheat lines in 1981-82 and 1982-83. Field sprouting of all genotypes as measured by both falling number and α-amylase activity was well below grain trade requirements (Anonymous, 1972; Mathewson and Pomeranz, 1977) both years.

The moderate level of sprouting resistance in the experimental white wheat lines would be adequate for the U.S. hard red winter wheat region. Preharvest sprouting undoubtedly was favored by the abundant precipitation during early spring of both years, but was disfavored by the more arid conditions that prevailed during grain development (Nielsen et al., 1984). At least two sources are available if higher levels of preharvest sprouting resistance are needed during extraordinarily adverse seasons. Moderate levels of resistance can be achieved by proper screening of lines, as evidenced by the generally higher resistance in progeny of KS75216/Plainsman V and Plainsman V/KS75216 than in KS75216. High levels of resistance, if needed, can be obtained from white wheat genotypes that possess the trait (Bhatt et al., 1981; McCrate et al., 1981).

Hard white winter wheat appears to be a viable and potentially valuable class in the major U.S. hard red winter wheat region. Many advantages favor its production and no agronomic disadvantages are apparent. Introduction of a new class of wheat, however, must recognize the tradition of the established class and the adjustments that must be made by the grain trade. These challenges are beyond the scope of the present study.

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Table I. Entry numbers and pedigrees of hard white winter wheat genotypes grown at Manhattan, Hutchinson and Powhattan, Kansas, during 1981-82 and 1982-83.

Entry No.	Pedigree
KS82W401	Plainsman V/KS73159
KS82W402	"
KS82W403	KS75216/Plainsman V
KS82W404	"
KS82W406	"
KS82W407	"
KS82W408	"
KS82W409	"
KS82W410	"
KS82W411	"
KS82W412	"
KS82W414	"
KS82W415	"
KS82W416	"
KS82W417	"
KS82W418	"
KS82W419	"
KS82W420	"
KS82W422	Plainsman V/KS75216
KS82W423	"
KS82W424	"
KS82W425	"
KS82W426	"
KS82W427	"
KS82W428	"
KS82W429	"
KS82W431	KS75216/Plainsman V
KS82W432	"
KS82W433	"
KS82W434	"
KS82W435	"
KS82W436	"
KS82W437	Timwin/Bezostaia
KS82W439	"
KS82W440	"

(continued)

Table I. Entry numbers and pedigrees of hard white winter wheat genotypes gwown at Manhattan, Hutchinson and Powhattan, Kansas, during 1981-82 and 1982-83 (continued).

Entry No.	Pedigree
KS82W441	"
KS82W442	"
KS82W443	Plainsman V/3/Sturdy//Atlas 50/Kaw
KS82W444	Plainsman V//Caprock/Purdue H.P.
KS82W445	"
KS82W447	Plainsman V/Newton
KS82W448	"
KS82W449	"
KS82W450	"

Table II. Mean plant characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Kansas, during 1981-82 and 1982-83.

Selection number	Days to anthesis	Days to maturity	Plant height	Days to anthesis	Days to maturity	Plant height
	——Julian days——		cm	——Julian days——		cm
KS82W401	139.3	173.0	86.6	150.6	180.3	95.0
KS82W402	140.0	172.0	94.6	150.0	180.0	94.6
KS82W403	135.0	171.3	89.6	145.0	176.6	94.3
KS82W404	134.3	168.3	75.6	145.3	176.6	91.0
KS75216	137.8	171.3	87.3	146.6	177.8	93.8
KS82W406	135.0	169.6	86.0	143.6	176.0	93.3
KS82W407	135.3	170.6	88.3	147.3	177.6	99.0
KS82W408	135.6	171.3	85.6	146.6	177.0	88.0
KS82W409	135.6	171.0	92.6	145.6	177.3	94.6
KS82W410	136.6	171.0	89.6	150.0	179.3	95.6
KS82W411	136.0	170.0	86.0	144.6	176.0	90.0
KS82W412	135.3	170.6	85.3	144.6	175.6	95.0
Plainsman V	135.1	168.6	76.5	147.0	177.1	90.5
KS82W414	134.3	166.3	80.0	146.3	176.6	92.3
KS82W415	135.6	171.0	85.3	148.3	178.3	93.6
KS82W416	135.0	167.6	79.6	144.6	176.3	86.3
KS82W417	136.3	170.6	81.0	147.3	178.3	88.6
KS82W418	139.3	171.0	92.3	149.6	179.0	93.0
KS82W419	128.0	169.6	86.0	146.6	177.0	92.0
KS82W420	139.3	170.6	85.3	148.3	178.3	87.6
Newton	139.0	171.5	87.5	147.6	178.3	95.0
KS82W422	139.6	172.3	93.0	146.6	177.6	91.6
KS82W423	138.6	170.6	86.0	147.6	178.0	91.0
KS82W424	139.3	171.3	88.6	148.6	179.0	95.3
KS82W425	135.0	169.6	84.3	146.6	177.0	89.3
KS82W426	135.6	169.0	81.0	147.6	178.0	94.6
KS82W427	135.6	169.6	82.6	145.6	176.6	91.0
KS82W428	135.3	169.0	79.3	146.0	176.3	92.0
KS82W429	135.6	170.0	84.0	144.0	175.6	91.3
KS82W431	135.0	169.3	85.0	146.3	177.3	96.0
KS82W432	134.6	169.3	79.3	145.6	176.3	93.0
KS82W433	133.6	166.6	78.0	145.3	176.3	91.6
KS82W434	139.6	171.3	86.0	147.6	178.0	94.6
KS82W435	135.3	167.6	77.3	144.6	175.0	90.6

