

# 2003 Project Report

## *Winter Wheat Breeding and Genetics*

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## **CROP REPORT**

Winter wheat production in 2003 was estimated at 59.34 million bushels, up 227% from last year's drought impacted production and is the third largest production in the state's history. Producers harvested 1.38 million acres (1.6 million planted acres), for a state average of 43 bushels/acre, which is 14 bushels above last year and is the second highest yield in the state's history. Overall, the excellent winter survival rate at most locations was due to a mild winter and further aided by an early mild spring with adequate rain fall.

In 2003, the winter wheat breeding program conducted testing at eight sites throughout South Dakota. These environments included Aurora and Brookings (Brookings Co.), Platte (Douglas Co.), Highmore (Hyde Co.), Selby (Walworth Co.), Winner (Tripp Co.), Wall (Pennington Co.), the Northeast Research Farm near Watertown (Codington Co.), Kennebec ( Lyman Co.) and both irrigated and dry land environments at the Dakota Lakes Research Farm east of Pierre (Hughes Co.). Crop performance testing also was conducted at an additional nine sites west of the Missouri River in cooperation with John Rickertsen and Bruce Swan (SDSU West River Agricultural Research and Extension Center, Rapid City).

Fall stand establishment at most testing locations was average. Late planting at Selby and the Northeast Experiment Station resulted in limited plant development and were abandoned in the spring. Extreme drought and cropping history led to the abandonment of the dry land nursery at Dakota Lakes. Limited sub-soil moisture at all west river locations was aided by May and June temperatures that were 4 – 5° F below normal and supplemented by above normal rainfall. Plants produced very few tillers at the Central Crops and Soils Research Station in Highmore but compensated by good grain filling aided by a mid-June rainfall. Conversely, plants in the nurseries at Wall and Winner had excellent plant tillering but less than average grain yield due to poor grain filling caused by limited post-anthesis moisture. At Platte, Brookings, and Kennebec, yield and test weight were above the three-year average due to timely rainfall during plant development. One experimental variety yielded 99 bushels/acre at Brookings.

## **BREEDING PROGRAM**

### **Foundation Seed Increases**

Two lines are being increased for Foundation Seed, 'SD97W604' and 'SD92107-5', while a third line is being increased for Breeder Seed, 'SD97W609'.

**SD97W604** (SD89333 ('Gent'/'Siouxland')/'Abilene') is a hard white winter wheat (HWWW) with high yield potential, early maturity, and good noodle quality. SD97W604 ranked at the top in 2003 South Dakota Crop Performance Testing (CPT) Variety Trial. SD97W604 ranked above all available HWWW lines in 4-year grain yield average, polyphenol oxidase (PPO) enzyme levels, and winter survival ability. SD97W604 has exhibited moderate adult plant and seedling resistance to prevalent races of stem rust and has been postulated to carry *Sr24* and *Sr31* based on tests conducted by the USDA Cereal Disease Laboratory, St. Paul, MN. In tests done in the greenhouse at South Dakota State University, SD97W604 has exhibited resistance to RCR and was moderately resistant to TPMK and bulk mixture of stem rust races. SD97W604 is moderately resistant to field leaf rust and is tolerant to tan spot. SD97W604 was tested in 1999 in cooperative baking tests conducted by the USDA/ARS Hard Winter Wheat Quality Lab (HWWQL). Baking

scores were poor. Overall baking score of SD97W604 in the 2004 Wheat Quality Council testing was marginally better than the check 'Crimson'. The 1BL.1RS rye translocation in SD97W604, which confers tolerance to abiotic stresses, is also responsible for fair baking quality, confirmed by four years of predictive sedimentation tests and mixograph tests from two locations. Protein levels for SD97W604 have ranged from well above average to well below average in four years of testing. SD97W604 has low PPO levels, which is essential for good noodle quality, an attribute desired of HWWW varieties. Flour yield of SD97W604 is above average. Results of noodle-making tests indicate that SD97W604 possess good noodle quality. SD97W604 has a short coleoptile, a trait typical of most of the experimental and released white wheat lines currently available. As breeding for white wheat in South Dakota progresses, lines with longer coleoptiles will be selected and advanced. SD97W604 has fair to good resistance to pre-harvest sprouting and will be best adapted to west of the Missouri river environments. SD97W604 is on large-scale increase with intention to release in 2004.

**SD92107-5** ('Brule'/'Bennett'/'Chisholm'/'3'/'Arapahoe') hard red winter wheat is a reselection from the population from which variety 'Harding' was selected with better yielding ability and test weight. This line significantly yielded better than its sibling Harding in the last four years of CPT testing, and has a good disease package similar to it. However, SD92107-5 possesses better resistance to stem rust races than Harding. SD92107-5 is targeted for production systems where the potential for winter injury is of greatest concern, especially in the northern half of the state and conventional summer fallow production systems (with minimal or no crop residue at planting) across South Dakota. Across locations and years, SD92107-5 has shown superior performance in situations where winter injury has been an important factor in yield rankings and has shown good yield performance compared to other winter-hardy varieties after a mild winter. SD92107-5 has very good baking quality, similar to its sibling, and has better test weight. SD92107-5 will be purified this year with intention to increase in 2004 and release in 2005.

