IMPROVING SMALL GRAINS VARIETIES FOR NEBRASKA

2018 STATE BREEDING AND QUALITY EVALUATION REPORT

Report to the

NEBRASKA WHEAT DEVELOPMENT, UTILIZATION
AND MARKETING BOARD

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I. INTRODUCTION

Development research on Nebraska's small grains (winter wheat, barley, and triticale) varieties is a cooperative effort between the Agricultural Research Division, IANR of the University of Nebraska-Lincoln, and the Agricultural Research Service/USDA, Northern Plains Area. Winter wheat breeding, which includes hybrid, variety, line, and germplasm development, is a major component of the state's small grains improvement research. This report deals only with the state portion of the total small grains breeding effort (located in the Department of Agronomy and Horticulture at the University of Nebraska-Lincoln). Key contributions come from state and federal researchers and from Nebraska research and extension centers, as well as from state and private researchers in South Dakota, Wyoming, Kansas, Oklahoma, Texas, and Colorado. Other important contributions come from researchers in the Department of Plant Pathology (both state and federal); plant pathologists located at the USDA Cereal Disease Laboratory in St. Paul, MN, and USDA entomologists in Manhattan, KS and Stillwater, OK. All of these programs invest time and funds into this program. Grants from the Nebraska Wheat Development, Utilization and Marketing Board, provide key financial support for this research. Without the Wheat Board's support, much of the state breeding efforts would be limited and many of the wheat quality analyses to evaluate our breeding material would not be available.

II. THE 2017-2018 NEBRASKA WHEAT CROP

1. <u>Growing Conditions</u>

The 2017-2018 growing season would be considered being generally good for production in many areas with significant challenges in some regions. Growing conditions included timely planting into generally good soil moisture leading good fall stands and growth. The fields were planted on time for their respective eco-geographic zones and fertilizer was generally applied before planting, though the expected prices for the crop led to less inputs (fertilizer, pesticides) being used than when wheat is worth more. In general, diseases were moderate throughout Nebraska. Fungicides were frequently used as a preventative measure against fungal diseases. Rain at harvest reduced grain yield and quality.

2. <u>Diseases</u>

In 2018, in eastern Nebraska, wet weather diseases such as leaf rust and bacterial streak were found. Stripe rust and Fusarium head blight were minor though as predicted by ScabSmart, a pocket of Fusarium headblight was found in southwestern Nebraska. . In fungicide treated (76.0 bu/a) and untreated (70.9 bu/a) trials at Lincoln 2018, the yield loss due to foliar fungal disease was 7% (5.1 bu/a). This level of disease loss is much lower than in previous years. The fungicide treated plots were only sprayed once due to lower levels of disease and also bacterial streak (being caused by bacteria) is not controlled by fungicides. In 2018, cephalosporium stripe, caused by a soilborne pathogen *Cephalosporium gramineum*, was again found at North Platte. Wheat streak mosaic virus was generally minor in western Nebraska. Drs. Stephen Wegulo (plant pathologist), Jeff Bradshaw and Gary Hein (entomologists monitoring insect vectors of disease), and Satyanarayana Tatineni (USDA-ARS virologist) continue to be invaluable in disease identification, survey, and understanding. Little disease was found on winter barley and winter triticale.

3. Insects

Nebraska continues to have small outbreaks of Hessian fly and the diseases vectored by aphids (barley yellow dwarf virus). In 2018, wheat streak mosaic virus (WSMV) and others viruses vectored by mites or aphids were generally minor. The wheat stem sawfly continues to be pervasive throughout the Nebraska Panhandle and led to crop losses wherever there was severe weather before harvest due to extensive lodging and stem breakage.

4. Small Grains Production

In 2017-2018 season, 1,100,000 acres of wheat were planted in Nebraska and 1,010,000 were harvested with an average yield of 49 bu/a for a total production of 49,490,000 bu. The crop generally got off got a good start and survived the winter, but in the spring periodic episodes of drought and extreme heat (100 F at flowering) affected part of the crops. Leaf rust was the main disease and wheat stem sawfly was the major insect pest. In 2016-2017 season, 1,120,000 acres of wheat were planted in Nebraska and 1,020,000 were harvested with an average yield of 46 bu/a for a total production of 46,920,000 bu. The crop generally got off got a good start and survived the winter, but in the spring a number of diseases and wheat stem sawfly were abundant. In western and central Nebraska, wheat streak mosaic virus was quite common. Wheat stem sawfly also continued to expand into Nebraska from the west, though fortunately parasites lessened some of the damage. In eastern Nebraska, the rusts (led by stripe rust and then leaf rust were very common). In 2015-2016 season, 1,370,000 acres of wheat were planted in Nebraska and 1,310,000 were harvested with an average yield of 54 bu/a (a record yield/acre) for a total production of 70,740,000 bu. In 2014-2015 season, 1,490,000 acres of wheat were planted in Nebraska and 1,210,000 were harvested with an average yield of 38 bu/a for a total production of 45,980,000 bu. The yield losses due to controllable fungal diseases in eastern Nebraska in 2015, 2016, and 2017 were 44%, 32% and 16%, respectively. Despite continued genetic improvement, the main determinant in wheat production seems to be acres harvested, government programs, and weather (which also affects disease pressure and sprouting). This is an economic reality in understanding wheat yields and productivity in NE. Barley or triticale acreages are not reported in the NASS surveys but the general feeling is that locally produced barley is finding a fit for micromalsters and microbrewers, forage for dairies, and feed for animals. Triticale acreage continues to increase, primarily as an annual forage crop and to a lesser extent as a feed crop.

5. Cultivar Distribution

Nebraska began retaking the variety surveys in 2015, however due to financial constraints did not do one in 2017. Using aggregate data from the Nebraska Crop Improvement Association, approximately 67% of the wheat planted acres were planted to certified seed of 46 different cultivars. The certified seed planted acreage will vary by cropping system and region with more save seed in regions where less seed of other crops are purchased. Approximately 50% of the certified seed was developed by companies, 37 % by the USDA-University of Nebraska and 13% from other public breeding programs. From seed sales, Ruth (ranked 3rd in certified seed sales) had an excellent year and should be adopted well in across NE. Robidoux, Freeman, and many of the commercially developed lines continue to be popular. While no wheat listed below has all of the characteristics of an ideal wheat, the diverse wheat varieties provide the grower an opportunity to choose high yielding, high quality wheat varieties that have resistance or tolerance to the diseases or insects prevalent in his or her region. Cultivar diversity is useful, as it should reduce genetic vulnerability to specific disease and insect pests.

III. New Cultivars

The project formally released one new wheat line NE12561 which will be marketed through NuPride Genetics Network and named Siege and a second line in collaboration with Limagrain (LCS Valiant). Our first approved 2-gene Clearfield line (NHH144913-3 was discovered to have soft kernels and will need to be an indentity preserved wheat is it is marketed). Siege is a hard red winter wheat selected from the cross NI04420/NE00403 where the pedigree of NI04420 is NE96644 (=ODESSKAYA P./CODY)//PAVON/*3SCOUT66/3/WAHOO SIB and the pedigree of NE00403 is PRONGHORN/ARLIN//ABILENE. It is a semi-dwarf, moderately late in maturity, with good winter hardiness, and straw strength. It is moderately resistant to Hessian fly and leaf rust. It is resistant to wheat soilborne mosaic virus, stem rust, and stripe rust. It is susceptible to wheat streak mosaic virus. It has good test weight and above average protein content. Its end use quality is acceptable. It best adapted to Eastern and Southcentral Nebraska. Its straw strength may have utility under irrigated production though it will not top most irrigated trials. Certified seed will be available in 2019 to 2020. Information on LCS Valiant (derived from the cross NI03418/Camelot) can be found at the Limagrain website: https://limagraincerealseeds.com/central-plains/hard-red-winter-wheat-seed/lcs-valiant/

Our next white wheat has been developed, but a key need is identifying a buyer for it. NW13493 (derived from the cross SD98W175-1/NW03666) is a potential new hard white wheat. White wheat varieties always have to find a market before they can be released because without a known buyer is a concern on marketability which puts growers at risk. However, there is little doubt that if NW13493 were a hard red wheat, it would be released. It is a very high yielding, early, semi-dwarf with good winterhardiness and disease resistance (leaf, stem, and stripe rust; wheat soilborne mosaic virus). However, it is susceptible to wheat streak mosaic virus and Hessian fly. While it has good test weight, it tends to be slightly below average for grain protein content. It has very good end-use quality.

In 2017 we announced the release of 7 new triticale lines (NT055421, NT07403, NT09423, NT11406, NT11428, NT12414, and NT12434). NT12434 was licensed to Limagrain and will be marketed as LCS Bar. NT12414 is also under consideration for licensing. PVP certificates have been submitted for NT07403, NT09423, NT11406, NT11428, and NT12434. These five lines are currently grown from the New York to New Mexico. In 2018, one new forage triticale, NT13443 was released. NT13443 was derived from the cross 04TG 112/NE422T=(TRICAL /UB-UW26)//NE03T407 and is a winter forage triticale that grows well in the Central Great Plains under rainfed conditions. It has excellent winterhardiness and good bacterial streak resistance (a major disease of triticale and one that cannot be treated with fungicides). It is early (6 days earlier than NT441 and similar to NT426GT) and tall, similar in height and slightly better in forage production to NT441. Like most tall triticales, if intensively managed, lodging may be a concern. It has a relatively unique grain characteristic of being low in polyphenol oxidase (an enzyme that discolors wet dough products if they are allowed to rest, similar to an apple browning when bitten). We are exploring food uses for this trait.

Dry Forage Yield (Lbs/a)	Dry matter	IVDMD %	NDF %	ADF %	ADL %	Protein %	rank	
6675	0.273	68.9	65.1	38.6	5.4	12.0	8	NE422T
6675	0.287	68.4	63.4	37.0	5.4	11.2	9	NE426GT
6599	0.293	67.3	64.8	38.7	5.7	11.0	11	NT05421
6171	0.299	67.8	63.3	37.7	5.5	10.7	15	NT06422
6921	0.284	69.1	63.3	37.3	5.4	11.8	6	NT06427
5628	0.312	67.9	63.3	37.4	5.5	10.8	17	NT07403
7495	0.270	68.7	64.0	37.5	5.6	12.0	3	NT09423
5905	0.266	69.3	64.2	37.4	5.5	12.3	16	NT10417
6460	0.282	68.1	63.6	37.6	5.5	11.1	12	NT11406
7384	0.278	68.4	64.7	38.2	5.5	11.2	4	NT11428
6182	0.295	67.4	63.9	38.3	5.6	10.7	14	NT12403
6839	0.308	67.8	62.6	37.2	5.4	10.2	7	NT12404
7593	0.293	67.6	63.5	37.6	5.6	11.6	2	NT12406
7167	0.291	67.4	64.8	38.7	5.6	10.1	5	NT12425
6655	0.307	67.7	62.9	36.9	5.4	10.6	10	NT13416
8356	0.314	66.7	65.1	38.7	5.6	10.0	1	NT13443
6275	0.290	69.2	63.3	37.2	5.3	12.3	13	OVERLAND

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Ruth continued to do well. Below is the data from the State Variety Trial for 2016-2018.

		State Grain Yield bu/a	SE Grain Yield bu/a	SC Grain Yield bu/a	WC Grain Yield bu/a	West Grain Yield bu/a	Plant Height in	Test Weight lbs/bu	Grain Protein %
Agripro Syng	SY Wolf	**62.5**	68	62	72	48	33.3	56.5	13.4
Husker Gene	Freeman	**63.0**	63	58	74	57	34.0	55.5	12.7
Husker Gene	Ruth	**64.0**	62	62	76	56	36.3	56.3	12.9
Husker Gene	Overland	**58.8**	56	60	69	50	36.3	56.3	12.9
Husker Gene	Robidoux				73	55	34.0	57.0	12.5
	Wesly		52		62	47	31.7	55.0	13.3
	Scout 66	**42.3**	44	33	51	41	39.8	55.0	13.7
	Turdkey	**41.0**	42	37	49	36	39.8	54.3	14.3

IV. FIELD RESEARCH

1. Increase of New Experimental Lines

With the release of new varieties Husker Genetics Brand Ruth, Siege, LCS Valiant, Freeman, Goodstreak, Panhandle, Robidoux, and Settler CL over the past several years, most advanced current breeding lines are not expected to be released. However, a number of lines are targeted for advancement or possible release in 2019. Specifically, the following lines are under increase:

Crop	Line	Pedigree	Comment
Barley	NB15420	P-845/NB08410	Excellent Grain Yield
	NB14422	P-845/NB05419	Excellent Grain Yield
	NB15415	P-845/NB08410	Excellent Grain Yield
Triticale	NT14433	Haiduc/NE426GT//NT06427	Excellent forage triticale
	NT15406	Gorum/NE422T//NT08421	Excellent grain triticale
Wheat	NW13493	SD98W175-1/NW03666	Excellent grain yield and quality
	NE14691	SD05W138/NE01604	High yielding semidwarf line
	NE15624	NE05537/KS05HW15-2	High yileding semidwarf line
	NE14696	NE05537/Overland	Tall semidwarf with excellent disease resistance
	NW15443	OR 2060108/NW03681//NW03666	Good white wheat

	Sr	LR	YR	HF	SBMV	D. Bunt	Acid Soil
Panhandle	MR	MS	S	S	MR		
Freeman	MR	MS	MR	SEG	R		
LCS Valiant	MR	MR	S	MR	R		
Siege	MR	MS	MR	MR	R	S	MS
NE13515	MER	MS	MR	MS	R		
NE14434	MR	MS	MR/MS	S	R	S	
ND14696	,MR	MR/MS	MR	S	R		
Robidoux	MR	MS/S	MR	S	R		
NI12702W	R/MR	MR	MR	MR	S	MR	
NI13706	MR	MR	MR	S	R		
NI14729	MR	MS?	R/MR	R	R		
NW13493	R/MR	MR	MR/MS	S	MR	S	
Overand	MR	R	S	S	R?	S	
Wesley	R	S	MS/S	S	R		
NHH144913-3	MR	MS	MR	S	R	S	
NE14691	R	MS	MR	R	R	S	
NE15624	MS	MS	MR/MS	S	R	S	

R = resistant, MR = moderately resistant, MS = moderately susceptible, and S = susceptibl

2. Nebraska Variety Testing

Numerous entries were included in some or all of the locations in the Fall Sown Small Grain Variety Tests in 2018. Nine dryland locations in Nebraska were harvested for yield data and the data for the top ten lines grown across the state are presented below. Please note many of the locations in the West district were lost, so the data are biased to lines doing well in eastern central, and southwestern Nebraska. LCS Valiant (formerly NE10478-1, developed by UNL and marketed by LCS) did extremely well and 30% better than Turkey. Remarkably, Turkey did better than Scout 66 which is very unusual, though the difference was most likely not significant.

Name	Average
LCS Valiant	78.3
SY Monument	77.2
WB-Grainfield	76.9
NW13493	76.7
LCS Link	76.3
NHH144913-3	75.3
NI13706	75.0
LCS Chrome	74.8
Long Branch	74.3
SY Wolf	74.0
Ruth	73.8
WB4418	73.5
NE12561	73.1
AM Eastwood	72.7
NE13515	72.4
Freeman	70.9
Turkey	60.4
Scout 66	58.2

In 2017, Westbred Grainfield (44% better than Scout 66) topped the trial, followed by LCS Link (an LCS_UNL joint release). Ruth continued to do well, as did a number of new experimental lines. As expected, Scout 66 (57.3 bu/a) and Turkey (46.5 bu/a) were the bottom of the trial.

Dryland	Yield	Dryland	Yield
Entry	bu/a	Entry	bu/a
WB-Grainfield	82.7	NE12561	79.3
LCS Link	82.6	NI13706	79.3
NW13570	82.4	NE10478-1	79.0
Ruth	82.1	SY Wolf	78.8
NW13493	79.9	Long Branch	77.9

In 2016, the top ten entries for dryland production (12 environments) were:

2015-2016		Southeast	Southcentral	Southwest	West	State	rank
Brand	Variety	Average Yield (bu/a)	Average Yield (bu/a)	Average Yield (bu/a)	Average Yield (bu/a)	Average Yield (bu/a)	
Husker Genetics	Freeman	78	51	89	59	73.1	1
WESTBRED	WB-Grainfield	77	59	87	57	72.2	2
Husker Genetics	NE10589 (Ruth)	72	52	82	59	69.3	3
Limagrain Cereal Seeds	LCH13NEDH-14-69	75	55	81	55	68.7	4
WESTBRED	WB4721	74	56	79	53	67.2	5
Limagrain Cereal Seeds	PSB13NEDH-14-71	73	51	82	51	66.8	6
Syngenta AgriPro	SY Wolf	78	47	77	52	66.4	7
Dyna-Gro	HRX1652	62	40	80	61	65.8	8
-----	NE09517	68	51	77	55	65.3	9
-----	NI10718W	68	33	76	46	60.4	10
----	Wesley	62	36	75	49	59.8	11
Husker Genetics	Overland	59	35	75	51	59.7	12
----	Scout 66	38	14	54	44	43.3	13
----	Turkey	35	13	52	37	39.5	14
Average all entries		65.8	42.4	77.8	51.6	63.1	
Difference required for significance at 5%		16	10	6	6		

3. Irrigated Wheat Trials:

In 2018, one irrigated trial was harvested (Box Butte County). The Chase County trial was damaged by storms.

Box Butte County Irrigated Winter Wheat Variety Test - 2018				
Brand	**Variety**	**Grain Yield (bu/a)**	**Moisture (%)**	**Bushel Weight (lb/bu)**
CROPLAN by Winfield United	CROPLAN EXP 69-16	102	13	56
Husker Genetics	Robidoux	101	13	55
AgriPro Syngenta	SY Wolf	100	13	55
WestBred	WB4418	100	13	55
AgriMAXX	AM Eastwood	99	14	56
-----	NHH144913-3	99	13	55
WestBred	WB4303	97	13	53
-----	NE12561	97	13	56
WestBred	WB4458	96	13	54
-----	NE15420	96	13	54
Limagrain Cereal Seeds	LCH14-77	95	14	56
WestBred	WB-Grainfield	95	13	54
Limagrain Cereal Seeds	LCS Chrome	94	11	56
WestBred	WB-Cedar	94	13	55
PlainsGold	Langin	92	11	56
Dyna-Gro Seeds	Long Branch	91	12	55
WestBred	Winterhawk	90	13	55
CRFW	Cowboy	89	13	55
AgriPro Syngenta	SY Sunrise	88	13	56
Limagrain Cereal Seeds	Avenger (LCH14-55)	87	12	56
Limagrain Cereal Seeds	LCS Link	85	13	55
-----	NI13706	85	14	56
----	Wesley	81	12	53
Average of all entries		**94**	**13**	**55**
Difference required for significance at 5%		**8**	**NS**	**NS**

Many high yielding lines were identified and confirmed (e.g. Robidoux and SY Wolf). In 2017, one irrigated yield trials was harvested (Chase county). Box Butte county trial was lost.

Brand	Variety	Grain Yield (bu/a)	Moisture (%)	Bushel Weight (lb/bu)	Plant Height (inches)	Grain Protein (%)	Kernel Weight (1000/lb)
WestBred	WB4303	122.8	8.8	63.0	34	12.4	13.3
CROPLAN by WinField	EXP 69-16	116.0	9.1	65.5	34	11.7	12.8
AgriPro Syngenta	SY Wolf	112.6	9.1	65.9	34	12.4	14.3
Limagrain Cereal Seeds	LCS Link	112.3	9.2	64.9	37	11.9	14.5
Dyna-Gro Seeds	Long Branch	110.8	9.0	64.5	36	11.6	14.3
PlainsGold	Langin	110.7	9.0	63.8	32	11.1	14.6
WestBred	Winterhawk	109.0	9.1	66.3	38	11.9	12.8
AgriPro Syngenta	SY Sunrise	107.6	9.0	64.3	33	12.5	13.4
WestBred	WB-Grainfield	107.2	9.1	65.2	33	11.7	14.2
CROPLAN by WinField	EXP 26-16	106.9	9.2	67.1	38	12.0	12.5
-----	NI13706	105.3	9.1	66.6	33	13.3	14.3
----	Wesley	102.9	9.0	64.9	35	12.4	14.0
Limagrain Cereal Seeds	LCS Chrome	98.6	8.9	63.6	38	14.3	17.2
Westbred	Aspen	98.3	9.1	64.4	33	13.0	14.2
Husker Genetics	Robidoux	97.7	9.1	65.3	36	11.7	14.2
WestBred	WB4458	97.7	8.8	65.3	36	14.5	13.3
AgriPro Syngenta	SY Flint	97.6	9.2	64.7	35	12.8	13.8
----	Mace	97.2	8.9	64.0	36	12.6	15.8
-----	NI10718W	96.1	9.0	63.5	36	12.5	13.8
-----	Ruth	93.2	9.2	66.6	37	12.6	13.7
PlainsGold	Avery	91.4	8.7	61.7	30	10.8	14.0
CRFW	Cowboy	89.6	9.0	64.6	36	12.1	14.3
Limagrain Cereal Seeds	LCS Mint	87.3	9.3	66.5	37	13.7	13.3
Limagrain Cereal Seeds	LCH14-77	86.2	9.1	64.5	37	11.7	14.4
-----	N11MD2166W	85.8	8.9	65.3	37	11.4	15.0
-----	NE12561	85.2	9.1	65.7	36	12.5	13.9
-----	NI12702W	84.4	9.8	67.4	37	12.3	13.3
PlainsGold	Snowmass	80.0	9.2	65.9	32	11.4	13.2
WestBred	WB-Cedar	79.0	9.0	64.8	32	13.1	13.0
-----	N13MD2589W	72.7	9.3	68.1	40	15.2	15.0
Average of all entries		**98.1**	**9.1**	**65.1**	**35**	**12.4**	**14.0**
Difference required for significance at 5%		**15.1**	**0.4**	**3.7**	**4**	**NS**	**1.4**

In 2016, two irrigated yield trials were harvested (Chase and Box Butte counties).

Brand	**Variety**	**Average Yield (bu/ac)**	**Box Butte Yield (bu/ac)**	**Chase Yield (bu/a)**	**Bushel Weight (lb/bu)**	**Height (in)**	**Kernel Weight (000/lb)**	**Grain Protein (%)**
WESTBRED	WB-Grainfield	94	94	93	56	37	16.8	15.0
PlainsGold	Antero	94	99	89	57	34	14.0	13.3
WESTBRED	WB4303	94	97	90	54	35	16.3	15.4
PlainsGold	Brawl CI Plus	92	79	105	58	35	14.1	15.4
Syngenta AgriPro	SY Wolf	92	98	85	55	36	14.9	14.8
WESTBRED	Winterhawk	91	93	89	56	37	15.8	14.8
Limagrain Cereal Seeds	LCH13NEDH-14-69	91	90	91	57	35	14.9	14.6
PlainsGold	Byrd	90	90	90	56	35	16.4	14.4
WESTBRED	WB4458	90	77	102	57	36	14.0	15.0
Syngenta AgriPro	SY Sunrise	90	85	95	58	35	14.4	14.4
Average of all entries		**83**	**85**	**81**	**56**	**36**	**15.5**	**14.8**
Difference required for significance at 5%		**18**	**20**	**12**	**3**	**2**	**2.1**	**1.1**

The irrigated data this year continues to show the benefits of having a dedicated irrigated wheat development nursery to select lines that have excellent performance (e.g. Robidoux).

