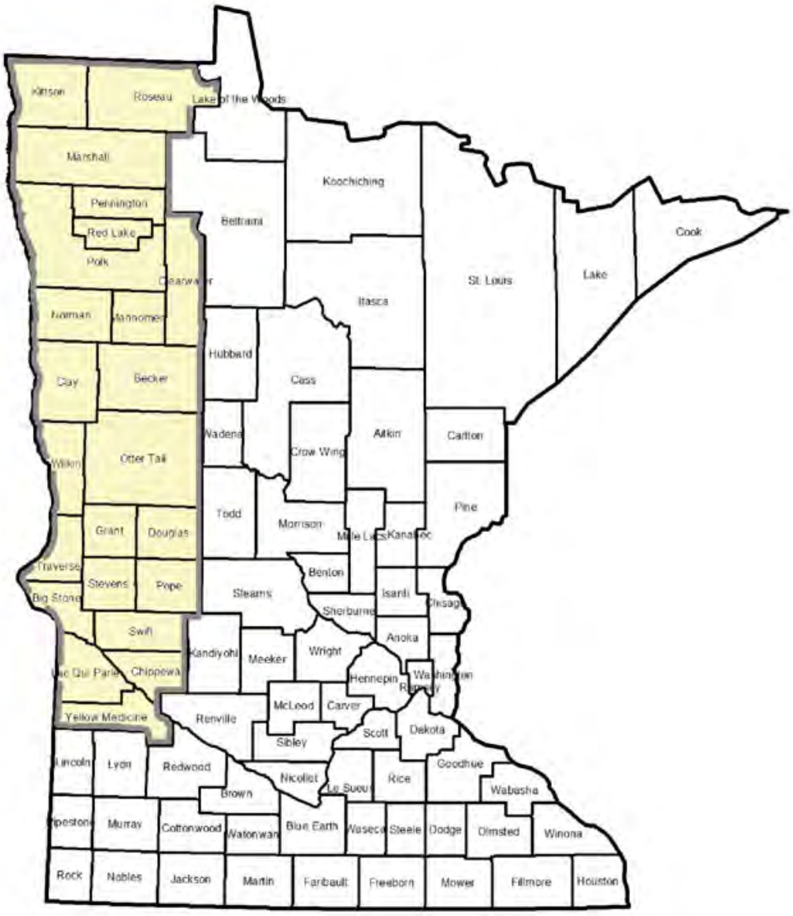
On-Farm Cropping Trials Northwest & West Central Minnesota and 2015 Minnesota Wheat Research Review



Minnesota Wheat Research & Promotion Council

University of Minnesota Extension

Driven to Discover℠

MinnesotaCorn Research & Promotion Council

Minnesota Soybean Research & Promotion Council

This is the nineth year the Research Review and On-Farm Cropping Trials have been combined into one booklet. Up until then, these reports have been published separately.

On-Farm Cropping Trials

The mission of the UMN Extension and NWROC is to contribute, within the framework of the Minnesota Agricultural Experiment Station (MAES) and the College of Food, Agricultural, and Natural Resource Sciences to the acquisition, interpretation and dissemination of research results to the people of Minnesota, with application to the knowledge base of the United States and World. Within this framework, major emphasis is placed on research and education that is relevant to the needs of northwest Minnesota, and which includes projects initiated by Center scientists, other MAES scientists and state or federal agencies.

Contributors to the On-Farm Trials include: Doug Holen, Extension Educator, Extension Regional Office, Morris, holen009@umn.edu; Phillip Glogoza, Extension Educator, Extension Regional Office, Moorhead, glogo001@umn.edu; Jochum Wiersma, Small Grain Specialist, Crookston, wiers002@umn.edu; Madeleine Smith, Extension Plant Pathologist, Crookston, smit7273@crk.umn.edu; Howard Person, Extension Educator, Pennington and Marshall Counties, Thief River Falls, perso005@umn.edu; Jim Orf, Dept Agronomy & Plant Genetics, St. Paul, orfxx001@umn.edu; Jeff Coulter, Extension Agronomist, Dept of Agronomy, St. Paul, coult077@umn.edu; Albert Sims, Soil Scientist, Crookston, simsx008@umn.edu; J Dan Kaiser, Extension Soil Scientist, St. Paul, dekaiser@umn.edu; Randy Nelson, Extension Educator, Clay County, MN, nels1657@umn.edu; Jerry Buckley, Extension Educator, Norman and Mahnomen Counties, gbuckley@umn.edu ; Bruce Potter, IPM Specialist, SWROC, Lamberton, bpotter@umn.edu ; Ryan Miller, Extension Educator, Extension Regional Office, Rochester, mill0869@umn.edu; David Nicolai, Extension Educator, Extension Regional Office, Farmington, nico0071@umn.edu; Art Killam, Research Plot Coordinator
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This project was made possible thanks to the hard work of many people. This includes farmers, County and Regional Extension Educators, and specialists who conducted these trials, and their names are listed.
Previous On-Farm Cropping Trials booklets can be found at http://smallgrains.org/wheat-research-reports/

2015 Wheat Research Review

Researchers submit progress reports on projects funded partially or in full by the committee’s recommendation. Research progress is communicated to the public. Crop scientists participate in a research reporting session held each year that is open to the public. The Council feels this committee has been an efficient vehicle for not only prioritizing wheat checkoff funds, but also in improving the dissemination of results.Better practices to plant better wheat is our goal. To that end, we encourage your input on this committee, and your feedback on the wheat research projects that are funded by the Minnesota Wheat Checkoff.

Members of the 2015 - 2016 Small Grains Research & Communications Committee include Brian Borge;
Tony Brateng; Ryan Casavan, BASF; Mark Fillbrandt, Bigg Dogg Agg; David Garrett; Doug Holen, U of M Extension Service; Carter Hontvet; Peter Hvidsten; Scott Lee; Kevin Leiser; Richard Magnusson; Dave Willis, Agaassiz Crop Management; Ex-Officio Members: Greg LeBlanc, MN Wheat Council; David Torgerson, MN Wheat; Jochum Wiersma, U of M Small Grains Specialist; Marv Zutz, MN Barley.

Information about the committee and previously funded research can be found online at www.smallgrains.org. Click on the Research Committee tab.

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On-Farm Cropping Trials For NW & WC MN

Wheat Research Reports - Funded in part by the Minnesota Wheat check-off

Corn Hybrid Response to Planting Rate in Northwestern MN

Locations: Ada (Norman Co.), Callaway (Becker Co.), and Fosston (Polk Co.)
Plot Layout: All combinations of hybrid and planting rate replicated 4 times at each location
Row Width: 30-inch

Objective:
Evaluate corn response to planting rate for three hybrids of differing comparative relative maturity (CRM).

Results:
Average corn grain yield ranged from 174 to 202 bu/acre among locations. Corn yield was affected by planting rate at Ada and Callaway, but not at the lower-yielding Fosston site. Greatest yield occurred with the highest planting rate at Ada and with moderate to high planting rates (34,700 seeds/acre or greater) at Callaway.

Yield differed among hybrids at Ada and Fosston. At both of these locations, yield was greatest with the 86 CRM hybrid and least with the 74 CRM hybrid, but did not differ between the 80 and 86 CRM hybrids.

Grain moisture at harvest was greatest with the 86 CRM hybrid and least with the 74 CRM hybrid at Ada and Fosston, but did not differ between the 74 and 80 CRM hybrids at Ada.

Planting rate	Ada	Callaway	Fosston
seeds/A	------------ Yield (bu/A)† ------------		
23,100	176 d‡	179 b	173 a
28,900	199 c	193 ab	172 a
34,700	203 bc	205 a	170 a
40,500	212 b	205 a	177 a
46,300	220 a	208 a	176 a

† Averaged across three hybrids at Ada and Fosston. Results from Callaway are for the 86 CRM hybrid only.

‡ Within a location, values followed by the same letter are not different at the 10% probability level.

Hybrid†	Comparative relative maturity	Ada	Callaway	Fosston
		------------ Yield (bu/A)‡ ------------		
P7443R	74	194 b§	—	165 b
39V07	80	204 ab	—	176 a
P8640AM	86	208 a	198	180 a
		-- Grain moisture at harvest (%) --		
P7443R	74	12.5 b	—	16.9 c
39V07	80	12.9 b	—	20.9 b
P8640AM	86	15.0 a	22.0 a	23.6 a

† DuPont Pioneer.

‡ Averaged across five planting rates. Data for the 74 and 80 CRM hybrids at Callaway were excluded due to high variability.

§ Within a location, yield or grain moisture values followed by the same letter are not different at the 10% probability level.

For Additional Information:
Jeff Coulter, Jerry Buckley, and Nathan Johnson
Univ. of MN Extension

Funding provided by the Minnesota Corn Growers Association. Thanks to North Dakota State University for planting the trials.

Pre-plant versus side-dress Nitrogen for corn in NW Minnesota

Nearest Town: Ada (Norman Co.) & Fosston (Polk Co.)
Soil Type: Norman County: Wheatville loam
Polk County: Chapett fine sandy loam
Row Width: 30"
Experimental Design: Split plot within a randomized complete block design
Main plot pre-plant nitrogen rates: 0, 40, 80, 120, 160, and 200 lbs N per acre
Split plot side-dress N (pre-plant N + side-dress N): 0 + 120, 40 + 80, 80 + 40, 120 + 40, 160 + 40, and 200 + 40 lbs N/acre
Nitrogen source: urea (46-0-0)
Side-dress urea treated with Agrotain and applied between V4-V6
4 replications
Previous Crop: Norman County: previous crop spring wheat
Polk County: previous crop soybean

Purpose of Study:
To determine if split application of nitrogen would result in greater corn yield in Northwest Minnesota

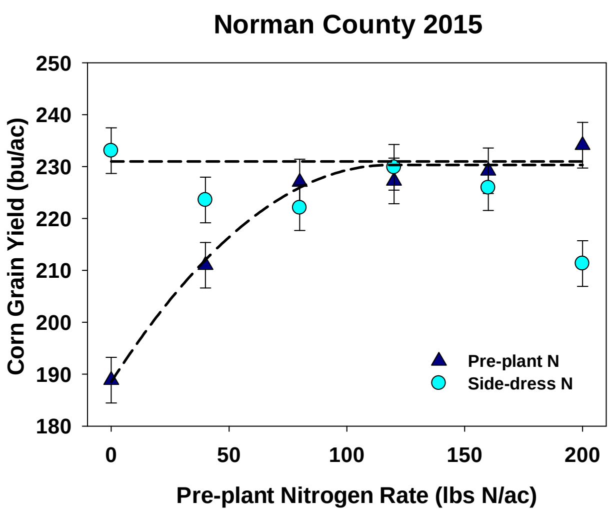
Results:
Corn grain yield was increased by pre-plant nitrogen at both locations. Economic optimum nitrogen rates (EONR) for both locations were near 100 lbs of N per acre at Norman Co. and 175 lbs at Polk. Higher EONR at Polk was likely a result of previous crop and a sandier soil.

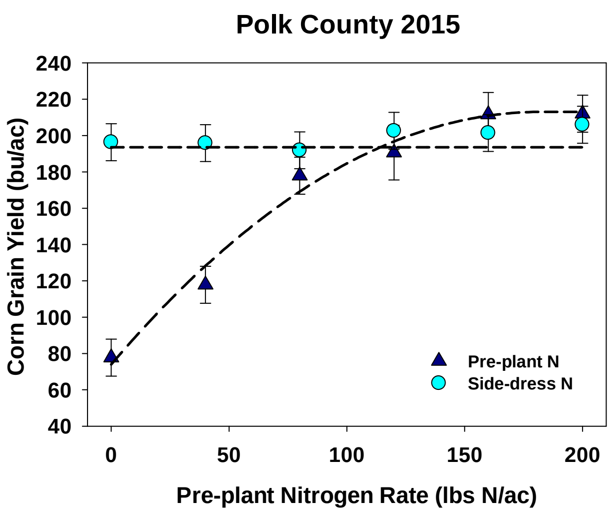
Side-dress application of nitrogen increased corn grain yield for the lowest three pre-plant application rates, 0, 40, and 80 lbs of N per acre. There was no yield advantage of split application of nitrogen for pre-plant nitrogen rates 80 lbs of N or greater.

Side-dress application of nitrogen did not increase yield for applied N rates higher than the EONR. Application of 120 lbs of N resulted in similar yield when applied all as a pre-plant or a side-dress application. The results agree with research from 2014 where there was no yield advantage from side-dress application of nitrogen.

Table 1. Summary of ecomonic optimum nitrogen rates using the maximum return to N model for Northwest Minnesota from 2014-2015.

		Ratio of Price N:Price per bushel of corn					
Year	Location	0.00	0.05	0.10	0.15	0.20	0.25
		-------------------lb N/acre------------------					
2014	Mahnomen	107	107	107	107	107	107
	Norman	99	93	88	82	77	71
2015	Norman	118	106	93	81	68	56
	Polk	182	173	165	156	147	138





For Additional Information:
Contact Daniel Kaiser (dekaiser@umn.edu)

Project Funding Provided by:
Minnesota Corn Research and Promotion Council

Corn Response to Sulfur Fertilizer — Norman/Polk Co.

Nearest Town:	Ada (Norman Co.) & Fosston (Polk Co.)
Soil Type:	Norman County: Wheatville loam
	Polk County: Chapett fine sandy loam
Row Width:	30”
Experimental Design:	Randomized complete block design
	Four sulfur rates: 0, 10, 20, and 30 lbs S per acre
	Sulfur source: ammonium sulfate (21-0-0-24)
	Sulfur applied at or prior to planting
	4 replications

Purpose of Study:
To determine if sulfur can increase corn yield on high organic matter soils in Northwest Minnesota.

Results:

Corn grain yield was increased by sulfur at the Fosston location (Polk co.). Statistically, the 10 lb application rate produced the greatest grain yield and also reduced grain moisture at harvest.

There was a numerical trend with higher yield at the Norman Co. location but the effect of sulfur rate was highly non-significant. Corn grain moisture did not differ at the Norman Co. location. It is unlikely that sulfur impacted yield at the Norman location in-spite of visual deficiency symptoms early in the growing season.

There was no difference in yield or grain harvest moisture across the four locations studies in 2014 and 2014 (data from the two 2014 location are included in the 2014 on-farm cropping trial report). The lack of response across all locations further supports that there is significant variation among sites in the potential response to sulfur.

A response to sulfur is probably at both locations as 0-6” oil organic matter content was 2.8% at the Norman Co. location and 3.3% at the Polk Co. location. The major difference between the location was soil texture where the Polk location was sandier than the Norman Co. location.

Table 1. Summary of corn grain yield (adjusted to 15.5% moisture) response to sulfur rate at locations in NW Minnesota and the two year study average.

Sulfur Rate	Norman	Polk	2yr-Avg.
-lb S/ac-	----------Bushels/acre----------		
0	232	211 b	181
10	234	219 ab	183
20	235	221 ab	185
30	240	226 a	189
	Statistical Significance		
P>F	0.53	0.09	0.18

Table 2. Summary of corn grain moisture response to sulfur rate at locations in NW Minnesota and the 2-year study average.

Sulfur Rate	Norman	Polk	2yr-Avg.
-lb S/ac-	----------------%----------------		
0	13.1	19.3a	17.4
10	12.8	17.5b	16.8
20	13.0	17.2b	17.7
30	13.1	17.5b	17.2
	Statistical Significance		
P>F	0.67	0.01	0.24

For Additional Information:
Contact Daniel Kaiser (dekaiser@umn.edu)

Project Funding Provided by:
Minnesota Corn Research and Promotion Council

2015 Corn Hybrid Trials — Marshall/Polk/Mahnomen/Norman Counties

Cooperator: Kyle Merkens (Pennington), Wayne Olson (Polk), Bill Zurn (Becker), Danny Brandt (Norman)
Nearest Town: St. Hilare, Fosston, Callaway, Ada
Previous Crop: Pennington—wheat, Polk—1111, Becker—soybeans, Norman—soybeans
Planting Date: St. Hilare, Fosston and Ada were planted on May 1st and Callaway on May 4th
Row Width: 30" rows
Harvest Date: Ada 10/7, Fosston 10/9, Callaway 10/15, St. Hilare 10/16
Experimental Design: Alpha lattice design with 4 replications

Purpose of Study:
Evaluate the performance of commercially available corn hybrids in Northwest MN

Results:
Yield and moisture data from 4 replications is summarized in the tables below. Yields are adjusted to 15.5% moisture. There were significant differences in moisture and yield between corn hybrids at all locations

North zone, early maturing (<81 RM) corn hybrid trial results, Pennington Co., St. Hilaire, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
Peterson Farms Seed	21N78	78	17.2	140.1
Wensman	W8076VT2RIB	79	17.1	127.4
NorthStar Genetics	NS 77-311	77	16.2	123.8
Wensman	W80809VT2RIB	80	17.3	121.2
NuTech/G2 Genetics	3A-080	80	17.4	119.0
Partners Brand	PB 5030GT	80	17.0	118.9
Legacy Seeds	L-2213 VT2PRO	80	16.6	118.7
Thunder Seed	4578 RR	78	16.9	116.3
Legacy Seeds	L-1814 VT2PRO	79	17.9	113.7
NuTech	3A-678	78	17.7	112.3
Pioneer	P7632	76	17.0	111.1
Proseed	1280 VT2P	80	16.5	110.4
REA Hybrids	1B790	79	18.0	106.3
Nuseed	8001 VT2P RIB	80	16.7	103.2
REA Hybrids	1B801	80	16.6	102.1
NorthStar Genetics/Viking Seed	VS 78-510	78	17.8	102.0
REA Hybrids	1B102	76	16.7	101.3
Thunder Seed	4377 RR	77	18.4	100.0
NuTech/G2 Genetics	5F-379	79	16.6	96.0
NuTech/G2 Genetics	5F-775	75	17.2	85.8
Partners Brand	PB 4833RR	78	17.5	78.2
Mean			17.2	108.4
CV (%)			6.5	27.0
LSD (0.05)			1.6	41.6
LSD (0.1)			1.4	34.8

For Additional Information: Jerry Buckley, Howard Person and Nathan Johnson—U of M Extension

Project Funding Provided by:
Minnesota Corn Research and Promotion Council

North zone, late maturing (≥81 RM) corn hybrid trial results, Pennington Co., St. Hilaire, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
NuTech/G2 Genetics	5Z-783	83	18.4	135.2
Legacy Seeds	L-2415 VT2PRO	84	17.4	133.1
NuTech	5B-782	82	17.0	128.5
Proseed	1182 GTCBLL	82	17.1	127.7
Partners Brand	PB 5203-3000GT	82	17.2	126.2
Legacy Seeds	L-2314 VT2PRO	83	17.4	124.4
Thunder Seed	4585 RR	85	17.3	124.2
Thunder Seed	5181 RR	81	17.9	124.0
REA Hybrids	2V550	85	17.3	122.8
Dekalb	DKC 31-10	81	18.3	120.9
Proseed	1382 VT2P	82	17.5	117.4
Thunder Seed	4383 VT2PRIB	83	16.7	116.0
Peterson Farms Seed	71D83	83	17.8	115.7
Proseed	PX85 VT2P	85	17.4	115.5
Thunder Seed	6385 RR	85	17.2	112.8
NorthStar Genetics/Viking Seed	VS 81-481	81	15.6	109.6
Channel	183-23VT2PRIB	83	16.5	105.5
REA Hybrids	1B820	82	17.7	104.3
NorthStar Genetics/Viking Seed	VS 85-572	85	16.8	102.4
Proseed	1083 GT3000	83	16.0	101.4
Producers Hybrids	4363VT2RIB	83	17.3	98.3
Pioneer	P8210HR	82	17.7	94.8
NorthStar Genetics	NS 82-182	82	16.3	94.5
Channel	181-92VT2PRIB	81	17.3	93.1
Proseed	1384 VT2P	84	16.7	92.7
Proseed	1385 VT2P	85	17.5	92.2
REA Hybrids	2B840	84	17.5	92.1
Channel	182-62VT2PRIB	82	16.6	91.8
NuTech	5N-183	83	17.4	88.2
Croplan	2123 VT2P	81	16.4	88.0
Wensman	W80827VT2RIB	82	17.0	80.9
Mean			17.2	108.8
CV (%)			6.5	27.0
LSD (0.05)			1.6	41.6
LSD (0.1)			1.4	34.8

For Additional Information: Jerry Buckley, Howard Person and Nathan Johnson—U of M Extension

North zone, early maturing (<81 RM) corn hybrid trial results, Polk Co., Fosston, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
NuTech	3A-678	78	21.7	196.6
NuTech/G2 Genetics	5F-379	79	19.6	196.1
Legacy Seeds	L-2213 VT2PRO	80	21.4	194.8
REA Hybrids	1B801	80	19.5	192.3
Wensman	W8076VT2RIB	79	18.6	190.5
NuTech/G2 Genetics	5F-775	75	18.0	188.7
REA Hybrids	1B790	79	19.0	186.9
Peterson Farms Seed	21N78	78	18.2	185.2
Thunder Seed	4578 RR	78	18.7	183.5
Partners Brand	PB 5030GT	80	26.1	181.9
NuTech/G2 Genetics	3A-080	80	21.0	181.0
Legacy Seeds	L-1814 VT2PRO	79	19.9	179.4
Proseed	1280 VT2P	80	18.8	178.5
REA Hybrids	1B102	76	19.1	177.4
Pioneer	P7632	76	19.2	177.1
Wensman	W80809VT2RIB	80	19.2	176.8
Partners Brand	PB 4833RR	78	22.4	176.6
NorthStar Genetics	NS 77-311	77	22.3	174.5
Thunder Seed	4377 RR	77	20.5	174.1
Nuseed	8001 VT2P RIB	80	20.4	172.3
NorthStar Genetics/Viking Seed	VS 78-510	78	21.4	170.5
Mean			20.2	182.6
CV (%)			7.3	9.5
LSD (0.05)			2.3	26.6
LSD (0.1)			2.0	22.6

For Additional Information: Jerry Buckley, Howard Person and Nathan Johnson—U of M Extension

North zone, late maturing (≥81 RM) corn hybrid trial results, Polk Co., Fosston, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
Proseed	1385 VT2P	85	21.1	217.2
Legacy Seeds	L-2314 VT2PRO	83	19.2	207.9
NuTech	5N-183	83	21.7	207.8
REA Hybrids	2V550	85	23.0	207.7
Thunder Seed	4585 RR	85	25.1	204.6
Wensman	W80827VT2RIB	82	22.0	203.3
NuTech	5B-782	82	22.3	200.6
Channel	181-92VT2PRIB	81	21.8	199.0
REA Hybrids	2B840	84	21.8	198.4
Croplan	2123 VT2P	81	18.0	196.0
Producers Hybrids	4363VT2RIB	83	19.5	195.5
NorthStar Genetics	NS 82-182	82	22.7	194.4
Proseed	1384 VT2P	84	20.9	194.3
Peterson Farms Seed	71D83	83	19.0	193.9
Proseed	PX85 VT2P	85	26.2	193.0
Channel	182-62VT2PRIB	82	20.8	190.3
Dekalb	DKC 31-10	81	20.7	187.5
Proseed	1382 VT2P	82	22.4	186.0
Thunder Seed	6385 RR	85	21.0	185.5
Thunder Seed	5181 RR	81	21.2	182.5
Proseed	1182 GTCBLL	82	25.8	177.6
Pioneer	P8210HR	82	17.6	177.4
NuTech/G2 Genetics	5Z-783	83	23.5	177.2
REA Hybrids	1B820	82	21.5	176.9
Partners Brand	PB 5203-3000GT	82	22.6	175.5
Proseed	1083 GT3000	83	23.2	175.4
Legacy Seeds	L-2415 VT2PRO	84	20.6	175.3
Channel	183-23VT2PRIB	83	21.6	175.2
Thunder Seed	4383 VT2PRIB	83	20.9	171.1
NorthStar Genetics/Viking Seed	VS 85-572	85	21.6	168.0
NorthStar Genetics/Viking Seed	VS 81-481	81	21.4	150.8
Mean			21.6	188.6
CV (%)			7.3	9.5
LSD (0.05)			2.3	26.6
LSD (0.1)			2.0	22.6

For Additional Information: Jerry Buckley, Howard Person
and Nathan Johnson—U of M Extension

Central zone, early maturing (<86 RM) corn hybrid trial results, Becker Co., Callaway, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
Channel	185-15VT2PRIB	85	21.3	222.1
Thunder Seed	4585 RR	85	21.9	219.8
REA Hybrids	2B840	84	19.4	215.4
Thunder Seed	4585 RR	85	20.8	212.2
Proseed	PX85 VT2P	85	21.7	204.4
Producers Hybrids	4593VT2RIB	85	18.5	204.4
NuTech	5B-782	82	17.7	201.2
Proseed	1385 VT2P	85	20.2	200.7
Peterson Farms Seed	75K85	85	21.7	200.6
NuTech	5N-8402	84	19.8	197.4
Legacy Seeds	L-2314 VT2PRO	83	17.5	191.1
NuTech	5N-183	83	19.8	190.8
Thunder Seed	5181 RR	81	19.0	178.2
Channel	183-23VT2PRIB	83	18.6	171.1
NuTech/G2 Genetics	5Z-783	83	19.6	168.9
REA Hybrids	2V550	85	21.6	164.4
Partners Brand	PB 5203-3000GT	82	22.3	164.3
Legacy Seeds	L-2415 VT2PRO	84	18.6	159.6
Proseed	1384 VT2P	84	18.9	152.5
Thunder Seed	6385 RR	85	18.7	148.9
Thunder Seed	4383 VT2PRIB	83	19.2	148.5
Thunder Seed	6385 RR	85	18.4	143.3
REA Hybrids	1B820	82	18.4	138.7
Channel	182-62VT2PRIB	82	17.4	134.1
NorthStar Genetics/Viking Seed	VS 85-572	85	18.5	129.7
Dairyland Seed	DS-9683	83	22.2	113.4
Mean			19.7	176.0
CV (%)			4.2	8.2
LSD (0.05)			1.3	22.6
LSD (0.1)			1.1	18.9

For Additional Information: Jerry Buckley, Howard Person
and Nathan Johnson—U of M Extension

Central zone, late maturing (≥86 RM) corn hybrid trial results, Becker Co., Callaway, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
NuTech	5N-290	90	23.2	246.7
REA Hybrids	2B871	87	21.3	240.4
Thunder Seed	7188 VT2PRIB	88	23.0	236.1
NorthStar Genetics/Viking Seed	VS 88-116	86	23.0	235.0
Peterson Farms Seed	74K89	89	23.3	232.9
Nuseed	8701 VT2P RIB	87	21.8	220.3
Legacy Seeds	L-2924 VT2PRO	89	22.3	219.1
Dairyland Seed	DS-9791RA	91	26.2	218.1
REA Hybrids	2B860	86	22.3	215.8
Wensman	W80880VT2PRO	88	22.0	212.1
Legacy Seeds	L-2813 VT2PRO	87	21.0	210.6
Producers Hybrids	4913VT2RIB	89	21.7	209.6
NorthStar Genetics/Viking Seed	VS 92-110	92	25.7	206.8
NorthStar Genetics/Viking Seed	VS 91-591	91	23.3	206.4
Integra Seed	9412	91	22.8	202.2
Thunder Seed	4391 VT2PRIB	91	25.1	201.6
Peterson Farms Seed	73D91	91	22.8	201.4
Channel	190-13VT2PRIB	90	22.0	197.1
Dekalb	DKC 36-30	86	21.5	197.1
Legacy Seeds	L-2643 VT2PRO	86	20.6	196.4
Channel	186-31VT2PRIB	86	21.5	191.9
NuTech	5N-8602	86	19.6	191.1
Partners Brand	PB 5630GT	86	20.6	191.0
Thunder Seed	4389 RR	89	20.6	187.3
Channel	187-42VT2PRIB	87	21.3	186.9
NuTech	5N-186	86	18.2	186.9
Thunder Seed	4389 RR	89	20.9	186.2
Pioneer	P8673	86	20.8	184.4
Legacy Seeds	L-3011 VT3PRO	90	22.7	180.0
REA Hybrids	2B870	87	19.7	171.1
Wensman	W80866VT2RIB	86	19.5	167.1
Wensman	W80874VT2PRO	87	24.4	163.2
Dairyland Seed	DS-9487RA	87	23.4	156.5
Dairyland Seed	DS-9186RA	86	19.5	156.4
NuTech/G2 Genetics	5Z-488	88	19.6	150.1
Integra Seed	9361	86	20.0	149.6
Peterson Farms Seed	77H87	87	19.9	149.3
NuTech/G2 Genetics	5D-091	91	23.7	138.6
Mean			21.9	194.6
CV (%)			4.2	8.2
LSD (0.05)			1.3	22.6
LSD (0.1)			1.1	18.9

Central zone, early maturing (<86 RM) corn hybrid trial results, Norman Co., Ada, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
Channel	185-15VT2PRIB	85	14.4	265.9
Thunder Seed	4585 RR	85	15.6	255.4
Peterson Farms Seed	75K85	85	14.9	252.4
REA Hybrids	2V550	85	14.3	251.9
REA Hybrids	2B840	84	13.4	251.5
Thunder Seed	4585 RR	85	15.2	249.8
Proseed	1385 VT2P	85	14.5	248.2
Producers Hybrids	4593VT2RIB	85	12.5	246.6
NuTech	5N-8402	84	14.3	244.9
Proseed	PX85 VT2P	85	16.7	241.4
Partners Brand	PB 5203-3000GT	82	15.3	240.5
Legacy Seeds	L-2314 VT2PRO	83	12.7	239.8
REA Hybrids	1B820	82	13.4	235.9
Legacy Seeds	L-2415 VT2PRO	84	13.4	234.7
NuTech/G2 Genetics	5Z-783	83	12.8	234.7
NuTech	5N-183	83	13.1	232.9
Channel	182-62VT2PRIB	82	13.1	231.3
Proseed	1384 VT2P	84	13.2	231.1
NuTech	5B-782	82	13.5	228.8
Thunder Seed	5181 RR	81	11.7	225.6
Thunder Seed	6385 RR	85	13.5	222.7
Channel	183-23VT2PRIB	83	14.0	222.4
Thunder Seed	6385 RR	85	12.7	214.8
Dairyland Seed	DS-9683	83	14.6	207.6
Thunder Seed	4383 VT2PRIB	83	14.1	204.5
NorthStar Genetics/Viking Seed	VS 85-572	85	13.7	204.4
Mean			13.9	235.4
CV (%)			9.1	5.6
LSD (0.05)			2.2	20.4
LSD (0.1)			1.9	17.3

For Additional Information:
Jerry Buckley, Howard Person and Nathan Johnson—U of M Extension

Central zone, late maturing (≥86 RM) corn hybrid trial results, Norman Co., Ada, MN, 2015.

Brand	Variety	RM	Moisture	Yield
		(days)	(%)	(bu/a)
Legacy Seeds	L-3011 VT3PRO	90	17.1	270.0
Thunder Seed	7188 VT2PRIB	88	16.5	267.2
Thunder Seed	4389 RR	89	16.7	266.5
Wensman	W80880VT2PRO	88	15.9	266.4
Legacy Seeds	L-2924 VT2PRO	89	17.1	263.8
Nuseed	8701 VT2P RIB	87	16.1	262.6
Producers Hybrids	4913VT2RIB	89	15.7	260.5
REA Hybrids	2B860	86	16.6	259.5
Peterson Farms Seed	74K89	89	15.3	258.0
Thunder Seed	4389 RR	89	16.2	258.0
Dairyland Seed	DS-9487RA	87	16.4	256.9
NorthStar Genetics/Viking Seed	VS 88-116	86	15.6	253.8
Peterson Farms Seed	73D91	91	16.1	252.5
NuTech/G2 Genetics	5D-091	91	17.4	251.8
NorthStar Genetics/Viking Seed	VS 92-110	92	17.9	251.7
Channel	190-13VT2PRIB	90	14.6	251.3
NorthStar Genetics/Viking Seed	VS 91-591	91	16.4	249.6
Channel	190-13VT2PRIB	90	15.9	247.3
Thunder Seed	4391 VT2PRIB	91	16.8	246.0
Dekalb	DKC 36-30	86	13.5	245.7
Peterson Farms Seed	77H87	87	15.7	245.1
Integra Seed	9412	91	15.5	244.2
Wensman	W80874VT2PRO	87	16.0	244.0
Dairyland Seed	DS-9791RA	91	17.7	243.3
Wensman	W80866VT2RIB	86	13.7	242.4
REA Hybrids	2B871	87	16.3	242.4
REA Hybrids	2B870	87	13.2	242.2
Pioneer	P8673	86	15.3	239.6
NorthStar Genetics/Viking Seed	VS 92-110	92	14.1	238.6
NuTech	5N-8602	86	15.1	238.5
Legacy Seeds	L-2813 VT2PRO	87	14.7	235.4
NuTech	5N-290	90	16.3	234.7
NuTech	5N-186	86	13.0	234.4
NuTech/G2 Genetics	5Z-488	88	15.5	234.2
Legacy Seeds	L-2643 VT2PRO	86	16.3	234.2
Integra Seed	9361	86	16.2	232.2
Channel	186-31VT2PRIB	86	14.7	228.4
Channel	187-42VT2PRIB	87	16.0	227.0
Dairyland Seed	DS-9186RA	86	12.2	226.8
Partners Brand	PB 5630GT	86	13.2	219.1
Mean			15.6	246.6
CV (%)			9.1	5.6
LSD (0.05)			2.2	20.4
LSD (0.1)			1.9	17.3

For Additional Information:
Jerry Buckley, Howard Person and Nathan Johnson—U of M Extension

2015 Statewide Soybean Crop and Pest Survey

Cooperator: Minnesota Soybean Research and Promotion Council, NDSU IPM Survey

Purpose of Study:
The project objective was to gather field data on crop and pest progress for the soybean crop across the state of MN. Information was released through media (e.g., radio, internet-based news releases, archived web pages, consultant conversations and e-mail. The survey was conducted in coordination with the NDSU IPM Survey, providing extensive, continuous coverage of soybean across MN and ND.