**'SD97W609'** (Abilene/Karl) hard white winter wheat is a semi-dwarf, medium-maturing (similar to Arapahoe), good winter hardy line. SD97W609 has superior baking quality and is among the top 15% of lines for yield. It had the second best average yield in South Dakota in 2003. Furthermore, it has high test weight, average protein, good sprouting resistance, and moderate susceptibility to stem rust and leaf rust. It has a very short coleoptile and moderately high PPO. Currently it is on breeder seed increase with potential release in 2006.

Crossing and germplasm enhancement efforts continue to address hard red and white winter wheat, end-use quality, and important constraints facing producers in the northern Great Plains (*Fusarium* head blight (FHB), WSMV, leaf and stem rust, leaf spotting diseases, and winter survival ability). Ongoing research support projects include screening for resistance to FHB, genetic studies of stem rust resistance, and hard white winter wheat end-use quality.

### **Regional Nurseries**

The Northern Regional Performance Nursery (NRPN) was planted at Brookings, Winner, and the spring wheat stubble plots at Dakota Lakes (DLSWS). The NRPN consisted of four check varieties and 31 experimental lines from four public programs and one private company. Eleven advanced experimental lines were included from the SDSU Winter Wheat Breeding Program. Average grain yield and other characteristics for 2003 NRPN are presented in Table 1. In addition to the NRPN, the Southern Regional Performance Nursery (SRPN) was planted at Brookings and Dakota Lakes on pea stubble (DLP). While the SDSU breeding program does not typically enter

lines into the SRPN, evaluation of this nursery in South Dakota is important both as a means of germplasm exchange and in determining the range of adaptation of elite material from southern plains and western programs.

In addition to the regional yield nurseries, the Regional Germplasm Observation Nursery (RGON) was planted at Watertown and at Brookings in the mist-irrigated FHB disease nursery. This nursery consisted of 268 entries from nine different breeding programs and a periodic set of six checks, planted in double-row (3-foot long) plots with a single replication per entry. Thirty South Dakota advanced lines were entered in 2003 RGON.

### **CPT Variety Trial**

The South Dakota Crops Performance Testing (CPT) Variety Trial, under the coordination of the SDSU Crops Performance Testing Program (Dr. Bob Hall, Manager), was planted at 16 sites across South Dakota. These environments included most of the sites where winter wheat breeding activities are ongoing and several other sites in western South Dakota that are coordinated by personnel at the West River Agricultural Research and Extension Center (John Rickertsen, SDSU). In 2003, the nursery included 30 entries, consisting of 16 released varieties, 13 advanced experimental lines from our program and one from the University of Nebraska.

Nine of the thirteen experimental lines from the breeding program evaluated in the 2003 CPT (Table 2) were retained for further testing in 2004:

SD92107-5 -- Brule//Bennett/Chisholm/3/Arapahoe

SD97059-2 – ND8889/NE90574

SD97250 -- ND90109/NE87613

SD97W604 -- SD89333 (Gent/Siouxland)//Abilene

SD97W609 -- Abilene/Karl

SD97380-2 – Rawhide/Siouxland

SD98102 -- 2076-W12-11/Karl92//NE89526

SD97538 – NE90518/Martinof 93

SD97W671-1 – RioBlanco/Rose

**Table 1. Grain yield, Testweight and Agronomic Data for the 2003 NRPN in South Dakota. (Entries are ranked in descending order by statewide yield average).**