In 2017, due to financial restraints we had to drop the experimental line irrigated nursery. However, we were able to keep a dryland nursery that included lines that may have potential under irrigation. The selected lines tended to have better straw strength and shorter plant height. The goal of this nursery is to identify higher yielding lines under irrigation and under higher rainfall conditions, which periodically occur in Nebraska. The data for 2018 are:

Name	Lincoln	N.Platte	Alliance	St. Avg.	Rank	Flowering	Height	Test Wt.
	Yield	Yield	Yield	Yield		Date		
	bu/a	bu/a	bu/a	bu/a			in	
newname	yb_ln18	yb_np18	yb_al18			hdjd_ln18		twt_al18
NE17572	75.4	52.7	67.4	65.17	14	144.9	31.7	56.7
NE17625	61.8	56.5	67.9	62.07	27	145.0	33.4	57.3
NE17631	77.2	54.6	64.9	65.57	13	144.7	34.4	56.3
NE17499	66.8	48.3	60.2	58.43	36	144.7	33.6	56.3
NE17546	58.7	50.3	75.4	61.47	29	144.0	33.7	56.7
NE17565	75.2	58.4	64.2	65.93	10	144.7	34.6	55.7
NE17462	69	51.8	68.6	63.13	23	143.7	34.9	57.3
NE17620	81.8	64.5	69.8	72.03	1	144.6	33.6	60.1
NE17597	44.1	59	64.2	55.77	38	144.7	39.3	58.8
NE17662	75.2	51.1	71.5	65.93	10	145.0	34.8	57.8
NE17442	79.4	61.1	63.8	68.10	6	144.0	31.4	57.3
NE17469	61.1	62.6	67.2	63.63	20	144.0	36.9	57.7
NHH17559	66.2	61.2	66.1	64.50	16	144.7	34.2	56.8
NE17467	73.4	52	66.9	64.10	18	144.7	32.1	56.5
NE17607	73.5	62.2	67.7	67.80	7	145.6	33.0	56.0
NE17626	78.9	56.4	71.7	69.00	3	145.0	32.6	57.2
NE17464	70.2	52	59.1	60.43	32	144.0	31.3	55.7

NE17544	77.5	54.6	74.9	69.00	3	145.3	36.0	58.2
NE17589	71.8	59.7	74.7	68.73	5	144.3	35.1	57.8
NE17561	74.3	63	71.4	69.57	2	144.7	35.6	58.3
NE17468	64.6	55.2	68.8	62.87	24	144.7	35.5	59.7
NE17474	47.3	56.9	71.9	58.70	35	144.4	35.6	57.4
NE17541	50.4	53.9	69.4	57.90	37	144.3	35.7	56.4
NE17534	75.2	56.5	67.9	66.53	9	144.1	31.2	57.1
NHH17447	68.9	61	67.2	65.70	12	145.3	33.4	57.4
NE17403	60.7	52.1	67.1	59.97	34	143.7	31.1	55.1
NE17629	69.7	54.3	66.1	63.37	22	144.0	34.7	57.6
NE17476	63.8	57.4	69.9	63.70	19	144.0	33.0	55.5
NE17611	69.6	53.5	62.8	61.97	28	145.0	32.7	55.6
NE17440	27	67.7	64	52.90	39	144.0	38.0	58.2
NHH17448	66.2	52.5	67.9	62.20	26	144.7	35.5	57.5
NE17463	56.7	59.7	67.6	61.33	31	144.4	34.1	55.7
NE16401	72.5	58.8	62.8	64.70	15	145.0	30.2	57.1
NE16552	32.4	59.7	61.5	51.20	40	144.7	42.5	58.6
NI17411	77.1	54.4	59.2	63.57	21	144.3	32.3	59.1
NI15711	71.2	57.4	59.4	62.67	25	144.0	30.3	54.2
NI17414	76.5	45	62.6	61.37	30	145.2	33.3	57.1
NE15420	79.3	49.3	64.7	64.43	17	145.3	30.9	58.0
WB CEDAR	73.6	45.8	61.1	60.17	33	144.3	29.4	56.8
LCS Valiant	73.3	58.5	70	67.27	8	145.3	32.9	56.9
CV	**10.58**	**9.43**	**8.3**			**0.33**		**0.85**
GRAND MEAN	**67.19**	**56.04**	**66.74**			**144.58**		**57.13**
LSD	**11.62**	**8.64**	**9.06**			**0.78**		**0.79**

The data for 2017 are:

	Lincoln	N. Platte	Alliance	Rainfed A	RankD	Hdate	Height	TestWT	Lodging
	Yield	Yield	Yield	Yield		Julian			
Enry	Bu/a	Bu/a	Bu/a	Bu/a		d	In	lbs/bu	0-9
Antelope	54.7	50.2	60.8	55.23	29	136.3	27.0	57.7	5.4
Robidoux	70.4	57.5	74.3	67.40	5	136.7	28.0	56.4	4.7
NI10718W	53.7	57.2	51.0	53.97	32	136.0	27.2	54.2	5.3
WESLEY	51.0	57.0	59.5	55.83	26	136.7	26.5	55.3	3.6
NW07534	57.9	60.3	59.2	59.13	17	136.0	26.1	55.8	4.7
Settler CL	55.3	51.8	49.6	52.23	38	135.3	26.8	55.2	4.3
NI13717	69.7	57.2	62.8	63.23	9	135.0	27.8	58.9	5.0
NI14722	65.5	60.3	64.3	63.37	8	135.0	25.7	58.6	6.7
WB CEDAR	60.8	49.6	56.2	55.53	28	135.0	24.8	55.6	5.0
NI14729	57.1	65.3	70.9	64.43	7	136.7	28.4	56	6.3
NI14732	55.5	50.9	61.4	55.93	25	135.0	26.0	56.1	4.0
NI14733	53.9	54.3	60.2	56.13	23	135.7	28.9	55.7	5.7
SY Wolf	62.2	41.7	45.6	49.83	40	135.7	27.1	56.3	4.0
NI15705	61.9	43.1	52.9	52.63	37	136.3	26.0	55.2	3.0
NI15711	47.0	59.9	54.1	53.67	35	135.0	25.8	55.2	6.3
NI15713	58.3	48.4	60.5	55.73	27	136.3	26.6	55.2	5.0
NE14421	75.3	67.8	63.5	68.87	2	136.3	27.2	57.6	4.7
NE14531	56.3	60.4	58.4	58.37	18	135.7	28.8	54.3	5.3
NE14538	80.4	67.3	57.0	68.23	3	136.3	28.0	57.9	5.7
NE14606	65.5	65.3	65.3	65.37	6	137.3	27.9	53.6	5.0
NE10478-1	75.8	58.3	76.0	70.03	1	135.0	26.6	58.3	5.7
NE15420	65.8	42.4	60.0	56.07	24	135.7	25.9	56.4	3.0
NI17401	72.2	52.8	48.8	57.93	19	135.7	28.0	55	5.3
NI17402	68.7	53.8	50.6	57.70	20	135.7	26.9	52.7	2.7
NI17403	62.2	46.0	54.6	54.27	31	136.7	28.4	54.8	4.0
NI17404	55.5	47.9	56.8	53.40	36	135.3	29.4	56.3	4.0
NI17405	62.4	47.7	52.9	54.33	30	136.3	28.3	53.4	4.3
NI17406	68.0	46.8	64.1	59.63	16	135.3	27.1	54.5	5.0
NI17407	55.6	49.4	56.2	53.73	33	137.3	26.4	56.1	4.3
NI17408	79.2	51.3	51.8	60.77	13	135.0	26.1	56.3	5.0
NI17409	72.6	58.3	58.0	62.97	10	135.0	27.2	57.7	4.0
NI17410	76.8	53.1	58.9	62.93	11	135.0	27.3	57.8	4.0
NI17411	54.7	51.4	48.7	51.60	39	135.0	27.8	56.9	3.7
NI17412	69.6	46.7	56.8	57.70	20	135.0	27.0	58.2	6.0
NI17413	67.3	46.6	47.3	53.73	33	135.0	27.1	54.9	3.3
NI17414	73.5	57.1	55.9	62.17	12	135.3	27.7	56.3	5.0
NI17415	81.0	51.4	49.9	60.77	13	135.0	27.5	55	5.3
NI17416	72.9	44.1	53.1	56.70	22	135.3	27.1	55.6	5.7
NI17417	72.1	54.6	76.1	67.60	4	135.0	27.1	56.3	5.0
NI17418	63.2	50.5	65.6	59.77	15	139.7	29.2	54.9	5.0
Average	64.54	53.39	58.24			135.79		55.96	4.75
LSD	11.37	11.23	13.91			0.76		3.11	1.42
CV	9.01	10.77	12.22			0.34		3.4	18.26

The data for 2016 were:

	Lincoln	N. Platte	Alliance	Rainfed Avg.	RankD	Alliance	RankI		Rank					
Name	Yield	Yield	Yield	Yield		IR Yield		Avg.All		Hdate	Height	TestWt	Moist	Protein
	bu/a	bu/a	bu/a	bu/a		bu/a		bu/a		Jullian				
Antelope	**67.0**	**54.0**	**53.2**	**58.1**	35	97.8	21	68.0	36	133.0	35.1	61.1	10.1	15.6
Robidoux	**82.5**	**62.1**	**66.3**	**70.3**	9	106.4	11	79.3	7	134.0	35.9	61.7	10.6	15.3
NI10718W	**70.4**	**82.5**	**52.4**	**68.4**	11	103.1	16	77.1	10	133.7	34.9	59.6	9.9	15.8
WESLEY	**74.1**	**86.1**	**53.4**	**71.2**	6	93.5	30	76.8	11	133.7	33.3	58.9	10.1	16.5
NW07534	**78.6**	**65.6**	**63.3**	**69.2**	10	103.9	15	77.9	9	133.3	34.0	60.4	10.3	16.2
NI13703	**66.2**	**62.9**	**60.9**	**63.3**	20	94.1	27	71.0	25	132.7	34.8	60.9	10.3	16.8
Settler CL	**64.0**	**73.8**	**46.4**	**61.4**	29	90.0	36	68.6	34	133.7	34.1	60.4	9.8	15.5
NI13717	**71.2**	**69.9**	**49.6**	**63.6**	19	94.3	26	71.3	23	133.0	35.2	60.5	10.2	17.2
NI14722	**67.4**	**68.7**	**62.3**	**66.1**	15	104.2	14	75.7	12	133.0	33.1	62.1	10.9	16.1
WB CEDAR	**64.3**	**67.8**	**53.7**	**61.9**	25	90.6	35	69.1	32	133.0	33.1	60.7	10.3	17.5
NI14727	**64.0**	**61.8**	**44.4**	**56.7**	38	85.1	39	63.8	40	134.8	36.6	60.9	10.2	16.2
NI14729	**81.9**	**98.1**	**63.1**	**81.0**	1	110.6	4	88.4	1	135.3	36.9	60.5	10.6	15.2
NI14732	**71.9**	**67.2**	**47.4**	**62.2**	24	94.0	28	70.1	27	133.0	35.0	60.0	10.4	16.0
NI14733	**72.0**	**58.9**	**52.6**	**61.2**	31	85.3	38	67.2	38	133.4	37.6	58.5	11.0	15.2
NI14735	**58.9**	**75.3**	**54.3**	**62.8**	21	96.1	25	71.2	24	133.1	34.6	59.7	10.3	15.4
SY Wolf	**85.5**	**59.4**	**51.9**	**65.6**	17	104.7	13	75.4	13	133.4	34.3	61.1	10.7	16.2
NE07531	**80.6**	**61.7**	**59.6**	**67.3**	14	93.7	29	73.9	16	133.0	35.6	60.7	10.3	16.3
NI15701	**75.8**	**55.0**	**57.5**	**62.8**	22	91.0	34	69.8	28	133.0	34.8	60.2	10.3	16.2
NE15434	**70.7**	**45.5**	**56.0**	**57.4**	37	96.8	24	67.3	37	135.3	34.5	62.1	10.9	15.9
NE15420	**78.0**	**46.9**	**61.7**	**62.2**	23	111.4	3	74.5	14	133.3	32.3	60.5	10.3	16.1
NI15704	**75.3**	**45.8**	**52.7**	**57.9**	36	101.7	18	68.9	33	133.0	32.9	60.7	10.4	15.9
NI15705	**70.3**	**56.2**	**54.5**	**60.3**	32	108.7	6	72.4	20	133.0	32.1	59.7	11.3	16.1
NW15677	**70.4**	**37.5**	**57.0**	**55.0**	40	93.2	32	64.5	39	133.7	33.3	61.4	10.3	16.5
NI15710	**75.4**	**56.4**	**52.6**	**61.5**	28	97.6	22	70.5	26	134.7	33.6	61.3	10.7	15.9
NI15711	**75.2**	**53.6**	**55.7**	**61.5**	27	107.2	10	72.9	18	133.0	33.2	59.4	10.5	16.3
NI15713	**78.3**	**57.8**	**66.9**	**67.7**	13	114.6	1	79.4	6	134.3	34.7	60.0	10.5	16.2
NE14421	**74.3**	**85.4**	**66.8**	**75.5**	2	108.5	7	83.8	2	134.7	35.0	61.1	10.8	15.8
NE14448	**73.0**	**59.6**	**51.1**	**61.2**	30	105.5	12	72.3	21	133.0	37.7	60.8	10.3	16.3
NE14494	**82.9**	**60.1**	**52.5**	**65.2**	18	97.9	20	73.4	17	134.7	36.0	61.8	10.9	15.7
NE14531	**86.9**	**77.1**	**50.6**	**71.5**	5	112.6	2	81.8	4	133.1	37.3	60.7	9.9	16.5
NE14538	**83.8**	**75.0**	**61.9**	**73.6**	3	108.4	8	82.3	3	133.3	35.9	60.8	10.3	15.9
NE14606	**73.5**	**81.9**	**60.5**	**72.0**	4	109.7	5	81.4	5	134.3	36.0	60.7	10.4	15.7
NE14632	**73.0**	**66.6**	**57.6**	**65.7**	16	88.6	37	71.5	22	135.6	40.5	59.2	10.0	16.2
NE14656	**95.3**	**29.7**	**55.2**	**60.1**	33	98.5	19	69.7	29	133.7	33.9	60.7	10.8	15.3
NE14674	**54.4**	**55.6**	**59.5**	**56.5**	39	108.2	9	69.4	30	135.6	36.7	63.3	11.1	17.0
NE14686	**72.0**	**57.1**	**55.7**	**61.6**	26	91.8	33	69.2	31	135.3	37.1	59.9	11.0	16.9
NE14696	**69.1**	**55.2**	**50.7**	**58.3**	34	97.1	23	68.0	35	134.7	36.9	61.2	11.4	16.8
NE14700	**72.1**	**84.7**	**54.4**	**70.4**	8	79.5	40	72.7	19	135.0	37.6	58.2	10.0	15.4
Ruth	**88.2**	**54.5**	**61.4**	**68.0**	12	93.4	31	74.4	15	133.7	36.5	61.9	10.2	15.6
NE10478-1	**76.3**	**69.7**	**65.3**	**70.4**	7	102.3	17	78.4	8	133.0	34.4	62.0	10.5	17.6
Average	**74.1**	**63.6**	**56.3**			**99.3**		**73.3**		**133.8**	**35.2**	**60.6**	**10.5**	**16.1**
CV	**9.9**	**19.4**	**10.1**			**7.9**								
LSD	**14.3**	**24.1**	**9.3**			**12.9**								

The three-year averages for the lines tested in all three years (2016-2018) are below. Note very few lines were in common for all three years.

	Lincoln	N.Platte	Alliance	St. Avg.	Rank
	Yield	Yield	Yield	Yield	
	bu/a	bu/a	bu/a	bu/a	
newname	yb_ln18	yb_np18	yb_al18		
NE10478-1	75.1	62.2	70.4	69.2	1
NE15420	74.4	46.2	62.1	60.9	2
NI15711	64.5	57.0	56.4	59.3	3
WB CEDAR	66.2	54.4	57.0	59.2	4

The importance of the sustained effort in irrigation is that it provides us with a window into the highest yielding environments, something that rainfed environments rarely do. The mean yield of the lines in the 2014-2016 irrigated environments (104 bu/a) is roughly twice that of the 2014-2016 rainfed environments (55 bu/a) for the same years. As can be seen in the table, Robidoux (NI04421) continues to be an excellent rainfed wheat with broad adaptation. Settler CL continues to be one of our most broadly adapted wheats from rainfed to irrigated. Additional wheat experimental lines perform well extremely well in either rainfed or irrigated production systems. The question will be, "Can a wheat with excellent irrigated production capabilities have a sufficient market to warrant its release for irrigated production environments alone?" In 2019, we decided to try a contract grower to determine if our lines do well under irrigation. We will see what his data suggest.

4. **<u>Nebraska Intrastate Nursery:</u>**

In 2018, Nebraska Intrastate Nursery (NIN) was planted at eight locations in Nebraska: Lincoln, Mead, Clay Center, McCook (added due to generous support from Ardent Mills), North Platte, Grant (added due to a generous gift from Marvin Stumpf), Sidney (lost to severe storms the day we began harvesting the site) , and Hemingford (syn. Alliance). In addition, two replications at Lincoln were sprayed once with fungicides to control disease, while two replications were not treated which allowed a comparison of diseased vs. largely disease free genotypes. The fungal disease pressure was low in 2018. The sites at McCook and Hemingford were also sprayed with a single application of fungicide. At Lincoln, the untreated plots yielded 7% less than the fungicide treated plots (an average of 5.1 bu/a) in a year when disease was relatively minor compared to previous years. Note the benefit of the fungicide application varied considerably with the line. Those lines having little benefit were disease resistant or disease tolerant. The lowest yielding site in Nebraska was North Platte mainly due to drought. The drought in KS greatly hurt yield though many of our lines would not be adapted there. Lincoln and Grant had excellent yields. The 2018 data are:

	Mead	Linc IM	Lincoln	Benefit	C.Center	N.Platte	McCook	Grant	Aliiance	NEAvg.	Rank	Kansas	Rank	Average	Rank	Heading	Height	test Wt.
	Yield	Yield	Yield	**Of**	Yield	Yield	Yield	Yield	Yield			Yield		Yield				
Name	bu/a	bu/a	bu/a	**Fungicide**	bu/a	bu/a	bu/a	bu/a	bu/a			bu/a		bu/a				
	yb_m18	yb_lim18	yb_ln18	**%**	yb_cc18	yb_np18	yb_mc18	yb_grd18	yb_al18			yb_ks18						
NE16562	59.6	84.0	83.2	**101.0**	73.8	66.4	73.9	95.2	64.8	75.1	1	46.9	5	72.0	1	144.00	26.33	57.67
NE14691	60.2	85.1	78.5	**108.4**	77.9	52	65.7	86.6	54.5	70.1	2	42.9	23	67.0	2	146.00	27.70	58.70
NE16593	60.0	84.5	81	**104.3**	70.4	66	60.5	71.9	61.2	69.4	3	41.1	40	66.3	4	145.00	27.29	59.37
NE16468	55.7	90.9	76.6	**118.7**	69.0	64	57.6	73.9	65.9	69.2	4	40.2	46	66.0	6	145.50	26.25	57.83
NE16424	55.8	81.3	78.1	**104.1**	73.2	62.7	63.5	73.7	65.3	69.2	5	44.7	13	66.5	3	145.50	25.23	57.93
NE16593	58.9	69.9	70.1	**99.7**	69.9	61.7	69.5	84.7	66.7	68.9	6	43.6	19	66.1	5	144.50	27.49	58.47
NE14494	50.4	86.8	78.7	**110.3**	68.9	55.3	62.4	79.5	65.9	68.5	7	44.6	14	65.8	7	144.00	28.29	59.20
LCS Valiant	56.8	77.0	72.5	**106.2**	62.7	59.1	69.9	82.9	65.6	68.3	8	41.6	31	65.3	11	144.50	26.31	58.60
NE14696	58.9	75.5	74.6	**101.2**	66.4	60.3	66.3	83.0	60.5	68.2	9	46.5	8	65.8	9	145.00	28.93	57.87
NI13706	52.4	84.4	76.6	**110.2**	67.8	54.9	63.6	78.2	67.5	68.2	10	37.8	55	64.8	14	144.50	25.41	57.47
PSB13NEDH-14-83W	49.1	86.8	79.7	**108.9**	56.9	61.3	63.0	85.4	62.7	68.1	11	47.4	2	65.8	8	146.00	27.66	58.57
NE16402	49.0	80.3	72.9	**110.2**	61.5	62.5	62.2	92.8	62.4	68.0	12	44.1	17	65.3	12	145.50	27.15	58.73
NI17410	57.5	81.9	75.7	**108.2**	69.1	54.4	62.8	76.2	64.1	67.7	13	47.0	4	65.4	10	145.00	27.91	58.80
NE13604	55.0	72.6	75.2	**96.5**	65.9	60.1	66.3	83.0	62	67.5	14	39.0	50	64.3	17	145.50	27.11	58.60
NW13570	55.5	79.5	79.9	**99.5**	62.5	55.2	75.0	79.2	52.9	67.5	15	44.8	12	64.9	13	144.00	27.00	58.20
NE16451	55.4	75.2	74.1	**101.5**	70.1	58.7	65.8	70.9	66.7	67.1	16	38.8	52	64.0	20	145.50	26.39	56.53
NE15420	58.2	83.6	72.9	**114.7**	62.2	56.8	64.1	76.9	61.4	67.0	17	44.5	16	64.5	15	145.00	24.34	58.07
NE14531	55.8	79.1	74.7	**105.9**	65.7	58.2	57.8	84.0	59.8	66.9	18	41.9	29	64.1	19	144.50	28.13	58.53
NW15443	60.8	86.5	67.1	**128.9**	71.9	53.9	66.0	69.7	59.1	66.9	19	45.6	10	64.5	15	147.50	28.59	56.97
NE15624	56.8	76.7	73.7	**104.1**	65.3	65.4	64.3	66.8	61.7	66.3	20	36.7	57	63.0	24	145.00	25.13	57.43
NE13515	52.6	81.2	72.1	**112.6**	62.1	54.1	62.7	83.0	62.7	66.3	21	36.3	58	63.0	27	144.50	27.01	58.80
NE16634	54.7	86.8	73	**118.9**	64.8	59.4	66.2	64.4	59.8	66.1	22	38.3	53	63.0	25	146.00	28.03	58.80
NW13493	56.9	71.7	72.3	**99.2**	70.1	50.1	70.1	79.2	58.5	66.1	23	50.1	1	64.3	18	146.00	27.26	58.90
Robidoux	43.6	81.6	70.5	**115.7**	70.6	53.1	66.5	77.7	64.5	66.0	24	38.9	51	63.0	26	144.50	26.81	57.93
NE16412	51.2	66.7	61.1	**109.2**	68.6	65.6	68.3	81.6	64.6	66.0	25	37.0	56	62.7	33	146.50	27.00	57.47
NE16443	43.1	77.9	69.8	**111.6**	57.2	58.7	67.1	86.0	67.6	65.9	26	41.5	34	63.2	22	144.00	26.84	57.23
NE16659	49.3	78.1	73.3	**106.5**	60.2	63.7	65.1	78.5	58.5	65.8	27	43.9	18	63.4	21	145.50	27.11	56.80
NE14538	51.7	73.3	76.3	**96.1**	64.2	62.4	57.2	77.7	62.7	65.7	28	42.0	28	63.1	23	144.50	28.81	58.23
NE15410	53.7	66.2	55.5	**119.3**	60.8	68.5	70.1	82.8	66.6	65.5	29	39.1	49	62.6	36	144.50	28.13	57.83
Overland FHB-10	58.3	75.3	73.6	**102.3**	67.2	51.4	64.5	76.8	57.1	65.5	29	42.6	26	63.0	27	144.50	28.93	58.90
NI12702W	51.4	79.8	73.2	**109.0**	57.9	66.1	64.5	75.2	55.5	65.5	31	40.8	44	62.7	35	145.50	27.23	59.30
NE14421	49.7	71.7	75.8	**94.6**	62.0	62	64.3	72.9	64.6	65.4	32	41.6	31	62.7	34	144.00	25.85	58.03
NE15571	52.1	73.3	74.1	**98.9**	56.3	58.2	59.9	83.5	65.3	65.3	33	43.2	22	62.9	31	144.00	27.03	57.20
OVERLAND	57.7	79.1	72.4	**109.3**	71.8	48.5	62.0	67.8	62.5	65.2	34	44.6	14	62.9	29	145.50	27.98	59.03
NE14606	52.3	72.8	68.9	**105.7**	70.1	60.1	59.9	79.3	57.4	65.1	35	41.8	30	62.5	37	145.50	26.79	58.20
NE16563V	52.2	79.4	78.9	**100.6**	59.4	57.5	57.6	70.4	63.6	64.9	36	46.7	6	62.9	32	146.00	25.84	56.10
Ruth	49.7	81.7	72.4	**112.8**	51.4	55.4	63.8	80.8	63.7	64.9	37	47.2	3	62.9	30	145.00	27.30	58.53
GOODSTREAK	58.3	70.5	75.1	**93.9**	62.6	58	59.1	78.6	55.2	64.7	38	41.3	36	62.1	39	145.50	30.89	58.63
NE13434	59.1	78.9	71.6	**110.2**	56.0	55.5	65.5	68.1	59.5	64.3	39	45.5	11	62.2	38	145.50	27.93	58.43
NH144913-3	49.8	76.9	68.1	**112.9**	61.6	66.2	67.8	70.2	53.1	64.2	40	41.6	31	61.7	42	145.00	26.28	54.90
NE16578	52.5	76.8	64.3	**119.4**	58.1	59.1	68.2	72.6	62	64.2	41	43.6	19	61.9	40	144.50	27.38	56.17
NE16467	45.5	73.6	69.7	**105.6**	60.2	63.6	58.3	81.8	59.9	64.1	42	41.1	40	61.5	43	145.00	27.76	56.83
NE16587	52.1	78.6	70.2	**112.0**	58.5	57.3	61.9	74.4	57.8	63.9	43	40.8	44	61.3	44	144.50	25.81	58.27
NI17409	58.0	75.4	71.4	**105.6**	66.9	50.5	52.0	71.8	63.7	63.7	44	46.6	7	61.8	41	145.50	26.26	58.60
NI14729	45.1	75.7	64.1	**118.1**	64.5	53.7	64.3	77.3	63.3	63.5	45	41.3	36	61.0	46	146.00	27.29	56.50
NI15713	41.9	80.3	67.3	**119.3**	63.8	56.3	61.1	78.3	57.5	63.3	46	41.3	36	60.9	47	145.50	26.63	57.40
Panhandle	49.1	75.4	68.8	**109.6**	68.7	51.9	66.2	72.8	51.3	63.0	47	41.4	35	60.6	49	145.00	29.60	57.40
Freeman	48.9	65.2	65.1	**100.2**	57.2	58.5	65.6	80.6	62.9	63.0	48	42.1	27	60.7	48	145.50	26.65	57.40
NE16631	48.4	74.2	73	**101.6**	51.0	53.2	55.0	78.6	70.5	63.0	49	46.1	9	61.1	45	145.00	28.09	58.67
Siege	56.1	73.8	66.8	**110.5**	62.5	54.2	56.3	76.9	56.1	62.8	50	38.0	54	60.1	51	147.00	26.29	58.53
NE14434	38.8	73.5	76.6	**96.0**	53.4	59	61.2	73.9	64.6	62.6	51	42.9	23	60.4	50	147.50	27.66	57.57
NE16579	56.0	57.6	61.4	**93.8**	55.3	50.1	63.7	82.5	65	61.5	52	42.9	23	59.4	52	145.00	26.59	57.33
NI14722	45.1	62.3	65.5	**95.1**	59.3	48.4	64.3	78.1	64.7	61.0	53	34.1	59	58.0	54	145.50	25.39	59.17
NW15573	54.9	72.5	63.1	**114.9**	53.2	53	62.5	70.3	54.7	60.5	54	43.6	19	58.6	53	144.50	26.36	58.70
NI17417	54.5	73.4	69.7	**105.3**	61.2	38.6	53.6	73.7	54.6	59.9	55	25.3	60	56.1	58	145.50	25.95	59.10
NI13717	51.3	76.4	73.9	**103.4**	43.4	53.9	49.7	75.2	53.5	59.7	56	41.3	36	57.6	55	145.00	27.25	56.63
NW15404	53.8	67.4	66	**102.1**	51.7	50.7	59.9	64.2	59.7	59.2	57	41.0	42	57.2	56	145.00	26.21	57.57
NE16552	52.2	87.8	45.3	**193.8**	45.9	58	49.8	69.6	57.2	58.2	58	41.0	42	56.3	57	146.00	32.45	58.63
SCOUT66	46.6	48.0	48.3	**99.4**	56.1	46.8	54.4	68.0	57.8	53.3	59	39.6	47	51.7	59	145.00	31.64	59.27
CHEYENNE	46.9	48.7	57.3	**85.0**	58.8	44.5	46.7	63.8	49.9	52.1	60	39.5	48	50.7	60	145.50	31.95	58.27
GRAND MEAN	**52.78**	**76.02**	**70.86**		**62.6**	**57.08**	**62.62**	**76.89**	**61.01**	**65.0**		**41.95**				**145.20**	**27.35**	**58.00**
LSD	**11.89**	**11.91**	**11.23**		**9.76**	**11.88**	**13.41**	**13.84**	**9.81**			**6.08**						
CV	**11.63**	**6.44**	**6.52**		**8.05**	**8.56**	**8.81**	**7.4**	**8.31**			**8.92**						

In 2018 Nebraska Intrastate Nursery (NIN) advance wheat, 51 wheat cultivars or lines were analyzed for kernels characteristics, milling performances, ash and protein contents, dough rheological and bread making properties.