Results:
Field surveys of soybeans were initiated the second week of June. A total of 200 randomly selected MN soybean field were scouted from June 15 to August 22 (Figure 1).

A primary focus of the survey was documenting the progress of the soybean aphid population. Surveys used a protocol based on the "Speed Scouting" procedure *(see "overview" for discussion),* which bases treatment decisions for Soybean aphid on the ***treatment threshold of 250 aphids per plant.*** Scouts inspected a minimum of 31 plants at random; plants with aphids were noted and used to determine % plants with at least one aphid; and, aphid numbers/plant were visually estimated and tallied within a numerical range of: 0; 1 - 20; 21 - 40; 41 - 60; 61 - 100; 101 - 200; 200 + (Figure 6). Each scouted field was mapped using the GPS waypoint and presented as % plants infested, average number of aphids/plant and proportion of plants by population range.

The set of survey maps present two views of the aphid population's progress. The images in the left column (Figure 4) present percent infested plants. The right column (Figure 5) has the corresponding map for the same dates and presents the average number of aphids per plant site.

Each map summarizes field observations over a two week period and each map overlaps 1 week of the maps which precede and follow.

It was noted that surveyed fields likely were not approaching treatment thresholds until infested plants reached 90% or more of the plants with aphids (Figure 2). People scouting fields to determine infestation levels should keep this in mind and consider using Soybean Aphid Speed Scouting for assistance in determining the need and timing for insecticide treatments.

(continued)

Figure 1.

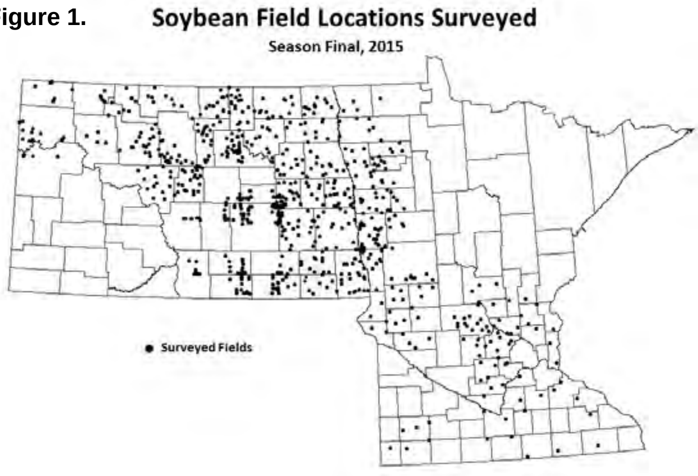


Figure 2. Average number of soybean aphids (SAB)/ plant plotted by the observed % of plants with at least one SAB present.

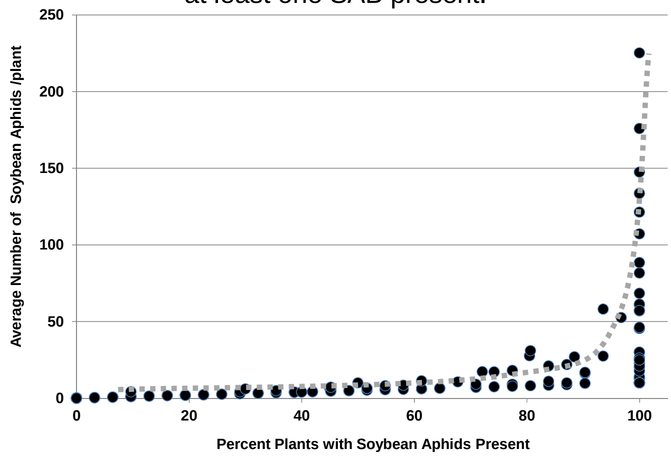


Figure 3.

For Additional Information:
Phillip Glogoza and Doug Holen

Project Funding Provided by:
Minnesota Soybean Research and Promotion Council

Figure 4. Percent of soybean plants infested with at least one soybean aphid.

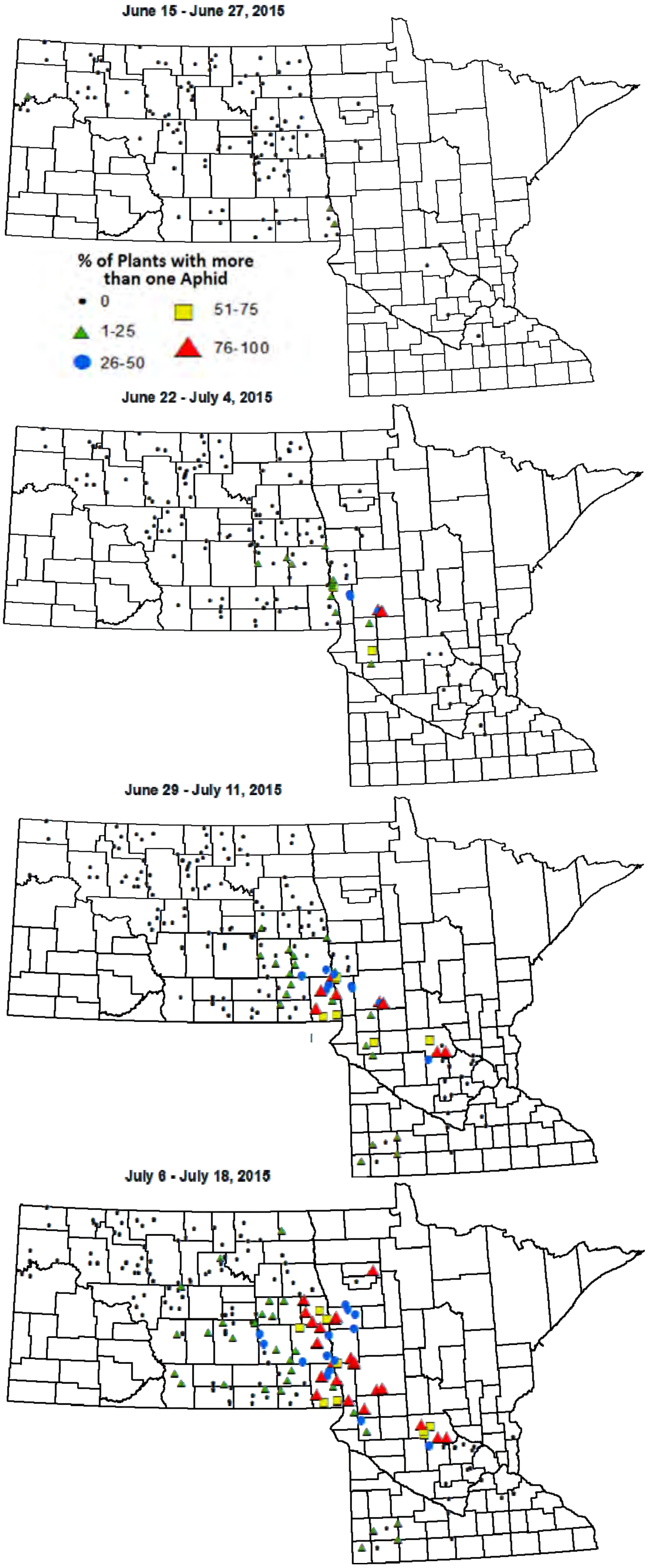


Figure 5. Average number of Soybean aphids estimated / plant .

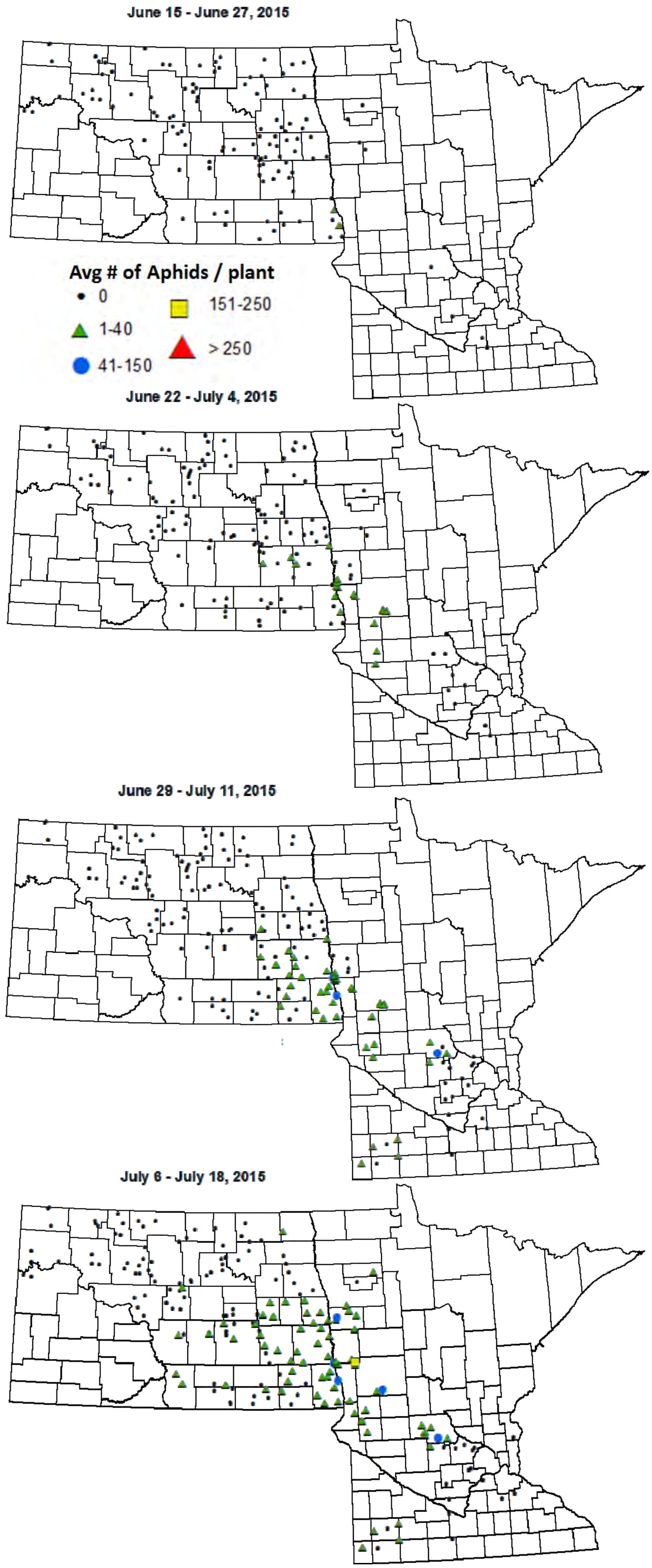
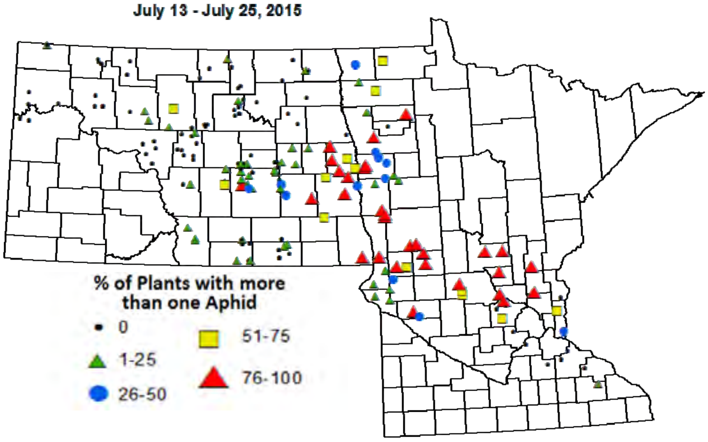
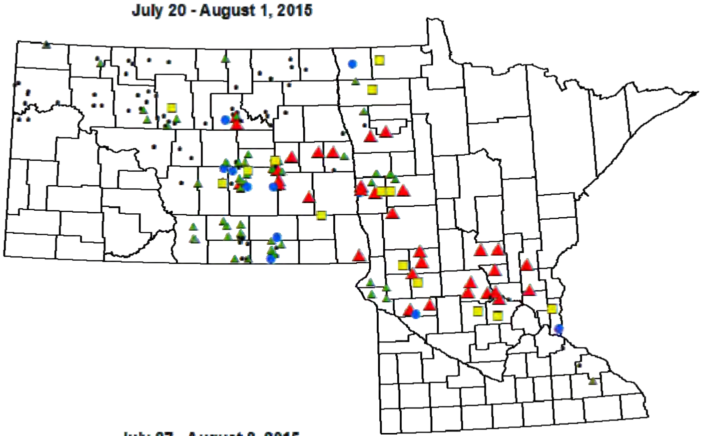


Figure 4. Percent of soybean plants infested with at least one soybean aphid. *(continued)*

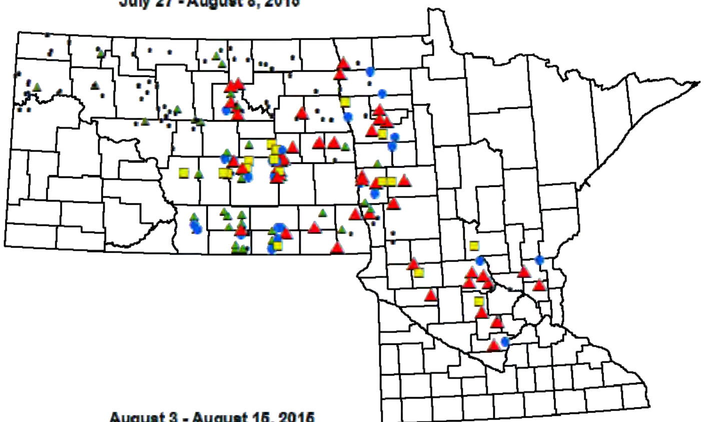
July 13 - July 25, 2015



July 20 - August 1, 2015



July 27 - August 8, 2015



August 3 - August 15, 2015

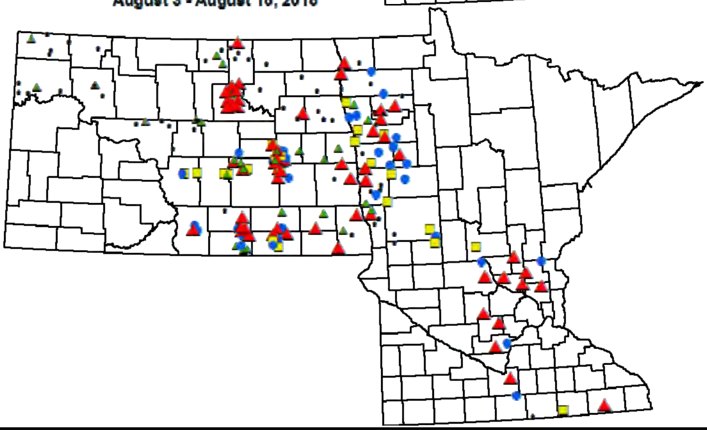
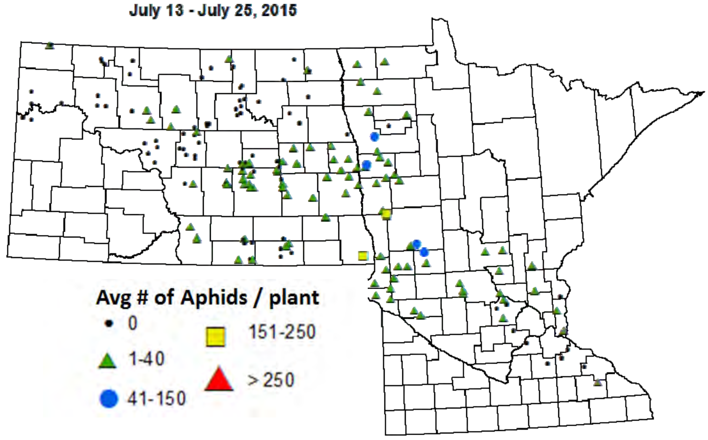
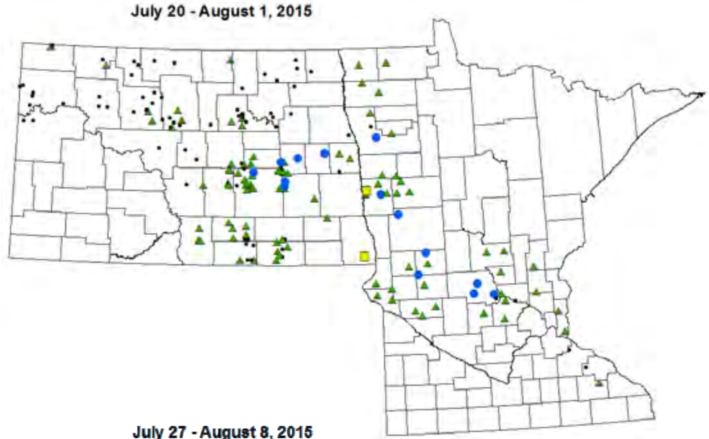


Figure 5. Average number of Soybean aphids estimated / plant *(continued).*

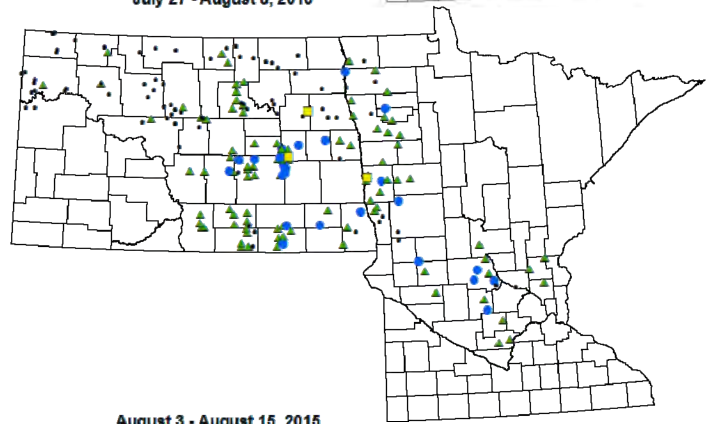
July 13 - July 25, 2015



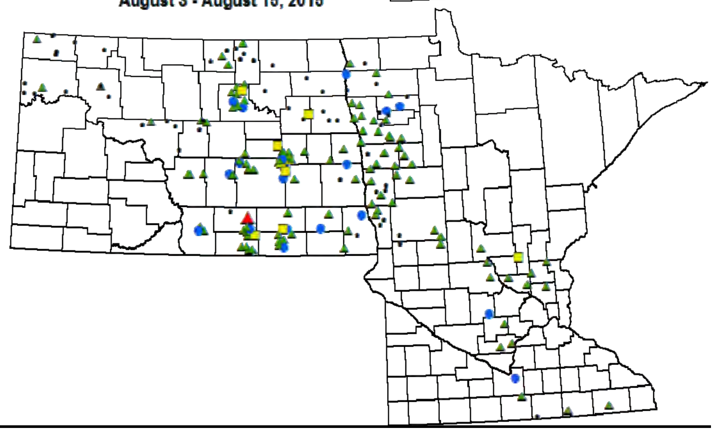
July 20 - August 1, 2015



July 27 - August 8, 2015



August 3 - August 15, 2015



Results (continued):

Detectable aphid infestations were initially found in WC MN and SE North Dakota during the June 22 - July 4 interval. June 29 - July 11 fields with 100% of the plants infested still averaged less than 40 aphids/plant. A few exceptions were found where populations were in the 41-150 aphid/plant range. Infested plant levels progressed rapidly from that point with aphid/plant numbers increasing.

The first randomly selected fields that reached treatment threshold based on Speed Scouting were surveyed July 13 - 18 though the procedure for estimating aphids/plant calculated slightly lower numbers. Wide spread insecticide treatments began at this time in most geographic areas of MN and in eastern North Dakota. Field surveys began to reflect the level of treating by the reduced aphid /plant numbers observed.

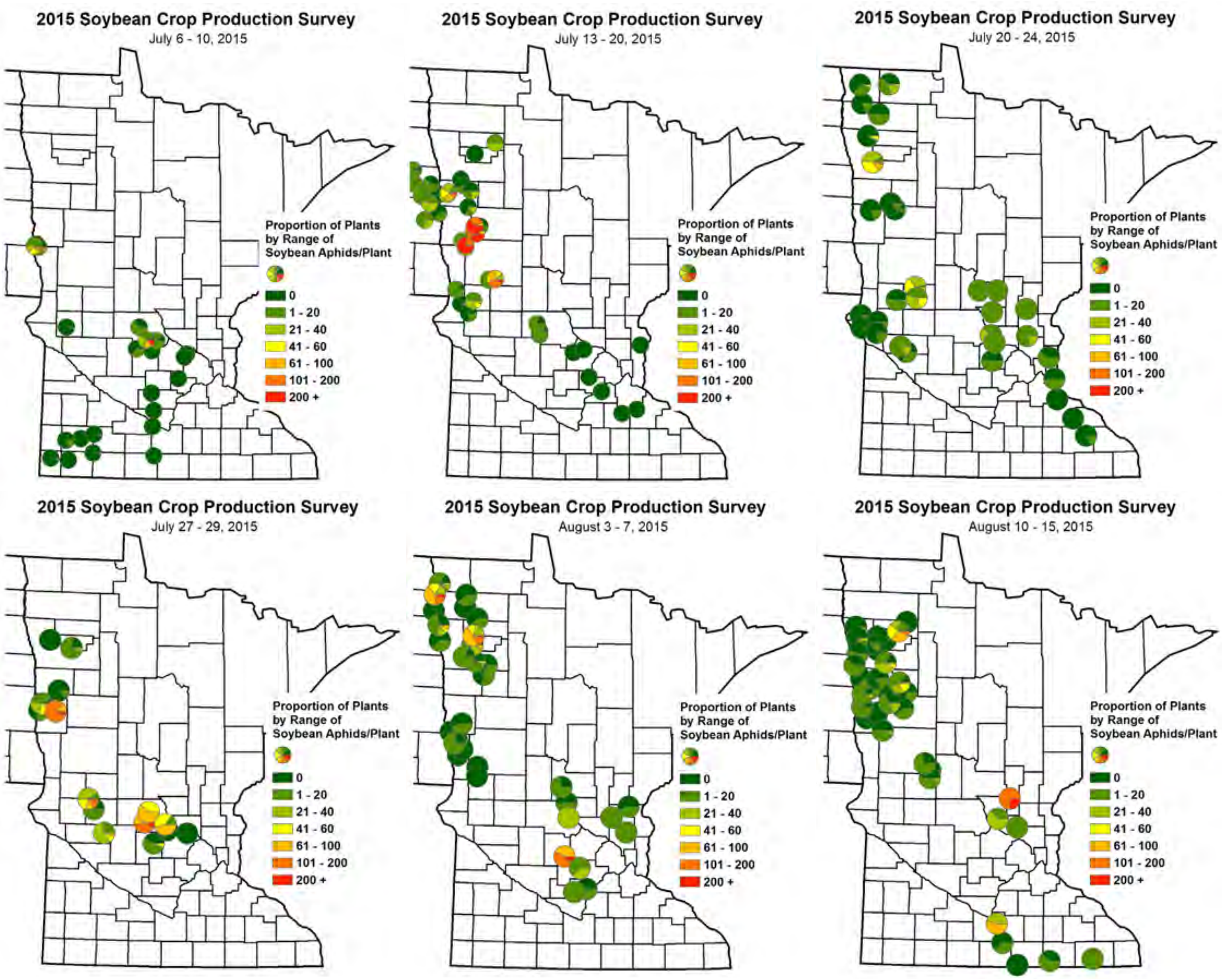
To receive notification of the survey, subscribe to the Northwest Cropping Issues Newsletter at:

http://nw-minnesota-crops.blogspot.com/

Archived maps for MN from 2011 to present are maintained by NDSU and can be found at:

https://www.ag.ndsu.edu/ndipm/ipm-survey-archives

Figure 6. Maps reporting Soybean Aphid (SAB) infestations by the proportion of plants tabulated by range of SAB/plant from July 6 to August 15, 2015.



For Additional Information: Phillip Glogoza and Doug Holen

Soybean Aphid Speed Scouting: An Overview

"Speed Scouting" *is the* method developed by researchers to speed up scouting and increase the likelihood of even a novice to make correct treatment decisions for Soybean aphid when the ***treatment threshold of 250 aphids per plant and 80+% of the plants with these levels*** is reached.

Who wants to count aphids on soybean plants? If you do, fine. Most people don't like the idea. They want a faster process. OR maybe, we let others do the dirty work and then just follow their lead for making treatment decisions.

It is strongly recommended you look in the field to watch how pest populations are developing. Personally, if "Speed Scouting" will get someone into the field who otherwise wouldn't, there is a benefit. Observing pest population growth from its beginning, through its peak, and then the decline, is very educational. It also builds confidence in a person's ability to make the correct treatment decision.

Speed Scouting is easy to learn. It is designed to be quick, so a person isn't dedicating excessive time to scouting fields. The method provides a statistical level of reliability, even for the beginner.

The method is formally referred to as a ***binomial sequential sampling*** plan. The binomial refers to two possible outcomes *(e.g., Yes or No; Infested or Not Infested)* when you look at a randomly selected plant. The sequential sampling aspect refers to the process of keeping track of what plants are and aren't infested *(based on the model's definition of "infested")* and being able to conclude, often times quickly, whether you need to treat or not.

Here is a quick overview:

After collecting data from commercial soybean in southern and central Minnesota, entomologists at the University of Minnesota developed a binomial sampling plan, called Speed Scouting for Soybean Aphid. The recommendation is to use this sampling plan through the pod set stage (R4).

A ***'binomial'*** plan refers to two choices; sometimes it means a presence/absence count or, as in this case, a pre-set cut-off number where counting can be stopped. For this procedure, the binomial sampling cut-off point is 40 aphids per plant. If a plant has:

- ***less than 40 aphids = not-infested***
- ***40 or more aphids = infested***

(remember, counting additional aphids is not necessary after 40, after practice you won't even count, you'll just know)

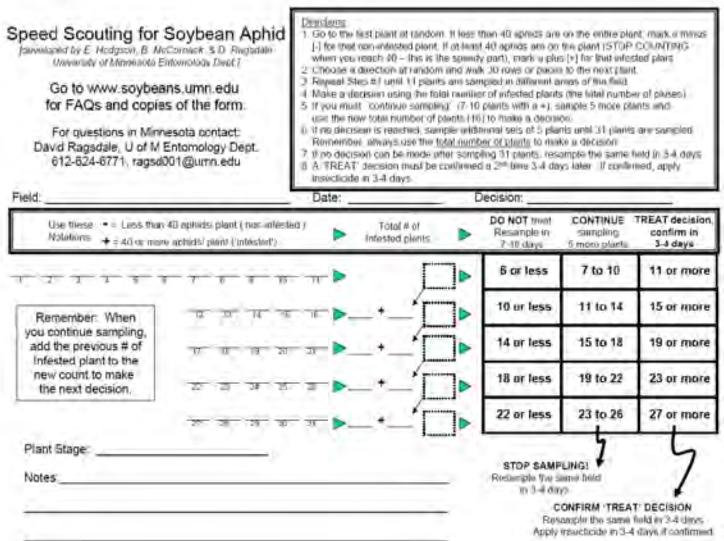
The field scout keeps track of the plants and how they are classified. A worksheet (see example) really is a must in order to keep track. Eventually, enough plants *(the minimum number of plants is 11)* will have been checked to start making some decisions. The statistical models these decisions are based upon will allow you to make one of three decisions with a high degree of reliability *(the model has been set at 75% reliability)*. Those decisions are:

1. **Do not treat** the field,
2. **Treat** the field, *or*
3. **Resample** the field in 3 to 4 days

The binomial sampling plan can improve the cost *(especially in time commitment)* of sampling because every insect no longer needs to be counted. Though not perfect, the model has attempted to balance reliability with cost of scouting ***(Your Time!)***. When fields are close to threshold levels, more plant samples are typically required to make a decision. *However,* when fields are clearly not at threshold or easily over threshold, decisions are made quickly and reliably.

A copy of the worksheet and directions for the procedure are provided on page 7. You can also obtain an electronic copy of the worksheet on the newsletter web page. There is also a worksheet that can be printed and cut to make pocket-sized cards for field recording.

Modifications:
After field validation during 2005, results revealed that the procedure can prematurely reach treatment decisions, typically at about 160 aphids per plant rather than the threshold of 250 aphids per plant. *To ensure the population is actually increasing, it is recommend that the field be re-checked in 3 to 4 days if there are **doubts** about decisions.*


Speed Scouting for Soybean Aphid
(developed by E. Hodgson, B. McCornack & D. Ragsdale
University of Minnesota Entomology Dept.)

Go to www.soybeans.umn.edu
for FAQs and copies of the form.

For questions in Minnesota contact:
David Ragsdale, U of M Entomology Dept.
612-624-6771, ragsd001@umn.edu

Directions
1. Go to the first plant at random. If less than 40 aphids are on the entire plant, mark a minus [-] for that non-infested plant. If at least 40 aphids are on the plant (STOP COUNTING when you reach 40 – this is the speedy part), mark a plus [+] for that infested plant.
2. Choose a direction at random and walk 30 rows or paces to the next plant.
3. Repeat Step #1 until 11 plants are sampled in different areas of the field.
4. Make a decision using the total number of infested plants (the total number of pluses).
5. If you must "continue sampling" (7-10 plants with a +), sample 5 more plants and use the new total number of plants (16) to make a decision.
6. If no decision is reached, sample additional sets of 5 plants until 31 plants are sampled. Remember: always use the total number of plants to make a decision.
7. If no decision can be made after sampling 31 plants, resample the same field in 3-4 days.
8. A 'TREAT' decision must be confirmed a 2nd time 3-4 days later. If confirmed, apply insecticide in 3-4 days.

Field: ____ Date: ____ Decision: ____

Use these Notations: − = Less than 40 aphids/ plant (non-infested) ; + = 40 or more aphids/ plant ('infested') ▶ Total # of Infested plants ▶

Plants	DO NOT treat Resample in 7-10 days	CONTINUE sampling 5 more plants	TREAT decision, confirm in 3-4 days
1–11	6 or less	7 to 10	11 or more
12–16	10 or less	11 to 14	15 or more
17–21	14 or less	15 to 18	19 or more
22–26	18 or less	19 to 22	23 or more
27–31	22 or less	23 to 26	27 or more

Remember: When you continue sampling, add the previous # of Infested plant to the new count to make the next decision.

STOP SAMPLING! Resample the same field in 3-4 days

CONFIRM 'TREAT' DECISION Resample the same field in 3-4 days. Apply insecticide in 3-4 days if confirmed.

Plant Stage: ____

Notes: ____

There is an APP for that. Just Search the APP Store for:
Aphid Speed Scouting
(University of Nebraska)

For Additional Information: Phillip Glogoza

Preemergence Weed control in Soybeans with and without Roundup — NWROC, Crookston, MN

Nearest Town:	Crookston, MN
Soil Type:	Donaldson and Wheaton loam soil
Weed Management:	***Preemergence*** treatments were applied after planting on May 22. ***Postemergence*** treatments were applied on June 29.
Experimental Design:	Randomized Complete Block with three replications

Purpose of Study:

This experiment was designed to evaluate weed control with several preemergence herbicides with and without a postemergence application of Roundup. Weed control and crop injury were rated visually. Crop injury symptoms included stunting and chlorosis of soybean. Yield data were not taken.

Results:

Rainfall of 0.31 inches occurred 6 days following the preemergence application. This resulted in variable activation of the preemergence herbicides.

Preemergence control of common **lambsquarters** (Colq) was only fair for most treatments with Verdict performing poor.