ENTRY	GRAIN YIELD (bushels/acre) <sup>1</sup>				TW <sup>1</sup> (lb/bu)	HEAD <sup>2</sup> (days)	HEIGHT <sup>2</sup> (inches)	LODGING <sup>2</sup> (score)	SURV <sup>2</sup> (score)
	AVE	BRK	DLSWS	WIN					
G980172W	58	95	32	48	59.9	5	30	1.4	8.5
G980926W	56	74	35	60	57.8	4	31	0.7	6.8
NE99489	56	91	25	51	58.2	5	34	1.7	7.8
SD97059-2	55	87	28	49	58.0	5	32	1.7	9.0
NW97S142-1	54	93	25	45	62.1	7	29	0.9	8.0
G980723	54	77	29	56	59.2	4	30	0.7	8.7
SD98243	53	84	27	49	56.9	3	32	1.7	8.2
SD97380-2	53	82	30	48	57.4	4	33	2.9	8.8
SD97W609	53	78	26	55	57.3	2	33	0.7	8.8
SD98102	52	78	29	51	59.0	5	34	1.4	8.7
SD96306	52	84	26	45	58.6	5	33	2.4	8.7
Nekota	52	79	27	50	57.6	2	29	1.9	8.5
NE99495	52	79	28	48	57.0	3	32	2.9	8.2
NW99L7171	52	83	28	44	58.7	7	33	0.7	7.2
NW98S097	52	83	23	48	58.3	5	33	0.7	7.5
SD97250-2	51	77	29	47	57.6	4	32	2.2	8.5
SD97W650	51	83	25	46	56.8	2	32	1.9	8.7
NE99464	50	78	25	49	58.0	5	34	0.7	8.5
NE00658	50	83	24	44	56.0	5	34	1.4	8.3
NW99L7068	50	76	27	47	54.2	0	29	1.7	8.5
NW97S139-2	50	73	29	48	55.7	4	32	0.7	7.8
NW97S218-lt	50	76	25	49	58.0	6	33	1.9	8.0
NW99L7083	49	75	24	50	53.6	0	31	1.7	8.3
SD97250	49	77	26	44	57.7	4	33	1.9	9.0
NI01808	49	75	26	47	51.9	6	32	0.7	8.0
NW97S412-1	49	71	27	48	56.2	5	32	0.7	7.0
SD97394-1	49	75	26	45	57.4	4	35	2.7	7.5
SD97049	48	77	18	49	57.6	3	30	0.7	8.5
Nuplains	48	78	23	42	60.6	7	30	1.2	8.5
NE00679	48	74	23	46	53.5	4	35	4.2	9.0
MT9426	47	71	26	44	54.9	8	32	2.9	8.7
NW97S139-1	47	69	27	44	54.7	4	30	0.7	8.3
NI01824	47	64	26	49	58.9	3	33	0.7	8.5
Harding	40	60	17	43	60.1	9	35	2.4	8.8
Kharkof	34	50	15	36	60.1	9	36	4.4	8.8
MEAN	50	77	26	48	57.4	4	32	2.0	8.3
L.S.D. (0.05) <sup>¶</sup>	6	14	5	8	1.0	1		0.9	1.1
C.V.(%) <sup>§</sup>	12	11	13	10	2.0	1		31.8	11.6

<sup>1</sup> Grain Yield (GY) and Testweight (TW) averages include data from Brookings (BRK), Dakota Lakes Spring Wheat Stubble (DLSWS) and Winner (WIN).

<sup>2</sup> Relative heading date (HEAD) and plant height (HEIGHT) represent averages of data from all locations. Lodging (scale of 1-5, 1 is best) and winter survival (SURV, scale of 0-9, 9 is 90-100 %) are from Brookings and Winner only.

**Table 2. Grain yield, Testweight and Agronomic Data for the 2003 Crops Performance Testing (CPT) Variety Trial. (Entries are ranked in descending order by statewide yield average).**

ENTRY	GRAIN YIELD (bushels/acre)												TW (lb/bu)	HEAD (days)	HEIGHT (inches)	LODGING (score)	
	AVE	BIS	OEL	MAR	HAY	STU	DLP	BROW	WAL	WIN	PLA	HIG					KEN
SD97W604	61	57	66	68	64	45	36	90	40	50	73	51	90	60.9	0	30	1.0
JAGALENE	60	55	77	68	62	44	33	90	35	46	65	57	89	60.9	2	31	1.0
SD97W609	60	52	69	64	57	44	39	83	43	53	73	61	85	60.3	1	31	1.0
MILLENNIUM	60	56	63	69	63	44	38	91	42	50	69	57	77	60.7	4	36	1.3
WAHOO	59	54	71	75	54	45	37	86	40	49	65	57	81	58.2	3	34	1.3
SD97538	58	49	69	72	56	47	36	87	41	44	65	51	84	59.3	3	33	1.3
WESLEY	58	52	65	71	62	41	36	83	44	43	66	55	80	59.2	2	30	1.0
SD98102	58	49	68	68	47	47	36	84	44	50	71	54	79	59.6	4	35	1.3
SD97380-2	58	50	69	67	57	46	39	89	37	47	60	56	78	58.9	2	35	1.4
SD97059-2	58	53	61	66	44	44	36	99	43	47	63	54	86	58.9	5	35	1.1
EXPEDITION	58	55	72	68	58	44	37	79	39	47	64	51	82	59.8	1	33	1.2
FALCON	57	56	67	61	51	44	36	83	41	47	60	56	85	59.4	5		
SD99W015	57	52	67	65	54	46	37	77	41	49	71	54	76	59.5	2	33	1.1
ARAPAHOE	57	53	65	68	57	46	38	85	36	45	60	57	78	59.3	4	35	1.3
SD97049	57	51	67	66	50	43	31	87	43	43	69	56	71	58.8	2	31	1.1
SD97W671-5	56	53	71	64	44	44	36	78	43	53	63	55	73	60.2	4	33	1.3
SD97088	56	48	65	67	48	44	34	89	45	44	65	54	72	59.8	4	36	1.4
TREGO	56	57	70	70	55	43	33	76	38	43	61	52	74	60.2	2	32	1.5
SD92107-5	55	50	66	67	47	42	31	83	44	44	59	55	74	60.3	7	37	1.3
ALLIANCE	55	53	71	69	54	44	37	71	44	41	55	53	73	58.5	2	34	1.4
HARDING	55	53	68	65	46	40	38	88	39	42	55	54	70	60.0	6	37	1.2
NEKOTA	55	51	70	60	52	42	34	79	42	49	62	49	68	59.9	2	33	1.2
JERRY	54	50	57	59	47	40	36	87	41	46	57	57	75	59.7	7	37	1.3
SD97250	54	51	67	61	51	44	34	79	37	46	62	53	67	59.2	4	35	1.3
CRIMSON	54	53	69	60	38	40	42	85	42	46	55	48	66	61.2	7	37	1.2
TANDEM	54	52	66	68	49	42	35	75	43	45	51	52	65	61.2	4	36	1.5
SD92107-3	53	48	61	65	44	43	36	87	38	42	56	53	69	59.5	6	36	1.1
NUPLAINS	53	49	65	58	50	41	38	87	44	45	51	50	60	61.2	6	31	1.0
AP502CL	53	51	73	61	60	38	36	63	40	43	61	40	71	57.5	1	31	1.0
RANSOM	50	47	55	56	45	39	33	78	37	45	49	48	64	58.7	7	37	1.5
MEAN	56	52	67	65	52	43	36	83	41	46	62	53	75	59.7	4	34	1.2
L.S.D. (0.05)	2	8	7	4	11	6	12	9	12	9	11	8	10	0.5	1	1	0.2
C.V.(%)	9	6	6	4	8	4	6	10	7	6	9	6	2	2.2	1	4	25.7