The wheat properties tested results were shown in Table 1. There were significant differences in kernels characteristics among these cultivars. The kernels hardness indexes were 51.5±9.7. Only 18% samples had high hardness (60.0-70.0), the rest of samples had low hardness (< 60) including Goodstreak, Ruth, Overland, and Freeman checks. 18 samples were classified as HARD, 31 samples were classified as MIXED, and the rest of samples were classified as SOFT. The kernels diameters and weights were 2.6±0.1 mm and 31.6±2.7 mg, respectively. Almost all (98%) samples had large kernels diameter (>2.4 mm) including all checks, and most (71%) samples had large weight (≥ 30.0 mg) including Ruth, Overland, and Freeman checks. Most (55%) samples had small kernels hardness variances (σ < 17), and almost all (98%) samples had small kernels diameters deviation (σ < 0.4), but most (73%) samples had big kernels weights variability (σ ≥ 8). Therefore, the kernels were very diverse in weight.

Table 1. Wheat Properties and Correlation [a]

N = 51	hard	d	wt	flrYld	brnYld	shrtYld	bran	short	mill	whtPro	flrPro	flrAsh
Mean	51.47	2.63	31.60	71.20	26.34	2.46	3.17	2.91	2.62	14.31	11.85	0.40
Std Dev	9.71	0.10	2.72	1.87	1.98	0.61	0.93	0.94	1.14	1.27	0.69	0.04
Min	14.17	2.34	26.05	60.91	23.45	0.23	0.50	0.50	0.50	11.48	10.50	0.34
Max	68.43	2.86	39.35	73.65	37.22	4.38	4.50	4.50	4.50	16.74	13.53	0.53
hard	1.0000	-0.1425	-0.2282	**0.5025**	**-0.6296**	**0.5058**	**0.6654**	*0.2783*	**0.5702**	-0.1410	0.1278	**0.5411**
d		1.0000	**0.8922**	0.1641	-0.1341	-0.0672	0.0579	0.1590	-0.0164	**0.3417**	**0.3417**	0.1737
wt			1.0000	0.0792	-0.0587	-0.0520	-0.0013	0.1061	0.0496	*0.3215*	*0.3311*	0.0969
flrYld				1.0000	*-0.9516*	0.0247	*0.6216*	*0.5416*	*0.4898*	-0.1516	0.0655	**0.3366**
brnYld					1.0000	**-0.3307**	**-0.7021**	**-0.4532**	**-0.5412**	0.1012	-0.1209	*-0.4428*
shrtYld						1.0000	*0.3758*	-0.1884	0.2568	0.1356	0.1912	*0.4070*
bran							1.0000	*0.4106*	*0.7520*	0.0904	0.2048	*0.5085*
short								1.0000	*0.4930*	0.1105	-0.0614	0.1192
mill									1.0000	-0.1157	0.0627	**0.4699**
whtPro										1.0000	*0.6495*	0.1071
flrPro											1.0000	0.2660
flrAsh												1.0000

a. Significantly correlated (correlation efficiency r) at p-value < 0.01 (bold) or < 0.05 (italic)

There were significant differences in milling performances among these cultivars. The flour, bran and short yields were 71.2±1.9%, 26.3±2.0%, and 2.5±0.6%, respectively. Almost all (98%) samples got high flour yield (≥ 68.0%). The bran, short and milling rates were 3.2±0.9, 2.9±0.9, and 2.6±1.1, respectively. Most samples got fair or better than fair bran cleaning and milling performance.

The kernels hardness indexes were significantly positively with flour and short yields, bran cleaning and milling performances as well flour ash contents, and negatively with bran yields. The kernels diameters were significantly positively with kernels weights and wheat and flour protein contents. Both kernels diameters and weights were significantly positively wheat and flour protein contents.

In addition, the flour yields were significantly positively with bran cleaning and milling performances as well as flour ash contents, and negatively with brain yields. The bran yields were significantly negatively with short yields, bran cleaning and milling performances as well as flour ash contents. The short yields were significantly positively with bran cleaning rates and flour ash contents. The bran rates were significantly positively with short and milling rates as well as flour ash contents. The short rates were significantly positively with milling rates. The milling rates were significantly positively with flour ash contents.

The flour properties tested results were shown in Table 2. There were significant differences in ash and protein contents respectively among these flour samples. The ash contents of white flour (WF) at 14% mb were 0.40±0.04%. Almost all (98%) flour samples had low ash content (< 0.50%) including all checks. The protein contents of whole wheat (WW) at 12% mb were 14.3±1.3%. Almost all (94%) samples had high protein contents in WW (≥ 12.0%) including all checks. The protein contents of WF at 14% mb were 11.9±0.7%. All samples had high (≥ 10.0%) protein contents in WF including all checks. Both WW and WF protein contents were strongly significantly correlated each other. After milling, protein contents were lost 2.1±1.1%. Some samples got high protein losses (> 2.0%). The falling number (FN) of WF at 14% mb were 369±102sec. Most (66%) flour samples had high FN (≥ 350 sec) including all checks.

There were significantly differences in dough rheological properties among these flour samples. The flour water absorptions (abs) at 14% mb were 63.3±1.8%. Most (76%) flour samples had high water abs (≥ 62.0) including Goodstreak, Ruth, and Overland, checks. The peak times (PT) were 6.8±2.1 min. Only 37% samples got good dough extensibility (3.0-6.0 min) including Goodstreak and Overland checks, and the rest of samples got much larger dough extensibility (≥ 6.0 min) including Ruth and Freeman checks. The peak torques (PQ) were 46.2±2.8 %TQ. Most (69%) samples got strong dough (≥ 45.0 %TQ) including Goodsreak and Ruth checks, and the rest of samples got less strong dough < 45.0% TQ) including Overland and Freeman checks. The total areas (TA) were 122±18 %TQ·min and tolerance rates (TR) were 4.4±0.8, respectively. Both TA and TR were strongly significantly correlated each other. Most (84%) samples got strong dough resistance for mixing (TA ≥ 100 %TQ·min), and almost all (98%) samples got fair or better than fair mixing tolerance including all checks.

There were significant differences in bread-making properties among these flour samples. The baking water abs at 14% mb were 62.8±1.2%. Most (88%) flour samples got high water abs (≥ 62.0%) including all checks. The mixing time (MT) were 7.7±2.3 min. Only 25% flour samples got normal MT (3.0-6.0 min) including Goodsreak and Overland checks, and the rest of samples got much longer MT (≥ 6.0 min) including Ruth and Freeman checks. The dough performance rates were 3.8±0.3. The weight losses were 18.4±0.6%. The bread areas were 110±4 cm^2. The loaf volumes (LV) and specific volumes (SV) were 920±46 cc and 6.5±0.3 cc/g, respectively. Almost all (98%) samples got LV ≥ 850 cc or SV ≥ 6.0 cc/g including all checks. After stored overnight, the bread crumb firmness and brightness was 2921±389 Pa and 147±3, respectively. The cell numbers, diameters, non-uniformity and elongation were 6564±213 2.0±0.1 mm, 4.7±3.7 and 1.49±0.01, respectively. Most samples had good crumb structures and texture. The overall bread rates were 4.1±0.4. Almost all (98%) samples got fair or better than fair bread quality including all checks, and most (77%) samples got good or better bread quality including Ruth and Freeman checks.

The wheat flour protein contents significantly affected on dough rheological properties, which impacted on final bread quality. For details, the WF protein contents were correlated significantly positively with falling numbers, water abs, dough strengths, dough performance rates, and loaf volumes, and negatively with mixing times, crumb firmness and elasticities, and cell non-uniformity.
In addition, the WF ash contents were correlated significantly positively with water abs, and dough strengths, and negatively with crumb firmness and elasticities. The WF falling numbers were correlated significantly positively with water abs, and negatively dough extensibility and mixing times. The WF water abs were correlated significantly positively with baking water abs, dough performance rates and weight losses, and loaf volumes, and negatively with mixing times, crumb firmness and elasticities, crumb brightness, and cell non-uniformity. The dough extensibility was correlated significantly positively with mixing times, and negatively with dough strengths, loaf volumes and areas, cell numbers and diameters as well as non-uniformity. The dough strengths were correlated significantly positively with dough resistances and tolerances, baking water abs, and loaf volumes, and negatively with mixing times, crumb firmness and elasticities. The dough tolerances were correlated significantly positively with mixing times and bread rates. The baking water abs were correlated significantly positively with dough rates, weight losses, loaf volumes and areas, cell numbers and elongations as well as bread rates, and negatively with mixing times, crumb firmness and elasticities, crumb brightness, and cell non-uniformity. The mixing times were correlated significantly positively with crumb brightness, and negatively with loaf volumes and areas, and cell numbers and diameters. The dough rates were correlated significantly positively with cell elongation and bread rates, and negatively with cell non-uniformity. The weight losses were correlated significantly positively with loaf specific volumes, and cell elongations, and negatively with crumb brightness. The loaf volumes or specific volumes or bread areas were correlated significantly positively with cell numbers and diameters as well as bread rates, and negatively with crumb firmness. The crumb firmness or elasticities were correlated significantly positively with cell diameters, and negatively with bread rates. The crumb brightness were correlated significantly negatively with cell non-uniformity and elongations. The cell numbers were correlated significantly positively with bread rates. The cell non-uniformity were correlated significantly negatively with bread rates.

In 2017, Nebraska Intrastate Nursery (NIN) was planted at eight locations in Nebraska: Lincoln, Mead, Clay Center, McCook (added due to generous support from Ardent Mills), North Platte, Grant (added due to a generous gift from Marvin Stumpf), Sidney, and Hemingford. In addition, two replications at Lincoln were sprayed three times with fungicides to control disease, while two replications were not treated which allowed a comparison of diseased vs. largely disease free genotypes. The sites at Grant, McCook, and Alliance were also sprayed with a single application of fungicide. At Lincoln, the untreated plots yielded 16% less than the fungicide treated plots (an average of 11.6 bu/a) in a year when disease was relatively minor compared to previous years. The lowest yielding site was Grant mainly due to drought. McCook had excellent yields. The 2017 data are:

	Mead	Linc. IM	Lincoln	C Center	N. Platte	McCook	Grant	Sidney	Alliance	**Average**	**Rank**
	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	**Yield**	
Name	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	**Bu/a**	
CHEYENNE	44.8	31.6	26.7	52.3	53.9	60.7	33.0	49.4	44.8	44.13	60
GOODSTREAK	59.8	65.0	44.1	55.1	48.8	71.8	36.9	55.3	59.8	55.18	58
Panhandle	53.4	66.3	42.4	56.2	50.2	83.4	49.7	64.1	53.4	57.68	57
Freeman	71.7	70.9	68.5	66.2	69.5	97.7	54.7	66.7	71.7	70.84	11
NE12439-H	62.7	83.4	69.4	69.6	68.7	91.0	45.6	60.4	62.7	68.17	23
NE12561	62.3	82.2	80.1	75.9	60.8	88.0	55.4	59.8	62.3	69.64	18
NE12589	74.2	71.0	55.5	70.4	63.0	95.9	47.1	58.5	74.2	67.76	26
NE13434	64.5	80.8	76.5	72.6	58.8	88.3	41.3	58.3	64.5	67.29	29
Ruth	68.6	91.1	80.5	77.6	62.8	111.3	49.9	62.5	68.6	74.77	2
NE10478-1	67.0	89.5	75.3	69.1	64.5	97.0	55.6	73.0	67.0	73.11	4
NE13515	59.6	74.0	72.1	71.3	63.8	98.7	58.0	60.4	59.6	68.61	21
NE13597	47.5	69.5	53.6	66.0	67.4	89.4	48.9	59.4	47.5	61.02	50
NE13604	67.9	66.6	45.5	68.4	64.4	101.3	50.8	64.9	67.9	66.41	34
NE14434	70.3	91.3	84.9	66.0	75.8	97.7	37.3	63.8	70.3	73.04	5
NE14448	56.0	59.6	56.5	69.7	62.9	75.2	45.1	54.7	56.0	59.52	53
NE14531	52.9	73.7	64.9	66.7	71.2	87.3	49.3	59.6	52.9	64.28	40
NE14538	51.7	88.3	69.1	66.5	78.5	92.1	47.0	52.9	51.7	66.42	33
NE14606	59.6	71.8	65.9	69.9	70.4	95.0	51.4	63.4	59.6	67.44	27
NE14663	58.6	68.7	57.7	66.7	66.8	90.6	48.8	58.5	58.6	63.89	42
NE14494	69.7	77.1	64.0	75.2	66.0	103.8	44.8	60.3	69.7	70.07	15
NE14691	57.2	86.8	72.0	79.3	70.4	88.3	51.7	55.2	57.2	68.68	19
NE14696	68.3	67.7	53.7	68.2	62.1	102.7	47.3	59.9	68.3	66.47	32
Robidoux	74.3	89.9	64.7	71.8	67.3	95.0	54.1	64.7	74.3	72.90	6
NI12702W	62.4	79.6	64.7	70.2	69.8	99.0	51.8	57.7	62.4	68.62	20
NI13706	73.3	80.0	86.2	67.0	76.7	82.8	60.4	58.6	73.3	73.14	3
NI14729	69.2	47.4	55.4	62.4	69.2	99.5	59.7	66.5	69.2	66.50	31
NI15713	66.6	65.5	52.6	62.0	60.0	91.9	46.7	64.7	66.6	64.07	41
NW13493	67.0	63.1	74.5	71.0	77.2	102.8	56.3	68.2	67.0	71.90	9
NW13570	61.3	80.3	60.1	77.6	69.6	98.7	59.2	66.5	61.3	70.51	12
OVERLAND	63.7	70.5	51.2	69.0	55.6	90.5	43.2	60.5	63.7	63.10	43
PSB13NEDH-14-83W	77.5	86.5	58.0	63.9	75.8	97.3	54.1	64.6	77.5	72.80	7
SCOUT66	53.8	46.2	37.6	50.1	50.7	63.5	40.3	50.2	53.8	49.58	59
Settler CL	44.9	76.5	52.9	60.4	66.2	87.3	50.2	64.6	44.9	60.88	52
WESLEY	55.7	66.9	60.8	59.2	69.1	81.2	50.8	57.2	55.7	61.84	48
NE15405	64.2	64.7	75.7	67.9	72.2	83.5	40.1	61.8	64.2	66.03	37
NE15406	77.2	75.8	67.9	69.7	64.9	97.0	58.7	62.1	77.2	72.28	8
NE15410	71.1	79.5	57.0	67.8	67.3	103.9	52.4	68.1	71.1	70.91	10
NE15417	62.2	68.9	62.7	65.9	66.7	87.3	39.3	50.0	62.2	62.80	45
NE15434	61.0	68.1	52.6	64.9	69.1	98.5	49.8	59.5	61.0	64.94	39
NE15440	63.2	76.9	69.8	62.9	68.6	83.0	52.1	60.4	63.2	66.68	30
NE15445	55.2	82.4	73.9	66.7	75.4	91.5	54.2	56.0	55.2	67.83	25
NE15468	62.9	75.5	62.9	70.8	64.8	97.0	50.6	65.7	62.9	68.12	24
NE15475	51.7	50.9	50.3	63.6	68.9	89.1	49.9	54.7	51.7	58.98	55
NE15545	57.4	72.6	58.7	66.0	55.5	88.9	36.0	56.0	57.4	60.94	51
NE15571	64.7	72.4	65.3	68.6	80.2	96.0	53.7	63.8	64.7	69.93	16
NE15595	63.9	79.7	58.9	65.6	52.6	103.2	52.9	65.5	63.9	67.36	28
NE15605	58.3	81.7	60.8	73.2	76.0	88.0	45.1	55.5	58.3	66.32	35
NE15624	78.8	91.6	82.0	76.0	67.1	97.4	56.4	67.7	78.8	77.31	1
NE15689	58.9	75.5	68.2	70.5	58.2	91.3	45.1	60.9	58.9	65.28	38
Misplant	64.0	85.1	58.9	62.2	67.0	101.3	46.0	65.9	64.0	68.27	22
NH144922-1	58.3	68.1	50.2	54.1	64.8	90.1	47.6	59.6	58.3	61.23	49
NW15404	66.7	79.4	72.2	73.9	67.8	95.2	53.0	58.1	66.7	70.33	13
NW15443	62.2	86.9	69.9	69.1	71.4	101.1	47.8	56.9	62.2	69.72	17
NW15564	55.2	80.9	61.4	71.2	69.3	93.8	53.9	54.8	55.2	66.19	36
NW15573	74.8	70.0	65.6	72.0	67.5	97.2	48.8	62.0	74.8	70.30	14
NW15677	62.8	69.7	67.7	62.3	57.7	80.4	46.7	56.1	62.8	62.91	44
NI14735	59.7	66.6	46.9	63.0	58.5	88.9	53.3	60.1	59.7	61.86	47
NE15420	49.2	72.5	53.3	66.3	47.8	69.1	49.6	63.4	49.2	57.82	56
NE09517_6	55.7	66.3	42.3	68.6	58.0	94.9	36.5	57.2	55.7	59.47	54
NE16422	47.2	74.5	67.9	58.7	59.2	83.5	58.0	61.7	47.2	61.99	46
GRAND MEAN	**62.07**	**73.59**	**62**	**67.08**	**65.41**	**91.47**	**49.24**	**60.47**	**62.07**		
LSD	14.92	18.13	14.18	6.58	9.98	16.66	9.98	7.12	14.92		
CV	12.49	12.11	11.26	6.04	7.53	7.49	8.34	7.25	12.49		

The 2016 NIN data are:

Name	Mead	Mead.IM	Linc.	Linc.IM	C.Center	N.Platte	McCook	Grant	Sidney	Alliance	Kansas	NE. Ave.	NE Rank	Ave	Rank	Test	Hdate	Height	Moist
	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield		Yield		**weight**	**Julian**		
	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a		bu/a		**lbs/bu**	**After Jan.1**	**In**	**%**
	yb_m16	yb_mim16	yb_l16	yb_lim16	yb_cc16	yb_np16	yb_mc16	yb_grd16	yb_s16	yb_al16	yldbua								
CHEYENNE	17.7	24.2	17.3	46.7	9.4	63.7	53.7	53.3	43.7	47.7	29.2	37.74	60	36.96	60	55.9	142.7	45.9	22.7
GOODSTREAK	40.3	54.2	22.6	56.4	16.8	63.9	64.9	62.2	41.4	48.4	34.5	47.11	58	45.96	58	57.5	137.3	42.7	13.0
PANHANDLE	32.2	58.4	42.3	63	15.4	68.9	78	65.9	54.4	59.2	35.9	53.77	54	52.15	54	56.1	137.1	42.9	11.3
FREEMAN	36.1	69.4	59.6	106.4	37.5	72.4	99.6	94.3	72.2	74.1	58.5	72.16	5	70.92	3	55.3	134.2	38.2	19.5
NE12438-H	44.3	71.2	31.3	65.7	15.2	56.5	67.2	67	38.2	47.7	42.0	50.43	56	49.66	56	58.9	134.2	40.3	21.2
NE12439-H	57.3	71.7	54.5	82.7	43.5	81.3	88.5	75.6	54	55.2	38.9	66.43	18	63.93	19	57.5	134.3	39.9	12.0
NE14691	59.6	57.2	71.1	81.2	57.4	85.3	76.8	80.3	72.1	52.8	51.2	69.38	13	67.73	12	57.4	134.8	40.0	13.2
NI10718W	44.6	71	55.5	93.6	27.7	79.4	88.8	75.5	45.2	55	41.5	63.63	27	61.62	29	56.8	136.1	38.9	11.9
NI14729	38.8	62.6	63.9	83.1	38.7	83.8	93.4	93	66.8	61.2	45.0	68.53	15	66.39	16	57.2	137.4	40.6	12.4
NI14735	33.1	60.9	49.1	86.2	24.6	62.1	62.5	72.1	38.2	59.8	33.2	54.86	53	52.89	53	55.3	135.3	38.9	13.6
NE15434	40	65.2	53.9	89.1	43.5	78.2	81.2	76.4	46.8	54.9	44.0	62.92	29	61.20	31	59.0	136.5	37.7	12.9
NW15677	60.7	55.8	69.5	85.9	39.3	46.4	71.2	73.4	64.3	61.7	41.7	62.82	30	60.90	32	57.9	133.7	38.4	14.1
NI15713	36.1	53.4	54.6	95.1	30.3	76.5	82.7	78.4	65.3	62.7	44.4	63.51	28	61.77	26	57.4	137.0	38.8	12.4
xHF09011_306	45.9	51.1	40.1	63.2	31.4	57.4	59.8	66.4	45.9	42.2	32.9	50.34	57	48.75	57	57.9	135.6	44.1	14.8
WESLEY	31.1	58.2	47.8	99.7	31.1	75.7	70.1	69.8	52.6	55.8	37.0	59.19	48	57.17	48	55.0	136.0	37.2	11.7
OVERLAND	34.3	53.8	48.8	83.7	31.5	66.4	82.1	79.4	61.7	57.8	41.5	59.95	45	58.27	45	57.9	140.4	39.7	14.8
NE09517-1	49.6	55.9	62.2	95.2	43.2	62.1	87.7	83.2	53	56.3	47.4	64.84	21	63.25	22	59.9	135.3	40.9	13.4
RUTH	48.9	77.6	65.5	104.5	46.9	69.4	84.7	89.5	59	58.1	58.3	70.41	11	69.31	8	60.9	136.5	40.5	12.5
NI12702W	50.4	53.5	62.3	83.8	47.6	83.7	82.8	82.3	61.1	53.1	42.0	66.06	19	63.87	20	61.2	137.5	39.4	15.8
NI13706	42.1	84.4	48.9	98.7	51.1	79.5	89.7	90.7	65.7	76.4	42.9	72.72	3	70.01	7	59.4	132.9	37.7	13.4
ROBIDOUX	39.9	65.5	62.7	99.3	50.7	67.5	97	95.7	70.8	72.5	55.1	72.16	5	70.61	4	59.0	135.6	40.3	12.3
Settler CL	33.7	67.3	40.3	81.2	33.1	81.5	103.4	77.3	54.4	51.3	41.0	62.35	34	60.41	34	57.4	135.6	39.0	12.0
SCOUT66	29.5	32.8	25.5	44.4	11	48.7	65.6	54.2	38.7	53.2	30.4	40.36	59	39.45	59	55.9	134.4	44.7	12.4
NE12561	58.4	72.9	46.7	94.1	59.9	60.9	83.9	86.8	61.8	60.8	57.7	68.62	14	67.63	13	60.2	133.7	38.8	12.4
NE12589	50.5	78.1	60	79.4	36.5	58.6	71.4	76.5	49.4	65.7	53.4	62.61	32	61.77	26	59.5	134.3	39.0	13.0
NE13425	61.8	70.7	45.8	91.7	33.7	61.1	68.2	79.3	51.2	55	34.0	61.85	35	59.32	41	57.6	133.9	39.4	19.9
NE13434	66.2	74.3	63.2	87.3	40	67.3	77.6	74.6	65.2	64	54.6	67.97	16	66.75	15	57.6	134.4	40.7	12.1
NW13493	62.7	78.1	70	100	60.9	55	88.9	94.1	47.1	68.6	46.9	72.54	4	70.21	5	59.9	135.3	39.1	12.5
NE13515	59.6	58.9	72	93.7	48.3	82.3	94.5	84.5	56	66	56.0	71.58	7	70.16	6	59.1	135.4	40.3	12.6
NW13570	50.1	74.4	58.2	109.3	60.4	51.9	105.8	88.4	59.4	57.7	45.3	71.56	8	69.17	9	59.0	138.7	39.7	12.3
NW13574	64.9	62.3	40.2	77.2	30.4	65.6	73.1	71.5	51.2	59.8	52.5	59.62	47	58.97	43	59.2	138.1	43.1	18.5
NE13597	37.1	60.1	59.8	41.3	43.2	81.3	95.4	81.7	63.9	59.7	37.5	62.35	33	60.09	35	57.8	133.9	37.7	11.7
NE13604	37.4	64.3	47.7	98.7	35.9	71	88.8	90.3	51.8	61.7	48.6	64.76	23	63.29	21	59.3	139.8	40.6	12.8
NE13625	58.7	64.7	39.5	84.5	32.9	62.4	87	70.9	52.5	55.2	44.8	60.83	41	59.37	40	58.8	136.9	40.9	12.6
NW13669	48.1	61	57.5	87.1	54.1	80	67.7	89	45.9	57.9	56.8	64.83	22	64.10	18	59.0	138.7	40.5	15.0
NE13672	23	56	46.2	55.6	26.6	75.2	87	73.1	37.8	50.6	36.8	53.11	55	51.63	55	55.6	137.1	38.1	12.5
LCH13NEDH-11-24	49.5	56.9	45.2	75.5	22.2	60	79.1	69.7	46.3	50.9	34.1	55.53	52	53.58	52	59.3	141.2	43.3	14.8
PSB13NEDH-14-83W	41.8	56.3	50.1	89.7	34.4	73.8	81.8	86	51.1	52.5	48.9	61.75	36	60.58	33	59.5	137.1	40.2	13.3
NE10478-1	61.3	86.2	57	95.1	46	81.1	104	81.2	57.2	68.4	59.2	73.75	2	72.43	2	59.4	133.8	37.9	11.9
NE14419	56.1	53.7	47.7	73.6	39.7	74.5	78.6	75.9	67	46.8	46.8	61.36	38	60.04	36	58.6	141.9	42.7	13.1
NE14421	59.6	71.5	64	96.9	51.8	77.2	91	76.9	51.9	64.1	38.3	70.49	10	67.56	14	59.3	136.4	39.6	12.4
NE14434	60.6	69.4	72.8	86	48.4	77.8	60.9	93.2	64.8	71.3	50.9	70.52	9	68.74	11	59.2	136.2	40.0	16.3
NE14448	66.3	61.7	60.8	90.9	31.1	76.6	90.7	68.8	54.9	51.6	39.2	65.34	20	62.96	24	59.7	134.0	42.1	12.2
NE14457	41.7	62.2	43.7	89.5	21.8	63.8	90.5	83.2	41	59.8	42.1	59.72	46	58.12	47	58.2	140.5	40.1	13.0
NE14480	42.4	65.1	55.6	96.1	49.5	54	56	78.3	50.3	64.2	44.5	61.15	39	59.64	38	58.9	138.4	40.9	14.6
NE14494	40.8	50.2	54.7	100	50.1	62.2	79.1	80.1	52.4	57.2	48.7	62.68	31	61.41	30	58.6	138.6	41.8	15.3
NE14531	51.2	76.7	65.2	70.8	38.6	82.4	84.6	84.3	54.5	58.8	42.4	66.71	17	64.50	17	59.8	134.0	40.5	12.4
NE14538	44.8	65.9	68.6	99.2	44.8	79.9	97	80.8	51.8	67.6	56.6	70.04	12	68.82	10	59.0	135.9	39.3	11.9
NE14546	48	65.8	51.2	90.4	34.7	61.1	75.4	79.2	45.9	58	38.4	60.97	40	58.92	44	58.6	136.0	39.3	13.0
NE14569	35.1	55.1	50.7	95.7	24.9	71.8	91.3	70.3	54.7	56.7	48.9	60.63	42	59.56	39	57.2	135.5	39.9	12.8
NE14606	47	75.5	60	83.8	43.4	69.6	83.3	70.9	48.4	62.7	49.3	64.46	24	63.08	23	58.4	138.3	39.9	12.2
NE14632	58.4	65.6	48.9	79.7	30.4	72.6	70.4	73.2	47.8	55.2	38.2	60.22	44	58.22	46	56.2	142.4	45.9	12.1
NE14654	47.7	60.1	53.3	86.1	46	52	66.7	87.1	47	59.6	53.5	60.56	43	59.92	37	58.8	138.4	41.3	13.5
NE14663	59.5	66.8	53.3	81	38.5	80.3	88.8	78.6	44	51.2	46.8	64.20	25	62.62	25	57.2	134.5	41.2	12.1
NE14674	45.3	39.5	50.5	57.4	34.9	73.1	94.5	65.1	44.5	54.3	36.0	55.91	51	54.10	51	59.0	138.7	41.4	15.3
NE14686	39.9	58.4	52.3	84.4	28.8	60.2	74.3	67.3	53.3	67	25.0	58.59	49	55.54	50	57.9	135.9	39.3	12.1
NE14696	34.1	53.5	51.8	90.4	34.5	67.5	93.5	88.6	65.8	56.8	41.4	63.65	26	61.63	28	59.1	140.5	42.2	12.7
NE14700	33.1	51.5	47.2	91.7	36.2	89.4	67.6	81.8	54.7	61.7	37.4	61.49	37	59.30	42	56.1	140.0	40.1	13.6
PSB13NEDH-14-71W	54.9	78.8	67.4	102.7	61.2	85.8	99.2	82.8	64.1	57.3	52.9	75.42	1	73.37	1	60.5	135.8	38.7	12.5
OVERLAND_FHB1_1	42.6	56.8	41.3	85.4	32.1	51.2	80.2	79.5	51.4	55.8	36.7	57.63	50	55.73	49	59.3	140.3	41.7	13.1
Alpha level	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01	0.05								
GRAND MEAN	**46.44**	**62.58**	**52.80**	**84.68**	**37.73**	**69.68**	**81.66**	**78.32**	**53.72**	**58.49**	**44.13**	**62.61**		**60.93**		**58.28**	**136.74**	**40.40**	**13.63**
LSD	16.17	16.57	17.38	38.78	12.12	15.37	31.06	14.55	17.31	12.48	**14.58**								

Data from 2016 to 2018 (three year average) from the Nebraska Intrastate Nursery for Grain Yield (bu/a) are presented below:

name	bu/a		bu/a	bu/a	bu/a	bu/a		bu/a	bu/a	bu/a	
Name	Mead	Linc.IM	Linc.	C.Center	N.Platte	McCook	Grant	Sidney	Alliance		
	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield		
	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a		
LCS Valiant	61.70	87.20	68.27	59.27	68.23	90.30	73.23	65.10	67.00	71.14	1
NI13706	55.93	87.70	70.57	61.97	70.37	78.70	76.43	62.15	72.40	70.69	2
Robidoux	52.60	90.27	65.97	64.37	62.63	86.17	75.83	67.75	70.43	70.67	3
NW13493	62.20	78.27	72.27	67.33	60.77	87.27	76.53	57.65	64.70	69.66	4
Ruth	55.73	92.43	72.80	58.63	62.53	86.60	73.40	60.75	63.47	69.59	5
NE14691	59.00	84.37	73.87	71.53	69.23	76.93	72.87	63.65	54.83	69.59	6
NW13570	55.63	89.70	66.07	66.83	58.90	93.17	75.60	62.95	57.30	69.57	7
Freeman	52.23	80.83	64.40	53.63	66.80	87.63	76.53	69.45	69.57	69.01	8
NE13515	57.27	82.97	72.07	60.57	66.73	85.30	75.17	58.20	62.77	69.00	9
NE14434	56.57	83.60	78.10	55.93	70.87	73.27	68.13	64.30	68.73	68.83	10
PSB13NEDH-14-	56.13	87.67	62.60	51.73	70.30	80.70	75.17	57.85	64.23	67.38	11
NE14494	53.63	87.97	65.80	64.73	61.17	81.77	68.13	56.35	64.27	67.09	12
NE14538	49.40	86.93	71.33	58.50	73.60	82.10	68.50	52.35	60.67	67.04	13
NI12702W	54.73	81.07	66.73	58.57	73.20	82.10	69.77	59.40	57.00	66.95	14
Siege	58.93	83.37	64.53	66.10	58.63	76.07	73.03	60.80	59.73	66.80	15
NI14729	51.03	68.73	61.13	55.20	68.90	85.73	76.67	66.65	64.57	66.51	16
NE14696	53.77	77.87	60.03	56.37	63.30	87.50	72.97	62.85	61.87	66.28	17
NE13434	63.27	82.33	70.43	56.20	60.53	77.13	61.33	61.75	62.67	66.18	18
NE13604	53.43	79.30	56.13	56.73	65.17	85.47	74.70	58.35	63.87	65.91	19
NE14531	53.30	74.53	68.27	57.00	70.60	76.57	72.53	57.05	57.17	65.22	20
NE14606	52.97	76.13	64.93	61.13	66.70	79.40	67.20	55.90	59.90	64.92	21
NI15713	48.20	80.30	58.17	52.03	64.27	78.57	67.80	65.00	62.27	64.07	22
OVERLAND	51.90	77.77	57.47	57.43	56.83	78.20	63.47	61.10	61.33	62.83	23
Panhandle	44.90	68.23	51.17	46.77	57.00	75.87	62.80	59.25	54.63	57.85	24
GOODSTREAK	52.80	63.97	47.27	44.83	56.90	65.27	59.23	48.35	54.47	54.79	25
SCOUT66	43.30	46.20	37.13	39.07	48.73	61.17	54.17	44.45	54.93	47.68	26
CHEYENNE	36.47	42.33	33.77	40.17	54.03	53.70	50.03	46.55	47.47	44.95	27

As can be seen from the excellent three-year yields of released lines (LCS Valiant, Ruth, Robidoux, Siege, and Freeman), our new and released lines continue to do well, but we have many experimental lines with excellent grain yields in the east, central, or west parts of Nebraska. Of particular note is NW13493, which is a high yielding white wheat As expected Cheyenne and Scout 66 were the lowest yielding lines. Both broadly and more narrowly adapted lines have value in wheat production.

5. <u>Nebraska Triplicate Nursery (NTN):</u>

The same comments about the NIN data apply to the NTN. Sidney was lost to storms before we could harvest the nursery. It was interesting to look at the three check lines in this nursery. Freeman had a bad year mainly due to sever shattering in eastern Nebraska (something not previously seen). Ruth had a good year, and Goodstreak did remarkably well for a tall wheat. A number of experimental lines did very well and were superior to Ruth. The data for 2018 are:

	Mead	Lincoln	C.Center	N. Platte	McCook	Grant	Alliance	St. Avg.	
	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Rank
	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	
NewName	yb_m18	yb_ln18	yb_cc18	yb_np18	yb_mc18	yb_grd18	yb_al18		
NE17483	56.8	82.7	73	69.2	59.8	84.8	65.5	70.26	1
NE17545	56	72.1	56	66.6	70.1	90.3	72.2	69.04	2
NE17443	48.9	73	68.4	64.9	71	85.7	64.5	68.06	3
NE17578	52.2	81.8	68.6	63	66.5	79.6	60.9	67.51	4
NE17441	60.7	79	66.3	60.6	59.6	74.5	70.2	67.27	5
NE17563	52.6	76.9	70.1	58.3	61.4	79.2	69.1	66.80	6
NE17415	60	76.7	60.8	59	62.8	77.8	69.3	66.63	7
NE17627	58.2	81.9	54.6	60.6	67.6	78.2	64.8	66.56	8
NE17506	57.9	77.5	67.1	61.1	57.4	72.6	68.1	65.96	9
NE17528	54.9	82.9	67.3	60.1	66.9	67.9	61.4	65.91	10
NHH17612	50.4	71.1	64.8	71.6	62.7	75.7	64.7	65.86	11
Ruth	49.3	73.3	54.2	69.5	62.9	79.1	71.3	65.66	12
NE17433	44.2	72.1	56.9	59.7	69.2	82.6	74	65.53	13
NE17609	48.6	74.2	61.7	55.5	69.5	76.9	68	64.91	14
NE17608	56.3	70.8	61.1	59.2	65.5	76	64.2	64.73	15
NE17524	52.2	78.6	59.1	54.2	68.8	76.4	61.4	64.39	16
NE17486	52.4	72.3	62.5	70.1	53.6	74.6	59.6	63.59	17
NE17616	56.4	75.3	65	55.8	56.6	73.4	62.6	63.59	17
NHH17503	55.3	76.1	70.7	53.2	55.2	71.2	62	63.39	19
GOODSTREAK	58.2	69.1	68.5	48.4	61.1	75.4	62.9	63.37	20
NE17452	45	73.4	66.1	56	63.7	78.8	60.4	63.34	21
NE17590	51.7	62.1	64.6	58.8	61.5	78.9	63.2	62.97	22
NE17470	55.4	64.2	60.6	56.7	63.1	74.1	64.8	62.70	23
NHH17450	46.1	67.7	61.7	58.8	65.2	78.5	60.2	62.60	24
NE17564	55.7	68.9	57.5	47.4	59.9	83.4	64.8	62.51	25
NE17512	52.2	77.1	58	41.3	60.6	80.4	66.5	62.30	26
NE17439	54.7	66.8	57.7	55.8	61.2	72.7	66.9	62.26	27
NE17481	53.2	68.4	63.9	60.9	59.4	75.6	53.9	62.19	28
NE17639	54.2	70.1	54.1	58.6	66.3	70	61.1	62.06	29
NE17614	48.7	73.3	62	50.6	58.7	75.6	65	61.99	30
NE17515	51.8	66.7	57.1	62.7	59.2	71.4	64.5	61.91	31
NE17417	56.2	64	55.1	61.6	60.1	71.5	64.8	61.90	32
Freeman	46.8	58.3	55.8	61.4	61.8	80.9	67.1	61.73	33
NE17603	56.8	74.5	65.4	44.4	56.3	68	65.5	61.56	34
NE17408	49.4	50.1	61.5	68.2	59.1	80.3	61.4	61.43	35
NE17661	52.1	72	56.3	55.4	56.9	71.3	65.4	61.34	36
NE17480	46.7	61.7	57.9	55.5	60.5	81.5	65.5	61.33	37
NE17576	44.6	68.3	60.2	67.3	55.2	74.1	59.4	61.30	38
NE17479	46.1	62	62.4	62.1	56.6	74.6	64.3	61.16	39
NE17596	45.6	59.8	62.1	66.5	61.7	69.1	63	61.11	40
NE17602	53.1	63.4	47.2	67.1	55.3	76.1	65.2	61.06	41
NE17582	49.4	70	55.8	51.2	52.1	81.1	66.1	60.81	42
NE17606	47.5	60.9	51	59.5	64.3	80.3	59.4	60.41	43
NE17496	51.1	55.5	53.8	64.2	58.4	76.9	62.2	60.30	44
NE17648	54.6	71.3	49.7	67.2	53.3	59.3	66.4	60.26	45
NE17434	52.1	62	53.1	60.8	56.1	72.2	65.5	60.26	46
NE17601	49.2	62.7	56.4	48.4	62.2	76.5	61.1	59.50	47
NE17547	43.9	53	59.5	66.7	60.6	73.2	58.5	59.34	48
NE17402	51.8	69.5	52.1	55.1	46.9	74.3	64.8	59.21	49
NHH17557	49.8	57.2	61.4	68	58	64.4	55.1	59.13	50
NE17550	47.5	61.4	52.4	59.1	61.1	64.4	66.5	58.91	51
NE17539	53.6	54.1	56.3	63.3	40.5	71	69.1	58.27	52
NE17427	48.2	63	48.5	57.5	61.6	72.7	55.5	58.14	53
NE17435	55.9	63.2	56.6	42.9	54	69.5	64.5	58.09	54
NE17593	52.8	65.6	49.1	57.7	51.1	68.8	59.8	57.84	55
NE17472	48.9	45.1	47.5	63.4	55.7	71.9	63.1	56.51	56
NE17538	49.6	48.3	43.1	51.5	55.6	69.4	66.8	54.90	57
NE17426	48.1	45.5	56.7	52.9	47.4	73.6	57.4	54.51	58
NE17444	39.6	53.8	46.2	53.3	50.3	69.4	67.5	54.30	59
NE17409	37.4	57.6	46.9	55.1	58.9	54.7	60.9	53.07	60
EAN	51.31	67.15	58.67	58.92	59.64	74.71	63.99		
	6.03	7.62	10.67	10.94	10.92	14.79	8.5		
	7.24	6.99	11.19	9.15	7.53	9.77	8.18		

The data for 2017 are:

Name	Mead	Lincoln	ClayCent.	N.Platte	McCook	Grant	Sidney	Alliance	Average	Rank
	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	
	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	Bu/a	
NE16424	68.60	87.70	74.50	66.60	105.30	56.70	80.10	66.50	75.75	1
NE16593	66.50	86.90	75.00	64.80	100.50	57.50	80.90	69.70	75.23	2
NE16562	67.40	89.40	78.40	63.20	90.60	58.00	83.00	63.70	74.21	3
Freeman	60.90	89.60	62.70	65.00	90.70	53.60	83.40	74.60	72.56	4
Ruth	63.50	90.50	74.70	61.30	101.40	52.30	68.30	67.10	72.39	5
NE16443	55.50	84.20	65.90	57.50	93.70	60.20	75.80	75.90	71.09	6
NE16579	67.00	83.50	64.70	64.80	102.90	48.10	67.50	67.90	70.80	7
NE16468	61.30	64.40	62.40	61.10	103.60	61.80	74.90	76.80	70.79	8
NW16563V	64.20	76.30	67.60	66.00	99.90	51.70	65.10	74.80	70.70	9
NE16451	67.60	87.40	72.30	56.70	101.00	54.70	65.00	60.30	70.63	10
NE16587	66.30	71.60	62.20	62.40	101.30	61.80	71.30	64.50	70.18	11
NW16687	66.00	79.40	71.60	62.70	107.70	53.50	62.80	57.50	70.15	12
NE16402	67.30	81.00	72.70	64.80	104.60	43.00	67.90	59.10	70.05	13
NE16467	62.20	78.40	68.40	62.10	96.70	53.80	70.00	65.70	69.66	14
NE16578	56.70	73.30	69.10	62.40	107.00	55.00	69.40	62.70	69.45	15
NE16606	62.00	77.50	65.40	60.50	103.10	53.10	70.10	62.90	69.33	16
NE16672	59.70	69.00	75.90	74.80	91.70	50.70	71.50	58.90	69.03	17
NE16640	65.00	73.80	70.10	61.50	97.80	49.00	69.80	64.60	68.95	18
NE16412	52.40	65.30	61.70	74.70	98.80	57.30	76.80	63.30	68.79	19
NE16604	68.70	71.10	67.70	62.60	99.40	49.50	67.90	58.30	68.15	20
NE16616	59.60	66.20	75.10	62.70	91.90	54.40	71.90	58.70	67.56	21
NE16596	56.40	65.00	68.40	67.10	93.70	48.60	73.60	65.30	67.26	22
NE16548	54.70	81.90	65.30	65.10	95.90	50.60	67.50	56.60	67.20	23
NE16631	50.40	80.30	71.10	59.20	89.70	50.60	68.40	66.50	67.03	24
NE16639	50.70	75.30	68.30	55.40	104.00	50.40	66.80	61.50	66.55	25
NE16554	52.70	69.40	75.10	51.80	98.60	58.80	69.10	56.60	66.51	26
NE16659	56.90	64.70	65.10	57.00	97.40	40.00	81.00	70.00	66.51	26
NE16521	56.60	67.70	65.30	58.20	94.80	50.40	72.70	65.60	66.41	28
NE16567	58.20	53.30	72.90	59.40	100.90	53.40	69.80	62.30	66.28	29
NE16588	65.50	65.70	71.90	58.60	94.90	44.20	68.10	60.60	66.19	30
NE16493	62.10	78.10	67.10	53.70	92.20	46.10	71.30	58.80	66.18	31
NE16478	49.80	74.90	68.70	61.50	92.10	50.70	71.20	56.90	65.73	32
NE16657	66.10	80.30	68.70	57.20	93.30	43.70	64.20	52.20	65.71	33
NE16612	61.10	79.10	64.80	58.40	97.10	46.60	67.50	50.90	65.69	34
NE16620	55.10	78.40	70.40	57.70	97.30	52.80	61.90	51.50	65.64	35
NHH16634	47.10	69.60	69.40	54.90	97.00	54.10	71.90	58.50	65.31	36
NE16660	53.30	69.90	69.70	56.70	96.90	50.10	67.30	58.60	65.31	36
NE16494	54.70	73.20	65.70	51.70	92.70	49.50	71.80	62.20	65.19	38
NE16576V	49.90	68.70	64.50	61.60	92.50	52.70	74.40	52.30	64.58	39
NE16648	49.90	65.20	69.00	46.20	104.90	53.10	64.00	62.70	64.38	40
NE16545	65.50	77.50	65.40	64.90	88.40	39.90	59.00	54.10	64.34	41
NE16549	57.20	73.90	62.40	65.80	85.70	40.50	71.40	56.90	64.23	42
NE16658	56.70	60.70	61.00	56.40	91.30	53.30	72.00	58.20	63.70	43
NE16479	48.40	64.50	61.70	50.00	100.90	52.70	68.90	61.90	63.63	44
NE16556	60.30	74.00	65.10	50.30	86.20	49.10	63.90	57.00	63.24	45
NE16566	68.50	58.30	61.30	56.90	91.00	48.70	69.90	51.00	63.20	46
NE16619	49.30	75.10	61.90	56.70	95.90	46.00	63.50	56.60	63.13	47
NE16439	57.20	73.50	58.20	59.60	83.30	51.20	64.50	55.50	62.88	48
NHH16422	37.70	75.20	64.70	46.50	92.00	59.40	66.30	56.10	62.24	49
NE16607	57.30	62.80	60.10	53.20	92.40	45.40	72.40	49.90	61.69	50
NE16553	39.60	60.20	67.40	59.60	92.70	43.90	72.10	56.20	61.46	51
NHH16688	46.80	62.30	61.40	64.20	89.40	45.20	63.40	58.10	61.35	52
NE16552	56.70	65.10	62.40	61.30	82.40	41.60	60.20	60.50	61.28	53
NE16401	54.80	69.40	62.10	41.70	95.20	47.40	65.30	50.30	60.78	54
NE16546	45.20	59.60	50.60	62.40	92.80	41.60	63.50	61.80	59.69	55
NW16686	56.90	65.40	62.00	68.60	76.00	41.00	61.80	39.20	58.86	56
NE16423	51.30	71.30	56.30	60.90	76.90	45.20	52.60	55.50	58.75	57
NE16438	51.10	68.80	61.90	58.20	68.70	41.60	59.20	54.90	58.05	58
Goodstreak	34.10	57.20	61.60	48.10	83.80	40.80	67.50	58.00	56.39	59
NE16673	41.40	57.50	61.80	47.30	82.90	45.70	62.10	50.90	56.20	60
Avearge	**56.93**	**72.33**	**66.48**	**59.37**	**94.39**	**50.04**	**68.92**	**60.10**	**66.07**	

The data for 2016 are:

Name		Lincol IM	Clay Cente	N. Platte	McCook	Grant	Sidney	Alliance	**Average**	**Rank**	Hdate	Height	Test Weig
		Yield	Yield	Yield	Yield	Yield	Yield	Yield	**Yield**		Days afer		
		bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	**bu/a**		Jan.1	(in)	lbs/bu
Freeman		93.3	56.1	77.1	100.5	91.8	70.4	77.6	**81.0**	**1**	131.9	36.9	56.65
NE15624		86.0	63.6	48.0	106.1	88.8	74.0	71.0	**76.8**	**2**	134.6	34.5	56.98
NE15445		76.0	57.3	87.9	100.8	75.1	75.2	50.3	**74.7**	**3**	132.3	35.0	55.85
NE15406		88.8	57.6	68.7	85.3	85.6	70.4	63.5	**74.3**	**4**	133.1	37.2	57.83
NE09517_6		80.0	52.9	77.6	89.6	78.3	62.9	65.3	**72.4**	**5**	134.8	39.1	60.38
NE15605		78.3	57.6	77.0	81.4	74.6	69.1	62.2	**71.5**	**6**	137.7	38.1	58.50
NE15410		73.4	53.3	55.7	90.7	86.4	68.8	62.9	**70.2**	**7**	131.1	38.0	56.75
NE15440		73.8	47.2	81.0	87.2	77.1	65.7	57.7	**70.0**	**8**	133.0	37.3	53.05
NW15404		83.5	62.9	49.3	80.7	76.9	74.0	61.7	**69.9**	**9**	133.3	35.7	58.63
NE15571		74.4	56.7	56.0	77.1	82.6	71.2	70.1	**69.7**	**10**	138.0	35.6	56.73
NE15405		68.0	51.7	75.9	83.7	74.6	73.5	60.0	**69.6**	**11**	131.9	39.5	57.50
NE15468		85.5	41.8	77.7	95.5	73.1	52.8	57.6	**69.1**	**12**	132.7	37.9	56.23
NW15443		96.2	52.3	64.1	87.3	74.8	52.2	57.1	**69.1**	**13**	138.0	38.5	55.63
NW15573		71.0	47.9	70.0	72.9	85.8	70.8	63.3	**68.8**	**14**	136.0	36.0	58.03
NE15434		76.2	45.5	71.2	88.8	71.7	66.0	58.7	**68.3**	**15**	135.0	37.3	56.55
NE15545		81.8	51.7	79.0	83.3	67.2	66.9	47.8	**68.2**	**16**	137.3	39.5	56.73
NW15485		88.0	61.0	46.2	64.4	86.4	65.8	63.4	**67.9**	**17**	132.7	33.1	58.18
NE15475		76.6	36.4	81.8	80.9	70.9	71.2	56.8	**67.8**	**18**	134.0	41.2	56.03
NE15417		84.6	42.6	79.1	71.1	74.6	65.0	54.4	**67.3**	**19**	134.1	35.7	53.58
NW15564		88.4	57.4	52.6	75.1	68.9	67.8	60.3	**67.2**	**20**	133.6	35.8	58.53
NW15684		90.5	45.9	67.6	91.5	78.1	43.1	53.0	**67.1**	**21**	139.0	38.5	56.85
NE15495		75.7	42.8	76.5	80.8	69.1	62.1	62.3	**67.0**	**22**	134.0	36.8	56.58
NE15689		83.5	58.6	48.2	75.2	71.6	74.9	52.4	**66.3**	**23**	132.6	39.1	59.18
NW15667		89.2	40.7	63.9	77.8	76.2	55.8	59.6	**66.2**	**24**	134.0	36.5	57.65
NE15519		72.9	44.3	63.1	80.2	77.8	62.9	60.4	**65.9**	**25**	131.9	39.3	55.63
NE15415		83.3	41.5	71.4	68.4	81.8	57.3	56.1	**65.7**	**26**	134.3	41.1	58.45
NE15595		77.2	48.7	32.6	88.7	83.6	67.1	60.5	**65.5**	**27**	139.7	37.5	59.33
NE15525		76.0	43.2	68.7	78.7	73.9	57.7	59.5	**65.4**	**28**	138.3	37.0	55.95
NE15668		72.4	39.7	71.6	85.6	71.9	55.3	60.7	**65.3**	**29**	136.4	37.3	51.00
NW15677		78.3	50.4	54.1	77.7	72.4	64.8	58.4	**65.2**	**30**	132.7	35.5	55.85
NE15655		63.3	40.7	75.7	94.2	61.9	65.9	54.0	**65.1**	**31**	140.4	34.6	53.65
NE07486_2		85.0	39.7	48.3	87.9	63.6	69.6	60.1	**64.9**	**32**	139.4	39.6	58.70
NE15572		73.4	45.4	71.2	71.4	70.6	65.9	55.6	**64.8**	**33**	138.3	39.5	54.68
NE15645		85.7	44.5	63.7	87.3	61.7	57.4	47.2	**63.9**	**34**	135.4	42.1	56.45
NE15508		75.3	52.4	48.5	59.7	74.6	76.1	58.3	**63.6**	**35**	131.0	34.3	58.15
NE15620		79.9	28.8	68.0	83.4	73.5	60.7	47.6	**63.1**	**36**	137.3	40.0	49.23
NE15614		76.1	37.0	67.9	76.1	70.2	58.0	55.1	**62.9**	**37**	138.3	39.3	56.50
NE15503		63.1	42.6	68.7	79.3	62.1	67.5	56.7	**62.9**	**38**	134.0	42.3	51.70
NE15662		74.7	40.2	60.8	64.5	74.7	70.6	54.5	**62.9**	**38**	141.0	39.6	57.48
NE15628		79.9	50.6	42.0	66.1	80.6	64.4	55.5	**62.7**	**40**	131.0	37.4	58.58
Camelot		65.2	28.3	70.3	83.6	73.8	54.3	62.9	**62.6**	**41**	132.6	39.0	55.83
NH144913-3		80.3	26.5	67.0	75.7	73.2	57.0	57.9	**62.5**	**42**	131.0	35.1	54.90
NE15683		71.7	25.4	73.9	91.1	69.1	52.0	53.0	**62.3**	**43**	131.4	37.3	57.13
NE15636		74.7	48.5	30.1	63.4	79.0	72.3	66.1	**62.0**	**44**	131.7	33.3	56.55
NH144922-1		74.7	31.1	67.3	76.3	72.9	50.8	60.0	**61.9**	**45**	132.6	37.2	52.85
NE15686		72.8	33.5	63.3	75.1	76.2	60.2	51.2	**61.8**	**46**	134.6	37.5	55.78
NW15466		68.5	52.2	45.6	84.9	65.6	63.2	46.7	**61.0**	**47**	140.3	39.2	57.83
NH144921-1		73.9	39.4	38.5	75.8	72.2	61.5	64.6	**60.8**	**48**	131.4	35.9	55.68
NH144925-4		79.1	25.1	61.9	64.3	70.5	56.5	65.7	**60.4**	**49**	135.0	38.7	56.25
NE15630		82.0	37.9	66.2	70.4	63.2	57.1	44.8	**60.2**	**50**	132.0	36.3	57.43
NE15654		74.9	28.6	66.9	81.3	68.8	51.4	48.2	**60.0**	**51**	138.3	38.5	56.75
NE15619		77.5	40.3	40.7	73.7	68.5	59.7	57.8	**59.7**	**52**	135.0	39.4	57.48
NE15474		64.8	40.0	55.7	82.2	65.5	57.6	50.3	**59.4**	**53**	141.1	38.9	57.80
NE15651		53.8	34.6	68.8	69.4	65.4	59.3	47.6	**57.0**	**54**	140.3	44.6	57.88
NE15460		70.6	31.8	56.6	84.9	54.9	54.2	44.1	**56.7**	**55**	134.6	40.3	57.15
NE15641		60.5	24.7	50.6	76.9	70.6	47.6	52.7	**54.8**	**56**	134.3	40.6	56.10
NE15675		66.3	28.0	60.1	72.4	56.0	50.7	42.5	**53.7**	**57**	137.4	43.3	57.05
GOODSTREAK		58.2	21.9	56.6	64.1	57.3	47.2	57.1	**51.8**	**58**	136.7	41.9	55.30
NE15691		65.1	27.9	41.2	64.7	67.7	43.1	46.8	**50.9**	**59**	135.0	41.7	58.23
NE15419		48.8	34.5	66.1	61.1	53.5	45.9	39.2	**49.9**	**60**	137.0	43.0	57.10
GRAND MEAN		**76.05**	**43.19**	**62.60**	**79.47**	**72.65**	**61.87**	**56.80**	**64.7**			**38.2**	
CV		**11.13**	**11.17**	**13.20**	**12.64**	**5.51**	**10.45**	**10.78**					
LSD		**16.39**	**9.34**	**20.09**	**24.42**	**9.73**	**10.50**	**9.94**					

6. Regional Nurseries

In 2018, we continued to combine the Southern Regional Performance Nursery (SRPN) and the Northern Regional Performance Nursery (NRPN) into one larger nursery. These were planted at Lincoln, North Platte, Sidney, and Alliance. At Clay Center, only the SRPN was planted. The NRPN and SRPN data from all locations is available at: http://www.ars.usda.gov/Research/docs.htm?docid=11932. It was useful to see Kharkof and Scout 66, older wheat cultivars, continue to be very low yielding, indicating that breeding has made ongoing and continued progress. The 2018 SRPN data are:

	Clay Center, NE		Lincoln, NE		North Platte, NE		Sidney, NE		Alliance, NE		Average
Line	Mean	Rank	mean	rank	Mean	Rank	Mean	Rank	Mean	Rank	kg/ha
Kharkof	2618	50	3062	50	2730	49	1917	44	2703	50	2582
Jagalene	3945	33	4775	29	3472	35	2703	29	4685	26	3724
KS13HW92-3	3943	34	5062	17	3360	39	3241	17	4338	39	3902
KS14HW106-6-6	4380	15	4479	43	4255	7	1668	47	5012	10	3695
KS14H180-4-6	4104	25	5266	8	4071	12	2434	37	5068	8	3969
KS15H79-4	4071	29	5286	7	3255	41	3329	13	4535	34	3985
KS15H116-6	4178	21	5530	3	3212	42	2697	31	5142	7	3904
CO12D1770	4295	19	5142	14	3564	34	3241	18	5326	2	4061
CO13D1783	3930	35	5006	19	3800	23	3265	15	5228	4	4000
CO13D1299	3970	31	4654	37	4284	6	3309	14	4934	13	4054
CO13D1383	4001	30	5089	16	4161	9	3524	9	5203	5	4194
CO13D1479	4593	7	5167	13	3945	19	3369	10	5187	6	4269
OK12716	4681	4	4983	23	4891	1	3954	1	4699	24	4627
OK12D22004-016	5006	1	5479	4	3896	22	3692	4	4990	11	4518
OCW05S616T-2	4127	23	4055	47	3717	27	3719	3	4048	46	3904
OCW04S717T-6W	3271	46	4291	46	2952	47	3652	5	4790	18	3541
OK12206-127206-2	4425	13	5048	18	3376	38	2556	36	4584	32	3851
AP-17CP020067	4625	5	5568	1	3614	32	2700	30	4719	22	4127
AP-17CP020068	3392	44	4985	22	4252	8	1453	49	4860	16	3521
AP-17CP020073	4445	12	4486	42	4118	11	2919	26	4699	25	3992
AP-17CP020081	2887	48	4873	24	3905	21	3087	23	4853	17	3688
AP-17CP020086	4909	2	5454	5	3710	29	3201	20	4719	23	4319
LCH14-52	3813	37	4777	28	3358	40	2233	42	4237	42	3545
LCH14-61	4073	28	4584	39	3203	43	1211	50	4246	41	3268
LCH14DH-21-1781	4084	27	4790	27	3714	28	2838	27	4268	40	3857
DH11HRW-51-9	4497	10	5237	9	4391	3	3248	16	5241	3	4343
DH11HRW-27-3	4329	18	4701	35	3732	26	2367	39	4564	33	3782
KS080099M-3	4093	26	4544	41	4320	5	3638	7	4757	21	4149
KS080093K-18	4398	14	5212	11	3575	33	3369	11	4468	36	4139
KS090049K-8	4793	3	5328	6	3694	31	2670	32	4761	20	4121
KS090387K-20	3851	36	4770	30	4161	10	2623	34	4665	29	3851
TX12V7415	4378	16	4746	33	2827	48	2280	41	4663	30	3558
TX13M5625	4602	6	4445	44	3995	17	2327	40	4194	44	3842
TX14A001112	4365	17	4672	36	4033	16	3053	25	4342	38	4031
TX14A001185	3777	39	4992	20	3800	24	3584	8	4649	31	4038
TX14A001249	3806	38	4732	34	4035	15	3161	21	4678	27	3934
TX14A001035	3746	40	5174	12	3419	37	2569	35	4512	35	3727
TX14A001215	3439	42	5555	2	3174	44	3241	19	4952	12	3852
TX14V70086	3602	41	4750	32	3800	25	2825	28	4358	37	3744
TX14M7061	3383	45	4829	26	3445	36	1701	46	4669	28	3340
TX14M7088	3394	43	4562	40	3932	20	3060	24	4788	19	3737
NF97117	2755	49	3185	49	3067	45	2374	38	3091	49	2845
NE10478-1	4573	8	4860	25	4373	4	1762	45	4925	14	3892
NHH144913-3	4210	20	5109	15	4508	2	1567	48	3943	47	3848
NW15443	4497	11	4988	21	3703	30	3336	12	4051	45	4131
NE15624	4542	9	5232	10	3948	18	3100	22	4925	15	4205
H3N13-0253	4111	24	4759	31	4066	13	3901	2	5490	1	4209
H4N13-0181	4167	22	4598	38	4053	14	3652	6	5044	9	4117
Scout 66	3141	47	3226	48	2694	50	2118	43	3753	48	2795
TAM107	3970	32	4441	45	2988	46	2643	33	4226	43	3510
Mean	4044		4811		3684		2831		4616		
l.s.d. (alpha = 0.05)	965		349		1020		2664		506		
MSE	354696		46326		162786		365016		97491		
n	3		3		3		3		3		
CV	14.7		4.5		11.0		21.3		6.8		

The data for the 2018 NRPN are:

		Lincoln, NE		North Platte, NE		Sidney, NE		Alliance, NE		Average
Line		mean	rank	mean	rank	mean	rank	mean	rank	kg/ha
Kharkof		3062	44	2730	45	1917	41	2703	45	2083
Overland		4990	12	3524	31	3134	16	4864	10	3302
Wesley		5281	5	3719	26	2650	32	4382	30	3206
Jagalene		4775	25	3472	33	2703	31	4685	23	3127
Jerry		4461	34	3304	37	1836	42	4257	37	2772
NW13MD108-3		4849	20	3887	18	3443	5	4313	34	3298
NW13MD109-1		3896	42	3430	34	3443	6	4616	25	3077
CO15SFD061		5443	3	3076	42	2878	24	4781	15	3236
CO15SFD092		4519	32	3179	40	3625	2	4773	17	3219
CO15SFD095		4013	39	3277	38	3087	18	4362	31	2948
CO15SFD107		4676	27	3401	35	3258	12	4824	11	3232
AP-17CP020072		5658	1	4084	11	2851	26	4804	12	3480
AP-17CP020137		4950	15	4416	3	3430	7	4284	35	3416
AP-17CP020142		5167	7	3775	23	3302	10	4560	28	3361
AP-17CP020143		4979	14	4147	10	3262	11	4911	7	3460
AP-17CP020147		4981	13	3701	28	3544	3	5427	1	3531
LCH14DH-21-1781		4790	24	3714	27	2838	27	4268	36	3122
LCH14-53		4609	30	3329	36	1500	45	4093	38	2706
DH12HRW-9-9		4811	23	4214	7	2825	28	4755	20	3321
DH11HRW-58-9		4380	35	3972	14	2394	36	4773	16	3104
16NORD-54		2038	45	3031	43	2542	34	3593	43	2241
16NORD-58		3934	41	3802	22	2307	37	4087	39	2826
16NORD-62		4062	38	3916	17	2081	40	3983	40	2809
NH144913-3		5109	9	4508	2	1567	44	3943	41	3025
NE10478-1		4860	19	4373	5	1762	43	4925	6	3184
NE14434		4764	26	3970	15	3315	9	4880	9	3386
NE14538		4925	17	4203	8	3336	8	4479	29	3389
NE14691		5611	2	3544	30	2858	25	4905	8	3384
NE14696		5077	11	4033	13	2576	33	4761	19	3289
NI14729		4593	31	3849	19	2808	29	4799	14	3210
NW15573		4308	37	3959	16	2925	22	4351	32	3109
NE14421		4672	28	4376	4	2885	23	4802	13	3347
NE15410		4495	33	4035	12	3147	15	4613	26	3258
NW15404		3999	40	3517	32	2989	20	4748	21	3051
MT1547		4815	22	3152	41	3477	4	3753	42	3039
MT1563		4642	29	3764	24	2993	19	4631	24	3206
MT1564		3380	43	3215	39	2946	21	4705	22	2849
MTS1588		4373	36	2825	44	3127	17	3542	44	2773
SD12008-2		4898	18	4154	9	3154	14	4333	33	3308
SD13062-2		5138	8	3813	21	2791	30	4613	27	3271
SD13W064-7		4947	16	4306	6	4143	1	4764	18	3632
SD14113-3		5102	10	3750	25	2293	38	4950	5	3219
SD14115-5		5180	6	3699	29	2508	35	5145	2	3306
CA9W09-903		5405	4	3831	20	2192	39	5140	3	3314
FA4W11-6067		4849	21	4692	1	3248	13	5024	4	3562
SAS Mean		4655		3748		2837		4531		
l.s.d. (alpha = 0.05)		423		575		N/A		702		
MSE		68104		125399		N/A		187247		
n		3		3		1		3		
CV		5.6		9.4		N/A		9.5		

7. Multiple-Location Observation Nursery

Seven locations in Nebraska (Lincoln, Mead, Clay Center, North Platte, McCook, Grant, Sidney, and Alliance) and one in Kansas were planted and harvested. To better estimate the yield at key locations, two replications were planted at Lincoln. The table below gives the grain yields for all of the harvested locations, the line average, and the rank of the top 15 highest yielding lines. In this nursery, we continued to use marker-assisted selection for line advancement. For the sixth year, we used genotyping by sequencing (GBS). Genotyping by sequencing was done in collaboration with Dr. Jesse Poland, KSU, because it is much less costly (less than 1/3 of the cost of other marker systems). The top fifteen lines out of 270 experimental lines are below. As can be seen soe of the selected lines had low genetic estimated breeding values (GEBVs) because they seem to do particularly well in some section of the state and the GEBVs are based upon the stte-wide averages.

entry	pedigree	SR score	Mead_yld_B+	Lincoln_yld_B	ClayCenter_y	NorthPlatte_y	McCook_yld	Grant_yld_B+	Sidney_yld_B	Alliance_yld	Kansas_yld_B	NE_All_Ave	GEBV_yldbua
NE18544	**NI09709/NI04421**	2+2X	**57.73**	**77.39**	**82.12**	**68.83**	**68.50**	**78.87**	**78.18**	**72.60**	**42.06**	**73.03**	**-0.34**
NE18412	**NW11590/T 154//N**	;	**62.68**	**78.82**	**81.30**	**72.10**	**69.03**	**77.73**	**74.65**	**64.58**	**43.49**	**72.61**	**-0.01**
NE18573	TX07A001118/Freen	2+;	62.61	78.99	87.54	60.69	66.69	78.73	73.55	65.20	42.20	71.75	**1.29**
NE18422	KS11U5899R2/NW1	;1+	58.99	72.70	78.53	67.67	66.90	77.27	82.30	68.99	42.61	71.67	**1.45**
NE18509	KS08HW35-1/Camel	22-N	62.72	77.61	60.22	75.89	70.16	76.72	76.31	71.65	44.55	71.41	**1.51**
NE18583	NE09517/SD06158	33+	59.13	78.38	73.69	68.84	70.09	75.58	76.59	65.08	42.84	70.92	**1.90**
NE18466	NE09521/Freeman	;/1-	60.97	72.60	68.70	49.27	69.93	78.17	84.84	79.01	44.34	70.44	**0.19**
NE18514	CO050337-2/SD050	2-;	63.54	72.77	63.89	74.01	64.46	77.38	76.54	67.33	41.56	69.99	**0.84**
NE18624	NW11511/Snowmas	1+	49.44	76.29	70.81	63.28	68.55	77.93	84.36	68.79	42.66	69.93	**0.27**
NE18553	U5935-2-3/NI07703	22+	52.56	75.42	75.33	67.32	66.36	77.12	79.21	64.95	42.31	69.78	**-0.15**
NE18640	NW03666/ms(t)-77(	1;	62.03	74.04	74.87	62.54	71.59	75.81	72.10	63.36	40.66	69.54	**2.50**
NE18435	TX07A001505/NE05	2-;	57.46	76.86	73.93	55.34	69.83	77.28	70.77	74.49	43.68	69.50	**-2.16**
NE18455	TX07A001505/NE06	;	58.11	71.49	62.99	74.79	63.87	76.84	83.05	64.57	42.77	69.46	**0.81**
NE18418	U5942-10-1/NW075	;/2-	62.75	70.48	67.93	57.32	67.74	78.43	77.97	71.26	42.19	69.23	**2.51**
NE18595	NW10487/NW0753	1;	63.41	82.39	67.36	50.74	65.33	76.70	76.52	71.32	42.62	69.22	**1.50**

In 2017, All eight locations in Nebraska (Lincoln, Mead, Clay Center, North Platte, McCook, Grant, Sidney, and Alliance) and one in Kansas were planted and harvested. To better estimate the yield at key locations, two replications were planted at Lincoln (but only one was harvested). The table below gives the grain yields for all of the harvested locations, the line average, and the rank of the top 10 highest yielding lines. Of these 10 highest yield lines, 3 were in the top 16 lines in the 2018 TRP nursery. Historically, these three lines would be the most likely to be released.

NewNames	Mead	Lincon	C.Center	N Platte	McCook	Grant	Sidney	Alliance	Kansas	NE Ave.	RANK NE Ave.	NE + KANSAS	RANK	GEBV_DUP2
	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield		Yield		
	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a	bu/a		bu/a		
	Mead_yld_B+	Lincoln_yld_B	C.Center_yld	N.Platte_yld	McCook_yld	Grant_yld_B+	Sidney_yld_B	Alliance_yld	KANSAS_yld_B+M					
NE17625	59.56	76.60	73.32	55.12	113.97	54.52	55.08	60.43	38.17	68.58	1	65.20	1	**1.12**
NE17626	50.66	73.67	81.44	56.31	101.64	54.14	55.64	59.97	41.71	66.69	2	63.91	2	**1.85**
NE17524	58.86	80.40	71.26	49.55	108.80	51.93	53.41	58.14	38.12	66.55	3	63.39	3	**2.12**
NE17549	54.84	69.75	72.52	53.80	107.43	54.44	53.12	59.42	35.97	65.67	4	62.37	4	**0.81**
NE17578	46.73	83.02	68.46	54.84	99.69	52.90	53.38	57.36	38.38	64.55	5	61.64	5	**2.16**
NE17550	50.49	82.02	70.87	51.89	91.54	53.30	55.31	59.46	39.11	64.36	6	61.56	6	**2.24**
NE17435	54.69	78.17	76.41	47.19	95.72	49.00	54.34	58.95	37.73	64.31	7	61.35	8	**2.09**
NE17631	51.07	71.81	72.16	49.86	103.46	55.84	52.66	56.58	33.03	64.18	8	60.72	14	**0.39**
NE17624	52.50	73.36	64.81	50.13	101.13	53.79	52.21	64.21	32.53	64.02	9	60.52	16	**1.90**
NE17441	50.85	64.23	63.90	49.91	123.34	49.67	53.70	55.57	39.81	63.90	10	61.22	9	**2.89**
NE17629	51.91	71.67	70.82	56.08	96.86	51.66	54.04	57.41	42.17	63.81	11	61.40	7	**0.55**

8. Early Generation Nurseries

A summary of the early generation nurseries is:

	Planted	Selected
WF2	1156	1098
Imi-WF2	103	73
WF3	973	520
Imi-WF3	111	59
Headrows	45760	1609
Imi-Headrows	3600	127
Preliminary Observation Plot	1320	250
Imi Preliminary Obs. Plots	235	20

These numbers are fairly normal for the nurseries. In retrospect, fewer WF3s should be selected with possibly more lines selected within a population.

9. <u>Winter Triticale Nursery</u>

In 2015, it appeared that NE422T has good forage potential for the southern Great Plains. We are beginning to move to higher and more consistent grain yield levels and much better seed quality, but identifying excellent forage types requires forage harvesting which is expensive and difficult for widespread trials. NE441T continues to be an excellent forage triticale also. Though the markets for biofuels fluctuate with the price of oil and other geologically based fuels, we believe that there is a future for triticale in a forage based, cover crop, or biobased energy system. Triticale can be grown over the winter as forage or grain crop in areas where maize cannot be grown successfully. The grain will substitute for maize in animal rations and the forage can be used as forage, cellulosic ethanol feed stocks, or as a ground cover, an emerging market. Sidney was lost to storms before harvest.

	Lincoln				Mead			Average		Mead Forage	
	Yield	Height	Flowering date	Test Wt	Yield	Height	Test Wt	Yield	Height	Dry Matter	Dry Biomass
Variety	lbs/a	in	D after Jan.1	lbs/a	lbs/a	in	lbs/a	lbs/a	in	%	lbs/a
NT16402	3692	45.9	143.4	48.7	3692	38.2	47.5	3692	42.1	0.28	3022
NT16404	3807	44.8	146.0	49.4	3207	46.3	51.1	3507	45.6	0.26	3047
NT16406	3664	46.7	146.6	48.0	3344	42.7	47.6	3504	44.7	0.25	2919
NT12404-1	4207	41.8	144.3	50.0	3794	39.3	48.3	4001	40.6	0.28	3007
NT12425-1	3424	35.3	143.4	50.1	3280	33.3	47.6	3352	34.3	0.26	2529
NT05421	3766	45.5	146.1	47.1	3418	46.2	47.7	3592	45.9	0.24	2891
NT06427	3764	43.2	144.9	45.3	3390	38.7	45.3	3577	41.0	0.25	2780
NT07403	4274	42.0	143.0	50.0	3739	40.7	49.4	4007	41.4	0.29	2975
NT09423	3768	42.1	146.2	49.1	3293	41.7	48.9	3531	41.9	0.24	2622
NT11428	4085	48.7	146.1	49.1	3534	45.7	49.6	3810	47.2	0.25	2771
NT12403	4409	44.9	144.3	48.8	3760	36.0	47.9	4085	40.5	0.27	2938
OVERLAND	3520	33.9	146.5	57.9	3222	32.3	58.3	3371	33.1	0.25	2525
NT13416	3652	45.0	144.5	48.8	3477	44.7	49.6	3565	44.9	0.28	3035
NT14407	3910	44.4	144.7	49.5	3869	43.0	49.6	3890	43.7	0.27	2964
NT14433	3269	46.1	145.8	50.6	3346	51.3	50.9	3308	48.7	0.27	3311
NT15406	3785	42.5	143.9	52.1	3370	41.7	50.7	3578	42.1	0.30	2947
NT15428	3886	43.1	144.4	48.4	3586	39.0	47.4	3736	41.1	0.27	2842
NT15440	3642	45.1	146.5	47.1	3342	45.0	47.7	3492	45.1	0.27	2893
NT441	3584	46.8	149.2	49.1	2998	46.3	49.5	3291	46.6	0.22	2871
NT13443	3220	52.7	147.2	49.1	3390	47.0	48.8	3305	49.9	0.25	2772
NT17441	4694	49.5	147.1	49.9	3924	49.7	49.8	4309	49.6	0.23	2798
NT17442	4196	48.0	148.9	50.4	3764	45.3	50.5	3980	46.7	0.22	2940
NT17430	3549	42.0	145.5	49.4	3528	36.7	49.2	3539	39.4	0.28	2693
NT17422	3943	44.5	145.0	47.0	3563	42.3	47.0	3753	43.4	0.27	2999
NT17406	3641	43.6	144.9	49.6	3321	43.0	50.3	3481	43.3	0.25	2716
NT17402	3170	40.9	143.8	48.1	3203	40.0	48.4	3187	40.5	0.26	2493
NT17407	4029	46.0	144.7	50.7	3421	45.7	50.9	3725	45.9	0.28	2991
NT17410	4409	43.0	144.3	46.7	3659	41.2	45.4	4034	42.1	0.26	2969
NT17403	3806	40.3	146.6	43.5	3550	38.2	44.7	3678	39.3	0.24	2645
NT17420	3751	45.9	145.1	49.8	3684	43.0	50.0	3718	44.5	0.28	2786
GRAND MEAN	**3814.6**	**44.1**	**145.4**	49.1	**3489.0**	**42.2**	49.0	**3651.8**	**43.1**	**0.3**	**2856.2**
LSD	540.2	4.6	0.88	0.6	377.2	4.6	0.9			0.02	306.5
CV	8.6	6.4	0.37	0.8	6.6	6.7	1.1			6.1	7.6

The grain yield data for 2017 are below. Note no forage data was collected in 2017 due to equipment breakdowns and a problem with planting.