Verdict provided the lowest control of **common mallow** (Coma) while Valor and Fierce provided excellent control of common mallow.

Overall control of **redroot pigweed** (Rrpw) was good to excellent with most of the preemergence treatments.

Preemergence control of **wild buckwheat** (Wibu) was poor for all treatments.

Dual + Reflex, Fierce, and Verdict + Zidua provided good to excellent control of **wild mustard** (Wimu) while Boundary, Valor, and Verdict provided only fair control.

The **postemergence application** of Roundup resulted in excellent control of all weeds present at application time.

Injury symptoms of preemergence herbicides alone were greatest with Fierce, Verdict + Zidua, and Boundary.

Common Lambsquarters (Colq)

Seedling Stage

3-5 Leaf Stage

common mallow (Coma)

Seedling Stage

n - Leaf Stage

redroot pigweed (Rrpw)

Seedling Stage

3-5 Leaf Stage

For Additional Information:
Jeffrey L. Gunsolus and Jochum Wiersma

Project Funding Provided by:
Minnesota Soybean Research & Promotion Council

Preemergence Weed control in Soybeans with and without Roundup [continued]

Preemergence weed control in soybeans with and without Roundup at Crookston, MN - 2015 (Gunsolus and Wiersma).

Treatment[1]	Rate[1]	Weed Control (7/14) Colq	Coma	Rrpw	Wibu	Wimu	Soybean Injury (7/14)
	(product/A)	---------------------------------(%)---					------------------------------
Preemergence May 22 / (Postemergence June 29)							
Boundary[2]	1.5 pt	68	73	83	30	70	8
Boundary / (Roundup[3] + AMS[4])	1.5 pt / (32 oz + 3 qt)	100	100	100	100	98	13
Dual II Magnum[5] + Reflex[6]	18 oz + 0.75 pt	62	83	97	17	100	0
'Dual II Magnum + Reflex / (Roundup + AMS)	18 oz + 0.75 pt / (32 oz + 3 qt)	100	100	100	98	100	5
Valor SX[7]	3 oz	50	98	70	40	62	3
Valor SX / (Roundup + AMS)	3 oz / (32 oz + 3 qt)	100	100	100	100	98	2
Fierce[8]	3.75 oz	63	100	100	35	93	15
Fierce / (Roundup + AMS)	3.75 oz / (32 oz + 3 qt)	100	97	100	100	100	27
Verdict[9]	5 oz	22	57	80	30	73	0
Verdict / (Roundup + AMS)	5 oz / (32 oz + 3 qt)	100	100	100	97	100	3
Verdict + Zidua[10]	5 oz + 2 oz	63	87	98	43	100	12
Verdict + Zidua / (Roundup + AMS)	5 oz + 2 oz / (32 oz + 3 qt)	100	100	100	100	100	23
(Roundup + AMS)	(32 oz + 3 qt)	98	100	100	88	100	2
LSD (0.05)		14	21	24	24	19	10

[1] Treatments and rates in parenthesis were applied postemergence
[2] Boundary 6.5L = S-metolachlor (5.25 lb ai/gal) & metribuzin (1.25 lb ai/gal).
[3] Roundup = Roundup PowerMax 4.5S = glyphosate.
[4] AMS = N-Pak ammonium sulfate solution (3.4 lbs/gal).
[5] Dual II Magnum 7.64EC = s-metolachlor.
[6] Reflex 2E = fomesafen.
[7] Valor SX 51WDG = flumioxazin.
[8] Fierce 76WDG = 33.5% flumioxazin & 42.5% pyroxasulfone.
[9] Verdict 5.57EC = = saflufenacil (0.57 lbs ai/gal) & dimethenamid-P (5.0 lbs ai/gal).
[10] Zidua 85WG - pyroxasulfone.

wild buckwheat (Wibu)

Seedling Stage

3-5 Leaf Stage

wild mustard (Wimu)

Seedling Stage

3-5 Leaf Stage

For Additional Information:
Jeffrey L. Gunsolus and Jochum Wiersma

Time of weed removal with Roundup in soybeans — NWROC, Crookston, MN

Nearest Town: Crookston, MN

Soil Type: Donaldson and Wheaton loam soil

Planting Date: May 26, 2015

Weed Management: Postemergence applications of Roundup PowerMax (32oz/A) + AMS (3qts/A) were applied on June 15 to 2 inch weeds, June 29 to 4 inch weeds, and July 7 to 8 inch weeds.

Experimental Design: Randomized Complete Block with three replications.

Purpose of Study:

This experiment was designed to evaluate weed control when Roundup was applied at three different application times. Weeds present were common lambsquarters (Colq), common mallow (Coma), redroot pigweed (Rrpw), wild buckwheat (Wibu), wild mustard (Wimu), and yellow foxtail (Yeft). Crop injury symptoms included stunting and chlorosis of soybean. Yield data were not taken. Weed control and crop injury were rated visually.

Results:

The earliest application controlled weeds present, but later germinating weeds resulted in lower weed control ratings at the July 14 rating.

The later two applications controlled most weeds with the exception of wild buckwheat at the July 7 application date. Control was reduced presumably due to wild buckwheat size.

Injury observed was chlorosis most likely due to weed competition.

Time of weed removal with Roundup in soybeans at Crookston, MN - 2015 (Gunsolus and Wiersma).

	Weed Control (7/14)						Soybean Injury
Treatment	Colq	Coma	Rrpw	Wibu	Wimu	Yeft	(7/14)
	(%)						
Roundup[1] (32oz/A) + AMS[2] (3 qt/A)							
Applied to 2 inch weeds on June 15	85	87	88	73	100	92	0
Applied to 4 inch weeds on June 29	100	100	100	100	100	100	7
Applied to 8 inch weeds on July 7	100	100	100	67	100	100	17
LSD (0.05)	7	ns	10	24	ns	ns	ns

[1] Roundup PowerMax 4.5S = glyphosate.

[2] AMS = N-Pak ammonium sulfate solution (3.4 lbs/gal).

For Additional Information:
Jeffrey L. Gunsolus and Jochum Wiersma

Project Funding Provided by:
Minnesota Soybean Research & Promotion Council

Yield and Quality of Organically Grown Soybean and Corn Treated With an Inoculant — Clay County

Cooperator:	Lynn Brakke Organic Farms	
Nearest Town:	Comstock, MN	
Tillage:	Spring: One pass with a field cultivator	
	Corn	**Soybean**
Previous Crop:	Alfalfa	Soybean
Planting Date:	5/16/15	6/5/15
Variety:	2883 blue corn	EXP 350
Row Width:	22 inches	22 inches
Inoculant:	TerraMax N-+-IF	TerraMax PFB-IF
Planting Population:	210,000/ac	32,000/ac
Harvest Date:	9/29/15	10/13/15

Purpose of Study:
Evaluate TerraMax, N-+-IF and PFB-IF, on corn yield and soybean yield and quality in an organic production system.

Methods:
Inoculants were applied in-furrow to soybean and corn using a John Deere 7300 Vacuum Planter. All plots except untreated check received inoculant at 12.8 fl oz or 25.6 fl oz per acre. Field plots were 18 rows wide and 30 feet long. Stand counts were taken on middle two rows (rows 9 and 10) on 24 June. At harvest, ten feet of row was collected from the middle two rows of each plot and used to determine yield and quality. Soybean and corn yields were adjusted to 13% and 15.5% moistures, respectively. Experimental design was a randomized complete block with four replicates. There were two locations for each experiment. Locations were combined for statistical analysis.

Results:
Stand counts were not statistically significant among treatments for soybean or corn (data not shown). There were no significant differences among treatment yields for soybean (table 1) or corn (table 2). There were no significant differences among soybean treatments for protein and oil (table 1).

Table 1. Yield and quality from organically grown soybean treated with an inoculant. Comstock, MN, 2015.

Treatment	Yield (*bu/ac*)	Protein (%)	Oil (%)
Untreated check	30.8	37.9	18.1
TerraMax PFB-IF 12.8 fl oz/ac	32.0	37.7	17.9
TerraMax PFB-IF 25.6 fl oz/ac	32.4	38.1	17.9
LSD 0.05	*NS*	*NS*	*NS*

Table 2. Yield and quality from organically grown and corn treated with an inoculant. Comstock, MN, 2015.

Treatment	Yield (*bu/ac*)
Untreated check	184.0
TerraMax N-+-IF 12.8 fl oz/ac	169.8
TerraMax N-+-IF 25.6 fl oz/ac	174.4
LSD 0.05	*NS*

For Additional Information:
Randy Nelson, UMN Extension Educator, Clay County

Acknowledgements:
Thanks to Hal Mickelson, Robert Bouvette Jr., Mark Hanson, Galen Thompson, and Chris Olson, Northwest Research and Outreach Center, Crookson, MN, for assistance with threshing and quality analysis.

A 2014 multi-site field study on the effects of Clariva seed treatment on soybean yield and Soybean Cyst Nematode reproduction — Statewide

Purpose of Study:
The soybean cyst nematode (SCN) is a serious pest of Minnesota soybean and has been managed with crop rotation and soybean varieties with resistance to SCN. Unfortunately, SCN populations virulent on (able to infest, reproduce on and damage) SCN resistant soybeans are increasingly widespread. Virulence on the PI 88788 resistance source is the most common, but numerous field populations virulent on Peking or both PI88788 and Peking resistance sources have been observed. The frequency of these virulent SCN populations has increased in Minnesota. Based on field collected samples, the percentage of SCN populations virulent on PI8788 increased from 13.6% to 72.4 % between 1997-1998 and 2007-2008 surveys. Those virulent on Peking increased from 3.4% to 15% over the same period (Chen, et al. 2011). Therefore, effective chemical or biological complements to resistant varieties would be helpful to soybean growers' SCN management programs. Seed applied pesticides for soybeans are being developed and marketed at an increasing rate. One of these is the bacterium *Pasteuria nishizawae*, a biological nematicide and a component of Clariva™ Complete seed treatment, Syngenta Crop Protection®.

The Minnesota Soybean Research and Promotion Council funded a 2014 project to provide geographically and environmentally robust data on Clariva for SCN management. One specific objective of this study was to evaluate the effects of the new biological nematicide on soybean yield, including potential interactions with SCN host plant resistance, environment and an insecticide plus fungicide combination.

Methods:
The study was co-located at University of Minnesota Soybean Breeding Project sites throughout Minnesota. These sites varied by geography, soil type, long-term field histories, SCN populations and planting date. Based on site location, a northern or southern set of soybean varieties was used (Figure 1).

At each site, four replications of each of six treatments were planted with a plot planter. Individual treatment plots were 10-foot wide by 12-foot long at every site. Row spacing was 30-inch except the northwest Minnesota sites where 10 -inch rows were planted. Twenty sites were planted, many of which had difficult planting and spring weather conditions. The southern sites were planted from May 7 to June 5 and the northern sites from May 23 to June 4. One northern site was not harvested because of herbicide damage and one southern site was not harvested because of severe late season hail.

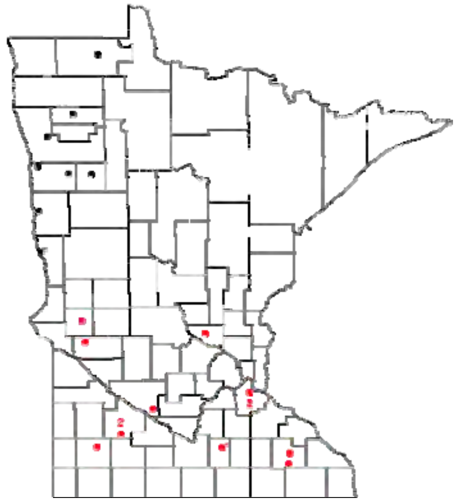


Figure 1. Sites of the 2014 soybean seed treatment trial. Red = southern varieties; black = northern varieties, * no yield obtained.

An SCN susceptible (NK S22-F8 southern sites, NK S06-R9 northern sites) and a PI88788 SCN resistant (NK S22-S1 southern, NK S06-H5 northern) variety were planted at each site. For each variety, seed was untreated, treated with Clariva Complete or treated with Cruiser Maxx + Vibrance, an insecticide/fungicide counterpart to Clariva Complete without the *Pasteuria* nematicide. Syngenta Crop Protection supplied the treated and untreated seed for each variety. For each variety, the treated and untreated seeds were of the same seed lot. Soil samples for fertility and SCN populations were taken from the center two rows at planting. SCN samples were also taken from the center two rows of each plot at soybean maturity. Additional mid-season samples were taken in sites known to have SCN populations in an attempt to detect any temporary suppression in SCN numbers. The SCN reproduction factor (*Rf*) was determined by dividing end of season populations (*Pf*) by initial populations (*Pi*).

Soybean aphid populations were scouted and several southwest and west central Minnesota plots were treated for aphids when populations in individual plots reached economic threshold. A plot combine was used to obtain yields from the center two rows of each 4-row plot.

The factorial design of this experiment (2 variety x 3 seed treatment) allowed us to examine the contributions of both SCN resistance and seed treatments to soybean yield and SCN populations across multiple environments

For Additional Information:
Bruce Potter, Senyu Chen, Phil Glogoza, Ryan Miller and David Nicolai

Project Funding Provided by:
Minnesota Soybean Research and Promotion Council

Results:

The spring of 2014 was challenging for planting soybeans into a good seedbed on a timely basis. Additional heavy rains and ponded water after planting caused stand issues at several sites. Because both seed treatments contained several fungicides and an insecticide, assigning yield benefits was expected to be difficult.

We used a conservative (*alpha = 0.05*) level to detect significant differences in yield and SCN reproduction. Using a less conservative alpha value did not change interpretations of yield differences.

Yield

Eight of 18 sites showed a significant yield difference by variety. In the south, these differences were the SCN resistant variety out yielding the susceptible in sites with SCN present. In the north, where differences occurred, the SCN resistant variety out-yielded the susceptible including a non-infested site in Polk County. *As expected, there was an interaction between varietal yield differences and site where resistant varieties were most likely to yield more as compared with susceptible varieties in SCN infested sites.*

Significant yield responses to either seed treatment, above the untreated controls, were not common in 2014. Two of 18 sites showed a yield increase with treated seed. In a Norman County site, both seed treatments yielded more than the untreated seed control. In an Olmstead County site with undetectable levels of SCN eggs, both seed treatments yielded more than the untreated varieties with the Clariva Complete treatment yielding more than both the fungicides + insecticide and untreated varieties. We did not observe an interaction between SCN resistant varieties and seed treatment on yields. It is possible that the yield responses to seed treatments were due to microbial pathogens or early season soybean aphids. Stand differences by treatment were not observed. A significant correlation between soil fertility test values and yield or seed treatment response was not detected.

SCN populations

SCN populations are extremely variable within fields, even within relatively small areas, and these data were no exception. However, some consistent trends were observed. The SCN resistant variety significantly (*alpha=0.05*) reduced nematode reproductive rates as compared to the susceptible at 11 of the 18 sites where SCN was detected. Seed treatments did not change SCN reproduction compared to untreated seed. Using a much higher alpha (0.20) increased the differences detected for SCN reproduction by variety to 14 of 18 SCN infested sites. It also, found an effect for seed treatment at a single site where the fungicide/insecticide treatment without Clariva had the least SCN reproduction. The less conservation criteria for determining if treatment differences also increases the risk of erroneous conclusions.

Two SCN infested southern Minnesota sites showed an interaction with variety and seed treatment but these were not consistent across the sites. In some cases, the Clariva treatment had greater reproduction than the seed treatment without nematicide or untreated seed. Care in interpreting SCN reproduction factors is needed as they are in part related to SCN initial population density, and soybean root volume and health.

At least one of the trial sites had an SCN population virulent on PI88788 resistance, but reproduction was still less than the susceptible variety. These data show that SCN resistance reduces SCN populations compared to a susceptible variety.

Other work

During 2104, an additional greenhouse study on efficacy was conducted and long-term field studies examining the impact of Clariva Complete on SCN population dynamics were initiated.

Weather induced variability was a factor in these 2014 data with respect to yields. This study will be repeated in 2015 but mostly limited to SCN infested sites.

References:

Chen, S. (ed.), J. Kurle, D. Malvick, B. Potter, and J. Orf. 2011. Soybean Cyst Nematode Management Guide. University of Minnesota Extension Publ. St. Paul, MN. 26pp.
(http://www.extension.umn.edu/agriculture/soybean/soybean-cyst-nematode/)

Products are mentioned for illustrative purposes only. Their inclusion does not mean endorsement and their absence does not imply disapproval.

Note: *The Clariva Seed Treatment Study was conducted again in 2015. Results of the 2015 project are still being completed and were not available by publication deadline.*

For Additional Information:
Bruce Potter, Senyu Chen, Phil Glogoza, Ryan Miller and David Nicolai

Table 1. Multisite factorial analysis of variance.

Factorial ANOVA	YIELD p(F)	SCN REPRODUCTION p(F)
SITE	1.0000	0.0000
VARIETY (SCN)	0.0000	0.0017
SEED TR.	0.1487	0.1531
SITE * VARIETY (SCN)	0.0000	0.0000
SITE * SEED TRT	0.8896	0.0128
VARIETY (SCN) * SEED TRT	0.5828	0.1500
SITE * VARIETY (SCN) * SEED TRT	0.9890	0.0020

Table 2. Factorial ANOVA for Yield and SCN reproduction (SCN resistance x seed treatment) at each site.

Factorial ANOVA	SCN Pi rating*	YIELD p(F) Variety	p(F) Seed trt	p(F) Variety x Seed trt	SCN Pf/Pi p(F) Variety	(reprod. Factor) p(F) Seed trt	p(F) Variety x Seed trt
Becker	1	0.3768	0.1345	0.7091	0.0158	0.2218	0.1843
Westbrook(Dovray)	3	0.3430	0.2339	0.7827	0.0012	0.4270	0.7789
Lamberton(Non-infested)	2	0.5107	0.7320	0.9824	0.2142	0.5099	0.4031
Lamberton (Infested)	3	0.0009	0.1655	0.7864	0.0001	0.1364	0.0248
Fairfax	3	0.0001	0.3786	0.2412	0.0001	0.5309	0.9018
Waseca (infested)	4	No yield - Hail damage			0.1569	0.9669	0.5658
Rochester - Lawler	1	0.5422	0.0100	0.7442	0.4397	0.7582	0.8304
High Tower -Welter	4	0.0010	0.4453	0.4851	0.0008	0.0612	0.0174
Rosemount - (infested)	2	0.0385	0.8216	0.8552	0.0640	0.8436	0.7802
Rosemount (non-infested)	2	0.1171	0.5029	0.4150	0.0000	0.9134	0.8585
Morris	2	0.5054	0.4712	0.4350	0.0029	0.3071	0.2613
Danvers	3	0.4572	0.5822	0.9901	0.5096	0.5615	0.5736
Crookston	1	0.0000	0.2833	0.1257	No SCN		
Shelley	1	0.2383	0.9867	0.3770	No SCN		
TRF	2	0.2002	0.9174	0.7573	0.0078	0.4297	0.4370
Moorhead-Kragnes	1	0.0013	0.4161	0.2865	0.0732	0.9577	0.9249
Gary	3	0.0004	0.0474	0.1221	0.0000	0.9738	0.8568
Kent	3	No yield - Herbicide damage			0.0281	0.2502	0.3331
Mahnomen	2	0.0000	0.2833	0.1257	0.0019	0.4822	0.5965
Roseau	1	0.9900	0.8135	0.2162	No SCN		

*SCN Pi rating: 1= <50 2 = 51-250 3 = 251-2500 4 > 2501-10000 5 > 10000

For Additional Information:
Bruce Potter, Senyu Chen, Phil Glogoza, Ryan Miller and David Nicolai

Table 3. Factorial ANOVA Probabilities(F) Yield and SCN reproductive index by variety (SCN resistance) at each location.

Site	Variety North/South	SCN Pi rating*	Yield Prob(F)	Yield Bu/acre Resistant	Yield Bu/acre Susceptible	SCN Reproduction Prob(F)	SCN Reproduction Pf/Pi Resistant	SCN Reproduction Pf/Pi Susceptible
Becker	South	1	0.3768	67.5	69.4	**0.0158**	**39.2**	**640.1**
Westbrook(Dovray)	South	3	0.3430	49.0	46.0	**0.0012**	**1.0**	**2.5**
Lamberton(Non-infested)	South	2	0.5107	60.5	63.7	0.2142	1.5	5.2
Lamberton (Infested)	South	3	**0.0009**	**30.0**	**17.1**	**0.0001**	**0.6**	**1.7**
Fairfax	South	3	**0.0001**	**50.2**	**39.6**	**0.0001**	**7.2**	**23.1**
Waseca (infested)	South	4	No yield			0.1569	0.7	0.5
Rochester - Lawler	South	1	0.5422	52.3	51.9	0.4397	3.5	12.7
High Tower -Welter	South	4	**0.0010**	**56.7**	**51.1**	**0.0008**	**0.6**	**1.3**
Rosemount - (infested)	South	2	**0.0385**	**45.2**	**48.3**	0.0640	0.8	8.5
Rosemount (non-infested)	South	2	0.1171	39.6	45.0	**0.0000**	**0.3**	**14.6**
Morris	South	2	0.5054	63.8	62.4	**0.0029**	**1.1**	**28.6**
Danvers	South	3	0.4572	38.9	42.8	0.5096	3.2	4.3
Crookston	North	1	**0.0000**	**40.0**	**31.7**	No SCN		
Shelley	North	1	0.2383	18.7	16.9	No SCN		
TRF	North	2	0.2002	34.4	32.1	**0.0078**	**2.4**	**19.9**
Moorhead-Kragnes	North	1	**0.0013**	**41.4**	**36.6**	0.0732	0.1	3.0
Gary	North	3	**0.0004**	**23.5**	**15.4**	**0.0000**	**1.6**	**12.4**
Kent	North	3	No yield	No yield	No yield	**0.0281**	**1.0**	**3.8**
Mahnomen	North	2	**0.0000**	**40.0**	**31.7**	**0.0019**	**0.2**	**2.3**
Roseau	North	1	0.9900	31.1	31.1	No SCN		

*SCN Pi rating: 1= <50 2 = 51-250 3 = 251-2500 4 > 2501-10000 5 > 10000

SCN Pf/Pi (Reproductive Factor) = SCN final egg density (plot)/initial SCN egg density (replicate mean)

Table 4. ANOVA Probabilities(F) Yields* and SCN reproductive index by seed treatment at each location.* Where yield differences are significant (*p= 0.05*) both seed treatments yielded greater than the untreated seed.

Site	Variety North/South	Pi Rating*	Yield Prob(F)	Yield None	Yield Clariva Complete	Yield Cruiser Maxx + Vibrance	SCN Reproduction (Pf/Pi) Prob(F)	SCN Reproduction (Pf/Pi) None	SCN Reproduction (Pf/Pi) Clariva Complete	SCN Reproduction (Pf/Pi) Cruiser Maxx + Vibrance
Becker	South	1	0.1345	65.7	68.2	71.4	0.2218	212.0	182.8	624.2
Westbrook(Dovray)	South	3	0.2339	48.7	43.7	50.0	0.4270	1.5	1.7	2.1
Lamberton(Non-infested)	South	2	0.7320	61.2	60.3	64.7	0.5099	1.3	3.3	5.5
Lamberton (Infested)	South	3	0.1655	22.7	20.2	27.7	0.1364	1.5	1.0	0.9
Fairfax	South	3	0.3786	46.6	44.9	43.2	0.5309	12.8	16.6	16.0
Waseca (infested)	South	4					0.9669	0.6	0.6	0.6
Rochester - Lawler	South	1	**0.0100**	**50.0**	**54.0**	**52.3**	0.7582	5.4	4.7	14.3
High Tower -Welter	South	4	0.4453	52.9	53.8	55.1	0.0612	1.1	1.0	0.7
Rosemount - (infested)	South	2	0.8216	46.2	46.7	47.3	0.8436	6.1	4.5	3.4
Rosemount (non-infested)	South	2	0.5029	40.0	44.7	42.4	0.9134	8.0	7.4	7.0
Morris	South	2	0.4712	61.5	64.8	62.9	0.3071	18.8	6.1	19.6
Danvers	South	3	0.5822	37.4	43.9	41.3	0.5615	1.7	4.3	4.5
Crookston	North	1	0.2833	35.0	35.3	37.3				
Shelley	North	1	0.9867	17.8	17.6	17.9				
TRF	North	2	0.9174	32.7	33.5	33.5	0.4297	5.9	12.9	14.7
Moorhead-Kragnes	North	1	0.4161	38.4	40.2	38.4	0.9577	1.9	1.4	1.4
Gary	North	3	**0.0474**	**16.2**	**22.1 A**	**20.0**	0.9738	6.8	7.0	7.1
Kent	North	3					0.2502	1.1	2.6	3.6
Mahnomen	North	2	0.2833	34.9	35.3	37.2	0.4822	1.2	1.7	0.8
Roseau	North	1	0.8135	31.2	31.8	30.3				

*SCN Pi rating: 1= <50 2 = 51-250 3 = 251-2500 4 > 2501-10000 5 > 10000

SCN Pf/Pi (Repriductive Factor) = SCN final egg density (plot)/initial SCN egg density (replicate mean)

Table 5. Probabilities and SCN reproductive rates for site x SCN resistance x seed treatment.

Site	Variety North/South	SCN Pi rating*	Variety x Seed Treat. Prob(F)	Susceptible None	Susceptible Clariva Complete	Susceptible Cruiser Maxx + Vibrance	Resistant None	Resistant Clariva Complete	Resistant Cruiser Maxx + Vibrance
Becker	South	1	0.1843	358.7	332.8	1228.7	65.2	32.8	19.8
Westbrook(Dovray)	South	3	0.7789	2.1	2.3	3	0.9	1	1.2
Lamberton(Non-infested)	South	2	0.4031	0.6	5.5	9.6	2.0	1.1	1.4
Lamberton (Infested)	South	3	**0.0248**	**2.5**	**1.4**	**1.2**	**0.4**	**0.5**	**0.7**
Fairfax	South	3	0.9018	20.1	24.4	23.7	5.6	7.8	8.2
Waseca (infested)	South	4	0.5658	0.6	0.4	0.5	0.6	0.8	0.7
Rochester - Lawler	South	1	0.8304	6.4	7.8	23.9	4.3	1.5	4.6
High Tower -Welter	South	4	**0.0174**	**1.3**	**1.7**	**0.8**	**1.0**	**0.4**	**0.6**
Rosemount - (infested)	South	2	0.7802	12.1	6.7	6.7	0.1	2.3	0.1
Rosemount (non-infested)	South	2	0.8585	15.8	14.6	13.5	0.2	0.2	0.5
Morris	South	2	0.2613	37.1	10.5	38.1	0.5	1.8	1.1
Danvers	South	3	0.5736	3.7	3.6	5.6	1.5	4.9	3.4
Crookston	North	1	No SCN						
Shelley	North	1	No SCN						
TRF	North	2	0.4370	9.5	22.9	27.3	2.2	2.9	2.1
Moorhead-Kragnes	North	1	0.9249	3.7	2.6	2.6	0.0	0.2	0.2
Gary	North	3	0.8568	12.6	12.3	12.2	1.0	1.6	2.1
Kent	North	3	0.3331	1.5	3.9	6.2	0.7	1.3	0.9
Mahnomen	North	2	0.5965	2.1	3.1	1.6	0.2	0.2	0.1
Roseau	North	1	No SCN						

*SCN Pi rating: 1= <50 2 = 51-250 3 = 251-2500 4 > 2501-10000 5 > 10000

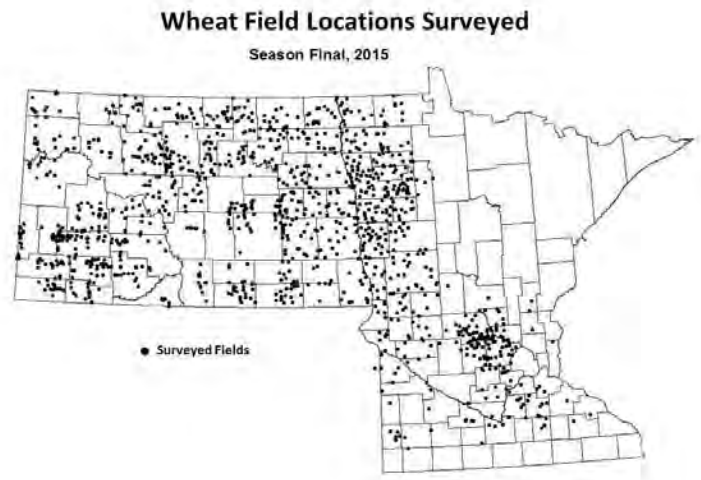
SCN Pf/Pi (Reproductive Factor) = SCN final egg density (plot)/initial SCN egg density (replicate mean)

For Additional Information:
Bruce Potter, Senyu Chen, Phil Glogoza, Ryan Miller and David Nicolai

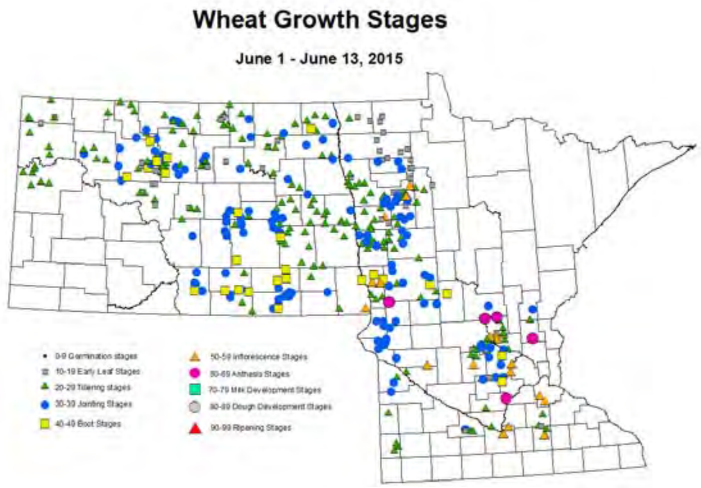
2015 Statewide Wheat Crop and Pest Survey

Cooperator: Minnesota Association of Wheat Growers, NDSU IPM Survey

Purpose of Study:
The objective of this project was to allow for timely wheat crop staging and pest identification across the state of MN in order to inform producers of current crop conditions and potential threats. Information was released through media (e.g., radio, internet-based news releases, archived web pages, consultant conversations and e-mail. The survey was conducted in coordination with the NDSU IPM Survey, providing extensive, continuous coverage of small grains across MN and ND.

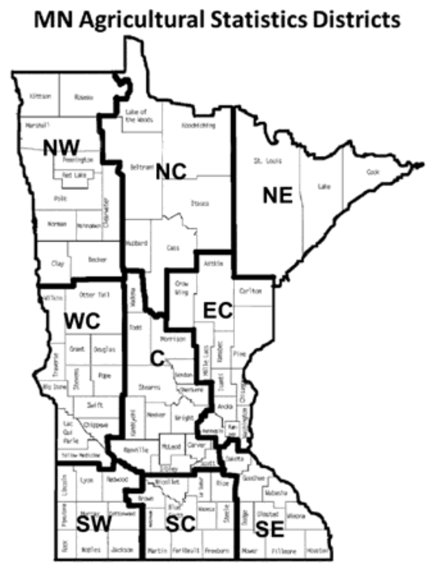


Results:
Field surveys were initiated the last 2 weeks of May. Thanks to favorable spring planting conditions, the crop ranged from tillering in the north to beginning anthesis in the southern survey locations *(see map for Growth Stages - June 1 to 13)*.



Small grain diseases by prevalence were Tan Spot, occurring throughout the region; *Septoria tritici* blotch occurring with high incidences in C MN; Barley yellow dwarf incidence was found where aphids established early in C MN; Bacterial leaf streak from C to WC MN; Wheat stripe rust occurred in C and NW MN; and, Head blight (scab) in WC MN where high humidity during heading contributed to higher than forecasted infections.

When reviewing the maps. ***Incidence*** is defined as “the percent of sampled plants with the disease.” ***Severity*** is defined as “the percent of plant tissue that is diseased on affected plants.” Therefore, maps that report incidence are reporting percent plants affected. Severity tells us how bad infections were.



The most important insect related production issues were the appearance of cereal aphids which reached threshold levels in C MN early and reflected the higher incidence of BYD. Armyworm did make their presence known in SW MN by early July, prompting some insecticide treatments.