(continued)

Table II. Mean plant characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Kansas, during 1981-82 and 1982-83 (continued).

Selection number	1981-82 Days to anthesis	1981-82 Days to maturity	1981-82 Plant height	1982-83 Days to anthesis	1982-83 Days to maturity	1982-83 Plant height
	——Julian days——		cm	——Julian days——		cm
KS82W436	135.6	168.3	80.0	147.0	178.0	91.3
KS82W437	139.6	168.6	90.0	147.3	178.3	90.6
KS82W439	139.3	171.3	87.0	145.0	177.3	90.3
KS82W440	140.0	173.0	91.0	146.6	177.3	94.6
KS82W441	139.6	172.6	90.6	148.3	178.3	93.3
KS82W442	139.0	172.0	90.3	150.3	180.3	89.3
KS82W443	136.6	170.6	76.0	149.6	180.3	88.6
KS82W444	137.6	170.6	86.0	146.0	177.3	89.3
KS82W445	138.3	170.6	64.3	148.6	177.3	92.3
KS82W447	136.3	170.6	84.3	145.3	177.0	93.6
KS82W448	134.3	168.0	75.3	145.6	176.6	93.0
KS82W449	136.3	170.6	86.6	149.3	178.6	92.3
KS82W450	134.3	165.6	70.6	147.0	181.0	90.0
LSD (.05)	1.5	2.6	4.0	4.8	3.2	7.2

Table III. Mean grain yield characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas, during 1981-82 and 1982-83.

Selection number	Yield	Kernel number per spike	100-kernel weight	Test weight	Yield	Kernel number per spike	100-kernel weight	Test weight
	$kg\ ha^{-1}$		g	$kg\ m^{-3}$	$kg\ ha^{-1}$		g	$kg\ m^{-3}$
KS82W401	4780	30	3.1	727	3611	31	3.4	778
KS82W402	4288	25	2.9	724	3398	30	3.2	765
KS82W403	4831	27	3.3	746	3323	30	3.6	772
KS82W404	4696	26	3.1	743	3394	33	3.3	786
KS75216	4827	28	2.9	714	3508	33	3.1	760
KS82W406	4813	27	3.1	734	3421	31	3.3	781
KS82W407	4429	25	3.3	728	3277	30	3.5	769
KS82W408	4706	26	2.9	737	3488	31	3.3	773
KS82W409	4991	26	3.1	734	3345	29	3.4	775
KS82W410	4464	29	2.9	733	3512	33	3.1	792
KS82W411	4759	27	3.0	731	3339	31	3.3	771
KS82W412	4803	26	3.2	734	3581	27	3.6	787
Plainsman V	4491	23	2.9	730	3471	31	3.2	790
KS82W414	4456	24	3.0	725	3448	31	3.2	781
KS82W415	4960	29	3.0	730	3533	31	3.5	777
KS82W416	4552	23	3.3	739	3392	28	3.5	780
KS82W417	4161	28	2.9	720	3444	30	3.3	790
KS82W418	4604	31	2.7	687	3605	34	3.1	783
KS82W419	4497	28	2.7	696	3373	31	3.1	775
KS82W420	4471	29	2.6	694	3474	30	3.2	765
Newton	5020	29	2.8	737	3501	34	3.1	783
KS82W422	4727	25	3.2	751	3699	30	3.3	768
KS82W423	4363	25	3.1	733	3434	32	3.1	772
KS82W424	5000	29	2.9	711	3634	34	3.4	771
KS82W425	4294	28	2.5	715	3267	31	3.1	765
KS82W426	4548	27	2.6	704	3334	33	3.0	752
KS82W427	4286	29	2.5	691	3363	29	3.4	753
KS82W428	4730	25	3.0	733	3742	32	3.2	775
KS82W429	4382	26	2.8	726	3529	31	3.2	776
KS82W431	4570	31	3.0	725	3449	31	3.4	777
KS82W432	4339	25	3.3	736	3473	31	3.4	796
KS82W433	4362	27	2.6	688	3330	32	3.0	752
KS82W434	4797	26	3.0	715	3461	29	3.3	776
KS82W435	4373	24	2.9	733	3374	32	3.1	776