	Mead	Lincoln	Sindney	St. Avg.	Rank	Height	Flowering date
NewName	Yield	Yield	Yield	Yield			d after Jan. 1
	lbs/a	lbs/a	lbs/a	lbs/a		inches	days
NT16401	3425	3991	3144	3520.0	16	52.4	137.1
NT16402	4399	5315	4049	4587.7	1	47.8	134.2
NT16403	3236	3691	3867	3598.0	12	54.0	139.7
NT16404	3004	2992	3447	3147.7	22	60.2	138.2
NT16405	2479	2153	2925	2519.0	28	57.6	140.3
NT16406	3148	2152	2766	2688.7	26	58.3	142.3
NT16407	4268	3143	3668	3693.0	9	55.9	141.1
NT16408	3008	4326	3529	3621.0	11	48.2	135.5
NT12404-1	4204	5344	3459	4335.7	3	49.2	136.3
NT12425-1	3512	4256	4319	4029.0	4	45.0	136.1
NE422T	2904	2042	2409	2451.7	29	64.8	145.4
NT05421	3439	3624	2884	3315.7	20	54.6	139.3
NT06422	3116	3517	3573	3402.0	18	55.5	136.4
NT06427	2881	3720	3368	3323.0	19	47.5	138.2
NT07403	3090	4124	3577	3597.0	13	47.0	133.9
NT09423	2588	2830	3407	2941.7	23	49.1	140.2
NT11428	3482	3421	3855	3586.0	14	57.4	139.5
NT12403	3613	4532	3430	3858.3	6	50.4	136.2
NT12406	3080	3318	3931	3443.0	17	53.2	138.8
NT13416	3776	4454	3714	3981.3	5	53.8	137.4
NT14407	3552	4107	3487	3715.3	8	51.7	135.3
NT14433	2860	2744	2943	2849.0	25	61.3	138.5
NT15406	4011	5085	3919	4338.3	2	48.4	133.8
NT15421	2989	3796	2864	3216.3	21	52.7	136.5
NT15425	2592	3471	2633	2898.7	24	57.8	137.2
NT15428	3563	3960	3866	3796.3	7	51.3	136.4
NT15440	3677	4074	3313	3688.0	10	54.5	139.9
NT441	2623	1918	2466	2335.7	30	61.5	144.4
OVERLAND	2741	2400	2850	2663.7	27	41.6	141.0
NT09404-1	3073	3937	3589	3533.0	15	53.5	139.3
GRAND MEAN	**3277.76**	**3614.56**	**3375.01**	**3422.443**		**53.2**	**138.3**
LSD	671.11	558.37	711.1				
CV	12.53	9.45	12.8				

The grain and forage yield for 2016 are: Note Lincoln site was affected by hail so we present average performance with and without the Lincoln grain yields included.

	Mead	Linc.	Sidn.	Avg.	M&S Avg.		TstWt	Protein	Moisture	Hdate	Height	Bacteria	**Forage**	**Forage**
	Grain Yld	Grain Yld	Grain Yld	Grain Yld	Grain Yld	**Rank**		Wheat Adj.		Julian		Streak	**Yield**	**Dry Matter %**
name	lbs/a	lbs/a	lbs/a	lbs/a	lbs/a		lbs/bu	%	%	D after Jan.1.	(in)	(1-9)	**lbs/a**	**%**
NT05421	3257	1872	3250	2793.0	3253.5	7	49.9	15.7	9.3	137.9	55.0	2.3	15593	0.282
NT06422	2445	1573	3066	2361.3	2755.5	21	46.3	15.3	8.7	137.1	52.0	3.1	12930	0.28
NT07403	3457	2617	2993	3022.3	3225.0	10	48.8	14.2	9.1	134.4	48.6	2.4	13074	0.288
NT12403	2936	2512	4074	3174.0	3505.0	3	49.8	14.5	9.3	135.6	50.0	4.1	12161	0.284
NE422T	1573	962	3149	1894.7	2361.0	28	50.4	16.6	9.6	148.2	61.3	1.5	11827	0.219
NT13416	3573	1943	3976	3164.0	3774.5	1	50.5	14.6	9.5	136.8	52.9	2.2	12918	0.286
NT13443	3185	1860	2723	2589.3	2954.0	16	50.9	16.6	9.1	141.1	60.2	1.2	14180	0.284
NT09423	1983	2312	3815	2703.3	2899.0	17	48.1	15.6	9.6	139.9	52.1	2.2	12029	0.275
NT11428	3471	2038	3359	2956.0	3415.0	4	50.0	14.8	9.2	139.6	57.4	2.3	12226	0.261
NT12406	1484	1275	3560	2106.3	2522.0	24	46.9	16.5	9.2	138.4	50.6	3.6	11828	0.266
NT12425	2701	1414	2984	2366.3	2842.5	20	49.5	16.7	9.2	140.6	55.5	4.0	13319	0.284
OVERLAN	1734	1659	2819	2070.7	2276.5	29	53.3	13.5	9.2	143.1	39.6	3.8	10929	0.279
NT06427	2965	2451	3482	2966.0	3223.5	11	45.9	15.6	8.9	138.8	48.1	1.6	12198	0.274
NE426GT	2297	2016	2759	2357.3	2528.0	23	48.0	15.2	8.8	139.1	51.0	3.0	13476	0.284
NT14430	1959	1635	2878	2157.3	2418.5	26	48.0	14.9	9.0	135.2	50.2	6.0	11281	0.313
NT14433	1773	1686	3046	2168.3	2409.5	27	50.3	16.2	9.3	139.4	60.1	3.3	13894	0.28
NT441	787	466	2732	1328.3	1759.5	30	45.1	15.3	9.4	147.0	59.0	3.1	10586	0.253
NT14407	3220	2293	3068	2860.3	3144.0	13	49.9	14.0	10.0	136.7	51.6	2.4	14370	0.294
NT15406	3949	2534	3108	3197.0	3528.5	2	50.6	14.0	9.1	134.7	51.0	2.2	13578	0.291
NT15410	2194	2225	3567	2662.0	2880.5	18	49.0	15.1	9.2	136.2	51.2	2.0	12771	0.272
NT15417	1827	2054	3882	2587.7	2854.5	19	48.1	15.6	9.0	138.4	52.5	1.7	12968	0.253
NT15419	2621	2660	3412	2897.7	3016.5	15	49.4	15.4	9.3	139.5	50.6	2.5	14124	0.276
NT15420	3173	1747	3065	2661.7	3119.0	14	48.6	15.1	9.0	139.8	53.5	1.5	11982	0.254
NT15424	2648	2492	2830	2656.7	2739.0	22	48.7	16.3	8.8	139.0	54.3	1.2	12696	0.271
NT15428	2792	1596	3705	2697.7	3248.5	8	48.9	14.9	9.9	135.2	47.8	3.0	12323	0.28
NT15429	2319	1796	4022	2712.3	3170.5	12	47.9	15.6	9.2	137.9	49.8	2.1	14692	0.271
NT15435	3105	1902	3525	2844.0	3315.0	5	48.5	15.7	9.1	140.2	54.7	2.1	12744	0.272
NT15440	3627	2684	2977	3096.0	3302.0	6	48.2	15.6	8.8	141.1	56.2	1.4	14209	0.261
NT15425	2068	1677	2916	2220.3	2492.0	25	49.2	15.5	9.2	138.7	56.9	1.6	14553	0.292
NT15421	3523	1953	2960	2812.0	3241.5	9	49.1	15.1	8.6	135.5	53.8	1.7	13686	0.312
Average	**2621.5**	**1930.2**	**3256.7**										**12971.3**	**0.28**
CV	**22.4**	**12.9**	**10.7**										**12.6**	**6.78**
LSD	**961.4**	**491.4**	**574.7**										**2295.1**	**0.03**

These trial results indicate that: 1. triticale produces more biomass and grain yield generally than wheat; 2. there is considerable GxE for forage yield; and 3. it very difficult to combine grain yield with forage yield. The comparison of triticale lines for forage was likely affected by different stages of harvest as seen by the different dry matter contents.

Of the lines tested in all the grain and forage trials, a few lines had good grain yield across the state, excellent forage yield in eastern NE. This highlights the need for testing our forage triticale lines in grain and forage trials across and beyond Nebraska.

The 2018 Forage data from western NE (thanks to Dr. Dipak Santra) are:

Name	yldkgha
NT07403	8713
NT09423	8880
NT13443	9943
NT441	9628
NT13416	8678
NT05421	10657
NT16404	11207
NT16402	7825
NT12425-1	8163
NT15406	7124
KWS Progas	9619
KWS Propower	9526
GRAND MEAN	**9163.48**
LSD	**2648.04**
CV	**20.09**

The KWS lines are hybrid rye lines, so it was interesting to compare them to winter triticale which are pure lines. The 2017 western triticale forage trial was lost due to weather.

The 2016 Forage data from western NE (thanks to Dr. Dipak Santra) are:

Name	Forage	Height
	Yield	
	lbs/a	in
NE422T	4659	47.0
NE426GT	4921	42.8
NT441	6261	44.8
NT01451	6741	46.0
NT05421	6098	43.0
NT06422	4553	61.0
NT07403	5808	50.5
NT09423	5900	43.5
NT11406	5534	44.3
NT11428	5065	45.8
Average	**5553.9**	**46.9**
CV	**17.5**	**15.2**
LSD	**1415.3**	**10.3**

The 2015 Forage data from western NE (thanks to Dr. Dipak Santra) are:

2015 Sidney Forage	Dry Forage Yield	Rank	Height	Mositure	Dry Matter
Name	lbs/a		(in)	%	%
NE422T	7605	1	68.0	0.65	0.35
NT01451	7452	2	46.3	0.58	0.43
NT06427	7290	3	46.0	0.55	0.45
NT06422	6794	4	47.0	0.61	0.39
OVERLAND	5811	5	38.3	0.57	0.43
NT07403	5344	6	41.8	0.64	0.36
NT09423	5251	7	47.3	0.63	0.37
NT11428	5235	8	53.8	0.63	0.37
NT05421	4310	9	51.0	0.61	0.39
NT11406	3356	10	45.5	0.62	0.38
CV	29.2		4.0	8.8	13.4
GRAND MEAN	5844.8		48.5	0.6	0.4
Heritability	0.3		0.9	0.1	0.1
LSD	2473.2		2.8	0.1	0.1

The three-year (2016-2018) grain-yield data summary for locations where we were able to harvest trials is presented below:

name	Grain Yield (lbs/a) Mead	Grain Yield (lbs/a) Linc.	Grain Yield (lbs/a) Sidney	**State Avg Yield lbs/a**	**State Avg. Hdate (d after Jan.1)**	**State vg. Heigh (in)**	Forage yldlbsa Dry	Forage dmpercent	Forage RANK
NT15406	3915.0	3663.0	3513.5	3697.2	137.5	47.17	3449.099	0.30	4
NT12403	3652.7	3601.3	3752.0	3668.7	138.7	46.95	3195.862	0.28	8
NT13416	3667.0	3291.3	3845.0	3601.1	139.6	50.54	3364.774	0.28	6
NT07403	3607.0	3493.3	3285.0	3461.8	137.1	45.64	3370.156	0.29	5
NT11428	3679.3	2997.7	3607.0	3428.0	141.7	54.00	2980.993	0.26	12
NT14407	3560.7	3423.0	3277.5	3420.4	138.9	48.99	3594.39	0.28	3
NT15428	3413.7	3047.3	3785.5	3415.5	138.7	46.74	3146.22	0.28	10
NT15440	3648.7	3366.7	3145.0	3386.8	142.5	51.92	3300.775	0.27	7
NT12425-1	3212.3	2983.3	3651.5	3282.4	140.0	44.96	3155.798	0.27	9
NT06427	3203.3	3187.0	3425.0	3271.8	140.6	45.53	3061.126	0.26	11
NT05421	3487.3	2971.3	3067.0	3175.2	141.1	51.81	3644.113	0.26	1
NT09423	2779.7	2811.7	3611.0	3067.4	142.1	47.69	2964.988	0.26	13
NT14433	2634.0	2592.0	2994.5	2740.2	141.2	56.72	3600.66	0.28	2
OVERLANI	2665.0	2427.0	2834.5	2642.2	143.5	38.08	2787.096	0.26	14
NT441	2331.3	1794.0	2599.0	2241.4	146.9	55.68	2774.629	0.24	15

The three-year (2015-2017) grain-yield data summary for locations where we were able to harvest trials is presented below:

	Grain Yield (lbs/a) Mead	Grain Yield (lbs/a) Linc.	Grain Yield (lbs/a) Sidney	**State Avg Yield lbs/a**	**Rank**	**State Avg. Hdate (d after Jan.1)**	**State Avg. Height (in)**
NE422T	1980	1546	2779	2121	**15**	138.3	52.2
NT05421	2709	2492	3067	2758	**8**	138.9	52.4
NT06422	2439	2394	3320	2694	**11**	138.2	51.2
NT06427	2694	2776	3425	2914	**5**	138.5	55.5
NT07403	2665	2878	3285	2831	**6**	141.0	54.4
NT09423	2180	2705	3611	2770	**7**	140.5	51.0
NT11428	2889	2447	3607	2933	**4**	143.3	60.9
NT12403	2677	2871	3752	2963	**3**	140.5	50.6
NT12406	2268	2215	3746	2704	**10**	138.9	55.1
NT12425-1	2673	2664	3652	2979	**2**	142.4	54.1
NT13416	2931	2728	3845	3124	**1**	137.3	46.2
NT14407	2732	2406	3278	2660	**12**	143.0	54.5
NT14433	1935	1976	2995	2198	**13**	140.1	55.5
NT441	1661	1115	2782	2152	**14**	137.5	51.3
OVERLAND	2577	1977	2973	2731	**9**	139.9	51.1

It is clear that we have made progress in grain yields in triticale and that normally triticale has a higher grain yield than winter wheat. Marketing remains the major limitation to improving triticale's impact in modern agriculture.

10. Collaborative Research on Wheat Diseases

Dr. Stephen Wegulo, Department of Plant Pathology, and his staff continue to inoculate our experimental lines with wheat stem rust and Fusarium head blight (FHB, research funded by the U.S. Wheat and Barley Scab Initiative), and as time permits with wheat leaf rust. We continue to improve the greenhouse tests for stem rust. With the advent of the new race of stem rust, Ug99 (which can overcome some of the previously very durable resistance genes in wheat which were the main genes used in our program), we have greatly increased our efforts to introgress and pyramid new genes with our existing genes through the use of molecular markers. AS he new race is in Africa, we hav continued our testing n Kenya as part of a USDA-ARS sponsored program and greatly expanded a program in Egypt which is cpapbe of screening lines for both stem and stripe rust resistance.

Work continues on introgressing the resistance from *Agropyron* (*Wsm1*), but there appears to be a significant reduction in yield with the gene which may preclude its widespread use. The newer source for resistance/tolerance, *Wsm2*, developed by Scott Haley (CSU) in collaboration with KSU is also being introgressed. It seems to have less effect on agronomic performance, but also may not be as effective in Nebraska as *Wsm1*. Thanks go to Dr. Gary Hein, entomologist, who is testing them in the field. The frequency of lines carrying *Wsm1* resistance remains far lower than expected. With the continued spreading of wheat soilborne mosaic virus into our Lincoln fields (a key early generation testing site), we are now able to select for wheat soilborne mosaic virus resistant lines and many of lines have this beneficial trait.

11. Fusarium Headblight (FHB) Breeding Research: F. Wang, S. Wegulo, G. Bai, P. S. Baenziger

In previous research, we found *Fhb1,* a major gene for scab (syn. Fusaium head blight) tolerance, was not pleiotropic or linked to genes that reduce grain yield. We are using high yielding *Fhb1* lines from segregating populations and Wesley *Fhb1 or* Overland *Fhb1* in our crossing block. For the first time, we are seeing lines in our multiple-location observation nursery that contain *Fhb1,* indicating our breeding strategy is beginning to work. The backcrossing approach is probably the best way to move needed genes into adapted line for further wheat improvement. Ms. Fang Wang discontinued her work on the detached leaf assay (a high risk, but potentially very valuable approach to screening thousands of lines for FHB tolerance) as it did ot work for all of the known tolerance cultivars. She continues to work on using genomic selection for enhance FHB tolerance. We wish to thank the **U.S. Wheat and Barley Scab Initiative** for the continued funding to evaluate our lines for scab tolerance.

12. Prospects for Selecting Wheat with Decreased Cadmium Concentration in Grain: C. Liu, M. Guttieri, P.S. Baenziger, D. Rose, and B. Waters

Wheat (*Triticum aestivum* L.) is a primary staple cereal and a significant source of mineral nutrients in human diets. Therefore, decreasing concentration of the toxic mineral, cadmium (Cd), could significantly improve human health. Previously we found, grain Cd concentration of some genotypes grown in Nebraska trials were above the Cd Codex guidance level (> 0.2 mg kg-1), and highly repeatable differences in grain Cd were found between pairs of low and moderate-Cd commercial cultivars. Grain Cd concentration was predicted by Cd concentration in aboveground plant tissues at anthesis. Genome-wide association scans using high density SNP markers identified markers on 5AL associated with grain Cd in a region homoeologous to the Cdu1 locus on 5BL in durum wheat (*Triticum turgidum* L. var. durum Desf.). Our current work is to study the uptake of Cd, and ways to select for lower Cd. In a recent study, a recombinant inbred population segregating for grain Cd concentration was used to assess the efficacy of two selection methods for decreasing grain Cd concentration in bread wheat: a hydroponic selection method used shoot Cd concentration in 2-wk-old seedlings growing in Cd-containing medium, and a marker-based selection method using markers linked to *heavy metal transporting P1B-ATPase 3* (*HMA3*), the gene underlying Cdu1. Both methods effectively selected low-Cd lines. The *HMA3*-linked marker-based selection was superior to hydroponic selection in terms of both simplicity and response to selection. The *HMA3*-linked markers explained 20% of the phenotypic variation in grain Cd concentration with an additive effect of 0.014 mg kg^{-1}. The hydroponic selection and marker-based selection may target two different and independent processes controlling grain Cd accumulation, and they had no effect on grain Zn and Fe concentrations. The ALMT1-UPS4 marker associated with Al tolerance was not associated with grain Cd concentration but increased grain Zn and Fe concentrations. The 193-bp allele of the *Rht8*-associated marker, GWM261, was associated with increased grain Cd concentration.

We are building a $F_{7;8}$ population of Wesley x Panhandle by single seed decent as an additional more homogeneous population of lines.

13. Hybrid Wheat: N. Garst, A. Easterly, H. Donoho, S. Blecha, Y. Delen, S. Palai-Delen, P.S. Baenziger, A. Ibrahim (Texas A&M University), J. Rudd (Texas A&M University), and Bhoja Basnet (CIMMYT) Saaten-Union Recherche in France, Jochen Reif (the Leibniz Institute of Plant Genetics and Crop Plant Research in Germany), and Friedrich Longin (University of Hohenheim in Germany)

One of the great opportunities and challenges for wheat improvement is the development of hybrid wheat. Currently numerous companies have hybrid wheat breeding efforts with Saaten-Union Recherche being one of a few companies that markets hybrid wheat. Our belief is that the public sector needs to have a public, transparent hybrid wheat breeding effort to advance the science and educate the next generation of plant breeders. We have been working on hybrid wheat for the past 5 years. As of January 2018, our efforts on developing a public, transparent hybrid wheat platform took a major step forward with the successful receipt of a NIFA-IWYP grant for hybrid wheat development. The University of Nebraska will be the lead institution and will work closely with Texas A & M University, Kansas State University, Saaten-Union Recherche in France, the Leibniz Institute of Plant Genetics and Crop Plant Research in Germany led by Jochen Reif, and the University of Hohenheim in Germany led by Friedrich Longin. This grant is for 3-years and will support additional testing of hybrids as well as fund research into some of the key questions regarding hybrid wheat production. In this research we have 4 main objectives.

Objective 1: Screen two large wheat breeding programs for the floral and plant traits needed for efficient hybrid seed production and performance.

This objective directly relates to the need to have a viable hybrid wheat production system that enhances cross pollination. The expected outcome will be to identify lines with excellent male and female floral characteristics including response to the CHA and in CMS backgrounds

Nebraska: In 2018, screening for anther extrusion was very difficult due extreme heat at flowering (39°C during the day) which led to temporary drought stress as determined by leaf wilting in the afternoons, also. The plants recovered overnight, but the effect of heat and drought on anther extrusion and pollen shed were obvious (see below for yields from the hybrid crossing block). The anthers in our best anther extrusion lines were greatly reduced and many lines with poor anther extrusion trapped their anthers. Similarly pollen shed duration was considerably less (discussed below). The Genotype by Environment interactions are high for this trait which was expected. As previously reported, screening in the greenhouse often did not predict anther extrusion in the field. In 2018, we evaluated for the second year, 299 lines the Hard Winter Wheat Association Mapping Panel (HWWAMP) developed as a resource for the Great Plains by the previous TCAP grant. The HWWAMP will be used in genome wide association studies to map QTLs for anther extrusion as these lines are already genotyped. As part of our chemical hybridizing agent (CHA) crossing block, we have noticed that the highest yielding crossing blocks are those where the delay between the male and female lines is good (females gape a few days before the males reach maximum pollen shed) and the male is an excellent pollinator as visually determined by anther extrusion. The CHA sprayed female lines in the crossing block were scored for gape date, duration of gaping, stigma exsertion, and gape closure to begin to understand the female side of hybrid wheat production. The gape day was recorded when 50% of the plot was gaping, and when 100% of the plot was gaping. Gape angle and stigma exsertion were both scored on these days. 50% gape day ranged from 143 Julian days to 152 Julian days in the hybrid crossing block. For example, hybrid seed production is consistently good when Freeman was used as a pollinator. Working with our German cooperators who identified two excellent anther extrusion lines (‘Piko’ and ‘Henrik’) for Europe, we have begun introgressing that germplasm into our lines. We sent our best male lines to Germany, but our lines are very early in those environments, hence unsuitable as parents. In addition, we received four rye introgression lines for chromosome 4R. Another 4R introgression line had been reported to enhance anther extrusion, but is generally unavailable. Two of the four lines had excellent anther extrusion and have been crossed to our germplasm. Finally, advanced derivatives from introgressing restorer genes from the Australian R-line (restorer line collection) were identified as having excellent anther extrusion which was to be expected as these were commercial hybrid male parents.

To better understand our CHA hybrid system and also to develop the cytoplasm male sterile system (CMS) using the *Triticum timopheevi* cytoplasm, in 2017, we planted seven backcross-5 alloplasmic lines (e.g. lines with an elite wheat line nucleus and the *timopheevi* cytoplasm, which should be sterile) with sufficient seed to plant a plot. These plots were surrounded by a mixture of herbicide tolerant males that differed for anthesis date with the idea that we can harvest and plant the F_1 seed. Seed production in 2017 on the CMS females was excellent (ranged from 918 g/plot to 2132 g/plot with similar plots of self-fertile cultivars having yields up to 2800 g/plot).

In 2018, we planted the progeny of these crosses in three plots and sprayed two of the plots with a low level of the herbicide. By spraying the F_1 plants which will be heterozygous at two herbicide tolerant loci, we hoped to kill any selfs or outcrosses to herbicide sensitive lines as a way of enhancing hybrid purity which could be valuable in commercial production fields. The herbicide spray may have reduced grain yield and both the sprayed as determined visually and by pollen proof bags and unsprayed plots as determined visually were highly sterile. The average grain yield in sprayed plots was 340 g, and the average grain yield in the unsprayed plots was 485 g (average of all CMS plots was 390 g). All seven unsprayed plots were consistently higher yielding than the fourteen sprayed plots, but that could be due to some of the plots having pollen proof bags (hence not able to be pollinated) or due to the effect of the herbicide. The CMS progeny were also bagged with the idea that the bags would be removed after periodic intervals to estimate how sterile the lines were and how long the stigma will be receptive to pollination. Our original intent was to remove the bags 3, 5, and 7 days after gaping in the unbagged plants, but due to the heat, we removed them 1, 2, and 4 days after the plot gaped. The data on length of stigma receptivity/pollen shed are currently being analyzed.