To receive notification of the survey, subscribe to the Northwest Cropping Issues Newsletter at:

http://nw-minnesota-crops.blogspot.com/

Archived maps for MN from 2011 to present are maintained by NDSU and can be found at:

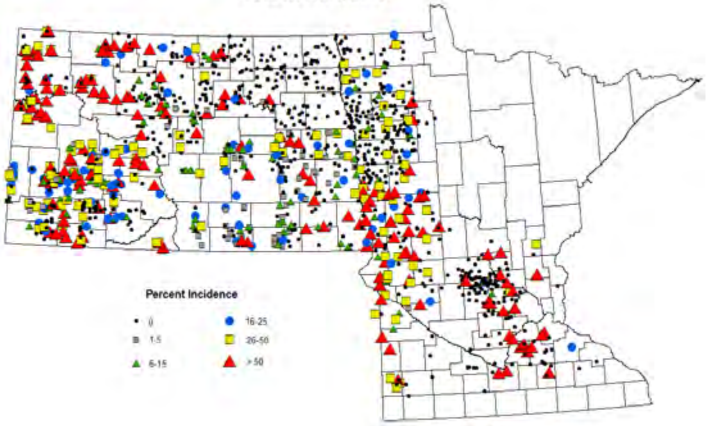
https://www.ag.ndsu.edu/ndipm/ipm-survey-archives

For Additional Information:
Madeleine Smith, Doug Holen, Phillip Glogoza and Jochum Wiersma

Project Funding Provided by:
Minnesota Association of Wheat Growers

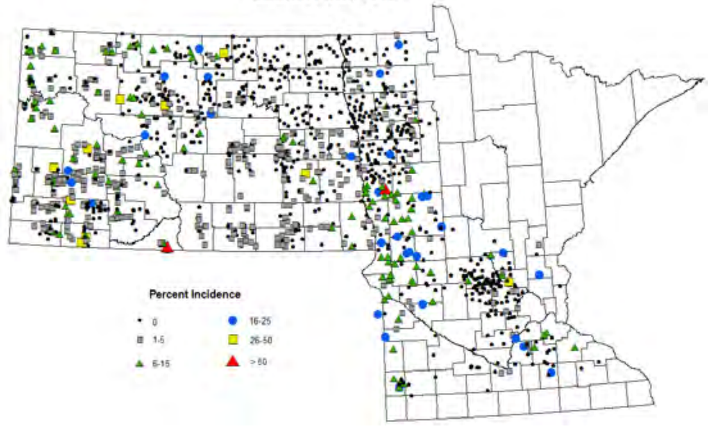
Tan Spot Percent Incidence

Season Final, 2015



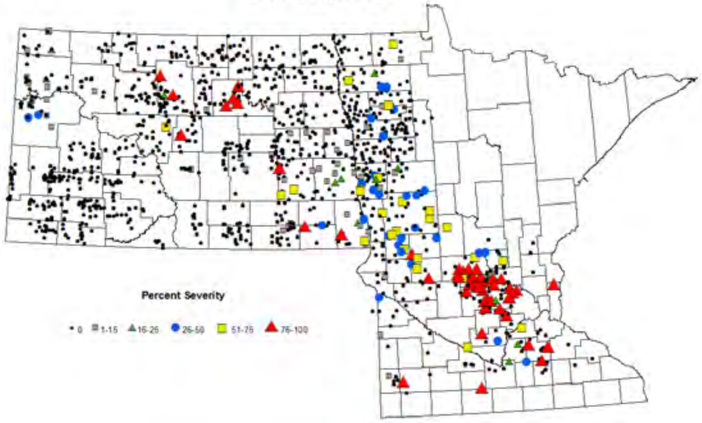
Tan Spot Percent Severity

Season Final, 2015



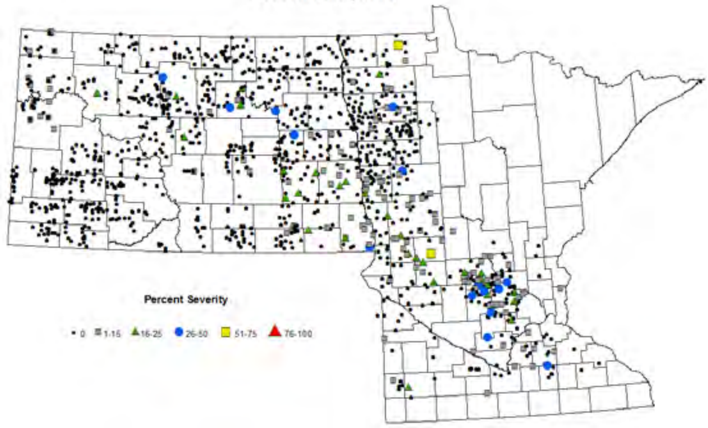
Wheat Septoria SSP Incidence

Season Final, 2015



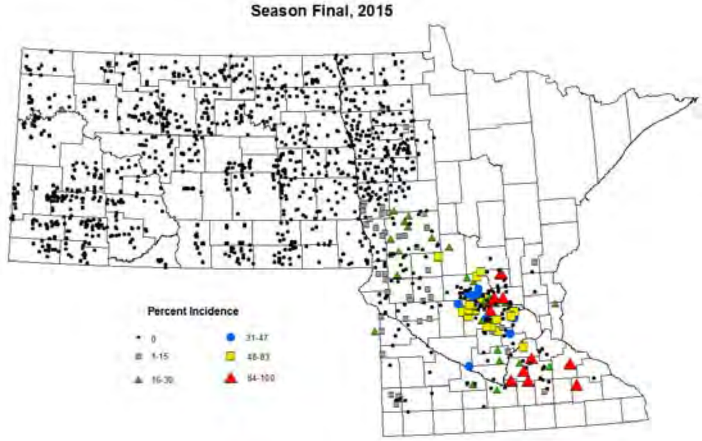
Wheat Septoria SSP Severity

Season Final, 2015



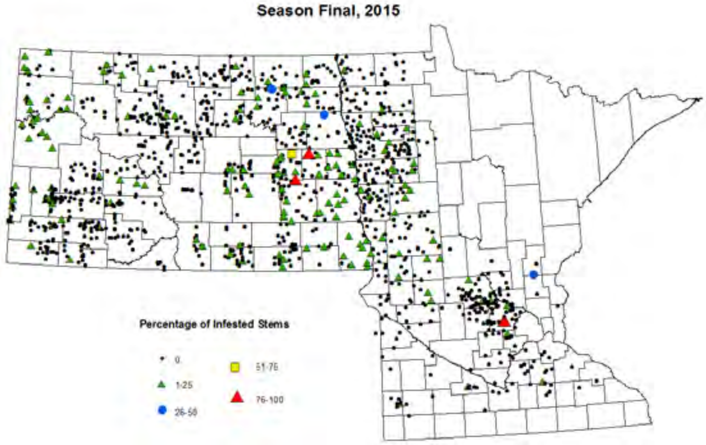
Wheat Barley Yellow Dwarf Virus

Season Final, 2015



Aphids in Wheat

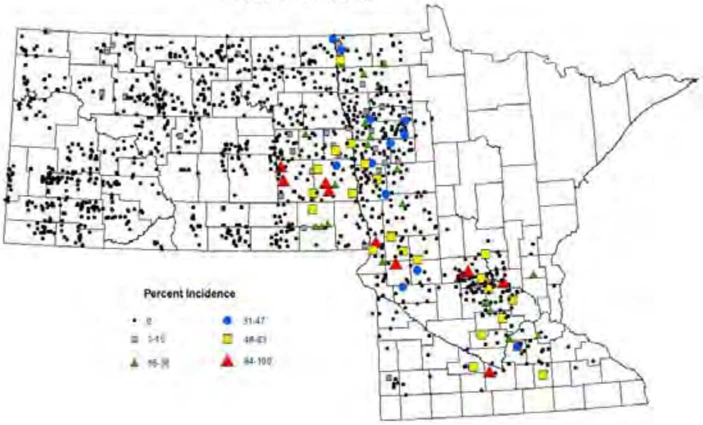
Season Final, 2015



For Additional Information: Madeleine Smith, Doug Holen, Phillip Glogoza and Jochum Wiersma,

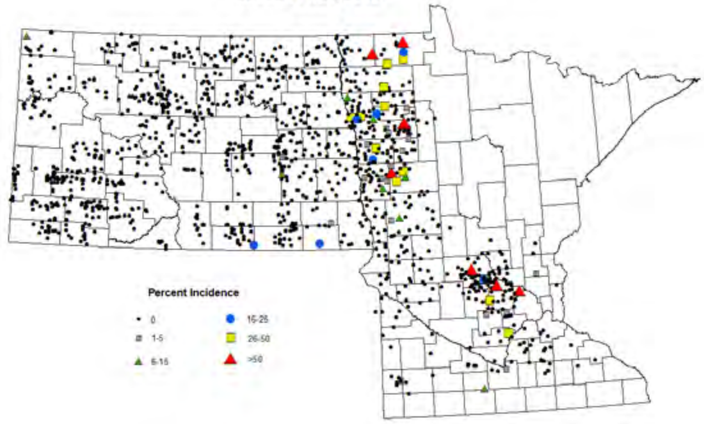
Wheat Bacterial Leaf Streak Incidence

Season Final, 2015



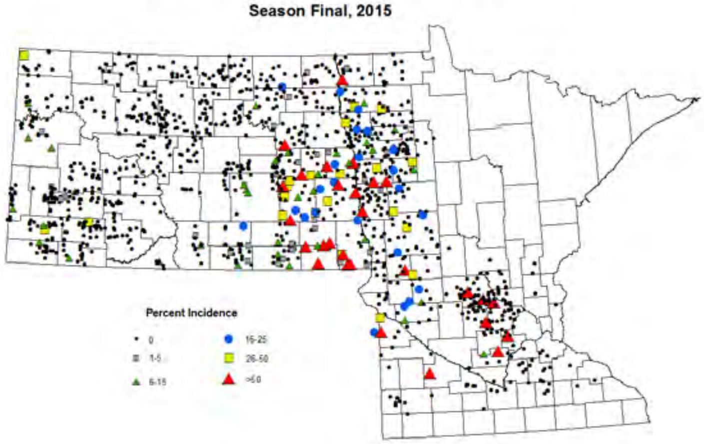
Wheat Leaf Rust Percent Incidence

Season Final, 2015



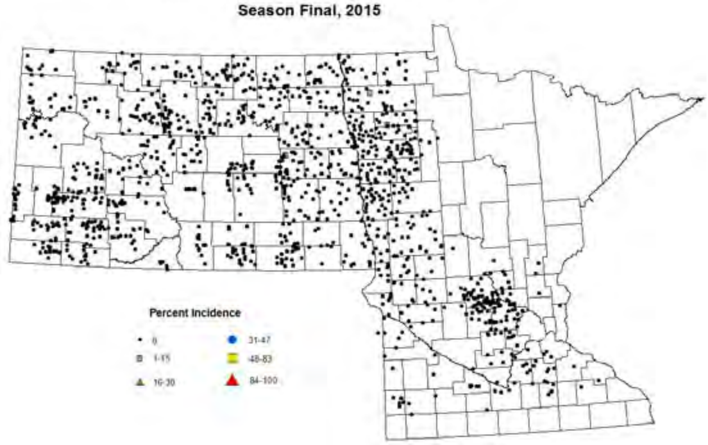
Wheat Stripe Rust Incidence

Season Final, 2015



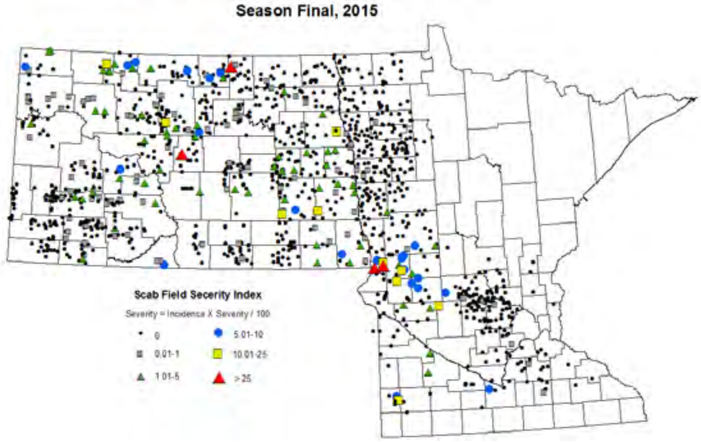
Wheat Stem Rust Incidence

Season Final, 2015



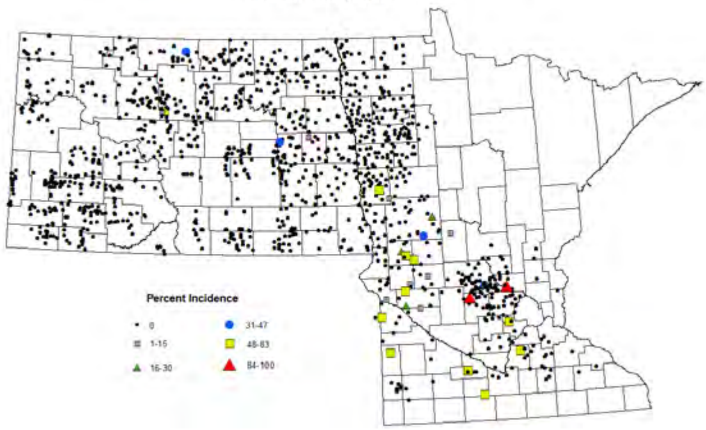
Wheat Scab Field Severity Index

Season Final, 2015



Wheat Spot Blotch Percent Incidence

Season Final, 2015



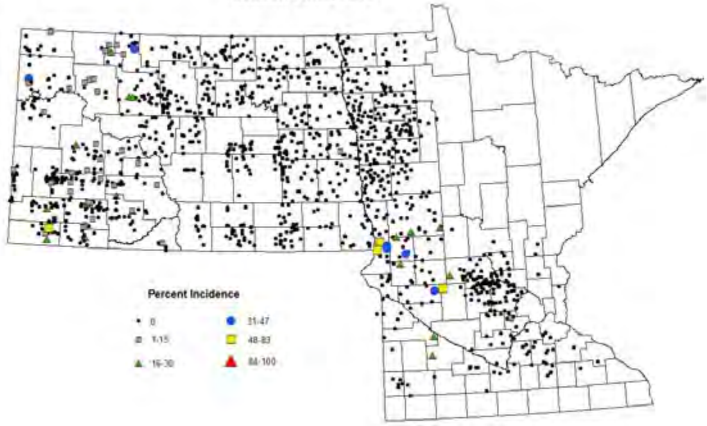
For Additional Information:

Madeleine Smith, Doug Holen, Phillip Glogoza and Jochum Wiersma,

Wheat Crop Survey (continued) — Statewide

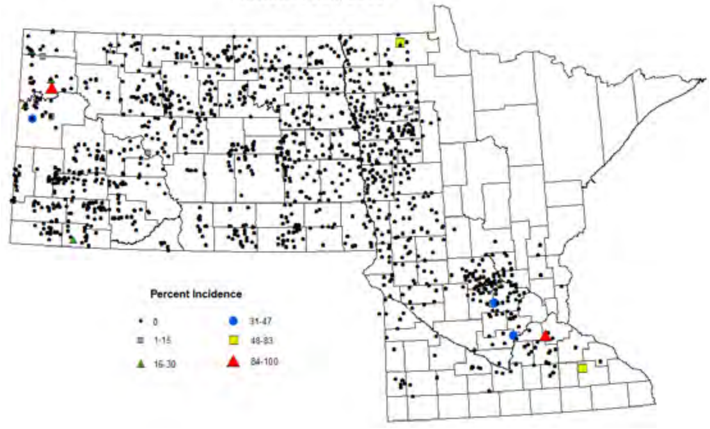
Wheat Black Chaff Percent Incidence

Season Final, 2015



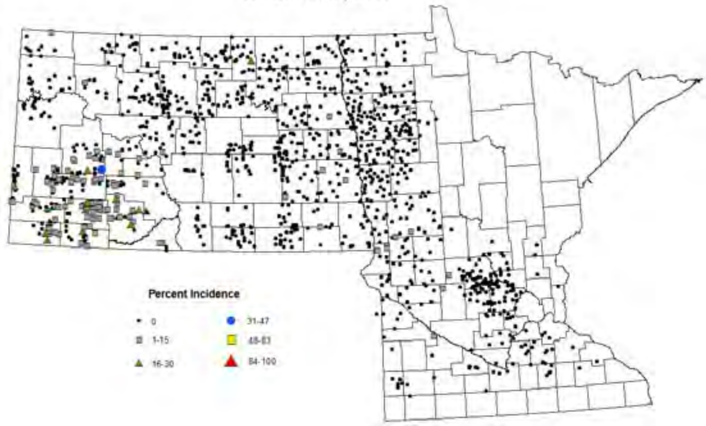
Wheat Powdery Mildew Incidence

Season Final, 2015



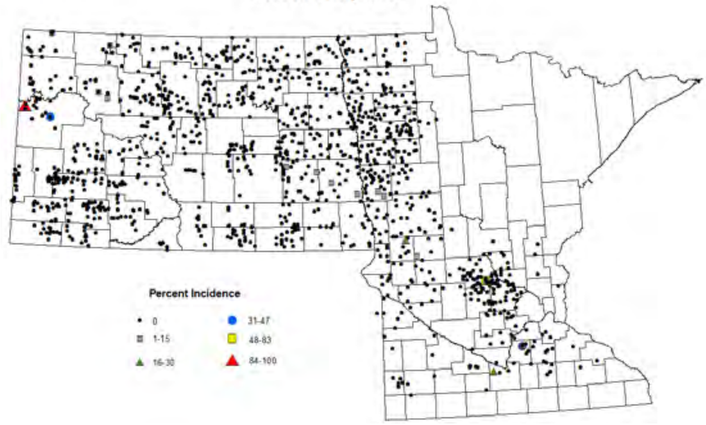
Wheat Ergot Percent Incidence

Season Final, 2015



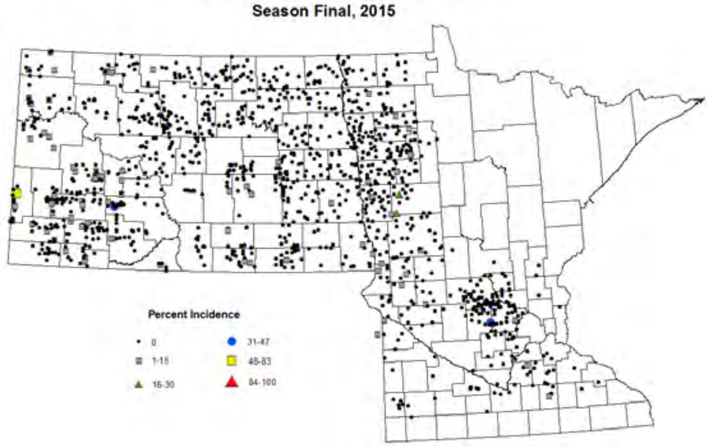
Wheat Streak Mosaic Virus

Season Final, 2015



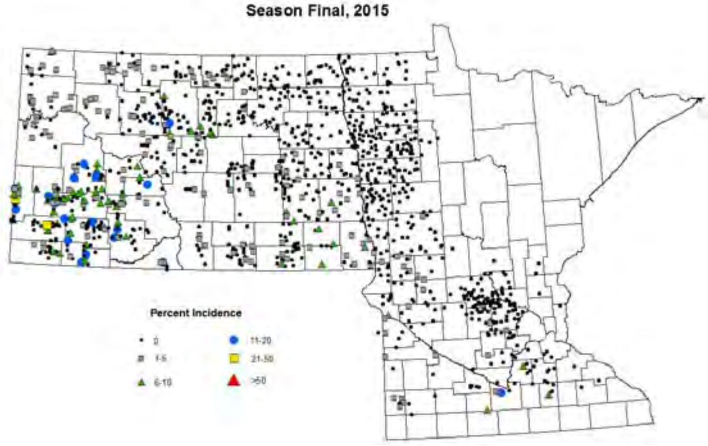
Wheat Loose Smut Incidence

Season Final, 2015



Wheat Stem Maggot

Season Final, 2015

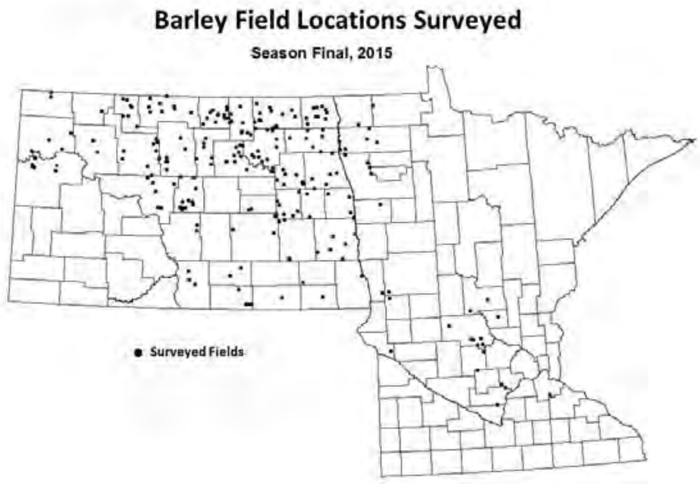


For Additional Information: Madeleine Smith, Doug Holen, Phillip Glogoza and Jochum Wiersma,

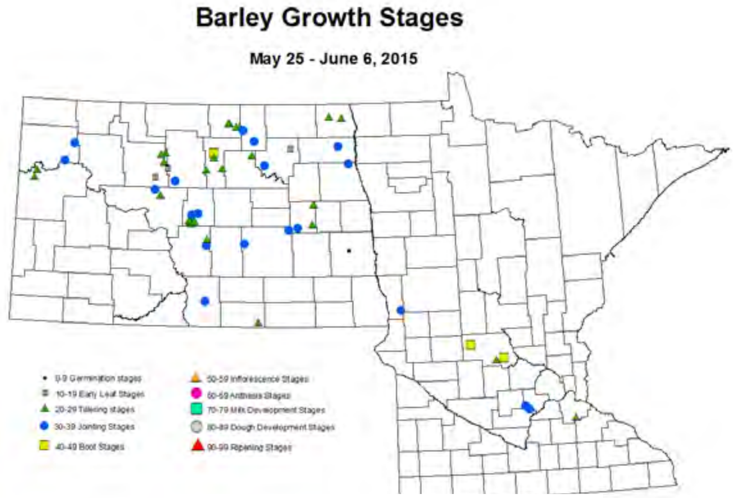
2015 Statewide Barley Crop and Pest Survey

Cooperator: Minnesota Association of Wheat Growers, NDSU IPM Survey

Purpose of Study:
The objective of this project was to allow for timely barley crop staging and pest identification across the state of MN in order to inform producers of current crop conditions and potential threats. Information was released through media (e.g., radio, internet-based news releases, archived web pages, consultant conversations and e-mail. The survey was conducted in coordination with the NDSU IPM Survey, providing extensive, continuous coverage of small grains across MN and ND.

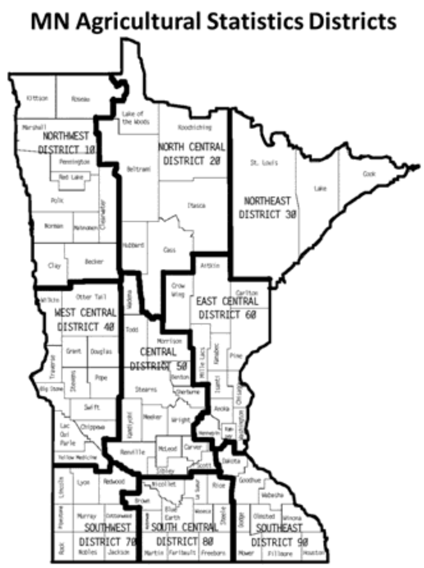


Results:
Field surveys were initiated the last 2 weeks of May. Thanks to favorable spring planting conditions, the crop ranged from tillering in the north to beginning boot stage in the southern survey locations *(see map for Growth Stages - May 25 to June 6)*.



Barley diseases by prevalence were Bacterial leaf streak from C and NW MN; Barley yellow dwarf incidence was greatest where aphids established early in C MN; *Septoria* blotch occurred with high incidences in C MN. Head blight (scab) in barley was only found in far NW MN. Barley Spot Blotch and Net Blotch were found in the region but were more often found in North Dakota than MN.

When reviewing the maps. ***Incidence*** is defined as "the percent of sampled plants with the disease." ***Severity*** is defined as "the percent of plant tissue that is diseased on affected plants." Therefore, maps that report incidence are reporting percent plants affected. Severity tells us how bad infections were.



The most important insect related production issues were the appearance of cereal aphids which reached threshold levels in C MN early and reflected the higher incidence of BYD. Armyworm did make their presence known in SW MN by early July, prompting some insecticide treatments in grain fields.

To receive notification of the survey, subscribe to the Northwest Cropping Issues Newsletter at:

http://nw-minnesota-crops.blogspot.com/

Archived maps for MN from 2011 to present are maintained by NDSU and can be found at:

https://www.ag.ndsu.edu/ndipm/ipm-survey-archives

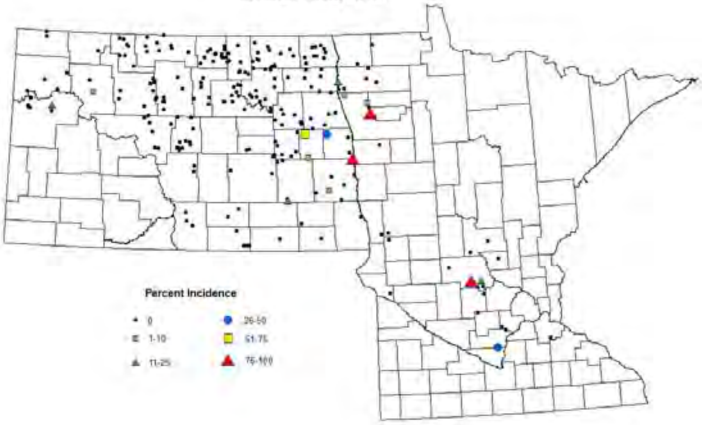
For Additional Information:
Madeleine Smith, Doug Holen, Phillip Glogoza and Jochum Wiersma

Project Funding Provided by:
Minnesota Association of Wheat Growers

Barley Crop Survey (continued) — Statewide

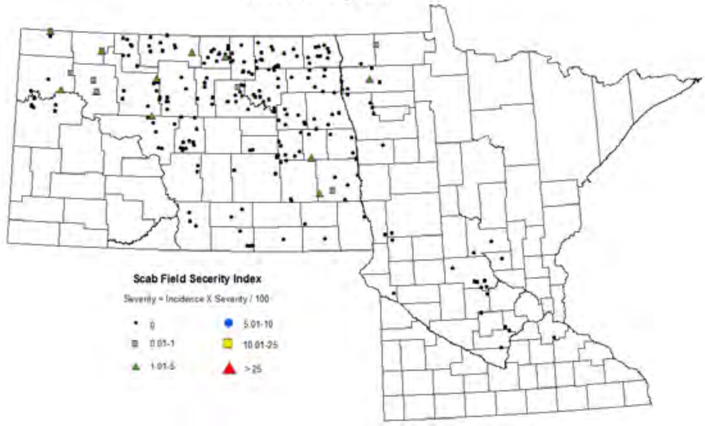
Barley Bacterial Leaf Streak Incidence

Season Final, 2015



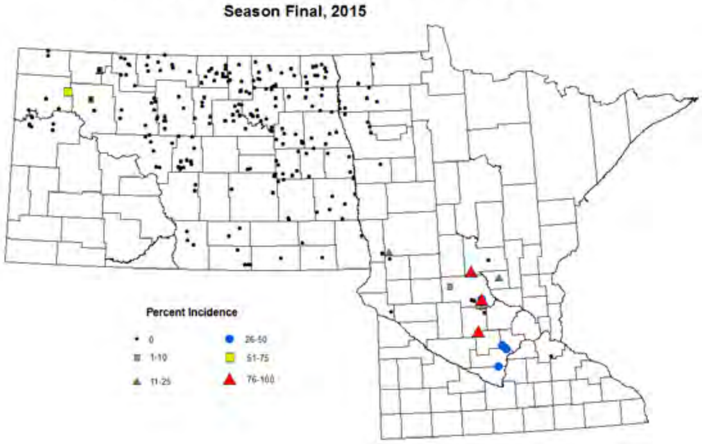
Barley Scab Field Severity Index

Season Final, 2015



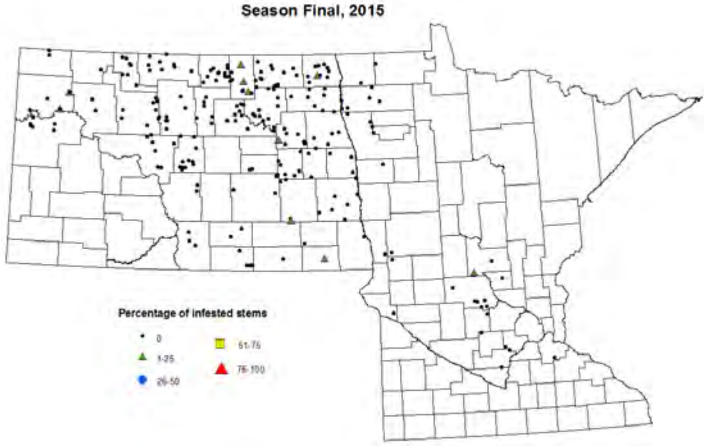
Barley Yellow Dwarf Virus Incidence

Season Final, 2015



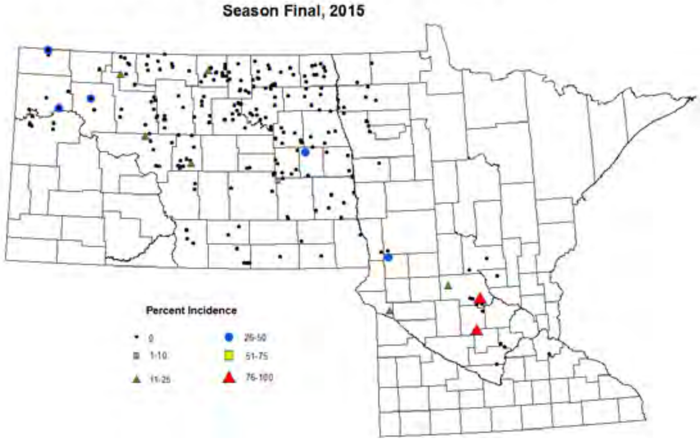
Aphids in Barley

Season Final, 2015



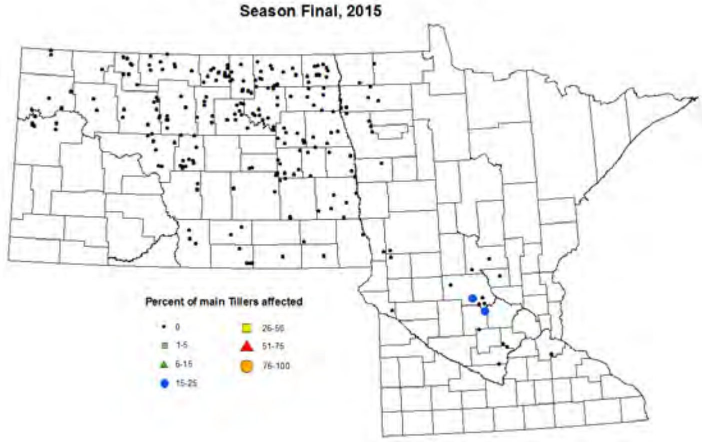
Barley Septoria SSP Incidence

Season Final, 2015



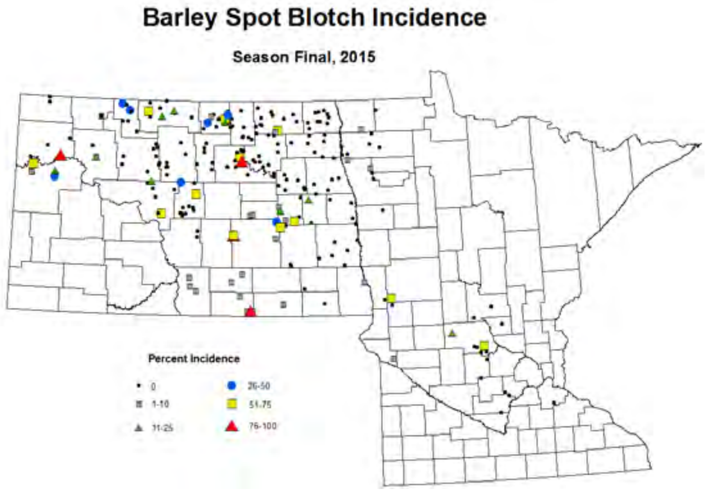
Barley Leaf Rust Incidence

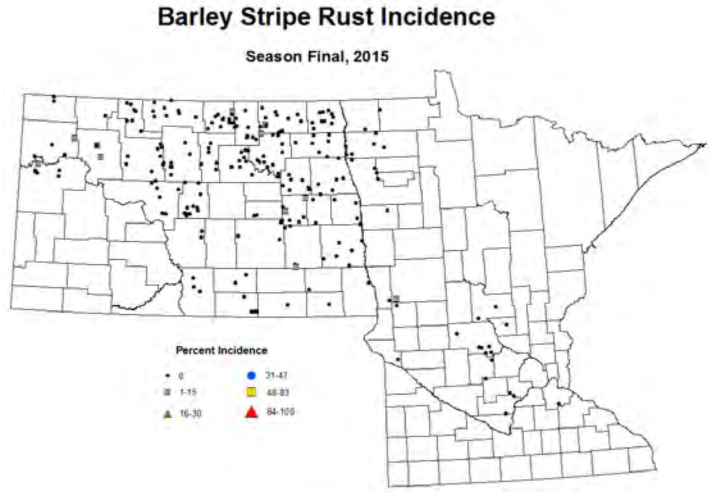
Season Final, 2015

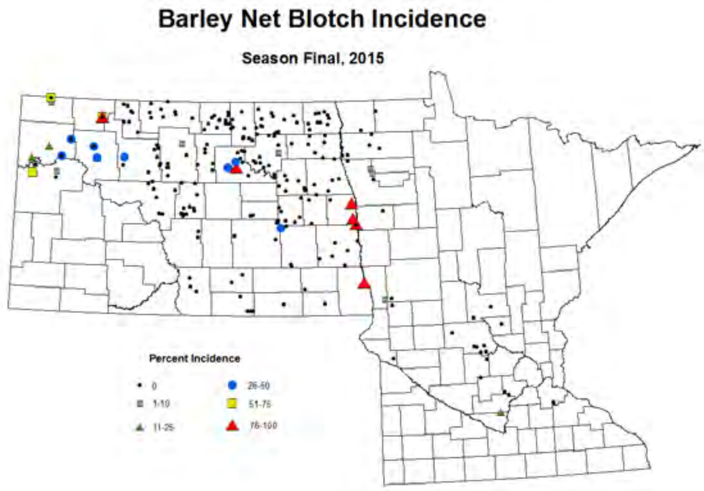


For Additional Information:

Madeleine Smith, Doug Holen, Phillip Glogoza and Jochum Wiersma







Results (continued):

For Additional Information: Madeleine Smith, Doug Holen, Phillip Glogoza and Jochum Wiersma

Minnesota Component of the Upper Great Plains Wheat Pathology Collaboration: Bacterial Leaf Streak, Root and Crown Rots and Viral Diseases of Wheat

Ruth Dill-Macky, Department of Plant Pathology, U of M

Research Questions

This project has three components each aimed at improving disease management practices and thereby reduced yield and quality losses for wheat producers in Minnesota. The project is focused on three diseases; bacterial leaf streak (BLS); root and crown rots; and viral diseases.