<sup>1</sup>BIS=Bison, OEL=Oelrichs, MAR=Martin, HAY=Hayes, STU=Sturgis, DLP= Dakota Lakes Pea stubble, BRC PLA=Platte, HIG=Highmore, KEN=Kennebec.

<sup>2</sup>TW= test weight; HEAD= relative heading date; HT=height; LODGING (scale of 1-5, 5 is flat); and PROT: each set of data is: TW, GY and HT = 12; LD = 8; PROT and HD = 7.

**Table 3. Grain yield, Testweight and Agronomic Data for the 2003 Advanced Yield Trial (AYT). (Entries are ranked in descending order by statewide yield average).**

ENTRY	GRAIN YIELD (bu/ac)							TW <sup>1</sup> (lb/bu)	HEAD <sup>1</sup> (days)	HEIGHT <sup>2</sup> (inches)	LODGING <sup>2</sup> (score)
	AVE <sup>1</sup>	BRK	DLP	HAY	HIG	WAL	WIN				
SD97380-2	54	83	38	50	55	50	51	58.8	2	32	2.2
SD00258	54	86	33	52	55	48	48	59.2	5	33	1.0
SD00111	54	74	41	51	54	53	48	59.5	3	32	2.8
SD00189	53	89	30	51	59	45	48	58.7	4	30	1.0
SD97W604	53	72	32	61	58	45	51	59.7	0	30	1.0
SD97W671-1	53	75	33	65	55	43	47	58.6	2	33	1.0
SD00032	53	79	35	44	58	48	51	59.7	4	37	1.5
96L9643-3	52	72	34	60	50	47	51	58.4	0	33	2.3
TREGO	52	75	38	56	52	42	49	59.7	1	31	2.5
SD97394-1	52	79	33	52	55	45	49	58.4	2	33	2.2
SD97W609	52	71	32	56	60	43	49	58.4	1	29	1.0
SD00260	52	79	35	51	54	42	48	59.6	4	35	1.3
EXPEDITION	51	68	37	50	51	48	53	58.6	0	31	1.3
SD97059-2	51	75	38	51	56	43	45	58.3	4	31	1.2
SD99073	51	72	34	50	54	47	48	59.5	4	32	1.3
SD97250-2	51	71	40	50	54	45	47	58.4	3	31	1.3
ARAPAHOE	51	79	33	51	56	43	44	58.3	3	32	1.7
SD99096	51	75	34	47	56	48	46	58.8	4	32	1.7
HARDING	50	77	38	39	57	45	46	59.5	6	27	1.2
SD97089-1	50	73	34	49	54	42	49	57.9	3	32	1.0
SD00261	50	74	36	40	54	47	50	59.7	4	33	1.0
SD00W087	50	78	35	39	53	45	51	60.4	5	35	2.2
SD00311	50	75	32	40	59	46	50	60.3	4	32	1.2
SD97W604-1	50	75	36	34	56	47	49	59.3	5	32	1.2
SD99W015	49	64	35	51	58	45	45	58.3	2	32	1.0
SD00235	49	73	37	40	51	54	42	57.9	5	32	1.7
SD99075	49	77	33	47	53	44	43	58.0	3	31	1.7
NUPLAINS	49	75	35	50	51	40	44	59.7	5	28	1.3
SD00W083	49	72	34	39	49	48	52	59.1	4	34	1.5
WESLEY	49	68	34	53	48	41	48	57.8	1	28	1.0
SD00W041	49	72	34	41	53	42	51	60.5	5	34	1.0
SD00127	49	70	37	43	46	48	48	58.8	3	33	1.2
SD00W021	48	77	36	38	49	41	49	59.5	5	34	1.0
SD00W024	48	76	36	36	55	48	39	59.0	5	33	1.2
SD00386	48	69	35	40	52	46	48	61.0	0	32	1.3
SD00305	48	71	32	42	55	44	43	59.7	7	35	1.7
ALLIANCE	48	69	34	46	54	43	42	57.9	1	30	2.3
SD00042	48	57	37	46	52	46	48	59.5	0	35	1.0
SD00330	47	73	32	38	49	44	46	59.1	4	35	1.3
SD00W028	46	72	36	40	46	42	44	58.4	3	30	2.8
CRIMSON	46	70	34	35	51	44	43	59.7	6	28	1.8
SD00W005	46	72	36	31	47	44	46	59.8	3	34	2.3
SD00W019	45	69	36	34	51	41	42	58.7	6	32	1.2
SD00W022	45	67	35	32	46	46	45	59.7	4	31	1.5
SD00W004	41	56	41	23	43	42	41	57.5	8	32	4.5
Mean	50	73	35	45	53	45	47	59.0	3	32	1.7
LSD (.05)	4	9	8	11	6	3	6	1.3	1		0.8
C.V. %	12	8	13	16	7	11	8	3.3	1		33.4