(continued)

Table III. Mean grain yield characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83 (continued).

Selection number	Yield	Kernel number per spike	100-kernel weight	Test weight	Yield	Kernel number per spike	100-kernel weight	Test weight
	kg ha^{-1}		g	kg m^{-3}	kg ha^{-1}		g	kg m^{-3}
KS82W436	4812	28	2.9	721	3573	32	3.3	745
KS82W437	4722	28	3.1	730	3511	34	3.3	748
KS82W439	4428	30	2.6	713	3236	35	2.9	726
KS82W440	4525	30	2.7	717	3409	36	3.1	725
KS82W441	4702	27	3.2	723	3208	34	3.3	735
KS82W442	4404	26	3.0	714	2701	35	3.1	707
KS82W443	4130	25	2.7	713	3158	33	3.0	786
KS82W444	4696	28	2.9	707	3315	34	3.2	749
KS82W445	3843	26	2.7	698	3218	35	2.9	775
KS82W447	5016	29	2.8	745	3605	33	3.1	782
KS82W448	4412	24	3.1	708	3170	32	3.2	761
KS82W449	5009	26	2.9	729	3292	31	3.4	785
KS82W450	3889	24	2.9	708	3253	32	3.1	782
LSD (.05)	510	2	0.2	17	327	4	0.3	

Table IV. Mean whole grain quality characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas, during 1981-82 and 1982-83.

Selection number	1981-82 Ash content	1981-82 Protein content	1981-82 Sedimentation value	1982-83 Ash content	1982-83 Protein content	1982-83 Sedimentation value
	$g\ kg^{-1}$	$g\ kg^{-1}$	cm^3	$g\ kg^{-1}$	$g\ kg^{-1}$	cm^3
KS82W401	16.8	121	61.6	17.2	125	77.6
KS82W402	17.6	129	60.5	17.4	127	76.4
KS82W403	17.4	119	67.6	15.7	117	83.0
KS82W404	17.1	120	68.1	16.2	115	80.5
KS75216	16.9	106	55.7	15.9	109	66.5
KS82W406	16.6	118	73.3	16.3	116	84.2
KS82W407	17.4	118	64.5	17.1	118	74.7
KS82W408	17.2	122	71.1	17.0	118	82.8
KS82W409	16.3	118	60.3	15.8	116	78.2
KS82W410	16.5	120	68.3	16.2	117	86.5
KS82W411	16.2	126	76.3	16.8	118	87.0
KS82W412	16.7	117	62.8	16.4	120	74.3
Plainsman V	17.2	139	82.0	16.6	131	89.5
KS82W414	17.3	121	74.6	16.9	118	86.1
KS82W415	16.8	115	64.3	16.3	114	72.3
KS82W416	15.4	124	69.8	15.8	117	80.8
KS82W417	19.6	126	63.3	16.5	122	81.2
KS82W418	16.4	122	61.8	16.1	121	74.0
KS82W419	16.8	123	72.8	16.1	117	80.0
KS82W420	16.0	114	61.1	15.8	112	83.5
Newton	15.7	109	60.6	15.6	108	79.9
KS82W422	16.6	110	67.3	15.7	110	82.5
KS82W423	17.6	112	64.3	16.1	117	79.2
KS82W424	16.8	118	63.8	15.7	113	79.1
KS82W425	17.2	126	67.3	16.8	121	87.1
KS82W426	16.9	123	70.8	16.4	122	84.8
KS82W427	16.0	128	71.6	16.0	121	81.7
KS82W428	17.0	114	72.5	15.6	114	90.8
KS82W429	15.4	124	71.5	15.5	114	82.3
KS82W431	17.5	118	67.3	16.4	113	82.8
KS82W432	17.4	123	62.5	15.9	117	78.7
KS82W433	16.0	124	66.1	15.9	123	78.2
KS82W434	15.9	116	64.0	17.1	111	78.2
KS82W435	18.2	125	63.5	15.8	120	81.6