Bacterial leaf streak (BLS) of wheat, caused by *Xanthomonas translucens* pv. *undulosa*, is prevalent in Minnesota, causing economic concerns to the wheat industry. Managing BLS is difficult due to the lack of resistant cultivars and other effective tools, especially as fungicides are ineffective against bacteria. Through previous research funded by the MWRPC, we have demonstrated the economic importance of BLS; obtained useful data on the responses of regionally adapted varieties and elite germplasm; gained first-hand knowledge of local pathogen populations; and established a regional collaborative nursery. Our research has provide valuable information for developing future control methods and set the groundwork for future research aimed to improve our understanding and develop methods for the control of the disease. In this project we focused on the identification of wheat germplasm with high levels of BLS resistance, characterization of genetic resistance, and investigated of biology of the pathogen and the factors affecting the epidemiology of BLS.

The root and crown diseases of wheat can cause significant yield losses, although they frequently go unnoticed. Root diseases generally compromise the root system, affecting the ability of the plant to take up water and nutrients, thus root diseases are especially damaging in years when water is limiting during grain filling. Surveys from 2012 to 2015 have identified several root rot pathogens impacting wheat crops in Minnesota. Identification of the pathogens involved in root rots is the initial step in disease control. In this project we have continued with research to identify the pathogens causing root disease and to understand the response of the wheat germplasm to these pathogens. Identifying highly susceptible varieties and sources of resistance that may be utilized in the development of varieties with improved tolerance to root and crown diseases are both goals of this project.

Viral diseases such as barley yellow dwarf, caused by barley yellow dwarf virus (BYDV); and wheat streak, caused by wheat streak mosaic virus (WSMV), can be devastating in years where conditions are favorable to the insect and mite vectors that transmit these viruses. Little is known about the epidemiology of the viral diseases of wheat in Minnesota and the factors that contribute to the risk that viruses are more severe in a given year. We also have limited data on the resistance of our elite varieties and breeding lines to viruses. In this project we aimed to identify the viral threats to wheat production in the region and characterize the viral strains of each virus identified. We also aim to provide recommendations on the reaction of commercial varieties and to direct breeding efforts with respect to virus diseases.

Results

We previously developed the basic protocols we need to work with BLS. In 2015 we again established a regional cooperative nursery (BLSCN) in which 114 entries from six wheat breeding programs (public and private) in the Upper Great Plains were tested for their reaction to BLS at four locations (St Paul, Crookston, Fargo, ND and Brookings, SD). The data from all four locations, currently being compiled in Minnesota, indicate that significant differences were again observed in these materials for reaction to BLS under field conditions in 2015. Information obtained on the response of released varieties and elite germplasm is being utilized by regional wheat breeding programs to the benefit of growers. Information on the response of released germplasm to BLS has been disseminated to Minnesota growers through the MN variety trials bulletin.

We have developed a greenhouse assay for BLS, using a simple leaf infiltration of the flag leaf, suitable for screening pathogen isolates and small to medium sized wheat populations. NDSU researchers have been using a similar method and we have been collaborating with them to standardize these greenhouse assays across our programs. Using this same greenhouse technique, Dr Zhaohui Liu at NDSU, evaluated the reaction in the greenhouse of a F_2 population derived from a highly resistant and a highly susceptible triticale in 2015. The preliminary data has shown that the resistance to BLS in this population is conditioned by a single dominant gene.

This triticale population will be advanced to the F_7 generation and will be used to map the resistance gene.

BLS on wheat is caused by *Xanthomonas translucens* pv. *undulosa*, but at least three other pathovars can also occur on wheat. We know that there is considerable genetic variability within *X. translucens* and it's pathovars, however we don't know its biological importance to disease or the implications to breeding for disease resistance. To determine the major pathovars present in the Upper Great Plains, we collected over 100 pathogenic isolates of *X. translucens* from wheat and barley grown in Minnesota, North Dakota and South Dakota. Using the BLS greenhouse assay we have developed, the virulence of *Xanthomonas* isolates from wheat and barley has been measured on genotypes of both barley and wheat. Bacterial isolates varied in virulence, and virulence was affected by host and by host genotype. We also used a PCR-based method to identify isolates to pathovar. While most wheat isolates proved to be *X. translucens* pv. *undulosa*, host origin was not always a predictor of an isolate's pathovar designation. Some isolates from wheat appeared more similar to isolates from barley, while some barley isolates were more similar to wheat isolates. Thus it appears, that at a minimum, there are two pathovars of *X. translucens* in the Upper Great Plains and there is wide variation among isolates with regard to virulence. We used MLSA (multilocus sequence analysis) to observe genetic variation among our collection of isolates. Preliminary phylogenetic trees show isolates from wheat grouping separately from isolates from barley. Furthermore, several isolates of interest (isolates from wheat that showed stronger symptoms in barley and isolated from barley showing stronger symptoms in wheat) grouped according to virulence rather than original host. These data suggest that MLSA could be a viable method to differentiate the pathovars of *X. translucens*. We are currently processing these data with MLST (multilocus sequence typing), which has the potential to differentiate isolates at a more subtle level.

Root rot disease survey work continued in 2015 to help establish the distribution and prevalence of root rot pathogens in Minnesota and to help determine yield losses from the pathogens of wheat roots. The results from the surveys conducted thus far (2012 onward) have indicated that there has been a switch in the prevalence of the pathogens that incite root diseases compared to previous surveys conducted over 20 years ago. This has helped us prioritize research needs and has provided isolates needed for establishing screening for resistance to root and crown rots. We are still completing the isolation of fungal pathogens from the samples collected in 2014 and 2015. One this is completed we will confirm the identity of the fungi isolated using morphological and/or DNA sequencing. We have made significant progress in developing methods suitable for inoculating plants with *Bipolaris sorokiniana* and *Fusarium spp*. in the greenhouse, facilitating our ability to screen materials for reaction to root rot pathogens. Field studies examining fungicides indicate that seed treatments do not aid stand establishment or provide a return on investment, with the final year of this study completed in 2015.

In the 2015 growing season we surveyed wheat-growing areas across SD and MN forplants showing symptoms of viral infection. Of particular interest were plants with symptoms of WSMV, and BYDV. In addition, samples of grasses in the vicinity of infected plants were collected to assess the presence of viral diseases in wild grass species. Samples exhibiting symptoms consistent with barley yellow dwarf were processed to determine the presence or absence of this virus. Preliminary results indicate that of the 152 Minnesota samples examined, 33 were positive for BYDV and/or CYDV. Of the positive samples, three samples had only CYDV, and two others had mixed CYDV and BYDV infections. The mixed infections occurred in the HRSW varieties Samson and RB07 and in a Minnesota breeding line, MN0675-4. CYDV was detected in the spring barley variety Lawson. Work continues to complete initial analysis of the Minnesota samples and from the South Dakota samples collected in 2015. Once this work is complete, we will determine the strains of BYDV present in BYDV-positive samples, using strain-specific PCR. Dr. Byamukama at SDSU is working with samples exhibiting wheat streak mosaic symptoms from both MN and SD, following similar procedures as those we are using for BYDV in Minnesota. Information on the distribution of strains for both viruses will be used in determine the relative roles of alternative host species such as the wild grasses and non-wheat hosts like barley and oats on viral epidemiology. Information on the prevalence of viruses and specific viral strains will be used to selecting appropriate strains when screening breeding material for resistance.

Application and Use

Our ability to determine the prevalence and impact of the diseases of wheat is essential to develop disease control strategies, including resistance. Developing resistant wheat germplasm will rely on collections of pathogens and the development of effective screening methods, both to identify sources of resistance and to introgress the resistance into adapted germplasm. In 2015 we utilized protocols we have developed to establishment screening nurseries for BLS and worked toward identifying the root rot fungi and viruses present in wheat. Screening techniques for root rots are being developed and will ultimately aid in the development of commercial cultivars with improved resistance to these pathogens.

Materials and Methods

BLS: Inoculated nurseries were established in each state to screen a cooperative nursery encompassing entries from the UMN, SDSU, NDSU, Limagrain, WestBred and Agripro spring wheat breeding programs. Entries were selected in consultation with all the breeders whose material is represented. In Minnesota we also screened advanced lines and several populations provided by Jim Anderson that we believe are segregating for their response to BLS. Multilocus Sequence Typing (MLST) analysis was used to generate genetic fingerprints for a collection of pathogen isolates, including isolates from SDSU. Sequence data was also generated for a subsample of this isolate collection.

Root Rots: Fields were systematically sampled and root and crown tissues were observed for symptoms to determine the incidence and severity of root diseases. Samples collected at each site were bulked, the root systems of sampled plants washed to remove soil prior to storage. Plants and tissue samples were stored at 4oC until we processed the sampled materials to recover fungal pathogens. Root, sub-crown internodes and crown tissues from

continued on page 38

continued from page 37

the collected plants were dissected and used for isolation of pathogens on selective media that facilitated the recovery of specific pathogens. Isolated fungi were initially identified based on morphological characteristics. We plan to confirm the identities of these isolates using genetic tests following DNA extraction. Greenhouse screening for resistance against root rot pathogens in Minnesota has focused on inoculation with *Fusarium* and experiments using a number of ways to produce inoculum have been developed and tested.

Viruses: Leaf material was collected from commercial fields and variety trial plots of spring wheat and barley around Minnesota in the growing seasons of 2013 (68 samples), 2014 (38 samples) and 2015 132 samples). In 2015, 210 samples were also provided from Dr. E. Byamukama (SDSU) from spring and winter wheat crops in South Dakota. All samples associated with the virus work were stored at -80°C until we could complete the RNA extractions. Whole plant RNA extractions were conducted using the RNeasy Plant Mini Kit (Qiagen) according to the manufacturer's instructions. Reverse transcription reactions to obtain cDNA were then conducted using the Omniscript RT-PCR reverse transcriptase kit (Qiagen) also according to the manufacturer's instructions. A two-step Multiplex Polymerase Chain Reaction (multiplex PCR), using primers described by Malmstrom and Shu (2004), was then utilized to determine the strains of BYDV or CYDV present in the collected samples.

Reference: Malmstrom, C. M., & Shu, R. (2004). Multiplexed RT-PCR for streamlined detection and separation of barley and cereal yellow dwarf viruses. *Journal of virological methods, 120(1), 69-78.*

Economic Benefit to a Typical 500 Acre Wheat Enterprise

We have demonstrated that Bacterial Leaf Streak is of economic importance to the wheat industry and data has been generated that a grower can use to select wheat varieties that are less susceptible to BLS. The preliminary data gathered from this project indicate that root rot and viral diseases are prevalent in commercial wheat fields in Minnesota. It appears that two root rot pathogens, *Fusarium* and *Bipolaris*, are abundant and that they likely contribute significantly to yield losses. Similarly BYDV appears widespread in wheat and is likely impacting yields in some years. While this information does not provide any immediate benefit to the grower an awareness of the problem is a critical first step if control measures for the root rots and viral diseases of wheat are ultimately to be implemented.

Related Research

This is a regional collaborative project involving pathologists in three states. We have established close relationships with research and extension plant pathologists and the wheat breeding programs (public and provate) in each state. The regional wheat breeding programs have benefited the project by providing field observations of the distribution of diseases, collection of symptomatic plants for isolate collection and wheat germplasm. The wheat breeding programs in the region (public and private) have themselves benefitted from knowledge of the reaction of released and advanced breeding lines to BLS.

Recommended Future Research

BLS: Although much progress has been made with BLS, additional research is needed. Our collaborative screening efforts have determined that the majority of our wheat cultivars and many advanced lines from the regional breeding programs are susceptible to BLS. We plan to move forward using screening nurseries to test wheat materials from diverse sources for their response to BLS. The primary goal of this effort will be to identify genotypes with high levels of resistance and to introgress resistance into wheat germplasm. Previous studies suggest that resistance to BLS is governed by multiple genes and quantitatively inherited; in addition, the evaluation of plant responses to BLS is challenging and influenced by environmental conditions; therefore, we believe that there is a need to develop DNA markers to facilitate the use of marker assisted selection for introgressing resistance this disease in wheat.

Root Rots: The survey of root diseases we have already conducted have demonstrated that root rot pathogens are readily found in wheat crops in Minnesota and that they most likely have a significant negative impact on yield. We anticipate completing the isolation of fungal pathogens from the samples collected in the most recent surveys and finish identifying the fungal species using morphological and/or DNA sequencing. We have made progress in developing testing methods suitable for inoculating plants with *Bipolaris sorokiniana* and *Fusarium spp*. in the greenhouse, though working with root disease has proven challenging and our progress has been slower than we would like. We need to verify the techniques we have developed and repeat the initial studies to confirm our findings. We plan to continue with a collaborative research approach, focusing on understanding the response of the wheat germplasm to root pathogens with researchers in neighboring states. In this work we will identifying highly susceptible varieties and lines with higher levels of resistance that may be utilized in the development of wheat varieties with improved tolerance to root pathogens.

Viruses: Once PCR analysis has been completed for the Minnesota and South Dakota Samples, the data should provide a picture of the prevalent strains of BYDV in this region. Knowing the viruses determines the risk factors associated with the transmission of both BYDV and CYDV, as different viruses and viral starins are transmitted with differing efficiencies by different aphid species. Historically MAV and PAV have been thought to be the most prevalent strains of BYDV found in North America. Depending on the year, the dynamics of cereal aphid populations change. For example, in Minnesota in some years Bird cherry oat aphids are more prevalent early in the growing season, while in other years, English grain aphids are more prevalent. Understanding the prevalent viral populations and the vector populations will influence the development of management plans targeting the control of these viruses.

Publications

Anderson, J.A., Wiersma, J.J., Linkert, G.L., Reynolds, S., Kolmer, J.A., Jin, Y., Dill-Macky, R.,

and Hareland, G.A. (2015). Registration of 'Rollag' wheat. *Journal of Plant Registrations*, 9:201-207.

Haugen, S., Wiersma, J.J. and Smith, M.J., 2014. Evaluation of Fungicides for Control of Stem Rust in the Upper Midwest. In: Proceedings of the 2*014 National Conference for Undergraduate Research*, Lexington, Kentucky, April 3-5, 2014.

Adhikari, A, Dill-Macky, R., Wiersma, J.J. and Smith, M.J. 2014. Fungicides as a first line of defense for effective control of stem rust in hard red spring wheat. Phytopathology 104:S3.8 (abstract)

Stanton, J. L., R. D. Curland, C. A. Ishimaru, M. J. Smith, R. Dill-Macky. 2014. Developing inoculation methods for screening wheat for reaction to *Xanthomonas translucens* pv. *undulosa* (Bacterial Leaf Streak). Phytopathology 104:S3.113 (abstract)

Smith, M.J., Wiersma. J.J., Friskop, A., Schatz, B., Gautam. P., Bergstrom, G.C., Cummings, J.A., Byamukama, E., Ruden, K., Bleakley, B., Murthy, N., Bradley, C.A., Ames, K., Pike, J., Bellm, R. and Milus. E. Uniform fungicide trail results for management of FHB and DON 2014. In: *Proceedings of the 2014 National Fusarium Head Blight Forum*, St. Louis, Missouri, December 7-9, 2014, p. 43.

Wheat Yield and Protein as influenced by In-furrow Phosphorus, Potassium and Coated Urea (ESN)

Nancy Jo Ehlke, Dept. of Agronomy & Plant Sciences, U of M

Research Questions

The soils of northern Minnesota are variable, in large part due to the activity of glaciers during the last ice age. These soils, which were influenced by the activity of glacial Lake Agassiz, have pH levels that range from 7.8 to 8.4. As soil pH levels increase from 7 to the mid-8's, the availability of certain essential elements necessary for plant growth and development is restricted and nutrient uptake by plant roots is hindered. As an example, research trials with phosphorus suggests plant roots have a limited time, in the cold soils of early spring, to utilize applied phosphorus as these soil factors reduce phosphorus availability for uptake by plant roots in high pH soils.

Recent research at the U of MN Magnusson Research Farm has suggested an improvement in wheat development, growth, and yield from phosphorus applied a 2X rate compared to the standard rate of phosphorus applied in-furrow. It is also theorized that broadcast applications of additional phosphorus on these high ph soils may have added benefit to not only the present wheat crop but the subsequent crop of soybeans. An increase in uptake of early season phosphate by wheat roots is theorized to improve plant growth and development which may lead to increased wheat yields, improved quality, and ultimately profitability.

A new formulation of nitrogen called ESN (environmentally sensitive nitrogen) is a time released coated urea product with improved seed safety compared to other forms nitrogen. This coated urea can be applied in-furrow at nitrogen rates up to three times the current safe rate of urea. The polymer coated, time released formulation supplies nitrogen to the crop throughout the entire growing season and reduces nitrogen loss through volatilization, denitrification, and leaching.

Phosphorus and ESN applied in-furrow at planting time have the potential to increase wheat growth, development and yields. Small plot and large on-farm research trials will be designed to provide scientific data to provide answers to these research questions in the spring wheat production systems in northern Minnesota's environmental conditions.

Results

The results from the 2015 small plot trial is attached. Results were fairly consistent between 2014 and 2015 in response to the fertility treatments. The 2015 wheat yields were only 60% of the 2014 yields but had 13% higher protein content. Few differences were observed based on fertililty treatments. However wheat yields did respond to the highest fertility rates, especially the rates with higher potash and sulfer applications. The in-furrow fertilizer applications did not appear to be detrimental to the wheat yields.

Application and Use

The rationale for this research is to compare the standard phosphate starter with and without ESN and a 2X rate of phosphorus fertilizer starter program in spring wheat. The elevated phosphorus levels may improve early season wheat growth and development in the high pH soils of northern MN. A coated urea product may offer the potential to improve wheat yield and quality (protein), especially if the product is not released into the soil solution until later in the plant developmental stages of the spring wheat.

Materials and Methods

Treatment applications, data collection, data analysis and summaries will be conducted by the University of Minnesota to insure unbiased, scientifically valid research results. This fertility research integrates small plot replicated trials with large, replicated on-farm trials. The Magnusson Research Farm (located 6 miles northwest of Roseau, MN) will be the site for the small plot replicated research trials. The Magnusson Research Farm is a 40 acre site that was gifted to the University of Minnesota to conduct agricultural research that will have a positive impact on crops produced in the area. The Farm is the northern most research site in Minnesota with unique environmental conditions that make this an attractive location for crop research. Results of this field research will be summarized for potential publication in regional publications (e.g. Prairie Grains Magazine) and scientific journals. Research findings from the large on-farm trials and the small plot trials will be presented at regional and local wheat growers meetings.

The experimental design for the small plot research was a randomized complete block with 4 replications. Spring wheat was seeded with and without a starter fertilizer. The starter fertilizer was applied down the tube with the seed. These small plots were managed similar to area wheat production fields. Flag leaves were collected for tissue analysis. Plots were harvested for yield with a small plot combine with sub-samples from each plot for wheat seed quality assessments.

The small plot fertility trial had 13 fertility treatments plus a control (no starter fertilizer) treatment for a total of 14 treatments replicated four times for a total of 56 individual plots. Total nitrogen application equaled 140# nitrogen for all plots.

Treatment list

No added P or K	MES 10 + K (9-30-30-7) - In-furrow
Standard P & K (9-30-30) - Broadcast	MES 10 (2x) + K (18-60-30-14) - In-furrow
Standard P & K (9-30-30) - In-furrow	Standard P & K + AMS (9-30-30-7) - In-furrow
Elevated P & K (18-60-60 - Broadcast	MES 10 + K + ESN (39-30-30-7) - In-furrow
Elevated P & K (18-60-60) - In-furrow	Standard P & K + ESN (39-30-30) - In-furrow
Elevated P normal K (18-60-30) - In-furrow	Standard P & K + ESN (69-30-30) - In-furrow
Elevated P normal K (13-45-30) - In-furrow	Elevated P normal K + ESN (39-60-30) - In-furrow

Data collected: Background soil fertility, plant vigor ratings, crop color rating, chlorophyll meter ratings (taken at jointing and flag leaf stages of wheat development), flag leaf tissue test, crop yield, and crop quality parameters (test weight, protein).

Economic Benefit to a Typical
500 Acre Wheat Enterprise

Where P_2O_5 levels are low, a wheat yield advantage may be realized. A higher soil P_2O_5 level may be measured in soil post-harvest indicating an accumulation of phosphorous in the soil is possible for future crop use.

Related Research

Minnesota Turf Seed Council has on-going fertility research program in perennial ryegrass. Minnesota Agricultural Fertilizer Research and Education Council funded fertility research in wheat in 2014 and 2015.

Recommended Future Research

With the positive yield trends observed for wheat in high pH, potash deficient soils, further fertility research should be done to better define best management practices. The effect of nutrients on the crop followiing wheat should also be quantified.

Publications

Ehlke, N.J., D.J. Vellekson and D. Grafstrom. 2015. Progress Report on Grass Seed Production. http://www.mnturfseed.org/html/progress_reports.html

2015 Wheat Fertility Trial-Variety - Samson Wheat, Magnusson Research Farm, Roseau, MN.

			Yield **			Test	RCI***	Harvest	Tissue Analysis			
TRT#	Treatment	App *	Bu./acre	% of mean	% Protein	weight	7/21	height	N	P	K	S
1	0-0-0	NONE	62	**94**	14.7	57.8	534	29	3.30	0.21	1.25	0.28
2	9-30-30	B	68	**103**	14.8	56.9	557	29	3.33	0.23	1.37	0.26
3	9-30-30	I	68	**103**	15.0	57.9	537	29	3.30	0.22	1.30	0.27
4	18-60-60	B	67	**101**	14.8	58.3	541	28	3.35	0.23	1.33	0.27
5	18-60-60	I	65	**98**	15.1	57.7	524	29	3.38	0.24	1.35	0.27
6	18-60-30	B	64	**97**	14.7	57.6	543	28	3.27	0.22	1.33	0.27
7	18-60-30	I	66	**100**	14.9	58.1	546	28	3.30	0.24	1.47	0.26
8	13-45-30	I	66	**100**	15.2	57.7	538	28	3.45	0.24	1.33	0.28
9	9-30-30-7s	B	69	**104**	15.0	57.0	568	28	3.35	0.22	1.28	0.27
10	18-60-30-14s	I	72	**109**	15.2	55.1	628	29	3.45	0.23	1.30	0.29
11	9-30-30-7s	I	65	**98**	15.2	58.3	649	29	3.48	0.23	1.25	0.29
12	39-30-30[1]	I	65	**98**	15.5	58.3	565	30	3.48	0.23	1.30	0.29
13	69-30-30[2]	I	61	**92**	15.3	58.3	562	29	3.55	0.23	1.33	0.29
14	39-60-30[1]	I	68	**103**	15.1	57.7	572	29	3.45	0.23	1.30	0.28
		LSD @5% level	5	8	2	2.2	92	2	0.25	0.02	0.17	0.02
		CV(%)	5.4	5.4	2.3	2.7	11.4	4	5.1	7.0	9.1	6.2

Experimental design: Randomized complete block design with 4 replications. Planting date: April 28, 2015. Fertility: a total of 140 lbs/acre nitrogen was applied to all plots. Wheat tissue samples were taken on July 8, 2015 at heading. App*: Fertilizer application method. I = in-furrow at seeding and B = broadcast prior to seed bed preparation. [1]ESN applied in furrow 30#N/acre
[2]ESN applied in furrow 60#N/acre Yield**: corrected to 12% moisture
RCI***: Relative Chlorophyll Index - the higher the number the more chlorophyll as a measure of nutrient status

University of Minnesota Wheat Breeding Program

James A. Anderson, Dept. of Agronomy & Plant Genetics, U of M

Research Questions

The objectives of this proposal are to i) develop improved varieties and germplasm combining high grain yield, disease resistance, and end-use quality; and ii) provide performance data on wheat varieties adapted to the state of Minnesota.

Results

During the 2014/2015 crossing cycle, 331 crosses were made. The State Variety Trial, which contained 33 released varieties, 8 University of Minnesota experimental lines, and 4 experimental lines from other programs was grown at a total of 15 locations in 2015. During the 2015 growing season, another 251 advanced experimental lines were evaluated in advanced yield trials at 8-11 locations. An additional 532 lines were evaluated in preliminary yield trials at 1-2 locations. A total of 7,907 yield plots were harvested in 2015. Fusarium-inoculated, misted nurseries were established at Crookston and St. Paul. Inoculated leaf rust nurseries were conducted at Crookston and St. Paul and a stem rust nursery was also conducted at St. Paul. The disease nurseries involve collaboration with agronomists and pathologists at Crookston and with personnel from the Plant Pathology Department and the USDAARS.

Data from the yield and scab nurseries are summarized and published in Prairie Grains and the MAES's 2015 Minnesota Field Crop Trials bulletin MN08165-8 (MN02268-1/MN01333-A-1) was released as 'Bolles' in 2015. Bolles has extremely high grain protein, competitive yields, and good disease resistance. Other advanced experimental lines that are candidates for release in the next 1-2 years are MN10261-1 and MN11325-7. Data summaries of these two experimental lines, recent U of MN releases, and popular varieties are shown in Table 1.

Application and Use

Experimental lines that show improvement over currently available varieties are recommended for release. Improved germplasm is shared with other breeding programs in the region. Scientific information related to efficiency of breeding for particular criteria is presented at local, regional, national, and international meetings and published.

Materials and Methods

All yield nurseries are grown in small, replicated plots (typically 40-75 sq. ft. harvested area per plot). Fusarium-inoculated nurseries at Crookston and St. Paul consist of single 4 to 6 ft. rows, with 1 to 3 replications. Fusariuminfected corn seed or spray-applied macroconidia are used as inoculum. The plot areas are misted periodically to maintain a high humidity environment for at least three weeks after anthesis. Leaf and stem rust nurseries are spray inoculated with spore suspensions and surrounded by a border seeded to mixture of susceptible varieties to further increase disease pressure.

Table 1. Comparison of Bolles, MN10261-1, and MN11325-7 with other wheat varieties. Varieties are sorted from highest to lowest yielding based on 3 Year yield.

Entry	Release Yr.	2015 MN Acreage %	Yield (bu/A) 2015	3-Year	Test Wt (Lb/Bu) 2-Year	Protein (%) 2-Year	Baking Quality 1-9	Straw Strength 1-9	Leaf Rust 1-9	Bacterial Leaf Streak 1-9	Scab 1-9
LCS Albany	2009	2.6	107	110	60.5	13.2	6	5	2	6	4
Prosper	2011	16.6	104	107	60.5	13.6	4	6	5	4	5
Faller	2007	12.2	102	106	60.3	13.5	4	5	5	4	4
MN11325-7	–	–	105	–	60.4	13.9	–	5	4	4	–
WB9507	2013	4.6	101	–	59.1	13.7	–	6	8	6	–
SY Rowyn	2013	1.9	102	103	60.9	13.8	4	5	3	2	4
MN10261-1	–	–	101	103	61.9	14.6	2	4	1	3	3
Samson	2007	2.8	106	102	59.0	14.1	4	3	5	6	8
Forefront	2012	7.1	99	101	61.1	14.6	4	6	2	3	3
Bolles	2015	0.4 (new)	97	99	60.1	15.8	1	4	1	4	4
SY Soren	2011	7.0	96	98	60.2	14.6	4	4	2	4	5
Linkert	2013	13.5	99	97	60.7	15.0	1	2	4	4	5
WB-Mayville	2011	13.6	98	96	59.6	14.6	3	3	3	6	7
Rollag	2011	4.1	98	96	61.4	14.9	6	3	4	4	3

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Choice of variety is one of the most important decisions growers make each year. The development of high-yielding varieties that are resistant to the prevalent diseases and have good end-use quality are necessary to increase grower profit and protect against constantly changing pathogens and pests. As an example, a new variety that yields 4% higher will produce 3 extra bushels in a field that averages 75 bu/A.

Related Research

These funds provide general support for our breeding/genetics program. Additional monetary support for breedingrelated research in 2015 came from the Minnesota Agricultural Experiment Station, the U.S. Wheat and Barley Scab Initiative via USDA-ARS, and National Research Initiative Competitive Grant no. 2011-68002-30029 (Triticeae-CAP) from the USDA National Institute of Food and Agriculture.

Recommended Future Research

We will continue to operate the breeding program using similar methodologies in the future, but are also exploring the integration of genomic selection with DNA markers to more efficiently select for important traits and speed our rate of genetic progress. If successful, I anticipate genomic selection being a routine feature of our breeding program, using even lower cost DNA marker systems in the future.

Publications

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2015. Spring Wheat. In Preliminary Report 24: 2015 Wheat, Barley, and Oats Variety Performance in Minnesota Preliminary Report, Edited by Jochum Wiersma.

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Spanic, V., M.N. Rouse, J.A. Kolmer, and J.A. Anderson. 2015. Leaf and stem seedling rust resistance in wheat cultivars grown in Croatia. Euphytica 203:437–448.

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Continuing Breeding Adapted Spring Wheat Cultivars to Better Serve MN Wheat Growers

Richard Horsley, Dept. of Plant Sciences, NDSU

Research Questions

This project aims to continue developing superior spring wheat cultivars targeted to MN, particularly the Western wheat growing environments. These cultivars should possess the following traits:

• High yield potential with shorter, stronger straw.

• Good quality characteristics which allow premiums for wheat growers and sustainable competition on the international market. These traits include mainly protein content, milling and baking characteristics.

• High levels of resistances to dominant diseases such as leaf diseases including leaf and stem rusts, a continuous threat to wheat.

• Good resistance to Fusarium head blight (Scab), still a major disease for wheat in MN and the region.

Resistance to leaf spotting diseases and bacterial leaf diseases that can be devastating in some years.

Results

The funds provided by this project us to test our elite HRSW germplasm and selected varieties in Alvarado and Wolverton, MN. Agronomic data including diseases reactions are collected on these advanced yield trials conducted at the two MN locations and three locations in in eastern ND (Casselton, Prosper, and Langdon). Table 1. Provides data from three eastern ND locations across two years, 2013 and 2014. Faller and Prosper continue to be the top yielding varieties, but they have mean protein below 14.0%. Varieties having mean yield greater than 80 bu/ac and protein greater than 14% include Bolles, Elgin ND, and RB07.