<sup>1</sup> Grain Yield (GY), Testweight (TW) and relative heading date (HEAD) averages include data from Brookings (BRK), Dakota Lakes Pea Stubble (DLP), Hayes (HAY), Highmore (HIG), Wall (WAL) and Winner (WIN).

<sup>2</sup> Plant height (HEIGHT) is an average of data from all locations except Hayes. Lodging (Scale of 1-5, 5 is flat) is an average of data from Brookings and Winner.

## **South Dakota Advanced Yield Trial (AYT)**

The 2003 Advanced Yield Trial (AYT) was grown at seven sites in South Dakota. The AYT included 45 entries, consisting of 36 advanced experimental lines from our program, three advanced experimental lines from Nebraska and six checks. Twelve of the 39 experimental lines were whites.

The screening tests performed on entries in the AYT included wheat streak mosaic virus field adult plant screening (Dr. Marie Langham, SDSU), multiple-race seedling stem rust screening (Dr. Yue Jin, SDSU – now at the Cereal Disease Laboratory, St. Paul, MN), field FHB screening, and field leaf-rust screening. The SDSU program also evaluated pre-harvest sprouting tolerance, PPO enzyme activity, coleoptile length, protein levels and mixograph performance. Based on field performance data (Tables 3) and screening results, seven lines were advanced to statewide yield trials (CPT) in 2004:

SD97394-1    Rose/SD88201 (Brule/Dawn)  
SD99073     SD92124 (Brule/Tam 105)/Arapahoe  
SD00032     CEP17/ND9257//SD94160 (NE82562/Rose)  
SD00111     KS93U134/Arapahoe  
SD00258     Millennium/NE93613 (NE82419/Arapahoe)  
SD00W024   SD94139W (ND8212/OK85310)/SD94217W (ND8212/OK85310)  
SD00W041   KS85W663-11-6-MB/SD94134W (ND8212/OK85310)

## **Preliminary Yield Trial (PYT)**

The 2003 Preliminary Yield Trials were separated into two PYT Red nurseries (to improve experimental design) and one PYT White nursery. The nurseries were planted on dry land pea stubble at Dakota Lakes, on spring wheat stubble at Selby, on oats stubble at Winner, and on fallow at Wall. Brookings (flax stubble) was added as a fifth site in 2003 to facilitate collection of data, especially sprouting tolerance data. The two PYT Red nurseries each consisted of 64 experimental lines, while the PYT White nursery consisted of 28 experimental lines.

All PYT experimental lines were resistant to bulk races of stem rust in greenhouse seedling tests. Lines with good field leaf rust tolerance that were chosen from a pool of the best 40 percent for yield rank were advanced from the 2003 PYT Red nurseries to the 2004 AYT nursery. Four lines from this pool that had good leaf rust tolerance were rejected for poor quality traits (mixograph or protein data). Three lines from the 2003 PYT White nursery were advanced to the 2004 AYT nursery. These lines had high test weight, moderate PPO levels and favorable mixograph scores. Two of the white lines, SD01W064 and SD01W009, yielded better than Wesley and similar to Arapahoe. A third line, SD01W062, a sibling of SD01W062, yielded less, but had a much longer coleoptile and higher protein levels. The two siblings have Russian parentage and originated in the University of Nebraska breeding program. SD01W009 originated in a discontinued USDA/ARS breeding program and is related to a line with excellent sprouting tolerance, 96L9643-3, that had been tested in AYT.