(continued)

Table IV. Mean whole grain quality characteristics of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas during 1981-82 and 1982-83 (continued).

Selection number	1981-82 Ash content	1981-82 Protein content	1981-82 Sedimentation value	1982-83 Ash content	1982-83 Protein content	1982-83 Sedimentation value
	$g\ kg^{-1}$		cm^3	$g\ kg^{-1}$		cm^3
KS82W436	16.8	119	69.5	16.8	123	87.8
KS82W437	16.0	113	67.1	16.0	111	78.1
KS82W439	15.9	113	64.3	16.2	114	78.5
KS82W440	16.3	113	66.1	15.7	113	77.4
KS82W441	17.4	111	66.1	15.5	112	80.8
KS82W442	18.4	115	66.6	16.2	114	81.8
KS82W443	17.5	136	77.0	17.6	134	88.1
KS82W444	17.2	103	54.5	16.3	111	69.5
KS82W445	16.6	137	79.5	16.2	133	87.2
KS82W447	16.6	119	71.5	15.7	117	87.5
KS82W448	16.0	127	74.6	15.9	119	88.7
KS82W449	16.0	116	67.8	16.2	114	86.2
KS82W450	17.8	119	70.5	16.5	116	77.6
LSD (.05)	1.3	6.4	4.6	0.6	---	6.0

Table V. F-ratios and coefficient of variation for ash content, SDS-sedimentation value, and whole grain protein concentration of hard white winter wheat genotypes and standard wheat checks grown at Manhattan, Hutchinson, and Powhattan, Kansas, during 1981-82 and 1982-83.

Source	Ash content		SDS-sedimentation value		Grain protein
	1981-82	1982-83	1981-82	1982-83	1981-82
Location	22.74**	11.58**	4.96*	296.83**	10.70**
Line	2.86**	4.8**	14.07**	6.77**	12.17**
Location X Line	2.39**	1.27	1.67**	1.57**	1.16
Block (Loc)	2.36	0.53	14.88**	2.15*	0.48
C.V.	6.9	4.4	6.0	8.0	4.7

*,** Significant at 5% and 1% levels, respectively.

Table VI. Mean breadmaking quality characteristics of hard white winter wheat genotypes and standard wheat checks during 1981-82.

Selection number	Mixing time	Loaf volume	Loaf weight	Quality estimate†
	min:s	cm^3	g	
KS82W401	4:12	845	144	OK
KS82W402	3:48	855	145	OK^{-}
KS82W403	4:55	830	142	OK
KS82W404	3:00*	865	142	OK^{+}
KS75216	5:23	790	141	OK^{+}
KS82W406	3:40*	825	140	OK
KS82W407	4:45	867	142	OK^{+}
KS82W408	5:38	852	144	OK^{+}
KS82W409	5:18	825	144	OK^{+}
KS82W410	4:48*	832	143	OK
KS82W411	5:20	890	142	OK^{-}
KS82W412	5:10	815	142	OK
Plainsman V	3:38*	929	144	OK^{-}
KS82W414	3:48*	912	139	OK
KS82W415	5:38	840	142	OK
KS82W416	2:40*	865	143	OK^{-}
KS82W417	4:50	835	144	OK^{-}
KS82W418	4:00*	800	144	OK^{-}
KS82W419	6:28	900	141	OK
KS82W420	4:50	832	142	OK^{-}
Newton	5:01*	757	142	OK^{+}
KS82W422	6:18	840	141	OK
KS82W423	3:30*	840	141	OK
KS82W424	4:42	840	144	OK^{+}
KS82W425	4:52	865	143	OK^{-}
KS82W426	4:18	880	143	OK^{-}
KS82W427	5:02	868	144	OK^{-}
KS82W428	4:15*	830	141	OK^{+}
KS82W429	5:32	888	141	OK^{+}
KS82W431	6:20	810	143	OK^{+}
KS82W432	4:05	760	143	OK^{-}
KS82W433	5:02	812	143	OK^{-}
KS82W434	4:32	785	142	OK^{+}
KS82W435	5:30	860	144	OK^{-}

(continued)

Table VI. Mean breadmaking quality characteristics of hard white winter wheat genotypes and standard wheat checks during 1981-82 (continued).