In trials grown in MN in 2015, the trial at Wolverton was sown in early April into dry soil conditions. Emergence was uneven; however, precipitation received later in May and June resolved the situation. Growing conditions at Alvarado were favorable throughout the growing season. Mean yield at Alvarado and Wolverton was 61.8 and 67.2 bu/ac, respectively (Figures 1 and 2. Mean protein was 15.7 and 14.9 at Alvarado and Wolverton, respectively (Figures 3 and 4). In looking for lines/varieties that have yield and grain protein greater than Elgin-ND, nine lines were found in Alvarado and eight were found in Wolverton. Three lines were found that yield and protein greater than Elgin-ND at both locations. A change for the 2016 trials in Minnesota will be the addition of Bolles to the trial as a check.

Grain from both 2015 locations will be sent to the NDSU Wheat Quality Laboratory of Dr. Senay Simsek for milling and baking evaluation. Additionally, seed from these trials will be shared with NDSU and USDA-ARS pathologists to determine their reaction to the common diseases that impact hard red spring production in the region.

Application and Use

Information from this research is used to identify improved varieties that are acceptable to growers in the wheat growing areas of Minnesota and acceptable those who use and process the harvested grain. NDSU varieties grown in Minnesota in 2015 included Prosper and Faller, which were grown on 16.6% and 12.2% of Minnesota's wheat acres, respectively.

Materials and Methods

1. Crosses and populations development:
About 170 new crosses were specifically made in fall 2014 to incorporate traits of economic values for wheat growers and industry in the Western MN and Eastern ND into our adapted germplasm. These crosses involved parental lines among the most grown cultivars and elite genotypes adapted to MN environments. These crosses were conducted in the Fall and Spring in greenhouse cycles. The F_1's generated by these crosses were either increased for another generation in the winter greenhouse to generate F_2 seed or crossed back to another parent to make three-way crosses. The F_2 segregating were grown in the field at Casselton and Prosper, ND. About 100-200 spikes were selected from the most promising F_2 population and this seed will be sown in Puerto Rico in November 2015 for generation advancement. In fall 2015, about 170 new crosses will be made to generate materials for the next cycle of breeding and evaluation.

2. Diseases evaluation/screening:
Germplasm planted in the field were subjected to screening for prevalent diseases in the field. In addition, rusts and Scab screening nurseries are installed in many locations including Prosper, Carrington, and Langdon, ND. Screening of elite material is also done in the greenhouse as well as by our colleagues in the Department of Plant Pathology and USDA-ARS. Diseases screened for include leaf and stem rust, FHB, and tan spot. A major goal of the program is to identify plants with resistance to the race of leaf rust that overcame the resistance previously provided by the gene LR21.

3. Early generations and preliminary and intermediate yield trials evaluation/testing:

In 2015, the breeding program evaluated about 170 F_2 populations and 16,500 F_3 and F_4 lines that were designed for the Eastern ND and Western MN. Similarly, about 1,500 F_4, 1500 F_5 and 600 F_6 or later lines were evaluated for disease resistances and agronomic traits in the preliminary yield trials (PYT) and intermediate trials (IYT), respectively. PYTs were evaluated in non-replicated plots while IYTs were evaluated in trials arranged as a randomized complete block designs with two replicates. Agronomic and disease notes are taken from the field and seed of these entries were evaluated for some quality traits in the laboratory (Dr S. Simsek). Promising lines will be advanced either to IYT (from PYT) or advanced yield trials (AYT) following cycle.

4. Screening and evaluation of advanced and elites lines:
a. MN Testing sites
As in past few years, with the support of the MNWRPC, the advanced yield trial including 75 lines and checks selected from previous yield trials was grown at Alvarado and Wolverton, MN. Entries are assigned to plots using a randomized complete block design and each entry is replicated four times at each location.

b. ND Testing:
The same yield trial conducted in MN sites was tested in 2015 in several locations across ND with three locations in eastern ND. These locations are Casselton, Prosper and Langdon. The other yield trials including PYT, IYT, and AYTs were conducted in many sites in the Eastern parts of ND. The number of replicates and experimental design of these trials are similar to those conducted in MN.

5. Quality Evaluation:
Grain samples from the 2015 from all of our trials grown in MN and ND will be sent to Dr. Simsek's laboratory for quality tests. Data on grain characteristics, milling, and dough and baking attributes will be generated for genotypes included in these trials. These data generated each year, are combined with the agronomic performance data so we can determine which lines to advance for further testing.

6. Markers Assisted Selection (MAS):
The use of MAS based on known molecular markers for some quality and disease resistance traits is conducted in collaboration with Dr. Shiaoman Chao. Dr. Chao is a scientist with the USDA-ARS in Fargo that oversees the genotyping center. DNA samples from about 1500 lines included in the yield trials will be sent to Dr. Chao's lab for genotyping with the markers associated with the QTL on chromosome 3BS for FHB resistance (FHB1) and the marker for the LR31 gene that confers resistance to the new race of leaf rust that is virulent on Faller and Prosper.

7. Uniform Regional Nurseries (URN):
We will be submitting new material from the breeding program to the URS in 2016. We will not have any restrictions on including data on our lines in any reports as has been the case previously. Our breeding program included five lines in the URN and we will grow the trial at five locations in North Dakota, including Prosper and Langdon.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

In 2014, the last year complete data are available, 66.5 million bushels of wheat was grown on 1.26 million acres. The farmgate value of this production was over $368 million. Given that Prosper and Faller were grown on 35.2% of Minnesota's wheat acres in 2014, the value of the crop produced from these varieties two varieties was approximately $126 million.

Related Research

I am going to use this section to update the Council on the hiring of a new hard spring wheat breeder at NDSU.

Dr. Mergoum resigned his position at NDSU on September 1, 2015 to take a job with the University of Georgia in Griffin, Georgia. A national search is ongoing at NDSU to fill the position, with University Distinguished Professor Dr. Elias Elias chairing the search. We are advertising at the Assistant/Associate Professor rank with the hope that a mid-career person with experience in wheat breeding will apply for the position. The search committee has been tasked to reach out to identify qualified candidates and inviting them to apply. The initial screening of applicants will begin on November 23. We have an aggressive timeline to fill this position. We will do phone interview of candidates in early December and invited the top individuals to campus in early January for on-campus interviews. We will keep stakeholder groups, including yours, informed of when these individuals will be on campus so you have the opportunity to meet with them and attend their seminars. For those that are unable to attend the seminars, we will have video recordings and we will provide a link so you can view them online. We hope to have the new breeder beginning their work at NDSU in early March. This timing would allow them to see their new breeding material in the field in Puerto Rico and Arizona.

In the interim until the new breeder is hired, I am working with the very qualified group of four technicians on the project. We selected materials to send to the off-season nurseries in New Zealand, Arizona, and Puerto Rico; and selected crosses to make in the fall greenhouse. Our goal for crossing this fall was to maintain our high yield and grain quality while incorporating genes for resistance to the new race of leaf rust, reduced plant height, and improved straw strength. We greatly appreciate the support provided by the MNWPRC to our program, which allows us to continue our efforts to develop and release improved cultivars for Minnesota growers.

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Recommended Future Research

• Baking and milling quality will be determined on grain harvested from the Alvarado and Wolverton, MN research sites in the Wheat Quality laboratory of Dr. Simsek.

• Reaction of entries to stem and leaf rust, tan spot, and FHB will be determined by NDSU and USDA-ARS scientists.

• Experimental lines currently in the breeding program with favorable agronomic performance, disease resistance, and end-use quality will be advance to the next level of yield trials, including the trial that is grown at Alvarado and Wolverton, MN.

• New populations will be generated through crossing. We need to increase the frequency of the allele for leaf rust that confers resistance to the race of leaf rust that is virulent on Faller and Prosper.

• Bolles needs to be added as a check for the trials grown in MN in 2016.

Publications

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Kumar, A., R. Seetan, M. Mergoum, V.K. Tiwari, M.J. Iqbal, Y. Wang, O. Al-Azzam, H. Šimková, M-C. Luo, J. Dvorak, Y.Q. Gu, A. Denton, A. Jilian, G.R. Lazo, and S.K. Kianian. 2015. Radiation hybrid maps of the D-genomie of Aegilops tauschii and their application in sequence assembly of large and complex plant genomes. BMC Genomics 16(1):800.

Appendix:

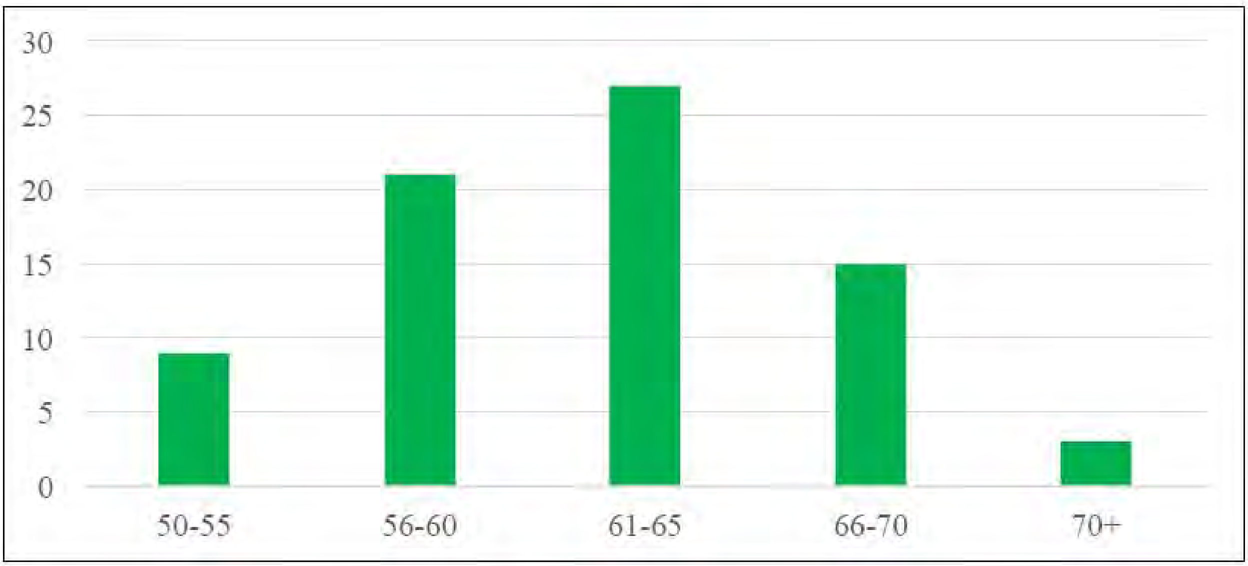

Figure 1. Frequency distribution of grain yield (bu/ac) for 75 hard red spring wheat lines grown in the NDSU yield trial at Alvarado, MN in 2015. Grain yield was 65.6 bu/ac for Elgin-ND, 66.4 bu/ac for Barlow, 74.8 bu/ac for Prosper, and 77.0 bu/ac for Faller.

Table1. Agronomic performance of selected varieties grown in Prosper, Casselton, and Langdon, ND (2013-2014)

Variety	Days to heading (days after 31 May)	Plant height (inches)	Foliar disease (%)	Yield (bu/ac)	Test weight (lb/bu)	Protein (%)
Station years	**6**	**6**	**1**	**6**	**6**	**6**
Advance	52.4	31.7	4.6	81.3	62.8	13.3
Barlow	50.3	33.6	5.8	76.2	62.5	14.2
Bolles	54.3	33.0	16.3	81.1	62.1	15.0
Breaker	53.3	33.2	5.5	80.0	63.3	13.7
Brennan	51.6	29.1	12.6	74.7	62.0	14.3
Elgin	51.5	36.7	6.3	84.7	62.0	14.0
Faller	53.3	33.6	12.9	93.3	62.4	13.1
Forefront	49.3	36.6	6.7	79.0	62.3	14.3
Glenn	50.3	35.7	5.8	76.3	64.1	14.5
Jenna	54.7	32.2	12.3	84.2	61.4	13.7
LCS Breakaway	50.2	30.4	27.4	80.0	63.4	14.2
LCS Powerplay	51.7	32.8	10.3	83.6	62.6	13.4
Linkert	52.5	28.9	4.4	75.0	62.5	14.7
Norden	52.4	32.0	16.1	79.0	63.5	13.5
Prevail	51.1	34.1	15.8	81.2	61.9	13.6
Prosper	52.9	33.6	6.1	88.2	62.2	13.1
RB07	51.0	32.3	12.1	83.0	62.2	14.1
Rollag	51.7	30.4	13.2	76.8	63.0	14.6
Smason	51.5	31.1	16.4	81.1	61.2	13.7
Select	49.0	34.3	15.9	77.3	63.0	13.7
SY Rowyn	51.2	30.5	17.9	81.1	62.2	13.4
SY Soren	51.5	29.1	12.8	79.4	62.5	14.2
Vantage	55.4	31.7	8.5	74.7	63.2	15.1
Velva	54.6	33.9	6.4	81.1	61.0	13.7
WB Digger	53.3	33.1	13.5	84.3	61.2	13.6
WB-Mayville	50.7	29.1	35.1	73.7	61.4	14.4
Maximum	55.4	36.7	35.1	93.3	64.1	15.1
Minimum	49.0	28.9	4.4	73.7	61.0	13.1
Average	52.0	32.4	12.3	80.4	62.4	14.0

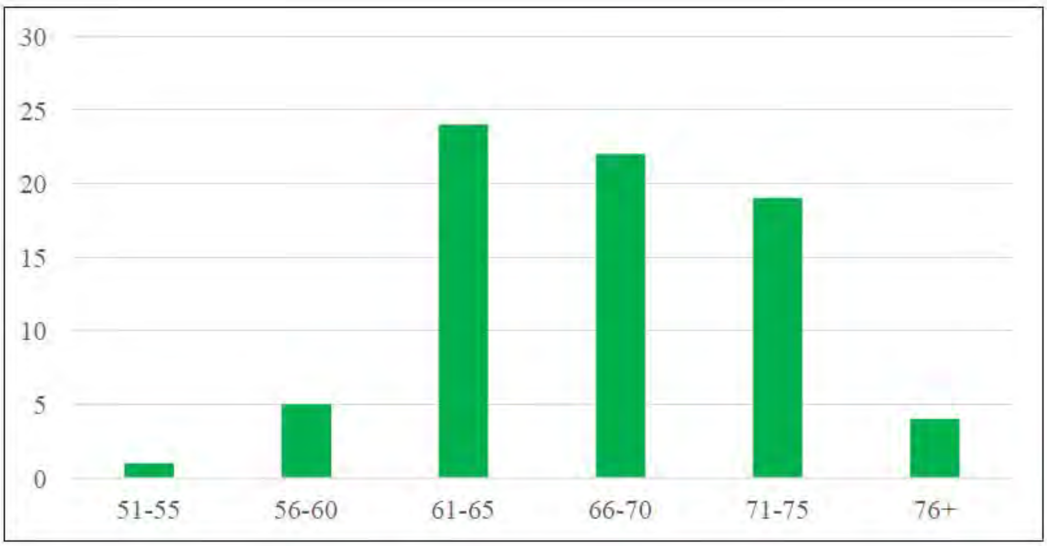

Figure 2. (left) Frequency distribution of grain yield (bu/ac) for 75 hard red spring wheat lines grown in the NDSU yield trial at Wolverton, MN in 2015. Grain yield was 69.1 bu/ac for Elgin-ND, 68.6 bu/ac for Barlow, 77.5 bu/ac for Prosper, and 78.2 bu/ac for Faller.

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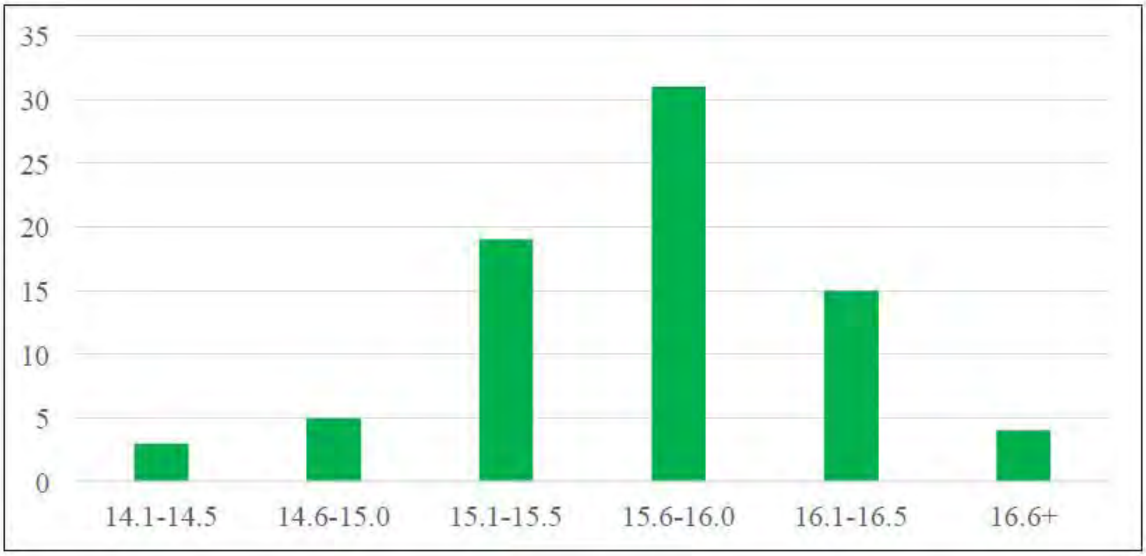

Figure 3. Frequency distribution of percent grain protein for 75 hard red spring wheat lines grown in the NDSU yield trial at Alvarado, MN in 2015. Grain protein was 14.9% for Elgin-ND, 15.2% for Barlow, 14.5% for Prosper, and 14.2% for Faller.

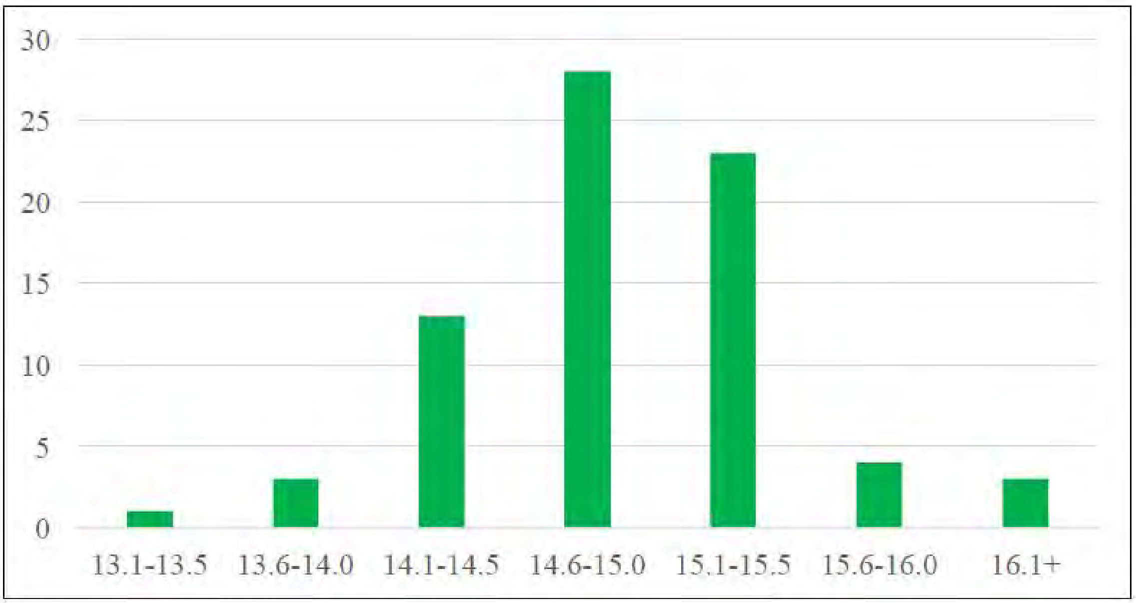

Figure 4. Frequency distribution of percent grain protein for 75 hard red spring wheat lines grown in the NDSU yield trial at Wolverton, MN in 2015. Grain protein was 15.1% for Elgin-ND, 15.0% for Barlow, 13.2% for Prosper, and 14.1% for Faller.

Variation in Response to N and S Among Spring Wheat Genotypes Grown on Irrigated and Non-irrigated Soils

Daniel Kaiser, Dept. of Soil, Water and Climate, U of M

Research Questions

1) Study the effect of sulfur rate on spring wheat grain yield and protein concentration and quality.
2) Determine whether spring wheat varieties differ in the potential response to sulfur fertilizer.
3) Evaluate if plant tissue analysis (flag leaf samples collected at anthesis) can indicate the responsiveness of spring wheat varieties to N or S
4) Determine the economic optimum nitrogen rate for spring wheat grown under irrigation.

Results

Statistical significance, by location, for spring wheat grain yield, grain protein concentration, and the total amount of protein produced per acre is summarized in Table 4. As expected, yield differed consistently among the varieties. Faller produced the greatest yield across sites followed by RBO7, Mayville, Glenn, Vantage, and lastly, Select. The only surprise out of the ranking was Glenn which was one of the top yielding varieties at Crookston. Grain protein concentration was greatest for Vantage and Glenn while Faller producing the least. Total protein produced per acre was greatest for the top yielding variety, Faller, and the varieties with the greatest protein (Glenn and Vantage). The only surprise in the site data was the high protein concentrations measured at Staples. We are in the process of analyzing the grain for total nitrogen to determine if the levels produced were as high as measured on the NIR. Higher levels might be expected if nitrate levels in the irrigation water were high enough to continually feed nitrate in the plant at or post anthesis.

There was no detectable increase in yield from sulfur at the Crookston and Fergus Falls locations (Table 4). In 2014 the 7.5 lb S rate produced a significant yield increase at Staples and there was no further increase to the 15 lb rate. In 2015 grain yield was again increased at Staples but only for the 15 lb S rate. The actual yield increase was less at 4 bu/ac in 2015 than occurred in 2014. Grain protein content was increased by sulfur at Staples and decreased by sulfur at Crookston. The decrease at Crookston was small on a relative basis. At Staples, the 15 lb S rate produced an increase of 0.8% protein. Average protein levels were above 16% so the increase in grain protein concentration would not have resulted in a discount. Grain protein produced on a per acre basis was only impacted by sulfur at Staples.

Asparagine data was collected on samples taken from the 2014 sulfur studies (Table 5). Asparagine is important as it is an indicator of the production of acrylamide. Acrylamide can be produced during baking or frying and can have negative health impacts on humans. Asparagine content in the wheat grain varied among varieties across locations. Glenn typically had the lowest asparagine content followed by Vantage and Faller. Past research on hard red winter wheat has shown that sulfur can reduce the amount of asparagine in the grain. For hard red spring wheat, application of sulfur decreased asparagine content at Staples and Kimball. In both cases the 7.5 lb S rate produced the greatest decrease in asparagine content. It was interesting that the content of asparagine was higher at Staples than the other locations. The higher asparagine content at Staples could have been a result of higher protein content at Staples compared to the other locations. Samples were saved from the 2015 site to test for asparagine content if funds allow.

Figure 1 summarizes flag leaf sulfur concentration by variety across the six locations conducted between 2014 and 2015. One question we were to address is weather there were differences among the varieties in their distribution of sulfur in the flag leaf tissue following application of sulfur fertilizer. The varieties were selected because they showed some differences in preliminary surveys of variety trials. Flag leaf sulfur concentration was impacted by the application of sulfur across the sites but there was no indication that there was a differing effect by variety (no significant interaction between variety and sulfur rate). The lack of impact of variety on sulfur content could be as a result of the rates being used are too high to achieve differences or the fact that the previous research correlated sulfur content of individual varieties with the average sulfur concentration based on location. Grain S concentration was also measured (Figure 2) with similar results as flag leaf S concentration.

A nitrogen trial was conducted under irrigation at Staples with three varieties and six nitrogen rates. Varieties different in their response to grain yield, protein concentration, and protein production per acre (Table 8). Effects of nitrogen by variety are summarized for grain yield, protein concentration, and protein yield per acre in Figures 3, 4, and 5, respectively. Economic optimum nitrogen rates are summarized for a situation with no discount in Table 9. No discount was assumed as the protein concentration, particularly for the 2014 data, was well above the threshold were discounts were expected. It took less N to maximize

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economic yield in 2014 than in 2015. The primary reason was that additional N was applied by fertigation by mistake in 2014 which inflated the protein concentration values. A recommendation of 200 lb of N per acre would not be out of line with non-irrigated sites. It should be noted that the varieties did differ in their yield potential but the amount of N needed to maximize yield was the same for both 2014 and 2015 studies. This indicates that yield goal may not be an important factor when considering what nitrogen rate should be applied.

Flag leaf nitrogen concentration was measured and the data are reported in Figure 6. There was no indication that the varieties varied in their response to N in the flag leaf tissue. The P value was close to significance but the main effect of variety and nitrogen rate were the only significant factors for the study.

Application and Use

The data from the first year of this project indicate that some changes may be required to the current fertilizer guidelines for wheat. Changes were made when the Fertilizer Guidelines for Wheat in Minnesota publication was updated in 2012. Some changes included a general framework of S guidelines for eroded low organic matter soils (less than2.0% organic matter in the top six inches). An addition year of data would be beneficial to compare the response that occurred at the Staples location to determine if our current suggestion of 25 lbs of S may be greater than what is required to grow wheat on irrigated sandy soils in Minnesota.

There may be some benefit in baking quality with S. However, until protein premium/discounts reflect quality over the quantity there may be a limited impact to the bottom line of a wheat grower. Since this work was being conducted in-kind at the USDA grain quality lab there was no cost for this work included in the budget of this grant. Previous research has demonstrated benefits of S on baking quality. This study provides a better comparison as it includes multiple varieties.

Our goal for comparing the varieties was to determine if tissue sampling could be used to determine responsiveness of varieties to S. Since there was no evidence that a variety by S interaction occurred, it is unlikely that the tissue data had much value in determining whether S would benefit one variety over another. One caution about this work is that since yield was only affected at one location it is hard to draw hard conclusions unless the effect can be replicated. More locations and one or two additional years of funding would greatly benefit this project to determine if similar effect can be replicated across sites and years. Overall, our data from this study and past research indicated that significant caution should be taken when using plant tissue samples for guiding fertilizer application.

Materials and Methods

Small plot sulfur fertilization studies on non-irrigated soils will be established alongside two spring wheat variety trials. The proposed locations are near Crookston or Stephen and Fergus Falls or Kimball. We are currently exploring the possibility for a site closer to Fergus Falls on a soil with an organic matter concentration around 2.0% or less. We will continue to maintain 1 site on a high organic matter soil in the primary spring wheat growing region to ensure no responses have been occurring as a follow up to the previous research.

Six wheat varieties will be selected using the stability analysis conducted for spring wheat flag leaf tissue among varieties in 2011 and 2012. Variety selection will not be based on current planting trends or popularity. Two varieties will be selected that were considered in the high, average, and low response to sulfur categories and that vary in protein and yield potential. The varieties selected are Faller, Vantage, Select, Glenn, Mayville, and RB07. Sulfur rates used will be a non-fertilized control (0 lb S). 7.5, and 15 lbs S per acre. Sulfur will be applied to the soil surface at planting. The source of sulfur will be ammonium sulfate (21-0-0-24). Nitrogen will be applied to balance the rate of nitrogen applied with the high rate of ammonium sulfate. Nitrogen, phosphorus, and potassium will be kept at non-limiting rates according to current recommendations.

An irrigated wheat site will be located at the Central Lakes College Ag and Energy Center at Staples. The irrigated site will consist of a third sulfur site as outlined previously and a nitrogen study. The nitrogen trial will consist of only three of the varieties utilized in the S study (Faller, Mayville, and RB07) and six nitrogen rates (0, 60, 120, 180, 240, and 300 lbs of N per acre). Nitrogen will be applied as urea (46-0-0) and applied at two times with half of the nitrogen applied after seeding but before emergence and the remaining applied near jointing. Additional nutrients (P, K, and S) will be applied as a pre-plant application. The varieties selected were done so based on previous flag leaf tissue data for N similar to selection characteristics outlined the preceding paragraph.

Grain yield will be measured for all plots and a subsample of grain will be collected and analyzed for protein concentration by NIR. Grain samples for the S study will be analyzed for total N and S.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Assuming a wheat price of $6 per bushel, the response at Staples would result in an additional $24 per acre in added crop value across the varieties. If S cost was $0.50 per lb of S, the rate needed to increase yield (15 lb per acre) would cost a grower $7.50 per acre resulting in a net profit of $16.50 per acre and would total $8,250 for a 500 acre operation. When S is deficient, application of S is typically highly profitable for hard red spring wheat.

Even with the low total cost associated with the rate of S needed to increase yield, if a site is not responsive a grower should highly consider using money intended for S for nitrogen especially in years where yield potential and protein discounts are greater. Since there has been no evidence for increased grain protein due to S application in several studies dating back to 2008 S should not play a role in making decisions on fertilizer application for increasing grain protein concentration.

Related Research

A S study was concluded in 2009 which was funded by the Minnesota Wheat Growers that studied the effect of S source, rate, and timing for wheat grown on soils with relatively high concentration of organic matter. This current study provided supporting data for the previous research but focuses on questions received following the previous study on whether we would expect response to S to be greater for varieties which are greater yielding than Glenn which was used in the previous research. We are also following up on information collected in a study funded in 2011 and 2012 that included a survey of flag leaf tissue nutrient concentration. The current research will determine if there is any value in tissue concentration data and whether tissue concentration can help predict a varieties responsiveness to a specific fertilizer.

Recommended Future Research

We are currently evaluating the sulfur guidelines which were modified for wheat. Our research should provide furhter information on the validity of the guidelines. For nitrogen, additional sites would be beneficial to bolster the current guidelines. Nitrogen rate trials on non-irrigated soils are continually needed to fine tune guidelines.

Table 1. Trial location, planting information, and monthly total precipitation for spring wheat S rate studies.

					Monthly Total Precipitation		
Location	County	Soil Type	Soil Texture	Seeding Date	May	June	July
					-----inches-----		
Crookston	Polk	Wheatville	Sandy Loam	28-Apr	2.7	3.7	5.0
Fergus Falls	Otter Tail	Dickey	Fine Sand	1-May	7.5	3.0	1.8
Staples	Wadena	Verndale	Sandy Loam	12-Apr	5.9	1.9	5.0

Table 2. Spring soil test averages across replications for Spring wheat S trials.

	Soil Test (0-6")†				
Location	P	K	SOM	pH	Sulfate-S‡
	-------ppm-------		---%---		--lb/ac--
Crookston	18	146	3.2	7.5	32§
Fergus Falls	31	111	2.8	6.1	40
Staples	19	101	1.9	6.6	40

† P, Bray-P1 phosphorus; K, ammonium acetate potassium; SOM, soil organic matter; pH, soil pH.

‡ 0 to 2 foot soil sulfate-S

§Sample was collected from 0-1'

Table 3. Summary of statistical signficance of main effects of variety (V), sulfur rate (S), and their interaction (VxS) for spring wheat grain yield, protein concentration, and total protein produced per acre.

	Grain Yield†			Grain Protein†			Protein Yield†		
Location	V	S	VxS	V	S	VxS	V	S	VxS
	P>F								
Crookston	<0.001	0.41	0.84	<0.001	0.02	0.48	<0.01	0.30	0.91
Fergus Falls	0.02	0.76	0.59	<0.01	0.66	0.02	0.05	0.79	0.58
Staples	<0.001	0.03	0.35	<0.001	<0.001	0.14	<0.001	<0.002	0.22

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Table 4. Summary of hard red spring wheat grain yield, grain protein concentration, and protein production per acre for individual varieties at Crookston (CR), Fergus Falls (FF), and Staples (ST) Minnesota during 2015. Average values were calculated for variety and sulfur main effects by and across locations (AVG).

	Grain Yield†				Grain Protein†				Protein Yield†			
Variety	CR	FF	ST	AVG	CR	FF	ST	AVG	CR	FF	ST	AVG
	bushels/ac (@ 13%)				%(@ 12%)				pounds/ac (@ 13%)			
Faller	103a	62a	68bc	78	14.5e	15.1b	15.9d	14.9d	906b	564a	617c	696b
Glenn	100ab	55b	67c	79	16.2a	15.0bc	16.4b	15.6b	985b	499b	635bc	741a
Mayville	87d	67a	73a	74	15.7b	14.7c	16.4b	15.4bc	825c	584a	688a	694b
RB07	94bc	64a	70abc	76	15.5c	15.2ab	16.1cd	15.3c	881b	579a	650bc	699b
Select	95bc	61ab	71ab	75	14.9d	15.6a	16.2c	15.2c	857bc	576a	658ab	683b
Vantage	90cd	68a	51d	71	16.2a	14.9bc	18.5a	16.3a	873bc	602a	540d	691b
S Rate (lb/ac)												
0	94	63	65b	75	15.5a	15.2	16.1c	15.3b	883	571	595c	687
7.5	97	64	66b	76	15.5a	15.0	16.7b	15.5a	908	574	630b	708
15	94	62	69a	76	15.4b	15.0	16.9a	15.6a	872	557	670a	707

† within columns for each main effect, numbers followed by the same letter are not statistically significant at $P \leq 0.05$ probability level.