Texas: We have screened TAMU wheat breeding nurseries (SOBS, AOBS, STP1-STP4, and AP1-AP10) and lines from UNL (NIN, TRP, IRDR, RPN; approximately 600 lines) for floral characteristics in spring 2014, and 100 promising lines were selected and planted at College Station during fall 2014. A set of promising 180 TAM germplasm lines, selected for floral characteristics, was planted in the field at College Station and McGregor in fall 2016 (representing STP 1 – 4, TXE, UVT) to look at genotype-by-environment interaction for anther extrusion and female stigma exertion and gape. We have evaluated 80 lines representing the Texas Uniform variety Trial (UVT) and Texas Elite (TXE) flor male (anther extrusion and anther score) and female (gape and stigma exertion) floral characteristics in the spring of 2017 and 2018. To obtain reliable readings of the female traits, we applied Croisor® 100 chemical hybridizing agent at Zadocks 34 stage in 2018. We have also taken notes on days to anthesis and plant height on all entries. All gender and non-gender traits were significantly different among lines in both UVT and TXE trials. Repeatability of the non-gender traits (days to anthesis and plant height) were high (0.90 – 0.98) in both 2017 and 2018. Repeatability of anther extrusion and anther score were moderate to high (0.62 – 0.70) whereas repeatability for the female traits were generally poor (0.05 – 0.37). Our program will continue to evaluate lines and UVT, TXE and advanced yield trials for both male and female floral characteristics.

3.2. Objective 2: Create and test hybrids to establish and confirm initial heterotic pools in wheat. All heterotic pool development begins with creating and testing hybrids.

The expected outcome is to gain a better understanding on how best to use Croisor® 100, determine the level of heterosis currently available in hexaploid hard winter wheat, and identify parental lines for future heterotic groups.

Nebraska and Texas: We continue to use Croisor® 100 to make hybrids. We continue analyzing the data, removing the spatial variation, comparing reciprocal crosses, and estimating heritability and heterosis from our 25 x 26 crossing block with the emphasis on determining the genetics of heterosis.

We successfully used the balanced missing design pioneered by our German cooperators for the 2017 and repeated it in 2018 crossing blocks. In this crossing block, we had 50 males and 100 females (total of 150 lines with 25 males and 50 females selected by both UNL and TAMU) where each male was crossed to 14 females. To ensure that environmental hazards did not destroy the crossing block, we grew three crossing blocks (1 in NE and 2 in TX). The NE (25 males and 100 females) and one of the TX (the remaining 25 males and the same 100 females) crossing blocks worked very well with a range of seed produced from 65g to 2070g with an average of 657g in Lincoln and 24g to 1182g with an average 326g in Texas in 2017. The harshness of the environments in 2018 reversed the hybrid seed production with Texas producing hybrid seed under irrigation from 418 g/plot to 2697 g/plot with an average of 1595 g/plot and Nebraska with the extreme heat at flowering producing hybrid seed ranging from 22.6g to 1781g with an average of 240g. By splitting the crossing blocks, we greatly lessened the potentially catastrophic loss of losing the crossing block. In addition, we have remnant seed from 2017 to fill in wherever we produced little seed in 2018. In this repeated crossing block, we confirmed that the flowering times in TX are considerably wider than at Lincoln, making it harder to estimate the anthesis to exposed stigma ”nicking” period when crosses should be most successful, however this may be overcome by the increased tillering due to irrigation which tends to widen the pollination period. The seed from both 2018 crossing blocks was sent to Lincoln for designing the hybrid yield trials for six locations (three in Nebraska [one is already planted] and three in Texas). We also had a small experiment to study CHA rates and different adjuvants to reduce phytoxicity and the amount of chemical needed to sterilize wheat plants. In 2017, the trial was successful, but we were able to obtain more of the European surfactants/adjuvants for the 2018 trial. The surfactants allow lower rates of the CHA to be used, hence less phytotoxicity. In the 2018 trial, we sprayed at the optimal growth stage and had excellent sterility in three of the four genotypes tested. NI13706 was a difficult line to sterilize in 2017 and remained so in 2018. The window of CHA application is narrow (perhaps to due the warm spring in 2018) and a four day later CHA application resulted in much lower levels of induced sterility.

As part of our international collaboration, we grew a small hybrid trial developed in Germany. As expected the German hybrids and parent lines were late developing compared to Nebraska lines. However, many of the later lines yielded well. We are unsure if there later development allowed them to escape the heat at flowering and if they benefitted by later rains after many Nebraska and Texas lines were already senescing.

3.3. Objective 3: Genotype the lines going into the heterotic pools and improve algorithms to separate lines into maximum likelihood pools for future testing and validation.

With the advances in genomics and genomic predictions, we will be able to estimate many more hybrid combinations than we can test which greatly improves the efficiency of heterotic pool development. The expected outcome is to determine lines with the best male and female floral characteristics and assignment to respective heterotic pools to improve heterosis and hybrid seed production efficiency in hexaploid wheat. We will have to wait until the hybrid yield trials are conducted in 2018 and 2019 to start working on developing the heterotic groups and patterns. The work that has been accomplished so far related to this objective is described in detail here:

DNA isolation, genotyping-by-sequencing, and SNP calls: All of the 150 parents have now been genotyped. Most were genotyped in 2017 and those that failed were genotyped in 2018. The detailed description of the methods of DNA isolation, genotyping using genotyping-by-sequencing (GBS), SNP calling using the IWGSC Ref Seq v1, and population structure of the parental lines and insilico generated hybrids (~11,175) using high-quality SNPs were described in the 2017 report and are not included in this report.

Genomic analysis of the diallel experiment: We have started the genomic analyses of the ~650 hybrids that were made using a full diallel design comprising 26 parents in 2015 and 2016 and the hybrid yield trials conducted in 2016 and 2017 at six locations (three in NE and three in TX). Although this work is not part of this grant, the knowledge and understanding gained will be relevant to the hybrid wheat efforts. Also, the analysis workflow built with the diallel experiments can easily be extrapolated to the larger crossing block used in the current grant. As a preliminary effort, we have mostly explored the experiments conducted in Nebraska. Once we have the analysis pipelines built, we will start exploring the experiments conducted in Texas. The yield data of the hybrids grown at three Nebraska locations were analyzed after accounting for spatial variations using ASREML-R. The complete details of the trial and phenotypic data analysis were described in the 2017 report as well in the doctoral dissertation of Dr. Amanda Easterly. The manuscripts describing this work are currently being prepared. The broad-sense heritability was relatively higher (~0.45) across the six environments (three Nebraska locations tested for two years). We also estimated heritability by adding environments sequentially in a two-stage analysis, and the heritability ranged from 0.24 across two environments to 0.68 across six environments. This result suggests that the data are robust and of sufficiently good standard for genomic analysis including genomic predictions. The 26 parental lines were genotyped using GBS and the SNP calls were made using the IWGSC Ref Seq v1 as the reference genome. After quality filtering, ~40,000 high-quality SNPs were available across the parental lines and the insilico generated ~650 hybrids. The population structure of the parental lines was investigated using both phylogeny (clustering) and principal component analysis. We did not observe any strong population structure and as observed within the panel of 150 parental lines, there were mainly three clusters – one containing just Nebraska lines, and the other containing just Texas lines, and a third one containing both Nebraska and Texas lines. This result was expected as the germplasm is shared between the two breeding programs annually. We noticed in Nebraska, the NExNE and NExTX crosses generally yielded higher than the TXxTX crosses. This result is in agreement with the data from in TX where they observed an opposite scenario, TXxTX and TXxNE crosses yielded higher than the NExNE crosses. This result is primarily due to the local adaptation of the parental lines and the hybrids made by crossing these adapted lines.

Further, we investigated whether there was a correlation between genetic distance (kinship) between parents involved in the crosses and the hybrid yield using the 674 hybrids tested across six environments in Nebraska. We noticed a negative trend between kinship coefficient and yield with Pearson's correlation coefficient being -0.07 and p-value < 0.1 (Figure 1). This result indicated that kinship between parents was moderately negatively correlated with yield. This finding is similar to what is observed in other hybrid crops such as maize, where generally crosses such as between Stiff Stalk and Non-Stiff Stalk (higher genetic distance and lower kinship between the lines in the two groups) tend to yield higher than the crosses made within the same group. It should be noted that the heterotic groups do not currently exist in wheat but the correlation observed between genetic distance and yield is certainly encouraging to establish them.

Next, we estimated the relative contribution of additive, dominance, and epistasis on hybrid yield using molecular markers and Bayesian generalized linear regression in BGLR R-package. The preliminary analysis suggests additive effect as the major contributor of the phenotypic variance of the diallel hybrid yield. The dominance and epistasis effects had relatively lower effects and majority of the variance was unaccounted for and was part of the error variance. The fact that additive effect was a major contributor was not surprising as the heterotic groups are currently lacking in wheat and this needs to be established going forward. It is important to note that majority of the variance is part of the error variance. This error variance suggests we may have to account for additional sources of phenotype and factors beyond just the molecular markers.

Lastly, we performed predictions using genomic best linear unbiased prediction (GBLUP) model in the BGLR R-package and genomic estimated breeding values for yield were obtained. We tested running the GBLUP model with just the additive effect as well as including both the additive and dominance effect. Including the dominance effect did not increase the predictive ability (correlation between observed and predicted values) and thus the results including the additive effect in the GBLUP model are briefly discussed. The cross-validation scheme was designed to investigate how well genomic prediction can predict the yield of the hybrids. We divided the ~650 diallel hybrids in training datasets comprising 10% to 90% of the hybrids and predicting the rest of the hybrids. Each run was repeated 100 times and average predictive ability was estimated. The average predictive ability to predict 80% of the hybrids using the remaining 20% of the hybrids as training set was 0.60. Similarly, the average predictive ability to predict 90% of the hybrids using the remaining 10% of the hybrids as training set was 0.52. We also noticed quite a bit of variation while predicting the randomly chosen 90% of the hybrids using the remaining 10% as the training set in each of 100 runs. Nevertheless, it is encouraging to observe the relatively high accuracy and smaller variation across the 100 replicates while predicting 80% to 90% of the hybrids using as few as 20% to 10% of the hybrids in the training set. Finally, it is also important to point out that heritability was a major factor determining the accuracy of predictions in our predictions. Hence, this should be strongly considered while running the predictions on the hybrids made in the newer balanced missing crossing block with 150 parental lines.

Hybrid yield trials in 2018: All six-hybrid yield trials (augmented designs using incomplete block designs with iblocks of 50 [40 hybrids and 10 commercial checks where 3 checks were from TX, 3 checks were from NE and 4 checks were completely unrelated to the TX or NE parent gene pools]) were harvested in 2018 (representing over 4000 harvested plots). The yield trials also included a few randomly chosen parental lines (~24) and all 10 checks grown once as entries (which would allow us to estimate commercial heterosis with respect to each of the 10 checks). We have conducted preliminary phenotypic analysis on the yield trials grown at three locations in Nebraska (Alliance, North Platte, and Lincoln). Once the workflows are built, we will subsequently investigate the experiments grown in Texas. The yield values were analyzed after adjusting for spatial variation in the fields using ASREML-R and Best Linear Unbiased Predictors (BLUPs) were generated for each hybrid, small subset of inbred parental lines, and the 10 check genotypes that were grown once as entries. At each of the three locations the highest yielding genotype was a hybrid. The hybrid yield at Alliance ranged from 3524 to 5259 kg/ha, North Platte – 2959 to 4035 kg/ha, and at Lincoln – 3396 to 5878 kg/ha. Lincoln was the highest yielding location followed by Alliance and North Platte. At North Platte, the performance of the genotypes was very different from the other two locations. It was a harsher environment with reduced yields. However, as is expected in other hybrid crops, in challenging environments, hybrids tend to perform better than the inbred lines. This better performance under stress was apparent in North Platte with overall the hybrids performing better than the inbred check genotypes and parental lines. Plant height recorded at the three locations indicated that the hybrids were significantly taller than the inbred lines with height of the hybrids ranging from 71 to 109 cm (Alliance), 56 to 99 cm (North Platte), and 66 to 112 cm (Lincoln). Hybrid vigor was apparent for plant height (please see section below on heterosis for more details). We also recorded heading date, physiological maturity, and lodging at Lincoln, NE. As was expected the heading date window was narrower for both inbred checks and hybrids (142 to 149 Julian days). We noticed the hybrids overall matured a bit later than the inbred checks with the range of hybrid physiological maturity values ranging from 161 to 174 Julian days and inbred checks 161 to 168 days. Minimal lodging was observed in the check and the hybrid genotypes with the exception of two genotypes. The inbred checks TAM113 and Robidoux were prone to lodging compared to the other genotypes.

The phenotypic analysis of the yield also suggested large genotype-by-environment (GxE) effects (Figure 2) which means that hybrids will need to be tailored to fit specific regions in the Great Plains. We noticed several patterns of clustering among the hybrids. For instance, there were hybrids that were high-yielding in one location and were among the lowest yielding hybrids in other two locations (Figure 2). Interestingly, we also noticed a subset of hybrids that were consistently higher-yielding in two or three locations. These were mainly NExNE or NExTX crosses. The hybrids that yielded higher in multiple locations are included in replicates in 2019 yield trials to get better estimates for these hybrids. The broad-sense heritability for yield was highest at Lincoln (0.56) and relatively lower at Alliance (0.28) and North Platte (0.26). Unfortunately, the large GxE effects also means that the across locations heritabilities will be lower. The heritability estimated across all three locations using a one-stage model was 0.20. We also estimated heritability by adding locations sequentially using a two-stage analysis using the BLUPs from the first-step – Alliance + Lincoln=0.26, Alliance + North Platte=0.19, Lincoln + North Platte=0.14, and Alliance + North Platte + Lincoln=0.21. The relatively lower heritability can affect our genomic predictions and our ability to define heterotic pools. The yield trials will be repeated at six locations in 2018-2019 and 2019-2020 to add more testing site data, providing increased opportunity to increase heritability, and hence more power for our ability to predict heterotic pools. All of the trials will have 750-850 plots (representing over 5000 planted plots). In addition, we decided to add a parental line trial at four locations so we will have parent-hybrid heterosis estimates in addition to commercial heterosis estimates in the same environments where the heterosis is expressed.

The IPK Gatersleben has developed a three-step approach for genome-based establishment of heterotic patterns. We support the consortia with the implementation of the three-step approach using data from hybrid wheat trials in the project. In the reporting phase, we employed an undergraduate student supporting the transfer of know-how in the simulated annealing algorithm. The 2018 and 2019 data will be used in this annealing algorithm.

Heterosis estimates for yield in 2017-2018 hybrid yield trials at the three Nebraska locations: We estimated commercial heterosis using the 10 check genotypes that were grown once as entries in the hybrid yield trial conducted at three Nebraska locations. The commercial heterosis was estimated as: (Hybrid-yield – Check-yield)/Check-yield * 100. The commercial heterosis at Alliance ranged from -28.3 (with respect to Freeman) to 22.7 (SY Wolf), North Platte: -15.5 (TAM304) to 28.1 (SY Wolf), and Lincoln: -38.5 (Gallagher) to 47.4 (TAM113) (Figures 3 – 5). Some of the checks are not well adapted to Nebraska environments and thus the increased heterosis estimates may be biased. However, it should be remembered that growers when chosing a line, must use previous data that may not well predict the next year's data. We also investigated the number of hybrids that outperformed the best performing check in each of the locations. In Alliance, there were 9 hybrids that yielded higher than the best performing check, Freeman. At North Platte, 200 hybrids outperformed TAM304 (best performing check), and at Lincoln 18 hybrids exceeded Gallagher (highest yielding check). The large number of hybrids performing better than the best performing check at North Platte was not surprising, as previously mentioned North Platte was a harsher environment, and as mentioned earlier, the hybrids overall outperformed the checks and inbred lines in this location. Using the small subset of inbred parental lines grown at the three locations, we compared the performance of the parent-hybrid trios. The hybrid vigor was apparent for plant height at all locations and for yield at North Platte. Which indicated that our hybrids were different from the female parent lines that were included in the trial. Note, the parental trial planned in 2019 will allow for robust mid-parent, high-parent, and commercial heterosis (using the released cultivars grown as checks in the trial) estimation of parent-hybrid trios and more importantly at the locations where the heterosis is expressed and observed.

3.4. Objective 4: Map restorer genes in *T. timopheevi* cytoplasm and create a series of CMS tester lines, their maintainer lines, and a series of elite restorer lines (R-lines) and begin to determine the efficacy of CMS-based hybrid systems.

Cytoplasmic male sterility is one of the two most commonly used wheat hybrid production systems, so it must be explored and improved. The expected outcomes will be to identify and tag R-genes for the *T. timopheevi* male sterile cytoplasm, the effect of CHA on different male sterile cytoplasms with restorer genes, new R-lines for the *T. timopheevi* cytoplasm, and a random mating population in the *T. timopheevi* cytoplasm.

Fertility Restoration (*Rf*) gene mapping at CIMMYT

For genetic mapping of fertility restoration, an Australian restorer source with *T. timopheevii* cytoplasm was crossed with a CIMMYT line (*T. aestivum* cytoplasm) and the progenies were advanced to the F4 generation to develop a recombinant inbred population (Figure 6). To ensure self- pollination in each generation, some spikes from each family were covered with glassine bags before flowering, and one random spike was harvested to advance population through single head-descent. A total of 299 $F_{4:5}$ recombinant inbred lines (RILs) were planted in the greenhouse in El Batan CIMMYT. Five heads per line were bagged before flowering to prevent pollen contamination and upon maturity, notes were taken on total number of spikelets per spike, sterile spikelets per spike and total number of seeds per spike. In addition, each RIL was crossed with a sterile tester and test cross progenies were evaluated in the field (Figure 7). The test cross progenies were visually rated in 1-10 scale for F1 fertility restoration. Comprehensive data on number of sterile spikelets per spike and total seed set of the test cross progenies is currently being calculated using 10 bagged spikes per cross.
Leaf tissue was harvested from the RIL population in the greenhouse and genotyped with 19000 SNP chip from TraitGenetics. The 19000 SNPs were filtered for monomorphism and the consensus genetic map location and physical location of the markers were extracted from the newly published wheat genome assembly. A total of 5995 markers were polymorphic and were used in genetic mapping. The

test cross visual observation, total seeds per RIL and total sterile spikelets per spike were used to conduct a marker trait association using single marker regression method in QTL ICI mapping software. Significant marker trait associations (LOD$\geq$4) were observed in chromosomes **1A, 1B, 1D, 6B** and **7B**. These loci might represent some of the previously reported *Rf* genes in A and B genome, and potentially a novel one in D genome. A common set of markers in 1A and 1B were found to be consistently associated with different traits evaluated in RILs and their test cross progenies. A high quality genetic map specific to the cross is being constructed using the markers and consensus genetic map positions. After preparation of the genetic map, composite interval mapping algorithm will be used to seek better confidence intervals of QTLs and their estimates of effect on fertility restoration.

Development of CMS tester lines

A new set of *T. timopheevii* CMS tester lines have been developed at CIMMYT via repeated backcrossing. After BC4 in the greenhouse, the A-Lines are being multiplied in isolation using corresponding B-Lines. These A-lines will be useful to produce and test CMS hybrid with proven R-lines, and they can also be used to study the seed production efficiency under different production schemes in the future.

Texas: We will continue to backcross our CMS lines to their maintainers in a greenhouse at College Station. We anticipate growing these A-lines lines in the field in fall 2018. We have been making crosses between adapted Texas male parents to several restorer sources to develop R-lines. The joint effort on mapping restorer genes will be utilized in our marker-assisted backcrossing efforts and is expected to help us pyramid restorer genes. A minimum of three different restorer genes is needed for full restoration of fertility in the A-lines.

Nebraska: We will continue to make backcrosses to our elite lines to develop CMS females and work with increasing female seed in the field. We have made a number of spring R-line crosses to NE winter males and are selecting for winterhardiness, male fertility, and agronomic performance. The progeny of our first set of R-lines x B-line crosses to create new R-lines in an adapted winter background are in the F_7 generation. After very useful discussions with our colleagues in industry, we worked our headrow nursery very hard at flowering to identify headrows (F_4) lines that were very fertile. The big disappointment was that many of the tagged headrows at harvest were completed shattered out. Shattering is rare in Lincoln, but this was year was the worst in my 32 years in NE. Of course, no grower wants shattering, so it we certainly were able to select against that trait. It should be noted that every head previously selected looked fertile when threshed. However, some headrows were completely sterile indicated that some of the harvested spikes were either weakly restored in a year with little stress (2017) or that the lines was extremely receptive to cross pollination. We will have to tag heads with excellent fertile anther production and extrusion in segregating populations at flowering. We will also begin intercrossing restorer line progeny to pyramid restorer genes as we wait for molecular markers to facilitate this work.

V. GREENHOUSE RESEARCH

Since 2012, the majority of F_1 wheat populations were grown at Yuma, AZ. Mainly populations needing additional crosses are being grown in the Lincoln Greenhouses. This change reduced our greenhouse space and greenhouse labor, and provided much greater quantities of F_2 seed. We made more than 100 triticale, 100 barley and 1000 wheat crosses in last year's fall, winter, and spring greenhouses.

VI. PROPRIETARY RESEARCH

Public Private (University of Nebraska) Collaborations:

In 2009, the University of Nebraska decided to sustain the wheat-breeding project via enhanced collaborations with commercial companies spanning the value chain. The University of Nebraska-Lincoln (UNL) has had a long-standing arrangement with BASF, providing access to the Clearfield technology. Infinity CL and Settler CL are outcomes of this research. We have one lead 2-gene line, NHH144913-3 that was approved by BASF for commercial release, however it is a soft wheat and will need an identity preserved market. We continue our collaboration with Ardent Mills who support our McCook Nursery and provide valuable information on the end-use quality of our lines at that site. Southwest Nebraska is a key sourcing site for their Colorado mills. In 2010, UNL developed a collaboration with Bayer Crop Science that allows non-exclusive access to UNL germplasm and is in accordance with the principles for collaboration approved by the National Association of Wheat Growers and with the U.S. Wheat Associates Joint Biotechnology Committee. This collaboration has led to extensive collaborations and interactions on genetics, plant breeding, and crop physiology. Having their excellent staff in Lincoln has been very advantageous to student and staff interactions. In 2018, we planted more than 750 doubled-haploid lines created in collaboration with Limagrain and are evaluating lines at Mead. So far one line LCS Link has been released from this cooperative effort. In addition, it opened the door for marketing a winter triticale by Limagrain and LCS Bar was licensed to them, as was LCS Valiant. We hope that these collaborations will continue. KWS created a doubled haploid population so we can study anther extrusion from the cross Freeman (excellent anther extruder) x Camelot (a very poor anther extruder). Our cooperation on hybrid wheat is only possible due to a collaboration with Saaten Union Recherche (now Asur Plant Breeding) in France and we are truly grateful that we are able to cooperate with them. We have additional research agreements with other companies for sharing germplasm to testing lines to marketing lines nationally and internationally.

We continue to develop germplasm exchange agreement with private companies as their germplasm is becoming increasingly relevant. Our goal continues to be the “People’s University” and to work will all public and private wheat researchers in a manner compatible with the landgrant mission. With the current level of private sector investments in research, additional public-private interactions are to be expected and we are developing relationships with many other organizations. A key goal will be to develop working relationships that benefit the producer, the customer, and the public good.

USDA-ARS projects at the University of Nebraska are not party to these agreements.