Selection number	Mixing time	Loaf volume	Loaf weight	Quality estimate†
	min:S	cm^3	g	
KS82W436	7:02	820	144	OK^-
KS82W437	6:08	788	145	OK^-
KS82W439	5:18	752	143	OK^-
KS82W440	5:50	750	143	OK^-
KS82W441	4:00*	788	142	OK^-
KS82W442	6:35	815	142	OK^+
KS82W443	3:35*	965	144	OK^-
KS82W444	5:08	762	142	OK^-
KS82W445	3:42	988	145	OK^-
KS82W447	6:25	860	142	OK^+
KS82W448	3:45*	912	145	OK^+
KS82W449	3:35*	815	143	OK
KS82W450	6:20	860	142	OK^+

† OK = Average performance; OK^+, OK^- = deviation from average performance.

* Oxidant required to reduce mixing time.

Table VII. Mean grain sprouting characteristics of hard white winter wheat genotypes grown at Manhattan, Hutchinson, and Powhattan, Kansas, during 1981-82 and 1982-83.

Selection number	1981-82 Falling number	1981-82 α-amylase activity	1981-82 Sprouting 1st week	1981-82 Sprouting 6th week	1982-83 Falling number	1982-83 α-amylase activity	1982-83 Sprouting 1st week	1982-83 Sprouting 6th week
	S	mDU $kg^{-1}S^{-1}$	%	%	S	mDU $kg^{-1}S^{-1}$	%	%
KS82W401	472	3.1	24.8	86.6	404	6.0	16.8	60.9
KS82W402	396	5.5	34.8	88.2	360	8.1	20.4	64.8
KS82W403	513	3.1	36.9	96.6	438	6.5	21.2	70.6
KS82W404	423	5.6	55.8	97.5	403	10.5	32.3	71.6
KS75216	310	10.1	62.0	90.0	301	15.8	34.4	81.4
KS82W406	514	3.2	45.2	96.2	417	8.5	34.7	78.6
KS82W407	450	4.3	37.5	97.2	371	10.1	31.3	73.3
KS82W408	531	3.2	39.1	95.8	444	6.5	23.6	72.4
KS82W409	438	3.8	42.4	95.8	397	7.6	24.9	70.7
KS82W410	469	3.2	43.3	96.5	426	5.6	25.8	71.3
KS82W411	499	3.3	41.9	95.8	413	6.9	24.8	79.1
KS82W412	413	5.4	41.4	95.8	391	8.2	20.4	68.7
Plainsman V	581	2.2	2.8	92.0	456	5.6	5.5	66.7
KS82W414	422	4.5	39.0	98.0	349	7.9	38.3	82.9
KS82W415	486	3.2	50.0	95.3	406	5.8	23.1	73.1
KS82W416	394	5.7	46.0	97.6	353	11.5	32.9	74.7
KS82W417	539	2.6	29.9	94.6	420	6.4	24.2	69.2
KS82W418	497	4.0	34.9	94.8	403	10.5	26.3	68.6
KS82W419	497	3.3	37.8	96.7	378	9.3	35.4	86.9
KS82W420	443	4.0	52.1	97.7	375	8.2	25.8	73.3

(continued)

Table VII. Mean grain sprouting characteristics of hard white winter wheat genotypes grown at Manhattan, Hutchinson, and Powhattan, Kansas, during 1981-82 and 1982-83 (continued).