Table 5. Effect of variety and sulfur rate on asparagine content in the wheat grain collected from 2014 at Crookston, Kimball, and Staples

	Grain Yield†			
Variety	CR	K	ST	AVG
	umol/gram (@ 14%)			
Faller	3.5c	3.9c	8.6b	5.2c
Glenn	3.3c	3.1d	5.1c	3.5d
Mayville	4.6b	5.8a	10.4a	6.6ab
RB07	3.7c	5.2b	10.1a	6.3b
Select	5.4a	5.2b	10.3a	6.9a
Vantage	3.1c	3.7c	8.1b	4.9c
S Rate (lb/ac)				
0	3.7	4.7a	9.7a	6.0a
7.5	4.0	4.4b	8.6b	5.5b
15	4.0	4.3b	8.0b	5.3b

† within columns for each main effect, numbers followed by the same letter are not statistically significant at P<0.05 probability level.

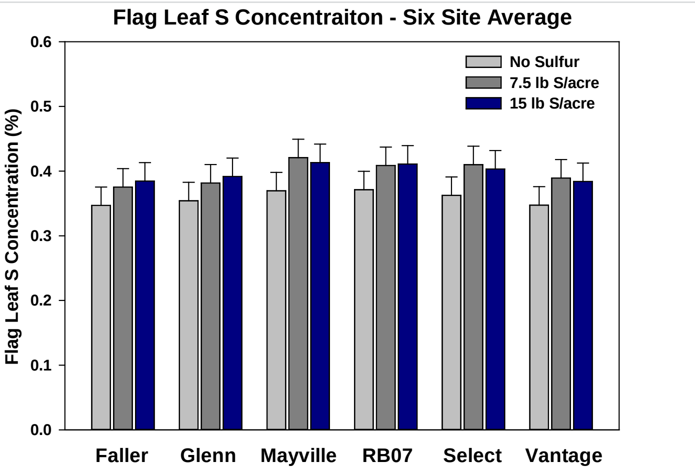


Figure 1. Flag leaf S concentration summarized by variety across six locations from 2014-2015

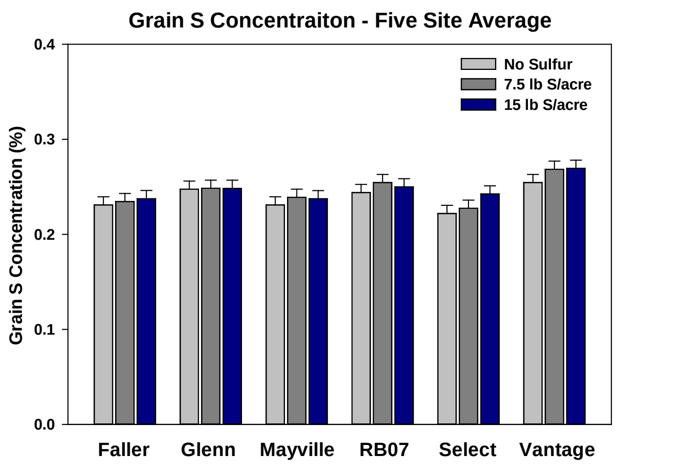


Figure 2. Grain S concentration summarized by variety across six locations from 2014-2015

Table 6. Spring soil test averages across replications for Spring wheat N trial.					
	Soil Test (0-6")†				
Location	P	K	SOM	pH	Nitrate-N‡
	-------ppm-------		---%---		--lb/ac--
Staples	17	84	1.5	7.0	34

† P, Bray-P1 phosphorus; K, ammonium acetate potassium; SOM, soil organic matter; pH, soil pH.

‡ 0 to 2 foot soil nitrate-N

Table 7. Summary of statistical signficance of main effects of variety (V), nitrogen rate (N), and their interaction (VxN) for spring wheat grain yield, protein concentration, and total protein produced per acre.

	Grain Yield†			Grain Protein†			Protein Yield†		
Location	V	N	VxN	V	N	VxN	V	N	VxN
	------------------				*P>F*			------------------	
Staples	<0.01	<0.001	0.33	<0.001	<0.001	0.75	<0.01	<0.001	0.38

Table 8. Summary of hard red spring wheat grain yield, grain protein concentration, and protein production per acre for individual varieties at Staples Minnesota from 2014-2016. Average values were calculated for data across six nitrogen rates and across years (AVG).

	Grain Yield†				Grain Protein†				Protein Yield†			
	2014	2015	2016	AVG	2014	2015	2016	AVG	2014	2015	2016	AVG
	-------------bushels/ac (@ 13%)-------------				--------------------%(@ 12%)--------------------				--------------pounds/ac (@ 13%)---------------			
Faller	--	62a	--	--	--	14.0b	--	--	--	543b	--	--
Mayville	--	63a	--	--	--	14.7a	--	--	--	577a	--	--
RB07	--	57b	--	--	--	14.7a	--	--	--	527b	--	--

† within columns, numbers followed by the same letter are not statistically significant at *P* ≤0.05 probability level.

Table 9. Summary of economic optimum nitrogen rates using the maximum return to N model for irrigated HRSW at Staples, MN in 2014 and 2015 assuming no discounts.\

	Ratio of Price N:Price per bushel of corn					
Location	0.00	0.05	0.10	0.15	0.20	0.25
	-------------------lb N/acre------------------					
2014	164	148	130	113	95	78
2015	238	205	171	137	103	70

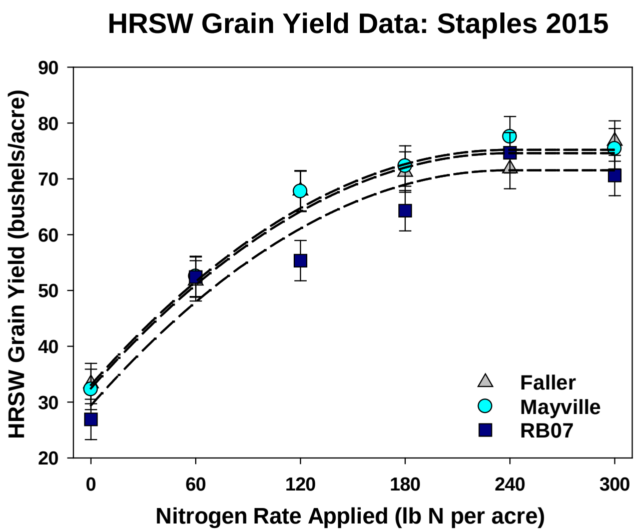


Figure 3. (left) Effect of nitrogen on grain yield of three hard red spring wheat varieties grown under irrigation.

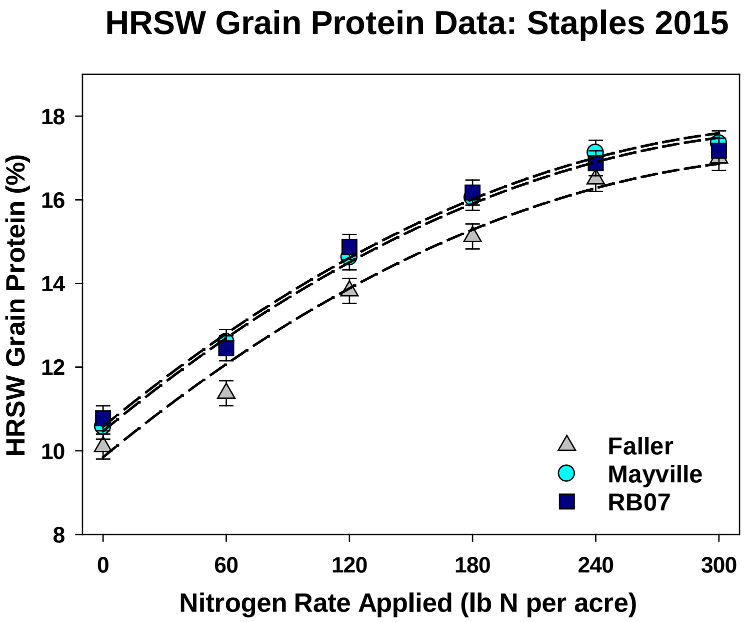
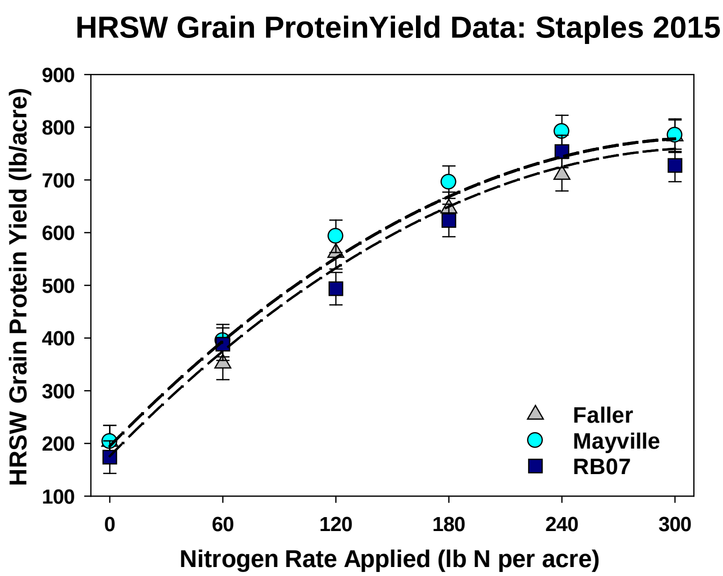


Figure 4. (left) Effect of nitrogen on grain protein concentration of three hard red spring wheat varieties grown under irrigation.

Figure 5. (right) Effect of nitrogen on grain protein yield of three hard red spring wheat varieties grown under irrigation.



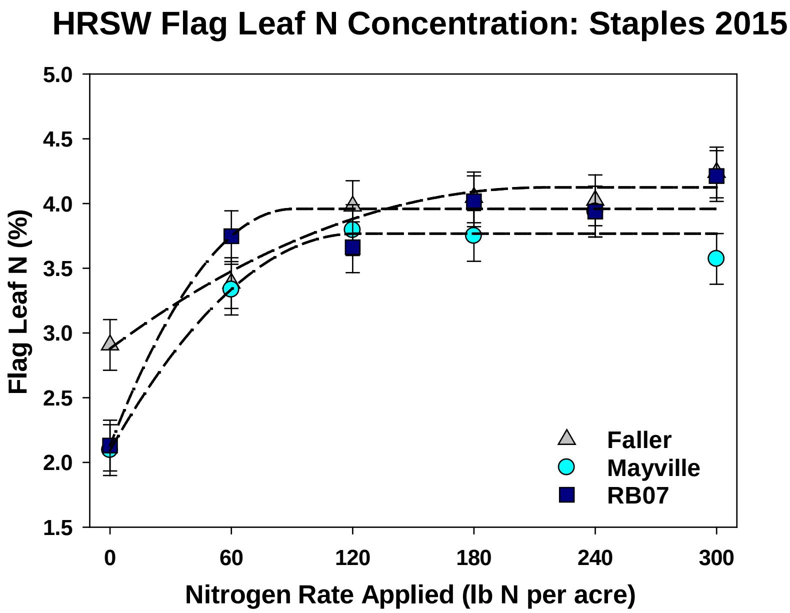


Figure 6. (left) Effect of nitrogen on flag leaf nitrogen concentration at anthesis of three hard red spring wheat varieties grown under irrigation.

Progress Report to Minnesota Wheat Research and Promotion Council on the Spring Wheat Protein Spread Project

Frayne Olson, Dept. of Agribusiness and Applied Economics, NDSU

Additional Items Since Our Last Progress Report

We have identified more elevators in western Minnesota and eastern North Dakota that have price data for alternative spring wheat protein levels. We continue to update our existing protein spread information, which uses data from the USDA Agricultural Marketing Service for two major terminal markets.

In February 2015, did two presentations about protein spreads and post-anthesis at the best of the best meetings in Moorhead, MN and Grand Forks, ND.

In September 2015 did a marketing seminar on protein spreads at Big Iron, Fargo, ND.

We continue to review research studies by Dave Fransen (NDSU) concerning post-anthesis application of nitrogen to enhance wheat protein.

We have developed a post-anthesis decision tool and will be further refining and debugging it.

Planning for the 2015/16 winter meeting season is underway, and we will coordinate with the Minnesota Wheat Research and Promotion Council to present results. We will be able to do more protein spread and post-anthesis presentations at winter extension meetings and marketing club meetings.

To date, we have gathered protein spread information from North Dakota elevators: Aneta, Rogers, and Valley City; and Minnesota elevators: Barnesville, Crookston and Wolverton.

In December, we will be gathering data from several more elevators from Minnesota and North Dakota.

Can Early Season NDVI and Canopy Cover Measurements Predict Yield Potential in Spring Wheat

Joel Ransom, Dept. of Plant Sciences, NDSU

Research Questions

Low protein can result in significant discounts at the elevator. Low protein often results when the crop's nitrogen requirement exceeds the availability of nitrogen in the soil because of higher than expected yield. This project hopes to answer the question of whether yield can be predicted early in the season in order to inform the decison as to whether additional in-season nitrogen may be profitable.

Results

Preliminary data from two locations show the value of in-season nitrogen applications for both yield (4-leaf or boot stage) and for protein (4-leaf, boot and post anthesis). The best timing for N for a protein increase was using UAN post anthesis (typically about a 1% increase). The predictiveness of NDVI on yield varied between locations and when the readings were taken. NDVI values at the 4 to 6-leaf stage were poor predictors of yield at both locations. At the boot stage, however, nearly 70% of the variation in yield at one location could be explained by NDVI values. Values of about 0.83, for example would predict yields of greater than 60 bu/acre. Based on an analysis of the relationship of weather and yield data from irrigated trials at Carrington (fifteen years), the number of days between planting and the boot stage could only explain about 8% of the variation in yield (poor predictor). In general, these data suggest that the best tool for predicting yield is the Greenseeker, using measurements taken at the boot stage. Though our data found that an application of N at the boot stage resulted in both yield and protein increases, in practical terms with currently used machinery that application may not be possible. The best use of additional N at this late stage would probably be UAN applied foliarly, post anthesis for a protein increase. Variability between the locations in the relationship between the NDVI values, yield and protein, suggest that additional research is needed in order to better understand what environmental factors impact these relationships.

Application and Use

These results confirm the value of applying UAN for a protein enhancement. They also suggest that yield can be predicted with some certainty using NDVI values later in the season (around the boot stage is more predictive than earlier). This information could be used by the grower to evaluate whether applying the additional N post anthesis is likely to be needed due to greater than expected yields (if that is indeed the case).

Materials and Methods

Experiments were established in five locations in Minnesota and North Dakota. These experiments included the following treatments: 70 and 100 lbs N/acre at planting, 70 and 100 lbs N/acre at planting plus 30 or 60 lbs N/acre at the 4-leaf stage, 70 and 100 lbs N/acre at planting plus 30 or 60 lbs N/acre at the boot stage, 70 and 100 lbs N/acre at planting plus 30 lbs N/acre as a foliar application post anthesis. Greenseeker data (NDVI) were collected at the 6-leaf stage and at the boot stage. Yield, test weight and protein were collected at harvest and correlations and treatment differences were statistically analyzed.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Applying UAN, post anthesis, can increase grain protein levels by about 1%. In years when the protein premium/discount is $1 per point of protein, this application could result in a net increase in income of $18,000 in 500 acres, assuming a 70 bu average yield [(500 acres x 70 bu per acre x $1 per bu of added value) - (500 acres x $34 per arce application cost and damage by wheel tracks) = $18,000]. When premiums/discounts are below 50 cent per point, this application is likely not to be profitable. Being able to estimate the yield and the protein market could help inform a decision that would have a profitable outcome.

Related Research

We collected NDVI data on the other soil fertility related research that is being conducted in order to increase the database that can be used to better understand the relationship between NDVI and yield.

Recommended Future Research

This research needs additional replication in time. The addition of an N rich plot is recommended for next year. Additionally, estimates of yield after heading (but before the post anthesis application of UAN is made) using traditional yield predicting techniques should be also be included.

Publications

Ransom, J. and G. Mehring. 2015. Can Early Season NDVI and Canopy Cover Measurements Predict Yield Potential in Spring Wheat. Abstracts of the American Society of Agronomy meeting #411-5.

The Economics, Nitrogen Use Efficiency, and Performance of Wheat in Response to Sulfur and Nitrogen Fertilizer

Jasper M Teboh, Carrington Research Extension Center, NDSU

Research Questions

1. Does sulfur fertilization enhance grain yield and protein content of spring wheat? If so, does performance enhancement justify the cost of application?
2. If wheat responds to N application, would sulfur application affect the magnitude of response to N?

Results

The study was conducted at three locations, Ada, East Grand Forks (EGF), and Thief River Falls (TRF).Five N fertilizer rates were randomly assigned to the main plots within each of the four blocks. Three subplot treatment levels were then randomly assigned within each main plot. Results were analyzed separately by location. At Ada, there was no apparent interaction between N and S, implying that yield response to N or S was not dependent on any level of either nutrient. There was a significant effect of S and N application on yield ($p<0.05$). Mean yield increased from 77.5 bu/ac with the check treatment, to 82.8 bu/ac at 10 lbs of added S, and 82 bu/ac at 20 lbs added S all averaged across N levels. The data analysis also suggested that the maximum yield response would have occurred near 200lbs added N, and 15 lbs added S. The predicted yield at these respective N and S rates was about bushels of wheat. Protein responded strongly to N but not S application. However, the results suggest protein could have been maximized at about 8 lbs of S, and about 274 lbs N, an N rate that is not practical and would not be recommended for both economic and environmental reasons.

At TRF, there was no significant yield or protein response from the S and N treatments even though there was a numerical increase in protein as N rates increased. Results from the EGF site showed that significant increase in protein content ($p=0.05$) was due to an interaction between S and N rates.

Application and Use

These results would provide producers with a possibility to identify needs for sulfur application across different soil types. Some producers still apply sulfur every year and others not, irrespective of the field planted to wheat. The question is, is it profitable? Decision making in fertilizer management and application of sulfur is essential for profit wheat production.

Materials and Methods

The study was conducted at three locations, Ada, East Grand Forks (EGF), and Thief River Falls (TRF). Five N fertilizer rates were applied at 60, 120, 180, 240 lbs/ac, including a check (0 lbs/ac added N) and randomly assigned to main plots and replicated four times. Three sulfur treatments (0, 10, 20 lbs/ac) were then randomly assigned within subplots in each main plot. Flag leaves were collected from each plot at anthesis and analyzed for N and S content. Yields, Protein, test weight (TWT), kernel weight were determined. Results were analyzed separately and yields and protein results presented by location.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The research would provide economic benefits to the producer by examining the net returns to S fertilizer input, and at different farming locations. The information provided will help guide producers in deciding whether to apply S to a field where, response is more likely, and not another field with less likelihood of a response as a result of soil types. This means farmers can save on input cost. Sulfur management recommendations will depend on multiple studies (years), and therefore no conclusion can be drawn from this first year of results.

Related Research

Important recent research work has been done on spring wheat response to sulfur and nitrogen parts of Minnesota (Kaiser et al., 2014). Many of the sites under study have shown weak response to sulfur. Teboh and Szilahi (2014) conducted a study that showed good yield and protein response of wheat to sulfur application (results reported in the Carrington REC Annual Research Report).

Recommended Future Research

This first year data is showing that wheat response to sulfur can vary by location. The variation may be due to soil type and climatic factors. Since soil test is not a reliable predictor of crop response to sulfur, soil organic matter and soil texture are important considerations for determining if crops will respond to S application. Since the net benefit of sulfur application will be based on how yields and protein are affected, often times showing a weak correlation to each other, return to investment from applying sulfur needs to be evaluated based on several years of data with different soil types. The use of tissue test to determine sulfur sufficiency needs to be further explored since critical period for both diagnosis and application may be crucial for any response benefits to be observed.

Use of Recurrent Mass Selection to Pre-breed Hard Red Winter Wheat for Resistance to Major Biotrophic and Necrotrophic Diseases

G. Francois Marais Dept. of Plant Sciences, NDSU

Research Questions

A recurrent mass selection pre-breeding program that is based on the dominant male-sterility gene, *Ms2*, is being done to facilitate the continuous development of improved hard red winter wheat breeding parents with high levels of winter-hardiness coupled with effective resistance against major diseases such as Fusarium head blight (FHB), leaf and stem rust, tan spot, bacterial leaf streak (BLS) and Stagonospora nodorum blotch (SNB). This long term pre-breeding program will operate in parallel with the conventional winter wheat breeding program and will serve to systematically assemble (pyramid) new useful genes in adapted genotypes that can be used more effectively in crosses with the elite germplasm.

During the funding period, selection has focused on:

a. Increasing the level of cold-hardiness in the population.
b. Acquiring genes for insensitivity to SNB and tan spot.
c. Establishing the durable rust resistance genes, *Lr34/Yr18, Sr2* as well as the FHB resistance genes, *Fhb1* and *Qfhs.ifa-5A*.
d. Introducing additional major and minor gene resistance to the cereal rusts.
e. Introducing BLS resistance.
f. Establishing a regular recurrent mass selection program with inbreeding and field testing of the male parents.

Materials and Methods

A base population in which the F_1 segregates 1:1 for the *Ms2* male sterility gene is being improved through recurrent selection. Both male and female plants are being selected; however, only male fertile progenies are being evaluated in the field. Female F_1 plants derive from the preceding season whereas male plants are being selected among advanced generation segregates that were grown in the field.

Plants destined for crosses are grown in containers. In each season the spikes of selected, male-sterile females are cut open to facilitate pollination. During pollination, selected female plants are positioned lower and surrounded by selected male plants. Mild wind agitation (fan) is used to enhance cross-pollination. The containers are arranged in a manner that promotes random pollination.

Characterization and selection of parent plants are based on markers (where available), seedling screening (rust, tan spot and SNB resistance) and field screening (winter survival, disease resistance, yield and quality). During the first three years of selection and crosses the emphasis has been on the introduction and dissemination of a broad range of leaf and stem rust resistance genes, effective FHB resistance QTL, tan spot and S nodorum blotch resistance as well as winter-hardiness genes. The majority of new resistance genes have only recently been transferred from spring wheat.

Results

Three cycles of crosses (February/March, 2013, 2014 and 2015, respectively) were made during the project period. The first two cycles were described in detail in previous progress reports.

<u>The third cross:</u>

In 2015 *Ms2ms2* female plants were used in crosses based on the presence of one or more of the resistance genes *Fhb1, Lr34, Sr26, Sr22, Sr39, Sr50* (markers), *Lr53* and *Lr56* (seedling resistance). These were pollinated with parents having one or more of the resistance genes *Fhb1, Qfhs.ifa-5A*, FHB 5AS and 5AL QTL from PI277012, *Lr19, Lr34, Lr46, Lr67, Lr50, Lr53, Lr56, Sr22* and *Sr35*. A large F_1 population has been generated for continued crosses and evaluation and is currently being vernalized in order to do the fourth crossing cycle in February of 2016. In December 2015, the latter F_1 will be seedling screened for resistance to leaf rust (mixed inoculum of six races) and stem rust (mixed inoculum of four races). Resistant plants will be transferred to cones for phenotypic selection of females.

<u>Development and selection during 2015 of the next (fourth) cycle male parents:</u>

1. Since Norstar is the most winter-hardy genotype available, backcrosses aimed at pyramiding combinations of resistance genes in its genetic background were initiated in 2013. The following gene pyramids have been established, confirmed with markers and planted for use as males in the 2015 crosses:
    a. Norstar-*Fhb1*
    b. Norstar-*RhtB1b-Fhb1-Sr26*
    c. Norstar-*RhtB1b-Fhb1-Sr2*
    d. Norstar-*RhtB1b-Fhb1-Lr34-Sr39*

2. Winter-hardy lines were selected from preliminary yield trials and will be used as males:
    a. Ten lines with either *Fhb1*or *Fhb1* plus *Qfhs.ifa-5A* that also have good leaf and stem rust resistance.

b. Twelve lines based on *Fhb1, Fhb1* plus *Qfhs.ifa-5A,* or the PI277012 5AS and 5AL FHB QTL, but having susceptibility to leaf and/or stem rust.

c. Six lines without known QTL for FHB resistance but with excellent yield, leaf and stem rust resistance.

3. Male parents with promising resistance to one or both of tan spot and S nodorum blotch were selected employing three different strategies as follows:

a. Approximately 1,764 male fertile F_2 plants from a recurrent selection base population with 110 parents (based on *Ms3*) were evaluated with mixed tan spot races. A random F_3 plant from each of 600 selected F_2 families was used to obtain 600 F_4 families. The latter were used to conduct both tan spot and SNB evaluations using mixed inoculum in each case. Based on the reactions $F_{4:5}$ families were identified for continued testing; 27 families were chosen based on tan spot resistance and 27 families were chosen on the basis of SNB resistance while 2 families showed some resistance to both diseases.

b. One hundred and thirty three inbred lines from the NDSU winter wheat breeding program were evaluated for resistance to mixed tan spot and mixed SNB races. Eight of the lines were selected for evaluation with individual races and toxins.

c. Diverse lines (including introduced winter and spring wheat as well as synthetics, and with widely different origin) were evaluated with mixed tan spot and SNB inoculum. A HRSW genotype plus six synthetics showed promising resistance. However, its transfer to winter wheat will be time consuming.

d. In an attempt to confirm the resistance, the selected lines are currently being finally evaluated for resistance to individual races and toxins of tan spot and SNB. Only a small group of the very best lines will eventually be used as parents.

e. Since resistance/insensitivity to the two diseases is quantitative and the majority of selections shows differential responses to races, pyramiding will be necessary in order to acquire broad resistance.

Application/Use

The (pre-breeding) population will be continually enriched with respect to useful disease resistance and adaptation genes. Annually, the F_1 produced in the preceding season will be selected for seedling rust resistance to mixed inoculum and marker genotyping will be applied as necessary. Following each selection cycle the best females will be used in the crossing block whereas the best male-fertile F_2 plants will be harvested separately and the F_3 field planted for continued inbreeding and selection for winter survival, disease resistance, yield and quality. In this manner new and diverse segregating families will be established each year. Superior inbred lines selected in the subsequent generations will be utilized as males in future crossing blocks and will also be evaluated further for possible commercialization.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The disease-causing pathogens targeted in the project annually cause significant wheat yield losses in the Northern Great Plains and even modest changes in the average level of resistance in new cultivars will be of considerable benefit to producers. The targeted diseases include some that are notoriously difficult to breed resistance for (for example tan spot, bacterial leaf streak, SNB and FHB) since resistance/ insensitivity is based on numerous quantitative trait loci each making only a small contribution to the total resistance phenotype.

The project aims to assemble a wide spectrum of useful known and new resistance and adaptation genes in the pre-breeding population. The majority of the target genes were not previously available in the NDSU HRWW breeding material. Pre-breeding through recurrent selection is being applied to gradually improve the general genetic background in which the newly introduced genes occur and to concentrate/assemble the numerous disease resistance loci into more complex combinations that will be more useful in pedigree breeding. This will make it possible to also develop new varieties with better resistance gene combinations and yield stability.

Related Research

A hard red winter wheat pedigree breeding program was initiated at NDSU during 2011. Annually, 500-700 new crosses are being made among winter wheat parents. A primary aim is to broaden the spectrum of disease resistance genes available for varietal development. Many of the known genes for resistance to the rusts, FHB, tan spot, SNB and BLS are not available in winter-hardy genetic backgrounds that are adapted to North Dakota. Furthermore the resistance genes often occur singly in very diverse and poorly adapted backgrounds making it even more difficult to combine multiple genes in a single line. This pre-breeding program is meant to supplement and facilitate the pedigree breeding effort.

Recommended Future Research

a. The recurrent selection pre-breeding effort will be continued in parallel, and supplementary to, the conventional HRWW pedigree breeding program.

b. We will continue to enrich and improve the base population with new resistance genes and will increase the frequencies of those genes through strict recurrent selection.

c. We will continue to develop and field test diverse inbred lines derived from the male F1 of each crossing cycle, focusing on the identification of inbred lines with complex resistance gene combinations.

Spring Wheat Responses to Starter Fertilizer, Micronutrient and Root Inoculant

Armitava Chatterjee, Dept. of Soil Science, NDSU

Research Questions

Can we increase spring wheat yields and protein contents with additions of (1) starter fertilizer (10-52-0), (2) Sulfur, (3) Copper, (4) Zinc, and (5) Root inoculant (Trichoderma spp) under field with poor micronutrient availability condition?

Results

We had frequent heavy rainfall events during the 2015 growing season. Rainfall amounts were comparatively greater during the early vegetative stage (May) compared to late vegetative or early reproductive stage (June-Aug) (Table 2.). Due to the frequent wet events, the whole growing season had relatively higher humidity compared to previous year due to which the leaf rust disease were sparsely observed in spring wheat.

Despite sparse occurrence of leaf rust diseases, the spring wheat grain yields were comparatively greater compared to previous cropping seasons. The average grain yield and protein content obtained from the unfertilized plots were 53.1 Bu/ac and 11.3%, respectively. Frequent rainfall events during this growing season prevented crop from having water stresses during all the stages of their growth, which might have resulted in higher grain yields.

All combinations of starter fertilizer (11-52-0), micronutrient (Cu, S, Zn), and root inoculants with the recommended NPK dose resulted in significantly higher grain yields and protein contents compared to the control (Table 2). The recommended NPK alone also resulted in significantly greater grain yields and protein content compared to the control treatment. The grain protein content was similar among all of the treatment combinations. Application of starter fertilizer (11-52-0) along with the recommended NPK dose significantly increased spring wheat yields by 5.1 Bu/ac compared to the NPK alone. Similarly, supplementing the recommended NPK dose with single micronutrient (Cu, Zn, or S), double micronutrients (Zn + S), or by all of the three micronutrients (Cu+Zn+S) did not resulted in significant yield advantage over recommended NPK. However, the addition of Cu and S with recommended NPK dose significantly increased spring wheat yields by 4.8 Bu/ac compared to NPK alone.

Addition of root inoculant (Trichoderma spp.) with recommended NPK did not showed any yield advantage over NPK alone. However, the combined application of root inoculant along with all three micronutrients (Cu + Zn + S) with recommended NPK significantly increased spring wheat grain yields by 4.5 Bu/ac compared to NPK alone.

Application and Use

Spring wheat grain yields and protein contents were highly influenced by the availability of nutrients during the early vegetative stage and late vegetative or early reproductive stages, respectively. Adequate and efficient use of fertilizers have potential to increase the spring wheat yield and quality. Although, spring wheat is most responsive to nitrogen, the role of micronutrients and root inoculants should not be avoided. Micronutrients such as Cu, Zn, and S as well as root inoculants might play a synergistic role in improving the production and quality of spring wheat. Our results suggested that the supplemental application of starter fertilizer (11-52-0), or root inoculant (Trichoderma spp.) along with micronutrients (Cu+Zn+S) might potentially increase spring wheat production under silt clay loam soil conditions. The addition of micronutrients showed yield advantage over recommended NPK, only in some cases (Cu + S) suggesting the need of further studies to confirm the results. Thus, the addition of starter fertilizer, or root inoculants, or micronutrients could be a beneficial approach to increase spring wheat production for wheat growers in Minnesota.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Soil fertility management has potential to increase grain yield and protein content.

Materials and Methods

A field experiment was conducted during 2015 growing season near Glyndon, MN on a Beardon Silty Clay Loam soil to determine the response of spring wheat to starter fertilizer, micronutrient, and root inoculant. Eleven treatments of various combinations were arranged in a randomized complete block design with four blocks. The treatments were: 1. Control (no fertilizer applied); 2. Recommended NPK; 3. Starter fertilizer (10-52-0) @ 3 gallon/ac with recommended NPK; 4. Sulfur @10 lb/ac (as ammonium sulfate) with recommended NPK ; 5. Copper @ 5 lb/ac with recommended NPK; 6. Zinc @ 1 lb/ac with recommended NPK; 7. Copper + sulfur (as $CuSO_4$ matching the amount of Cu and S with treatment 4 and 5) with recommended NPK; 8. Zinc + sulfur (as $ZnSO_4$ matching the amount of Zn and S with treatment 5 and 6) with recommended NPK; 9. Copper + zinc + sulfur (as $CuSO_4$ and $ZnSO_4$ matching the amount of Cu, Zn and S with treatment 4, 5 and 6) with recommended NPK;10. Root inoculant (Trichoderma spp.) with recommended NPK; and 11. Root inoculant+ (Trt. 9: copper + zinc+ sulfur) with recommended NPK. Individual treatment plots measured 10 feet wide and 30 feet long.