## **Early Yield Trial (EYT)**

From the 2002 head row nursery, 874 hard red lines and 142 hard white lines were selected for yield testing in the 2003 EYT. There was enough seed from the head row nursery to plant two locations of the EYT White nursery (Brookings and Winner ) and a third location of the EYT Red (Selby) in full-sized 7-row single replication plots. A check plot of Arapahoe was planted every tenth plot. Selections for advancement from the 2003 EYT nurseries to the 2004 PYT nurseries were based primarily on resistance to bulk stem rust at the seedling stage and field leaf rust. The pool of entries from which PYT lines were chosen were remarkably resistant to a bulk mixture of stem rust races: Only 15% of white lines and 19% of red lines were rated as susceptible. The pool was less resistant to field leaf rust: 40 % of white and red lines were rated as susceptible. Yield was a major criterion for selection among red lines, but not among white lines. From the pool of lines available for the PYT White nursery, less than ten percent were discarded for quality or agronomic characteristics (yield, spring stand, test weight, overall appearance and sedimentation values).

## **Head Row Nursery**

The 2003 F<sub>4</sub> head row nursery consisted of 24,425 head-rows selected from 325 populations (different cross combinations), of which 152 were white. Early-maturing Jagger and medium-maturing Arapahoe checks were placed systematically throughout the nursery to help provide selections that fall within an optimum maturity range. Of the white populations, 46 were re-selections from the EYT nursery, 18 were sorted from bulk seeds (15 from F<sub>4</sub> and 3 from re-selections) and 88 (63 from F<sub>2</sub> and 25 from F<sub>3</sub>) were obtained by a new method of eliminating red populations from progeny of red x white crosses. Instead of harvesting seed in bulk, then sorting seeds, heads were threshed individually and evaluated for seed color. Of the red populations, 50 were from the 2002 F<sub>3</sub> nursery and 123 were re-selections from the 2002 EYT nursery. Seed from white headrows was tested for PPO activity prior to selection for the 2004 EYTW nursery.

## **Early Generation Bulk Populations**

### *a) F<sub>3</sub> and F<sub>4</sub> Bulk Generations*

F<sub>3</sub> bulk populations were planted at Brookings and Dakota Lakes. The F<sub>3</sub> plots consisted of 140 red and 104 white bulk populations from crosses made in 2000, five white bulk populations from crosses made in 1999 and one white re-selection. Of the 110 white populations, 51 were sorted from seed of red x white crosses (5 three-way crosses and 46 single crosses) harvested in Arizona. The other populations were obtained from F<sub>2</sub> nurseries harvested at Highmore. Of the Highmore seed of white populations, 54 were from white x white single crosses and 5 were from red x white single crosses. Of the red populations, 125 were from single crosses, 8 were from three-way crosses or backcrosses, and 7 were from mixtures of populations. Observations of material in the F<sub>3</sub> nursery consisted of grain yield and test weight at Dakota Lakes and visual agronomic scores at Brookings. Data was adjusted by moving means relative to the check variety, Arapahoe. One hundred fifty heads were picked from selected F<sub>3</sub> plots at Brookings for entry into the 2004 headrow nursery.

### *b) F<sub>2</sub> Generation*

The F<sub>2</sub> bulk populations were planted in three nurseries: a nursery with full-sized plots (65 ft<sup>2</sup>) at Highmore and Brookings, a nursery with half-sized plots at Brookings, and a nursery with half-sized plots at Brookings and full-sized plots at Highmore. No off-season nursery was planted due to shortage of funds. One hundred ninety two F<sub>2</sub> populations with at least 50 grams of seed were grown in un-replicated 7-row plots with periodic checks at Highmore, while 81 populations were grown simultaneously at both Brookings and Highmore in un-replicated 7-row plots with periodic checks. At Brookings, 159 F<sub>2</sub> populations with 28 to 50 grams were grown in un-replicated half-sized 7-row plots.

The F<sub>2</sub> plots consisted of 163 red and 101 white bulk populations and 79 populations from red x white crosses made in 2001. (The red x white crosses are normally grown in an off-season nursery in Arizona.) Additionally, 13 red, 16 white and 8 red x white bulk mixtures (from crosses with F<sub>1</sub> yields of less than 28 grams) were planted in the F<sub>2</sub> nurseries. Crosses were allocated to the mixtures based on common parentage.

Selection for advancement was based on grain yield adjusted by moving means analysis relative to the check, Arapahoe. Test weight was measured but was not used for making selections. Of the 380 F<sub>2</sub> populations, 286 were retained as bulks for the 2003 F<sub>3</sub> Nursery.