VII. Winter Barley Research

We are sad to report that Paramount Seed Farms (a commercial seed company) went bankrupt and has recently been purchased. They no longer have the exclusive rights to our winter barley germplasm. We are fortunate that they took the initial risk of building a market for our germplasm when no one else was interested. No new barley lines were released in 2014-18, but P-845 (released in 2013). However, numerous new lines look very promising. and one new line are recommended for release as soon as the seed can be increased. After the Parmaount reorganization, future barley lines will be released non-exclusively. Non-exclusive releases are preferred by the American Malting Barley Association and by the Brewers Association, both of which are funding the barley efforts on malting barley. To optimize our barley breeding efforts, we have developed a breeding collaboration with the USDA-ARS at Stillwater OK (began in the 2017-2018 season) and a testing collaboration with the USDA-ARS in OK (began in the

2017-2018 season), Kansas State University at Hays KS, and with Dr. Dipak Santra at Sidney NE. We currently our testing our advanced lines in OK, KS, and NE. In 2018, Sidney was lost to storms. The data for 2018 are:

		Lincoln			Mead		Colby KS		Stillwater OK			Average	
	Yield	Height	Flowering	Height	Yield	Flowering	Yield	Test Wt	Yield	Flowering	Height	Yield	Rank
			Data			Data				Data			
	lbs/a	in	D aftr Jan.1	in	lbs/a	D aftr Jan.1	lbs/a	lbs/bu	lbs/a	D aftr Jan.1	in	lbs/a	
Name	aadn_ln18	htin_ln18	hdjd_ln18	htin_m18		hdjd_m18	ydlb_cks18	twt_cks18	ydlb_ok18	hdjd_ok18	htin_ok18		
P-954	3028	23.7	142.2	24.6	2297	145.5	2136	45.3	4248	111.7	28.3	2342	24
NB10444	2974	27.7	142.8	27.3	2330	147.3	2686	40.6	4163	112.4	29.0	2431	15
P-845	3456	25.0	137.0	25.4	2200	143.0	1862	42.1	3991	109.4	27.9	2302	27
NB11414	3196	24.7	139.6	22.9	2797	145.5	2296	43.0	3961	112.6	26.9	2450	13
NB11416	3356	25.3	138.5	25.4	2940	144.3	2248	45.1	3963	112.0	18.2	2501	7
NB12434	3090	24.7	140.9	23.5	2718	145.7	2149	48.0	4090	110.3	26.7	2409	17
NB12437	2880	25.0	142.8	25.6	2681	144.3	2901	43.0	4331	115.3	27.8	2559	4
NB14404	3571	26.3	137.4	24.3	2624	144.6	2049	43.2	4233	110.7	27.0	2495	9
NB14405	3147	27.3	142.6	28.3	2437	148.1	2633	44.2	3367	115.0	31.0	2317	25
NB14422	3823	24.0	140.6	22.7	2358	144.6	1982	41.9	4306	113.4	25.3	2494	10
NB14428	2852	24.0	142.3	24.5	1771	146.8	2146	42.8	4398	111.0	25.9	2233	30
NB14430	2819	24.3	139.6	23.4	2608	145.3	1929	47.3	4026	110.3	25.4	2276	29
NB15415	3490	25.3	140.0	25.9	2841	144.6	1985	49.7	4102	110.4	27.0	2484	11
NB15417	3162	25.3	138.8	26.9	2849	145.4	1930	45.7	4229	110.0	27.2	2434	14
NB15419	2829	24.7	141.5	26.3	NA	148.6	1978	41.7	4348	111.7	28.7	2289	28
NB15420	3508	27.7	137.0	26.4	3542	143.8	2095	46.4	4219	109.1	27.0	2673	2
NB15441	3199	25.0	139.6	26.4	3130	143.6	2158	47.1	4240	109.4	27.4	2545	5
NB15442	3362	26.3	139.9	25.1	2532	146.1	1948	45.8	4174	110.6	26.7	2403	19
NB16411	2732	31.0	137.0	26.8	2236	143.7	1748	46.1	2991	110.7	30.4	1941	37
NB16412	3153	25.7	141.5	25.3	2491	144.3	2215	44.5	4228	112.0	28.7	2417	16
NB16433	3024	26.7	138.5	25.9	2103	144.5	1877	45.5	3852	108.0	27.8	2171	31
NB16434	2245	26.0	140.9	23.5	1851	145.8	1671	42.5	3606	108.6	28.1	1875	38
NB16437	2506	28.3	137.2	25.3	2395	144.8	1981	42.2	3920	108.7	29.1	2160	32
NB17401	2783	28.7	142.0	26.8	3044	147.0	2453	46.8	4243	114.0	32.4	2505	6
NB17403	2865	28.0	140.7	26.9	2289	145.1	1650	38.1	3679	109.7	26.7	2097	35
NB17409	3179	27.3	142.4	25.5	2571	148.2	2542	43.9	4214	115.0	29.8	2501	8
NB17411	3293	28.7	141.0	25.5	2417	147.6	2662	44.1	3890	115.3	21.0	2452	12
NB17412	2919	26.7	142.1	24.9	2263	149.7	2601	44.5	4119	116.0	30.2	2380	22
NB17415	3032	26.3	141.1	26.8	3192	145.9	2396	45.3	4185	111.3	28.7	2561	3
NB17419	2750	24.3	136.7	24.9	2285	143.2	1135	35.2	4013	109.0	26.0	2037	36
NB17422	2943	26.7	141.5	27.0	1623	146.9	2092	42.3	3863	112.6	18.8	2104	34
NB17423	2907	26.7	141.6	23.7	2296	147.1	2238	39.9	4576	111.0	24.9	2403	18
NB17427	2814	23.3	141.0	25.0	1663	146.8	1856	41.3	4202	108.6	26.7	2107	33
NB17430	3362	26.7	137.2	24.4	2690	142.7	1884	40.0	4006	109.0	28.2	2388	21
NB17431	3370	28.3	141.3	28.7	3418	145.7	2541	44.6	4135	113.3	30.0	2693	1
NB17435	2337	27.3	138.6	26.0	2028	143.0	1380	35.2	3589	110.0	19.3	1867	39
NB17436	2504	29.3	138.6	27.7	2368	144.4	2573	36.9	4533	111.0	31.7	2396	20
NB17438	3056	24.0	137.4	25.2	2623	142.8	1741	42.4	4149	109.2	26.6	2314	26
NB17443	1324	35.7	139.2	32.9	1102	143.9	1441	29.5	2644	114.4	34.5	1302	40
NB10425	3242	27.3	141.7	28.4	2110	145.5	2240	41.6	4182	112.8	30.8	2355	23
GRAND MI	3002.1	26.5	140.0	25.8	2454.2	145.4	2100.7	42.9	4030.2	111.4	27.3	2316.6	
LSD	402.17	2.79	1.97	3.11	NA	2.29	442.78	4.87	433.81	1.17	9		
CV	8.19	6.48	0.86	7.37	8	0.96	12.89	6.95	6.58	0.65	20.2		

What is interesting in this data is that the checks P-845 (formerly NB99845) and P-654 (formerly NB86954) were in the lower half of the trial indicating we had many superior lines. With additional testing and seed increases, we expect a number of them to be released.

Unfortunately, in 2017, the Hays trial was lost to severe weather just before harvest (the most vulnerable time for barley if it survives the winter). However we had good winter barley trials in Nebraska and the data for 2017 are:

Name	Mead	Lincoln	Sidney	St. AVG.		Sidney	Heading	Height
	Yield	Yield	Yield	Yield	**Rank**	Test Wt.	date	
	lbs/a	lbs/a	lbs/a	lbs/a		lba/bu	Day after Jan. 1	inches
P-713	5096	4592	2945	4211	**36**	46.8	132.1	35.3
P-721	4614	4094	2937	3882	**40**	47.6	131.9	35.7
P-954	4664	4402	2912	3993	**38**	48.9	133.4	35.7
NB10444	5364	4830	3602	4599	**18**	47.7	132.6	37.1
P-845	4774	5599	3304	4559	**21**	48.2	132.3	34.4
NB11414	6054	5715	3945	5238	**5**	47.2	132.6	36.0
NB11416	5610	5853	3346	4936	**9**	48.1	132.2	36.3
NB11430	5131	5337	2904	4457	**29**	48.3	130.9	37.3
NB12419	4785	4959	3738	4494	**28**	47.7	134.2	36.5
NB12425	4226	5265	3694	4395	**34**	47.1	135.9	36.4
NB12434	6152	5731	3252	5045	**7**	48.8	131.0	36.4
NB12437	5991	5064	3341	4799	**12**	47.4	134.5	35.3
NB13401	5513	4447	3253	4404	**33**	47.9	132.2	35.7
NB13435	4915	4824	3953	4564	**20**	47.5	131.0	37.2
NB14404	6100	5588	2766	4818	**11**	48.3	131.5	35.8
NB14405	5067	4891	3803	4587	**19**	47.3	134.5	39.5
NB14412	4852	5193	3460	4502	**27**	47.1	134.7	33.9
NB14428	5492	5629	2972	4698	**16**	48	132.1	34.4
NB14429	5346	5672	2631	4550	**24**	48.4	131.6	35.2
NB14430	5546	5589	2542	4559	**21**	48.7	131.6	34.3
NB14433	5369	5950	3461	4927	**10**	47.5	131.4	35.1
NB14422	4998	6126	3893	5006	**8**	48	133.1	33.4
NB15414	4390	5634	3345	4456	**30**	48.1	131.4	34.4
NB15439	4505	4865	2294	3888	**39**	48.7	131.3	36.4
NB15420	6086	6348	3396	5277	**4**	48	131.3	35.6
NB15442	5966	5837	3603	5135	**6**	46.3	132.2	35.4
NB15440	4890	4688	3968	4515	**26**	47.2	131.9	36.2
NB15419	5800	5414	3166	4793	**14**	49.1	131.2	36.4
NB15441	6938	5485	3692	5372	**2**	47.4	131.6	36.5
NB15417	6487	6181	3488	5385	**1**	46.4	130.7	36.8
NB15443	5368	5753	3162	4761	**15**	47.9	131.6	36.9
NB15415	6489	5910	3649	5349	**3**	48.2	130.8	37.0
NB16409	4899	5625	2825	4450	**31**	46.8	130.5	37.2
NB16411	4963	5172	3837	4657	**17**	47.1	131.4	38.5
NB16412	5032	5169	3472	4558	**23**	46.1	131.5	36.9
NB16420	4585	4444	3626	4218	**35**	47.7	132.4	37.4
NB16429	5366	4555	3352	4424	**32**	48.8	133.3	36.3
NB16433	5294	5640	3462	4799	**12**	48.6	131.5	36.4
NB16434	4879	4965	2503	4116	**37**	48.6	131.0	36.3
NB16437	5325	4855	3442	4541	**25**	46.4	130.9	38.8
GRAND MEAN	**5323.08**	**5297.28**	**3323.37**			**47.74**		
LSD	**820.53**	**874.02**	**937.32**			**2.24**		
CV	**9.43**	**8.44**	**17.25**			**2.87**		

The 2016 winter barley data are:

Name	Colby	Mead	Sidney	Average	Rank	Anthesis	Height	Test Weight
	Yield	Yield	Yield	Yield		Date		
	lbs/a	lbs/a	lbs/a	lbs/a		D after Jan.1	in	lbs/bu
P-713	6164	3354	2585	4034	15	125.2	37.7	48.0
P-721	5766	2675	2354	3599	33	124.7	36.8	47.6
P-954	5492	3276	2398	3722	30	128.8	35.0	50.1
NB10417	5456	3027	2056	3513	35	122.7	38.3	46.5
NB10444	5741	3884	2360	3995	19	127.6	39.5	46.4
P-845	5976	3754	2494	4075	13	127.1	33.7	45.8
NB11414	5855	4168	2271	4098	12	126.2	36.9	49.3
NB11416	5797	4331	2798	4309	4	126.4	37.3	47.6
NB11430	5870	4356	2215	4147	11	123.8	38.0	49.1
NB12419	5888	3724	1963	3858	22	126.1	37.0	46.2
NB12425	6017	3917	2600	4178	8	129.0	36.5	46.1
NB12434	6419	4407	2053	4293	5	123.9	34.9	49.1
NB12437	5816	3757	2231	3935	21	129.1	35.0	47.4
NB13401	5675	3800	2659	4045	14	125.4	36.2	47.3
NB13435	6126	3093	2331	3850	24	126.6	38.0	49.0
NB14403	5950	2913	2705	3856	23	122.2	38.7	47.4
NB14404	5445	4346	2708	4166	10	124.4	36.7	47.3
NB14405	5650	3294	2342	3762	28	129.0	40.7	47.7
NB14412	6329	3785	2849	4321	3	126.0	33.5	44.6
NB14428	5764	4305	1925	3998	18	126.4	34.8	46.4
NB14429	5204	3712	2270	3729	29	125.2	35.6	48.4
NB14430	5513	4909	2542	4321	2	125.2	33.7	49.3
NB14433	5484	3833	2099	3805	26	125.0	35.2	45.7
TAMBAR 501	5876	3917	2164	3986	20	123.4	36.6	46.3
NB14422	5979	4133	2390	4167	9	125.3	33.2	44.5
NB15414	5573	3498	1603	3558	34	122.4	35.9	48.5
NB15439	5165	3766	1561	3497	37	126.1	37.1	48.1
NB15410	5681	2213	2027	3307	39	128.3	37.5	48.3
NB15420	6367	4350	2719	4479	1	123.2	36.4	48.2
NB15427	5043	3597	2437	3692	31	124.5	36.5	50.1
NB15409	5639	2391	2470	3500	36	128.8	38.1	48.3

NB15442	5902	3839	2306	4016	17	123.8	35.3	49.5
NB15412	4939	3132	1101	3057	40	123.3	37.4	49.4
NB15440	5697	3584	1641	3641	32	123.8	37.4	47.8
NB15419	5932	3251	2175	3786	27	127.8	36.9	46.1
NB15441	5947	4427	2220	4198	7	123.5	35.8	48.9
NB15417	5991	4016	2079	4029	16	124.6	36.9	49.7
NB15443	5763	3493	2211	3822	25	124.7	36.6	49.0
NB15415	6487	4098	2201	4262	6	123.8	36.2	48.5
NB15435	5283	3480	1416	3393	38	123.5	36.7	47.0
Average	**5767**	**3695**	**2238**			**125.4**	**36.5**	**47.8**

The three year data for 2016-2018 are presented below:

Name	COLBY	Mead	Lincoln	Sidney	Average*	Rank	Hdate	Height	Test weight	Average**	Rank
	Yield	Yield	Yield	Yield	Yield		D after			Yield	
	lbs/a	lbs/a	lbs/a	lbs/a	lbs/a		Jan. 1	in	lbs/bu	lbs/a	
NB15420	4231	4659	4928	3396	4561	1	130.6	26.7	47	4304	1
NB15415	4236	4476	4700	3649	4471	2	131.2	27.1	49	4265	2
NB15441	4053	4832	4342	3692	4463	3	131.2	27.1	47	4230	3
NB12434	4284	4426	4411	3252	4370	4	131.7	26.2	48	4093	7
NB15417	3961	4451	4672	3488	4345	5	131.0	27.3	46	4143	6
NB11414	4076	4340	4456	3945	4338	6	132.6	26.0	45	4204	4
NB14422	3981	3830	4975	3893	4261	7	133.0	24.5	45	4169	5
NB15442	3925	4112	4600	3603	4207	8	132.2	26.2	46	4060	8
NB14404	3747	4356	4580	2766	4154	9	131.2	26.3	46	3862	13
NB12437	4359	4143	3972	3341	4135	10	134.3	26.6	45	3954	9
NB14430	3721	4354	4204	2542	4074	11	131.7	25.1	48	3705	16
NB10444	4214	3859	3902	3602	4025	12	133.4	28.0	44	3894	11
NB14428	3955	3856	4241	2972	3996	13	132.7	25.5	45	3756	15
NB14405	4142	3599	4019	3803	3933	14	134.8	29.7	46	3891	12
NB15419	3955	4525	4122	3166	3929	15	132.6	27.4	45	3942	10
P-845	3813	3489	4528	3304	3898	16	131.0	26.2	45	3783	14
P-954	4056	3572	3715	2912	3782	17	133.2	26.6	47	3564	17

These data are interesting because the averages are developed in two ways. The first average (*) is over each trial (N=8) and the second is averaged (**) over locations (N=4) . In general, there is good agreement.

VIII. ALLIED RESEARCH

The wheat breeding or variety development project is only one phase of wheat improvement research at the University of Nebraska-Lincoln. The project interacts and depends on research in wheat germplasm development, wheat quality, wheat nutritional improvement, wheat cytogenetics, plant physiology and production practices, and variety testing. Much of the production research is located at the research and extension centers. All components are important in maintaining a competitive and improving wheat industry in Nebraska. The allied research is particularly necessary as grain classification and quality standards change and as growers try to reduce their production costs.

The program also depends on interactions and collaborations with the Wheat Board, Nebraska Wheat Growers Association, regional advisory boards, Foundation Seeds Division, Nebraska Crop Improvement Association, Texas A&M University, CIMMYT, the milling and baking industry, the malting and brewing industry, and other interested groups and individuals. The Nebraska Seed Quality Laboratory cooperates closely with the Wheat Quality Council to bake the large-scale cooperator samples. Ardent Mills also provides excellent milling and large-loaf baking data to support our small-loaf testing procedures. Numerous groups have visited the laboratory and participated in discussions on quality and marketing. Through these interactions, the program is able to remain focused and dedicated to being a premier provider of quality varieties, information, and technologies to help maintain the Nebraska Wheat Industry. We also wish to highlight the generosity of Mr. Martin Stumpf who recently donated one section of rainfed and irrigated land for an International Wheat Research Center in Grant, NE, and the funds for a new building on the site. Grant is one of the finest wheat producing regions in Nebraska and this location will be a huge benefit to the Nebraska wheat producers. We hope our program will live up the high expectations of the donor.

IX. COMINGS AND GOINGS

All projects are more than crosses, selections, evaluations, data, and seed. At its heart, it is the people who make this research possible. Dr. Madhav Bhatta successfully completed his Ph.D. degree. Drs. Zakaria Aj-Alouni and Ibrahim Salah El-Baysoni joined the project as visiting scientists. We are extremely grateful for the excellent work that the team has done and continues to do.

X. Publications from the Project:

1. Frels, K., M. Guttieri, B. Joyce, B. Levitt, P. S. Baenziger. 2018. Evaluating canopy spectral reflectance vegetation indices to estimate nitrogen use traits in hard winter wheat. Field Crops Res. 217: 82-92.

2. Navrotskyi, S., P. S. Baenziger, T. Regassa, M. J. Guttieri, and D. J.Rose. 2018. Variation in asparagine concentration in Nebraska wheat. Cereal Chem. DOI: 10.1002/cche.10023

3. Bhatta, M., T. Regassa, S. N. Wegulo, and P. S. Baenziger. 2018. Foliar Fungicide Effects on Disease Severity, Yield, and Agronomic Characteristics of Modern Winter Wheat Genotypes. Agronomy Journal. 110. 1-9. 10.2134/agronj2017.07.0383.

4. Eltaher S, A. Sallam, V. Belamkar, H. A. Emara, A. A. Nower, K. F. M. Salem, J. Poland, and P.S. Baenziger. 2018. Genetic Diversity and Population Structure of F3:6 Nebraska Winter Wheat Genotypes Using Genotyping-By-Sequencing. Front. Genet. 9:76.

5. Mourad, A. M.I., A. Sallam, V. Belamkar, S. Wegulo, R. Bowden, Y. Jin, E. Mahdy, B. Bakheit, A. A. El-Wafaa, J. Poland, and P. S. Baenziger. 2018. Genome-Wide Association Study for Identification and Validation of Novel SNP Markers for Sr6 Stem Rust Resistance Gene in Bread Wheat. Front. Plant Sci. 9:380. doi: 10.3389/fpls.2018.00380

6. Montesinos-López, O. A. , P. S. Baenziger, K. M. Eskridge, R. S. Little, E. Martínez-Crúz, E. Franco-Perez, 2018. Analysis of genotype-by-environment interaction in winter wheat growth in organic production system. Emirates Journal of Food and Agriculture. 2018. 30(3): 212-223.

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8. Elbaysoni, I.S., A. J. Lorenz, M. Guttieri, K. Frels, P.S. Baenziger, J. Poland, E. Akhunov. 2018. A comparison between genotyping-by-sequencing and array-based scoring of SNPs for genomic prediction accuracy in winter wheat. Plant Science 270: 123-130

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10. Belamkar, V., M. J. Guttieri, W. Hussain, D. Jarquín, I. S.El-basyoni, J. Poland, A. J Lorenz, P. S. Baenziger. 2018. Genomic Selection in Preliminary Yield Trials in a Winter Wheat Breeding Program. G3: Genes, Genomes, Genetics 8:2735-2747. https://doi.org/10.1534/g3.118.200415

11. Bhatta, M., A. Morgounov, V. Belamkar, J. Poland, P. S. Baenziger, Unlocking the novel genetic diversity and population structure of synthetic Hexaploid wheat. *BMC Genomics*. **19**, 591 (2018).

12. Bhatta, M., A. Morgounov, V. Belamkar, A. Yorgancılar, and P. S. Baenziger. 2018. Genome-wide association study reveals favorable alleles associated with common bunt resistance in synthetic hexaploid wheat. *Euphytica*, *214*(11), 200. https://doi.org/10.1007/s10681-018-2282-4

13. Mourad, A. M. I., A. Sallam, V. Belamkar, E. Mahdy, B. Bakheit, A. A. El-wafaa and P. S. Baenziger. 2018. Genetic architecture of common bunt resistance in winter wheat using genome- wide association study, BMC Plant Biology, 18: 280.

14. Sallam, A. A. Amro, A. EL-Akhdar, T. Kumamaru, and P. S. Baenziger. 2018. Genetic diversity and genetic variation in morpho-physiological traits to improve heat tolerance in Spring barley. *Molecular Biology Reports214: 169*, doi:10.1007/s11033-018-4410-6.

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conditioning low phytate and high grain protein concentration. *Crop Science*, *58*(5), 1942–1953. https://doi.org/10.2135/cropsci2018.03.0175

17. Yuan, W., J. Li, M. Bhatta, Y. Shi, P. S. Baenziger, and Y. Ge. 2018. Wheat Height Estimation Using LiDAR in Comparison to Ultrasonic Sensor and UAS. *Sensors*, *18*(11), 3731. https://doi.org/10.3390/s18113731

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21. Graybosch, R. A., P. S. Baenziger, R. L. Bowden, F. L., Dowell, L. Dykes, Y. Jin, Y., D. Marshall, J. Ohm, and M. Caffe-Treml. 2018. Release of 19 Waxy Winter Wheat Germplasm, with Observations on Their Grain Yield Stability. *Journal of Plant Registrations*, *12*(1), 152. https://doi.org/10.3198/jpr2017.03.0018crg

22. Kariyawasam, G., W. Hussain, A. Easterly, M. Guttieri, V. Belamkar, J. Poland, J. Venegas, S. Baenziger, F. Marais, J. B. Rasmussen, Z. Liu. Identification of quantitative trait loci conferring resistance to tan spot in a biparental population derived from two Nebraska hard red winter wheat cultivars. 2018. Molecular Breeding 38:140. [https://link.springer.com/article/10.1007/s11032-018-0901-3]

Summary:

In 2017-2018 season, 1,100,000 acres of wheat were planted in Nebraska and 1,010,000 were harvested with an average yield of 49 bu/a for a total production of 49,490,000 bu. In general, disease pressure was fairly low and mainly leaf rust with some pockets of Fusarium head blight. Wheat stem sawfly was prevalent in western Nebraska. In 2016-2017 season, 1,120,000 acres of wheat were planted in Nebraska and 1,020,000 were harvested with an average yield of 46 bu/a for a total production of 46,920,000 bu. In 2015-2016 season, Nebraskans planted 1,370,000 acres of wheat and harvested 1,310,000 acres with an average yield of 54 bushels/acre for a total production of 70,740,000 bu. The 54 bu/a yield was a record yield. Nebraska began retaking the variety surveys in 2015, however due to financial constraints did not do one in 2017. Using aggregate data from the Nebraska Crop Improvement Association, approximately 67% of the wheat planted acres were planted to certified seed of 46 different cultivars. The certified seed planted acreage will vary by cropping system and region with more save seed in regions where less seed of other crops are purchased. Approximately 50% of the certified seed was developed by companies, 37 % by the USDA-University of Nebraska and 13% from other public breeding programs. From seed sales, Ruth (ranked 3rd in certified seed sales) had an excellent year and should be adopted well in across NE. The project formally released one new wheat line NE12561 which will be marketed through NuPride Genetics Network and named Siege and a second line in collaboration with Limagrain (LCS Valiant). Siege is a hard red winter wheat selected from the cross NI04420/NE00403 where the pedigree of NI04420 is NE96644 (=ODESSKAYA P./CODY)//PAVON/*3SCOUT66/3/WAHOO SIB and the pedigree of NE00403 is PRONGHORN/ARLIN//ABILENE. It is a semi-dwarf, moderately late in maturity, with good winter hardiness, and straw strength. It is moderately resistant to Hessian fly and leaf rust. It is resistant to wheat soilborne mosaic virus, stem rust, and stripe rust. It is susceptible to wheat streak mosaic virus. It has good test weight and above average protein content. Its end use quality is acceptable. It best adapted to Eastern and Southcentral Nebraska. Its straw strength may have utility under irrigated production though it will not top most irrigated trials. Certified seed will be available in 2019 to 2020. Information on LCS Valiant (derived from the cross NI03418/Camelot) can be found at the Limagrain website: https://limagraincerealseeds.com/central-plains/hard-red-winter-wheat-seed/lcs-valiant/

Our next white wheat has been developed, but a key need is identifying a buyer for it. NW13493 (derived from the cross SD98W175-1/NW03666) is a potential new hard white wheat. White wheat varieties always have to find a market before they can be released becasue without a known buyer is a concern on marketability which puts growers at risk. However, there is little doubt that if NW13493 were a hard red wheat, it would be released. It is a very high yielding, early, semi-dwarf with good winterhardiness and disease resistance (leaf, stem, and stripe rust; wheat soilborne mosaic virus). However, it is susceptible to wheat streak mosaic virus and Hessian fly. While it has good test weight, it tends to be slightly below average for grain protein content. It has very good end-use quality. In 2018, one new forage triticale, NT13443 was released. NT13443 was derived from the cross 04TG 112/NE422T=(TRICAL /UB-UW26)//NE03T407 and is a winter forage triticale that grows well in the Central Great Plains under rainfed conditions. It has excellent winterhardiness and good bacterial streak resistance (a major disease of triticale and one that cannot be treated with fungicides). It is early (6 days earlier than NT441 and similar to NT426GT) and tall, similar in height and slightly better in forage production to NT441. Like most tall triticales, if intensively managed, lodging may be a concern. It has a relatively unique grain characteristic of being low in polyphenol oxidase (an enzyme that discolors wet dough products if they are allowed to rest, similar to an apple browning when bitten). We are exploring food uses for this trait. **Our program gratefully acknowledges the generous support of the Nebraska Wheat Board.**