Selection number	1981-82 Falling number	1981-82 α-amylase activity	1981-82 Sprouting 1st week	1981-82 Sprouting 6th week	1982-83 Falling number	1982-83 α-amylase activity	1982-83 Sprouting 1st week	1982-83 Sprouting 6th week
	S	mDU $kg^{-1}S^{-1}$	%		S	mDU $kg^{-1}S^{-1}$	%	
Newton	476	3.2	2.9	87.4	396	5.3	12.3	66.3
KS82W422	366	6.4	60.0	97.5	372	11.1	24.3	71.6
KS82W423	442	4.4	32.3	96.6	420	9.0	26.6	69.8
KS82W424	451	4.8	46.3	96.2	401	7.8	29.6	71.3
KS82W425	496	3.6	33.7	94.5	373	8.2	24.5	63.6
KS82W426	475	3.9	38.3	97.5	407	7.5	29.0	68.2
KS82W427	421	4.6	36.2	94.9	442	5.9	17.1	67.4
KS82W428	493	3.4	45.7	97.0	396	6.6	32.0	75.2
KS82W429	407	4.8	51.2	97.3	391	11.3	27.0	71.9
KS82W431	329	9.5	61.2	97.2	349	11.6	34.0	73.9
KS82W432	471	4.2	47.7	96.6	406	8.9	31.4	71.2
KS82W433	384	6.0	45.3	96.2	363	8.3	33.1	74.2
KS82W434	423	4.8	54.7	97.9	420	7.1	22.6	69.2
KS82W435	431	3.9	42.8	97.1	377	8.6	30.1	75.3
KS82W436	390	5.6	50.4	95.9	365	11.2	27.4	69.2
KS82W437	429	4.4	63.5	96.9	370	10.9	34.6	80.0
KS82W439	436	5.1	60.6	97.1	357	9.3	30.8	80.0
KS82W440	402	5.6	52.9	94.0	363	10.4	28.5	76.3
KS82W441	363	6.8	61.0	99.0	362	12.6	31.4	83.5
KS82W442	332	10.4	62.2	98.0	347	22.3	31.3	72.8
KS82W443	438	4.8	58.5	97.4	391	7.7	28.7	67.5
KS82W444	289	9.6	66.1	98.6	304	14.2	27.6	75.8
KS82W445	482	3.2	10.0	91.9	419	5.7	14.1	64.7

(continued)

Table VII. Mean grain sprouting characteristics of hard white winter wheat genotypes grown at Manhattan, Hutchinson, and Powhattan, Kansas, during 1981-82 and 1982-83 (continued).

Selection number	1981-82 Falling number	1981-82 α-amylase activity	1981-82 Sprouting 1st week	1981-82 Sprouting 6th week	1982-83 Falling number	1982-83 α-amylase activity	1982-83 Sprouting 1st week	1982-83 Sprouting 6th week
	S	mDU $kg^{-1}S^{-1}$	%	%	S	mDU $kg^{-1}S^{-1}$	%	%
KS82W447	508	2.9	27.9	92.4	401	7.9	18.3	75.4
KS82W448	393	7.5	49.7	96.3	378	10.8	30.7	77.6
KS82W449	429	4.8	47.6	97.3	330	24.5	30.6	73.8
KS82W450	397	6.3	46.5	96.3	373	12.1	31.4	72.5
LSD (.05)	48	0.9	10.3	6.6	43	1.0	6.0	3.8

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DEVELOPMENT OF HARD WHITE WINTER WHEATS FOR A HARD RED WINTER WHEAT REGION

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ABSTRACT

Hard white winter wheat (HWWW) occupies a very limited area of the U.S., but its purported advantages suggest its production in the major hard red winter wheat (HRWW) region may be feasible. Objectives of our investigations were to develop experimental HWWW lines that combined desirable attributes--yield, functional quality, and resistance to preharvest sprouting--in single genotypes for comparison with popular cultivars in the major U.S. HRWW region. Forty-four lines from seven parental combinations were tested in randomized complete block designs at three Kansas locations during the 1981-82 and 1982-83 seasons. Agronomic traits, grain yield, grain quality, and preharvest sprouting were measured. Plant characteristics and grain yield were similar in the HWWW experimental lines and the HRWW check cultivar, Newton. Mean grain, SDS-sedimentation value and grain protein content of most experimental lines equaled or exceeded that of Newton. Dough mixing times were frequently shorter for the experimental lines than Newton, whereas loaf volumes were greater. Falling number was usually similar in all genotypes, but α-amylase was higher in field-harvested grain of white lines than the HRWW checks; both measures were more favorable than grain trade standards. We concluded that production of high yields of high quality hard white winter wheat grain in the U.S. "Breadbasket" is feasible.