### **Greenhouse Crossing and Increase Program**

The basic strategy of the greenhouse crossing program is to make adapted/adapted and adapted/un-adapted//adapted crosses (three-way crosses) with adapted winter wheat from our program and neighboring programs and un-adapted (e.g., spring wheat or other exotic germplasm) material with special desirable traits. Unique germplasm with resistance to *Fusarium* head blight, wheat streak mosaic virus, aphids, stem and leaf rusts, and hard white grain characteristics continue to be used in the crossing program. During 2003, 888 successful crosses were made during two greenhouse cycles (599 in the spring and 289 in the fall).

## **RESEARCH SUPPORT PROJECTS**

### ***Fusarium* Head Blight**

We made significant progress in evaluating germplasm and developing segregating populations that possess enhanced scab resistance. We have been evaluating elite breeding lines, introduced germplasm, regional nurseries, commercial varieties, and segregating populations in our mist-irrigated scab nursery since 1999. Approximately 6000 plants were evaluated for scab resistance during the 1999 season. 1500 of the plants were kept and were planted into the field in 2000 (as F<sub>3:4</sub> progeny rows). Forty-four lines were selected out of 1500 based on agronomic performance and were planted in 2001 – 2002 season in the early yield trial nursery (as F<sub>3:5</sub> lines). These lines were also planted in the greenhouse to confirm resistance. Heads were also picked from the best promising F<sub>3:4</sub> progeny rows and planted in the mist-irrigated nursery to get scab reaction data prior to line entry in the preliminary yield trials the following year. In the 2001 – 2002 growing season, we planted 3631 progeny rows, with resistant sources, under normal winter wheat production practices in Dakota Lakes, SD. These progeny rows were planted in spring wheat stubble with supplementary irrigation. The best 291 lines were advanced to the F<sub>3:5</sub> yield trials and observation rows of these were evaluated in the mist-irrigated nurseries in the field and greenhouse in 2003.

We have used marker assisted selection, in collaboration with Dr. Yang Yen, SDSU Molecular Biologist), as a complementary tool to our traditional breeding methods, to evaluate resistance in our promising advanced generations (AYT and CPT).

We investigated planting schemes between 2001 and 2003 to determine if direct seeded row materials are affected differently than transplanted hill plots when they are inoculated with FHB. Preliminary results suggested that there were indeed significant correlations between the two methods. We also started using point inoculation to evaluate winter wheat lines and varieties for scab tolerance under greenhouse conditions in 2002 and continued that in 2003. Mr. Subas Malla joined our program in the fall of 2002 to pursue an M.S. degree. He is conducting independent research regarding the genetics of scab resistance in hard winter wheat germplasm.

### **Stem and Leaf Rust**

Though our present stem rust (SR) resistance sources are effective, there is always concern that the resistance might break down at some point in the future. We are working collaboratively with Dr. Yang Yen, SDSU Molecular Biologist to transfer several novel/under-utilized broad-spectrum stem rust resistance genes into selected adapted lines in our germplasm. Research studies in coming years will focus on assessment of positive or negative effects of these genes with regard to yield, quality, or other agronomic traits. The first backcross cycle will be conducted in the spring of 2004. The same concept will be utilized in building parents with broad, durable resistance for crossing with high yield potential germplasm that lack in SR resistance but possess good leaf spotting disease resistance. Our objectives are to: 1) to conduct a preliminary screen for the few existing markers linked with stem rust resistance genes, to assess the potential for using these markers in selection for the respective resistance genes, and 2) to begin to search for molecular markers linked to the novel and under-utilized genes mentioned above. Resistance in these unique sources is believed to be conferred by a single major gene. The F<sub>2</sub> generation of resistant-by-susceptible line will be increased in spring 2004. We look towards marker assisted selection as a complement and not a replacement to more traditional methods, and we believe that it offers unique opportunities for enhancing the efficiency of variety development.

Future research will utilize a combination of greenhouse and field screening to breed for durable resistance to leaf rust (LR). The EYT, PYT, AYT, and CPT entries will be screened in the greenhouse and in the field (transplanted nurseries). The head-row nursery will be planted on spring wheat stubble at Dakota Lakes Research Farm every other year to stimulate disease expression and facilitate screening for both LR and SR.

### **Winter Hardiness**

Multi-year, replicated field-testing forms the basis for the improvement of winter survival ability in our new wheat cultivars. Physiological and molecular markers of freeze resistant genotypes also will be required to complement field-testing especially during milder years. We have established collaboration with Dr. Fedora Sutton, SDSU Plant Molecular Physiologist to conduct studies geared towards understanding the physiological basis and identifying genes and proteins necessary for freeze survival.

## **White Wheat**

The number of white samples examined in routine quality tests more than doubled from 1998 to 2003. Tests included protein, test weight, computerized mixographs, sedimentation, PPO activity, sprouting tolerance and coleoptile length in addition to seedling stem rust, and field wheat streak mosaic virus (WSMV) and scab screening.

In previous years, our breeding efforts for hard white winter wheat (HWWW) have centered on making crosses between adapted red lines and un-adapted white germplasm. We incorporated resistance to prevalent races of stem rust and increased the winter survival ability of HWWW. We also increased coleoptile length of our HWWW germplasm and decreased PPO activity (a predictive measure of noodle-making quality) without sacrificing bread-making qualities. In 2003, for both red and white germplasm in advanced nurseries, we increased coleoptile length by an average of 1 cm. The percentage of white lines (40 %) with coleoptiles longer than the variety 'Harding' was twice that of red lines (20 %) in 2003 advanced nurseries (the coleoptile length of Harding is considered to be a standard for acceptable emergence following deep planting). In 2004, few of the long coleoptile lines were advanced to the AYT nursery with the result that only 2 of 7 white lines and 3 of 36 red lines had coleoptiles at least as long as Harding. However, in the 2004 preliminary yield trial (PYT) nursery, 40 % of both red and white lines had coleoptiles at least as long as Harding.

Pre-harvest sprouting resistance continues to be one of our biggest challenges and commands our intense effort. 'Nuplains' and 'Trego', the only two elite white varieties with acceptable adaptation for some environments in South Dakota, have been identified as very good lines for sprouting resistance. Of the tested experimental lines entered into 2003 and 2004 advanced nurseries, '96L9643-3' rated very good both years; 'SD97W671-1' rated good in 2003 and fair to good in 2004; and 'SD97W604' (2004 potential release) and 'SD00W087' rated fair to good both years. Of other experimental lines entered into 2004 advanced nurseries, nine SD01W lines as well as 'SD97W609' (2006 potential release), 'SD97W604-1' and 'SD99W015' rated very good for sprouting tolerance.

The number of white entries in early generation nurseries has fluctuated widely from year to year; whereas the number of white entries in later generation nurseries has been fairly stable. The Headrow nursery at the Dakota Lakes Research Farm consisted of 3933 white progenies in 1998, 5340 in 1999, 1635 in 2000, 7502 in 2001, 1954 in 2002, 11,707 in 2003 and 4915 in 2004. The EYT nursery had 125 white entries in 1998, 182 in 1999, 174 in 2000, 117 in 2001, 99 in 2002, 141 in 2003 and 270 in 2004. The PYT nursery had 44 white entries in 1999 and 2000, 40 in 2001, 26 in 2002, 29 in 2003, and 39 in 2004. The AYT nursery had 3 experimental white entries in 1998, 26 in 1999, 22 in 2000, 10 in 2001, 11 in 2002, 14 in 2003 and 8 in 2004. The CPT nursery had 3 experimental white entries in 2000 and 2001, 5 in 2002, 4 in 2003 and 5 in 2004. Two lines, SD97W604 (SD89333 ('Gent'/'Siouxland')/'Abilene') and 'SD97W609' (Abilene/'Karl'), are on Foundation and Breeder Seed increase, respectively with potential release in 2004 and 2006, respectively.

## **Development of Combined Meal PPO and Sedimentation Test for HWWW**

We developed a protocol that simultaneously measures meal sedimentation and polyphenol oxidase (PPO) activity for early generation quality screening during the short turnaround period between harvest and planting. Our regular sedimentation tests were usually conducted with 1 gram

of ground meal from a 10-gram sample to predict gluten strength, while our PPO assay (predictive measure of noodle discoloration) was conducted with five whole seeds samples. A final combined protocol was selected based on correlations with standard tests for sedimentation and PPO, as well as computerized mixograph data. The combined protocol was built on the meal SDS-sedimentation protocol, with adjustments in temperature, MOPS (3-(N-Morpholino) Propane-Sulfonic Acid) buffer concentration, lactic acid concentration, and the timing of steps. In this combined protocol, 4 ml of 10 mM L-DOPA (L-3,4-dihydroxyphenylalanine) replaced 4 ml of water, while various levels of lactic acid were tested. PPO color development improved with time and was acceptable at 42 minutes. Use of the most promising combined protocol (5 ml lactic acid, 4 mL 10 mM L-DOPA in 150 mM MOPS buffer, with ambient temperature of 24° C. and measurement of sedimentation at 41 minutes and color at 42 minutes) provided acceptable PPO and sedimentation scores. The stability (CV% = 12.8) of PPO values in the combined protocol was greatly improved compared to that (CV%= 22.3 %) of the 5-grain visual PPO test. The stability of the sedimentation portion (CV% = 3.4) of the combined protocol matched that of the standard meal sedimentation test (CV% = 4.5). Both sedimentation tests were highly correlated with mixograph scores loading on a factor associated mainly with mixing tolerance. Highly skewed results for meal PPO and sedimentation obscured distinctions among higher values. All protocols (standard or new) produced highly significant location-by-entry interactions, indicating a need to test over multiple environments before using data for screening purposes. Further tests will be conducted on seed harvested from 2005 Advanced Yield Trials to confirm the repeatability of the combined protocol.