The initial nutrient status of the soil was presented in Table 1. The soybean stubbles were removed from the field before the application of the treatments. All of the above mentioned treatments were mid-row banded, and spring wheat was planted on April 18/2015 with an 8' wide, small plot sized grain drill. ND Wheat variety Faller was planted at the seeding rate of 2 bushels per acre. Overall germination and plant stands were very good. Husky herbicide was applied one time for weed control on the spring wheat.

At physiological maturity, the middle five rows of each plot were harvested using the small plot combine harvester on August 4/2015. Wheat grains were dried at 60˚C for 3 days and adjusted to 14% moisture level before recording grain yield. Grain protein content was analyzed using Infratec 1241 Grain analyzer (FOSS analytical AB, Hoganas, Sweden). Statistical analyses were performed using PROC-ANOVA procedure for RCBD in SAS 9.3 (SAS Institute Inc, Cary NC). Means comparisons were conducted at the 90% confidence level using Fisher's least significance difference method.

Table 1. Initial nutrient status of the soils.

Soil depth	pH	EC	Initial nutrient status			Soil texture	Particle size distribution		
			NO_3-N	P	K		Sand	Silt	Clay
inches		dS m^{-1}	lb ac^{-1}	-----------ppm--------			-----------------g kg^{-1}----------------		
0 - 6'	8.1	0.30	28	8	125	Silty Clay Loam	92	578	330
6-24'			21						

Table 2. NDAWN monthly weather data for the 2015 growing season.

Year	Month	Fargo				
		Avg Air Temp (°F)	Avg Wind Spd (mph)	Avg Solar Rad (Lys)	Total PET Penman (inch)	Total Rainfall (inch)
2015	April	47E	9.1	435	7.11	0.63
2015	May	55	8.3	423	5.84	7.86
2015	June	67	6.4	505	6.87	2.51
2015	July	72E	7.1E	546E	7.84	2.80
	Averages:	60E	7.7E	477E		
	Totals:				27.65	13.80
	Max:	72E	9.1E	546E	7.84	7.86
	Min:	47E	6.4E	423E	5.84	0.63
	Std. Dev.:	12E	1.2E	58E	0.83	

Table 3. Effect of starter fertilizer (11-52-0), micronutrients (Cu, Zn, S) and root inoculants (Trichoderma spp.) on spring wheat grain yields and protein content at Glyndon, MN under Bearden silt clay loam soil conditions in 2015 growing season.

Treatments	Grain Yields	Grain protein content
	Bu/ac	%
1. Control (no fertilizer applied),	53.1 ± 3.0 C	11.3 ± 1.3 B
2. Recommended NPK,	70.4 ± 6.0 B	12.2 ± 0.4 A
3. 11-52-0 @ 40 lb/ac with recommended NPK	75.5 ± 1.9 A	12.3 ± 0.6 A
4. Sulfur @10 lb/ac (as ammonium sulfate) with recommended NPK	71.9 ± 0.5 AB	12.2 ± 0.8 A
5. Copper @ 1 lb/ac with recommended NPK	73.7 ± 2.4 AB	12.3 ± 0.7 A
6. Zinc @ 1 lb/ac with recommended NPK	72.7 ± 1.2 AB	12.3 ± 0.5 A
7. Copper + sulfur (as $CuSO_4$ matching the amount of Cu and S with treatment 4 and 5) with recommended NPK	75.2 ± 1.4 A	12.2 ± 0.5 A
8. Zinc + sulfur (as $ZnSO_4$ matching the amount of Zn and S with treatment 5 and 6) with recommended NPK	73.3 ± 3.6 AB	12.2 ± 0.4 A
9. Copper + zinc + sulfur (as $CuSO_4$ and $ZnSO_4$ matching the amount of Cu, Zn and S with treatment 4, 5 and 6) with recommended NPK	73.1 ± 3.7 AB	12.2 ± 1.0 A
10. Root inoculant (Trichoderma spp.) with recommended NPK	72.7 ± 3.3 AB	12.6 ± 0.5 A
11. Root inoculant+ (Trt. 9: copper + zinc+ sulfur) with recommended NPK	74.9 ± 4.5 A	12.0 ± 0.7 A
Mean ± standard deviations followed by the same uppercase letters within each column were not significantly different from each other.		

Minnesota Small Grains Pest Survey

Madeleine Smith, Dept. of Plant Pathology, NWROC

Research Questions

This project aims to provide a statewide survey of small grains growing regions of Minnesota (MN) during the growing season in order to provide timely monitoring of disease issues throughout the state and release information to growers on best management practices for the diseases detected. In addition, the project aims to work with U of MN Plant Disease Clinic and the USDA-ARS Cereal Disease Lab in submitting samples for regional/national monitoring as well as race identification for cereal rusts.

Results

Disease distribution maps can be viewed at https://www.ag.ndsu.edu/ndipm

Field surveys began in the last 2 weeks of May. The wheat crop ranged from tillering in the north to the beginning anthesis in the southern survey locations.

The most prevalent and the earliest disease to appear in wheat throughout MN was tan spot. Due to the weather conditions early in the spring, many diseases developed later in the growing season than in previous years. Septoria tritici blotch occurred with high incidences in central MN later in the growing season. Barley yellow dwarf (BYD) incidence was found where aphids established early in central MN and by the end of the growing season, BYD was distributed widely throughout the state. Bacterial leaf streak (BLS) was later in development than in 2014, but was prevalent again in central and west central MN. 2015 also saw an influx of stripe rust which caused a problem in central and northwest MN. Despite what appeared to be drier conditions in some parts of the state, Fusarium head blight (scab) was prevalent in west central MN, where high humidity during heading contributed to higher than forecasted infections. Most growers seemed to combat high disease levels, and therefore potential high vomitoxin levels, by blowing infected grain out of the back of the combine and/ or mixing grain from less heavily infected fields with diseased grain.

The most important insect related production issues were the appearance of cereal aphids which reached threshold levels in central MN early and reflected the higher incidence of BYD. Armyworm did make their presence known in southwest MN by early July, prompting some insecticide treatments.

In barley, field surveys were initiated the last 2 weeks of May. The most prevalent diseases in 2015 on barley were BLS, particularly in central and northwest MN. Central MN saw a high incidence of cereal aphids and this correlated with subsequent high incidence of BYD. Septoria blotch occurred with high incidences in central MN. Fusarium head blight (scab) was only found in far northwest MN. Although spot blotch and netblotch were found in the region they were more often found in North Dakota than MN. Traditionally netblotch has been one of the main diseases on barley in MN.

In oats the most prevalent diseases were oat crown rust and Septoria blotch. The first infections of oat crown rust appeared in mid to late June and rapidly developed in southwestern Minnesota. Many oat growers applied fungicide to control oat crown rust as losses in 2014 were high (as much as 40%) due to this disease.

Application and Use

By providing growers with information on both prevalence and potential risk factors for developing diseases, as well as management options, it is hoped that growers will be able to make informed decisions about pesticide applications in a manner that will minimize potential yield losses in their operation, whilst at the same time minimizing expenditure.

Materials and Methods

The small grains growing regions in MN were divided in to three areas as follows: NW Red River Valley; West Central and Southwestern MN; and Central and Southeastern MN.

Three scouts were assigned to these three areas (scouts hired with additional financial support from the Minnesota Soybean Research and Promotion Council and the Midwest Forage Association).

Scouts received training on disease identification and sample handling from the research team prior to scouting fields.

Fields were scouted from early May until mid-August once a week. Fields were selected at random with each scout scouting approximately 20-30 fields per week depending on weather conditions. In addition to the scouting of commercial fields, sentinel plots of varieties of wheat, barley and oats, susceptible to a range of diseases, were planted at on-farm locations around Minnesota. These were also assessed by the scouts throughout the growing season. Fields were assigned an ID number and GPS coordinates in order to generate disease distribution maps in conjunction with the North Dakota State University IPM survey.

Fields were assessed for both disease incidence (how many plants were infected by a certain disease) and severity (how badly a plant was infected by a particular disease). These were recorded as percentage incidence and severity.

Weekly data was recorded in Microsoft Excel and disease distribution maps were compiled and placed on the web at https://www.ag.ndsu.edu/ndipm/wheat and https://www.ag.ndsu.edu/ndipm/barley. Postings were also made to MAWG crop disease website and the National and Minnesota Fusarium head blight risk forecasting websites (http://www.wheatscab.psu.edu/).

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The benefits to a 500 acre wheat enterprise will vary depending on the season, a variety's level of disease susceptibility or resistance, disease prevalence, and the cost of individual pesticides. However, it is hoped that the information provided by the survey will prevent unnecessary pesticide applications and thus increase a grower's return on investment for a given growing season.

Related Research

This project is done in collaboration with the North Dakota State University IPM team including: Patrick Beauzay, Janet Knodel, Andrew Friskop, Sam Markell; in order to provide a regional picture of disease distribution and risk forecasting.

This project also feeds in to the Upper Great Plains Wheat Pathology Collaboration (UGPWP) recently funded by MWRPC by both providing current information on pathogen and insect distribution and population structures, but also by providing an insight in to upcoming disease issues in the state that inform future research aims and objectives of this interdisciplinary plant pathology team.

Recommended Future Research

This project will continue for 2016 and 2017 and continue to provide information on disease detection, prevalence and management.

Strategies for Meeting N Requirements of Wheat with New Fertilizers and Fertilizer Additives

Joel Ransom, Dept. of Plant Genetics, NDSU

Research Questions

Nitrogen fertilizer is the single most expensive input used in wheat production. Losses of N can be substantial through leaching and denitrification, particularly in the RRV region. This project seeks to answer the questions: Can nitrogen stabilizing technologies improve nitrogen efficiency and allow for greater flexibility in the timing of N application, without the risk of serious N loss to the environment? In the first year of the project we also sought to answer the question of how much ESN could be safely applied with the seed at planting?

Results

When averaged across all locations and rates of nitrogen, there was little difference in yield between the treatments that were 100% ESN or 100% urea regardless of timing (fall verse spring). ESN treatments tended to have greater protein (on average 0.5% higher) than urea treatments, however. At the highest yielding location, Gentilly, ESN treatments averaged about 3 bu greater in yield with 0.6% higher protein than the urea treatments. The treatments with Instinct added to the urea were similar in yield to those of ESN and urea at the same rate. Protein with the Instinct treatments tended to be intermediate between ESN and urea. There was only a slight difference between the 75:25 and 50:50 blends of ESN:urea for yield and protein for both the fall and spring application dates. Splitting the N in the spring (50% at planting and 50% as UAN at the 4 leaf stage), had similar yield and protein values to urea all applied at planting. The results that we obtained this year were generally similar to those of 2014 for spring wheat. In 2014 we also found that ESN could be mixed with the seed at planting at much higher rates than can be mixed with urea alone.

Application/Use

Even though the results from the two years of study were quite similar, additional replication in time and location will be needed before a firm recommendation can be made on the use of the nitrogen extending products we tested. These products did not increase wheat yield sufficiently to justify their cost in most of the environments where this research was conducted in 2015 and 2015. Applying ESN instead of urea consistently improved grain protein, but generally only by about 0.5%. This could result in additional revenue to the grower, but the amount would depend on the yield of the field and the protein premium obtained when the grain is sold.

Material and Methods

During the final year of this project the experiments have focused on comparing fall nitrogen fertilization with spring fertilization using ESN, urea and urea with Instinct. Experiments were established in three locations: Casselton in North Dakota and near Gentilly and Stephen in Minnesota. There were 25 treatments that included a combination of the following factors: timing (either spring or fall); fertilizer type (ESN, urea or urea plus Instinct), and N rate (50, 75 or 100% of optimum N rate). All fall applications were made after soil temperatures had dropped below 50 degrees. A split application (50% at planting and 50% as UAN at the 4 leaf stage was also included. Yield and grain protein were measured at harvest.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Given the preliminary nature of our results, we are not able to calculate an economic benefit to the farmer with any confidence. In some environments, the use of nitrogen extending technology may actually cost more than can be recovered by the added value of either yield and/or protein. Better understanding when these technologies will be most profitable will be an important aspect of this and future research.

Related Research

We collected NDVI data that will be used to assist in confirming the value of using the Greenseeker in predicting crop responsiveness to additional N. These extra data will help expand the database available to that project which will broaden its frame of reference and improve the accuracy of its outputs.

Recommended Future Research

We recommend an additional year of research and a proposal for an extension of this work will be submitted for 2016 funding. Fall treatments have been applied at three locations in anticipation of an extra year of funding.

Optimum Seeding Rates for Diverse HRSW Cultivars

Jochum Wiersma, Dept. of Agronomy & Plant Sciences, NWROC, Crookston

Research Questions

Yield of HRSW is affected by many agronomic practices starting with choice of the cultivar, the planting date, and seeding rate. Previous research has shown that optimum seeding rates differ for individual cultivars (Wiersma, 2004). This research project explores the relationship between a set of genetic traits, including Rht-B1 and Rht-D1 genes for semi-dwarf stature and the Ppd-D1 gene for photoperiod sensitivity of individual HRSW cultivars at different planting dates and seeding rates. Can we predict the likely response of newly released cultivars to plant populations based on the presence or absence of key genes? Using statistical techniques it is possible to develop regression models that supersede individual cultivars and looks to explain how a group of genetically similar cultivars respond to seeding rate and planting date changes.

Results

In 2015 locations had variable responses to seeding rate averaged over cultivar for grain yield (Table 2). Kimball and Lamberton had the largest increase in grain yield as seeding rates increased while Hallock, Crookston, and Prosper all had smaller yield differences between seeding rates. A delay in planting date lowered grain yield at all three locations (Table 3). The additional sensor data that was added to this research in 2015 had mixed results. Greenseeker data was not correlated with yield across cultivars. The greenseeker was predictive of yield within seeding rates for a specific cultivar, for Kelby especially (Table 4). There were very good correlations between the greenseeker and a phone based free app called Canopeo early in the season before the sensors saturated, and the two can be used interchangeably. Lodging was a confounding factor at several locations in 2015. Lodging increased linearly with seeding rate for many lodging prone cultivars (Table 6).

Application and Use

The environmental conditions in 2015 favored lodging if the agronomic practices such as seeding rate, cultivar, or nitrogen fertility were favorable. Some cultivars used in this research had no increase in yield as seeding rate increased due to severe lodging, which increased with higher seeding rates (Table 7). When choosing a seeding rate and considering to go higher, it is important to check straw strength of the cultivar, as some cultivars will not stand even with the recommended seeding rate in certain environments. Generally, overseeding has more negatives than postives and should be avoided unless specific outcomes are planned for and expected. The planting date aspect of the trials was evidence that planting on time will result in far greater yield than late planting.

Materials and Methods

Six field locations were established in 2015. Crookston and Lamberton, MN and Prosper, ND were a randomized complete block design (RCBD) with planting date as the whole-plot, cultivar as the split, and seeding rate as the split-split. Hallock, Perley, and Kimball, MN were identical without planting date. Planting dates were separated by three to five weeks. There were twelve cultivars and five seeding rates from 0.6 to 2.2 million pure live seeds/acre. The data collected were stand counts, spike counts, height, lodging, and grain yield components. Greenseeker and Canopeo were used for sensor data.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

As an example, the seeding rate for maximum net income with yields from Kimball, MN, 2015, is 1.4 million seeds/acre while 2.2 million seeds/acre is the lowest (Table 5). If a farmer were to plant 500 acres with the math from Table 5, planting at 1.4 million seeds per acre would net $32,135 more than the most uneconomical seeding rate of 2.2 million seeds per acre. Additionally, any economic benefit to a farmer from not harvesting lodged wheat can be in part solved with seeding rate for certain culltivars.

Recommended Future Research

This research is being used towards a PhD graduate degree for Grant Mehring at North Dakota State University with Dr. Jochum Wiersma and Dr. Joel Ransom as co-advisors to the research. The is a lot more to understand about this research to answer the initial research question posed several years ago. With additional statistical analysis and interpretation that is ongoing during Fall-Winter-Spring of 2015 and 2016 more detailed conclusions will come out of this research and be published in the appropriate media. As it is to date, there is enough data to end field work until the analysis has been finished. At that point there may be an indication of a need for further research on the subject of seeding rates for diverse HRSW cultivars.

continued from page 65

Publications

Mehring, G.H., J.J. Wiersma, and J.K. Ransom. 2014. Optimum Seeding Rates for Diverse Hrsw Cultivars. Paper presented at American Society of Agronomy annual meeting, Long Beach, CA.

Mehring, G.H., J.J. Wiersma, and J.K. Ransom. 2015. Tillering Response in Hrsw Cultivars As Influenced By Planting Date, Plant Population, and Genetic Background. Poster presented at American Society of Agronomy annual meeting, Minneapolis, MN.

Appendix

Table 1. The HRSW cultivars included in research and presence of Ppd-D1, Rht-D1, and Rht-B1 genes

Group	Cultivar	Ppd-D1	Rht-B1	Rht-D1
1	Albany	b	b	a
	Faller	b	b	a
2	Knudson	a	b	a
	Samson	a	b	a
3	Briggs	b	a	a
	Vantage	b	a	a
4	Sabin	a	a	a
	Oklee	a	a	a
5	Kelby	a	a	b
	Kuntz	a	a	b
6	Marshall	b	a	b
	Rollag	b	a	b

Table 2. Effect of seeding rate on yield a 6 study locations, with 2 planting dates at 3 locations, 2015.

	Location								
Seeding Rate	**Hallock**	**Crookston PD 1**	**Crookston PD 2**	**Perley**	**Prosper PD 1**	**Prosper PD 2**	**Kimball**	**Lamberton PD 1**	**Lamberton PD 2**
Million seeds/ac	**----------bu/ac----------**								
0.6	83.2	91.9	76.7	103.3	70.4	51.4	82.2	76.3	64.1
1.0	84.6	95.0	79.9	107.9	71.2	53.6	90.1	81.3	67.3
1.4	84.3	94.8	81.0	104.5	70.0	54.9	92.3	86.2	68.8
1.8	81.9	96.3	81.9	104.2	69.6	54.5	91.8	87.3	68.0
2.2	84.0	94.2	80.2	102.5	66.3	55.1	82.2	87.0	69.9
Mean	83.6	94.4	80.0	104.5	69.5	53.9	87.7	83.6	67.6
Min	81.9	91.9	76.7	102.5	66.3	51.4	82.2	76.3	64.1
Max	84.6	96.3	81	107.9	71.2	55.1	92.3	87.3	69.9
Range	2.7	4.4	4.3	5.4	4.9	3.7	10.1	11	5.8
LSD (0.5)	NS	2.5	2.5	3.2	2.2	2.2	4.9	3.7	3.6

Table 3. Effect of planting date by seeding rate interaction averaged over HRSW cultivar on yield at Lamberton and Crookston, MN, and Prosper, ND, 2015.

Planting Date	Lamberton, MN 2015					
	600,000	**1,000,000**	**1,400,000**	**1,800,000**	**2,200,000**	**LSD**
	------------------------------------bu/ac------------------------------------					
Early	76.3	81.3	86.2	87.3	87.0	3.7
Late	64.1	67.3	68.8	68.0	69.9	3.6
	Crookston, MN 2015					
Early	91.8	95.0	94.8	96.3	94.2	2.3
Late	76..7	79.9	81.0	91.8	80.2	2.4
	Prosper, MN 2015					
Early	70.4	71.1	70.0	69.6	66.3	2.2
Late	51.4	53.6	54.9	54.5	55.0	2.2

Table 4. Costs and benefits associated with seeding rate with yields from Kimball, MN, 2015.

Seeding Rate	Seeding Rate	Seed cost[1]	Yield	Gross Income[2]	Net Income
Seeds/ac	**-Bushels/ac-**	**--$/acre--**	**-Bushels/ac-**	**----$/ac----**	**----$/ac----**
600,000	0.9	10.80	82.2	415.10	404.31
1,000,000	1.5	18.00	90.1	454.90	436.90
1,400,000	2.1	25.20	92.3	466.00	440.80
1,800,000	2.6	31.20	91.8	463.44	432.24
2,200,000	3.2	38.40	82.2	414.93	376.53

[1] Certified seed cost of $12.00 per bushel of HRSW. [2] December wheat price of $5.05.

Table 5. Correlations between NDVI at different timings and yield for different cultivars sown at differing densities, at three locations in ND/MN. Bolded values are significant at the 5% level.

	Prosper, ND 2nd PD			**Perley**	**Crookston, MN 1st PD**	
	Early	**Mid**	**Late**	**Mid**	**Early**	**Mid**
Albany	-0.37	-0.34	-0.26	-0.22	0.25	0.32
Briggs	0.38	0.40	**0.55**	-0.33	-0.21	-0.23
Faller	0.44	**0.54**	0.32	-0.27	-0.14	-0.01
Kelby	**0.59**	**0.71**	**0.73**	**0.57**	**0.65**	**0.63**
Knudson	0.23	0.36	0.46	-0.36	-0.19	0.57
Kuntz	0.34	0.43	0.40	-0.15	0.23	0.37
Marshall	0.30	0.25	0.26	-0.15	-0.26	-0.15
Oklee	0.00	0.24	0.05	0.01	0.46	0.36
Rollag	0.44	0.39	0.38	**0.64**	**0.57**	0.37
Sabin	-0.12	-0.15	-0.17	-0.30	-0.07	-0.38
Samson	0.47	0.36	0.37	**0.61**	0.41	**0.50**
Vantage	0.30	0.44	0.43	0.28	**0.51**	**0.57**

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Table 6. Effect of the interaction between seeding rate and cultivar on lodging at Kimball, MN, 2015.

	Seeding Rate (seeds acre^{-1})				
Cultivar	**600,000**	**1,000,000**	**1,400,000**	**1,800,000**	**2,200,000**
	-------------------------------- 1- 9[z] --------------------------------				
Albany	1.3	2.7	4.0	3.3	6.7
Briggs	1.3	1.3	4.7	1.7	4.3
Faller	3.0	5.0	6.7	7.3	6.7
Kelby	2.3	1.3	2.3	3.3	2.3
Knudson	1.7	2.3	1.7	2.3	4.0
Kuntz	1.3	1.7	1.3	2.0	6.5
Marshall	1.0	1.3	2.0	3.0	5.3
Oklee	2.3	2.7	6.7	6.7	6.0
Rollag	1.0	1.0	1.0	1.0	1.0
Sabin	2.7	5.7	6.0	7.3	7.3
Samson	1.0	1.0	1.0	1.0	1.3
Vantage	1.0	1.0	1.0	1.0	1.0
Mean	1.7	2.3	3.2	3.3	4.4
LSD 0.05[x]			2.2		

[Z] Lodging is based on a visual 1-9 scale with 1 being erect and 9 being flat on the ground.
[x] Can be used to compare within any column or row, but not between a column and row.

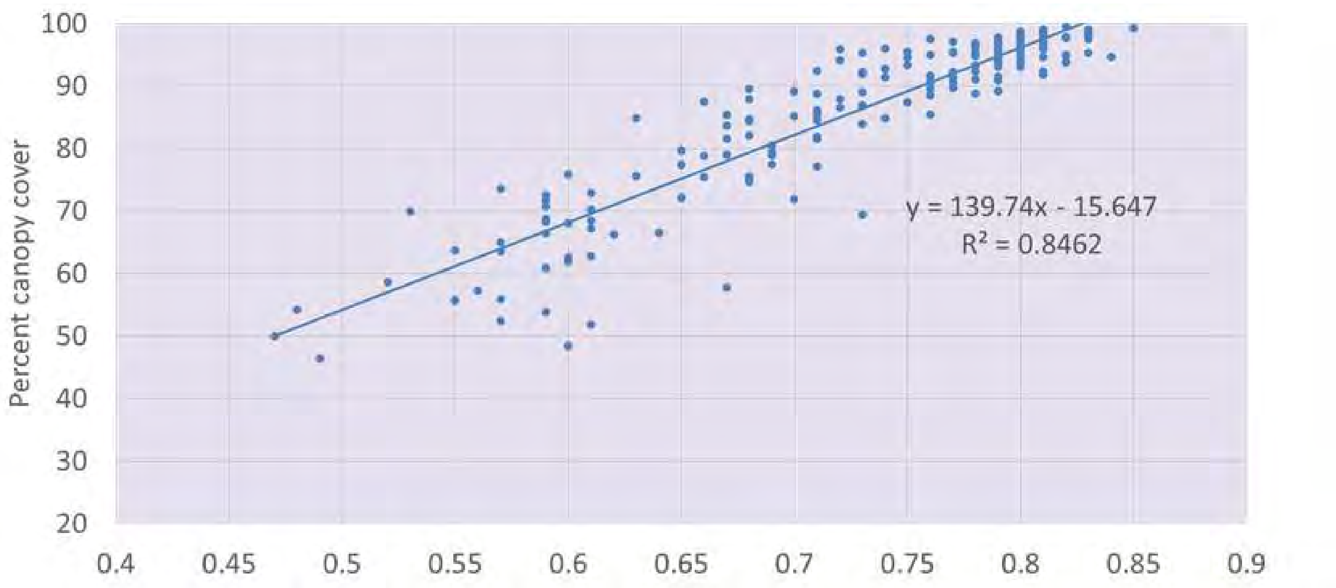

Figure 1. The relationship between canopy closure and NDVI at the 5 leaf stage was consistently very high at eight weeks after planting, Prosper, ND, 2015.

Investigation of Remote Sensing for Disease and Pest Tracking in Small Grains

Madeleine Smith, Dept. of Plant Pathology, NWROC

Research Questions

To determine if there is the potential to use remote sensing data to distinguish between different pests and disease that might be observed in commercial fields in Minnestoa as tool to help growers with scouting and targeted pesticide applications.

Results

Reflectance data was collected from varietal trials for spring wheat and spring barley and from Bacterial leaf streak and Fusarium head blight (FHB) trials. Data analyses is ongoing; Data presented here represents preliminary analysis of reflectance data collected from spring barley varietal trials as an example of the types of analysis. Figure 1 shows the % reflectance on the X axis plotted against wavelength in nm on the Y axis for the plots associated with the spring barley varietal trial from a single date (07/02/15). Different colors represent different plots. From the graph it can be seen that irrespective of whether reflectance values were high or low for a given plot, the trend of reflectance across wavelengths was similar. The space between lines at individual wavelengths indicates variation in the reflectance response between plots.

Figure 2 shows the data for the reflectance data from the highest disease severity plots (Fig. 2a) and from the lowest (fig 2b) for the spring barley data set. Fig. 2 shows that there was not a large difference between reflectance values for overall leaf disease levels between the lowest and highest disease severity. However, Fig. 2a does show that there are some clear differences between plots. Further analysis will be conducted to see if this is related to variety and/or the individual diseases present within a given plot.

These data indicate that varietal response may cause variations in reflectance readings before adding disease as a contributing factor. There are some indications that wheat variety can influence spectral reflectance (Bertrand et al. 1985, Miralbés 2008) but this research was conducted on limited varieties.
Overall this data shows that there is a clear need for higher number of replications between varieties to be able to fully distinguish the extent of the differences between varieties.

Normalized Difference Vegetative Index (NDVI) values were calculated for each plot. NDVI is an index that reflects the health and stress levels in plants and is the relationship of reflectance between near infrared (NIR) and red wavelengths. It is calculated as (NIR – Red)/(NIR+ Red); the reflectance values used were 800nm for NIR and 640 for Red. An Analysis of Variance (Fig. 3) indicates there was a significant difference in the NDVI values of the various plots. This indicates that whether differences in reflectance resulted from variety or disease, it was great enough to differentiate between plots. Analyses separating wheat varietal plots and for individual disease plots is ongoing.

References

Bertrand, D., Robert, P., & Loisel, W. (1985). Identification of some wheat varieties by near infrared reflectance spectroscopy. Journal of the Science of Food and Agriculture, 36(11), 1120-1124.

Miralbés, C. (2008). Discrimination of European wheat varieties using near infrared reflectance spectroscopy. Food Chemistry, 106(1), 386-389.

Application/Use

Remote sensing technology has developed exponentially in the last few years, whether UAV mounted cameras or tractor mounted technologies. There is now a huge interest in using these technologies in the agricultural arena for pest and disease scouting of fields which saves growers time, and ultimately inputs, by being able to identify problem areas within fields and target control measures accordingly. This could ultimately lead to more efficient use of pesticides and save money in times where inputs do not need to be applied.

Material and Methods

A Flame -T Ocean Optics Spectrometer was used to collect reflectance readings from the canopies of small grains cereal plots planted at the Northwest Research and Outreach Center in the growing season of 2015.

All readings were taken on clear days between the hours of noon and 2 pm to minimize the impact of changing light conditions or reflectance readings. A spirit level was used to ensure the input and output fiber optics were maintained at constant angle to the crop canopy. Readings were collected from a foot above the canopy.

Data was recorded at wavelengths between 400 and 1000 nm. Data was analyzed using the Ocean View Software V1.5, spectral curves and vegetative indices were created in Microsoft Excel, and statistical analyses were conducted using SYSTAT V13.4.

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Economic Benefit to a Typical
500 Acre Wheat Enterprise

Remote sensing is a constantly evolving technology and has enormous potential to help growers save time scouting their crop and money by reduced pesticide applications. The extent to which remote sensing can ultimately reduce costs for growers will largely depend on the ability of the technology to accurately distinguish specific crop issues, in addition to whether growers will need to contract these services from commercial providers, or be able to purchase and run their own set ups. Using remote sensing equipment to scout crop issues will also allow for less saving in man power by potentially reducing the need for more than one individual to scout and only visiting fields which look to have specific problems.

Recommended Future Research

It is clear from the preliminary analysis of these data that the spectrometer could clearly distinguish differences between plots in reflectance values. Once analysis is complete, we will be able to look at disease data and varietal data and see the relative sensitivity of the spectrometer to each of these factors. It is also clear that continuation of this work will require higher levels or replication to cope with the variation observed in reflectance readings between plots during the course of these experiments.

Future research should involve a smaller set of varieties with a higher level of plot replication to tease out factors influencing spectral readings.

Once data has been collected from these types of experiment, it should then be possible to compare these to UAV readings and determine the relative sensitivity of the two methods as validation of readings taken using a UAV. Ultimately the UAV is likely to be one of the more time saving methods of reflectance data collection if the quality of the data and imagery is sufficient to distinguish pest issues. Using the spectrometer to analyze reflectance data is the first step in this valdiadtion process.

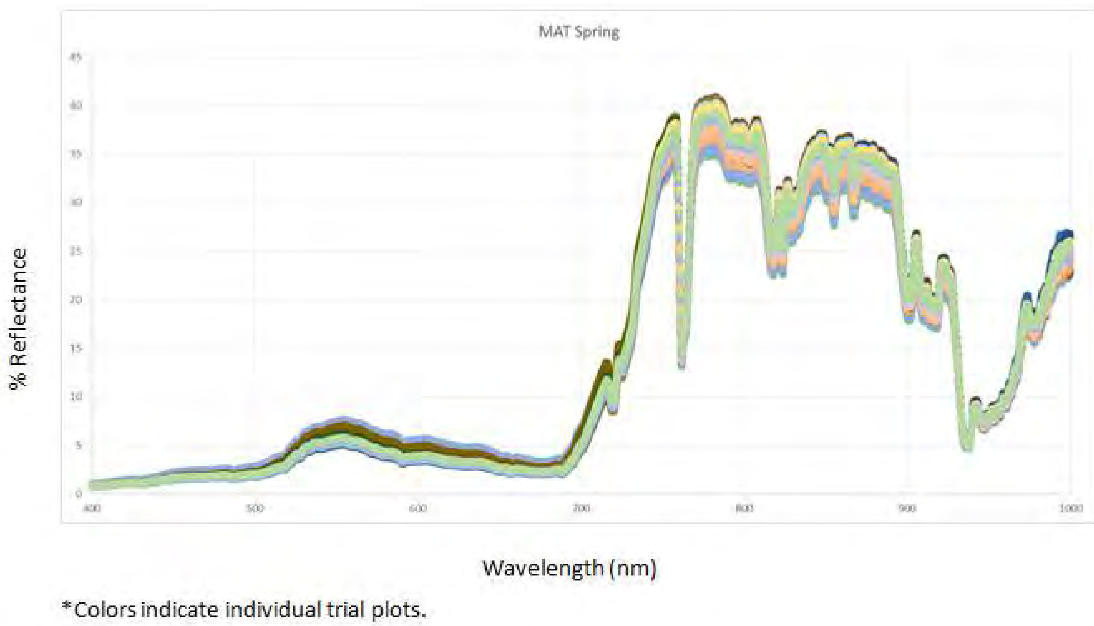
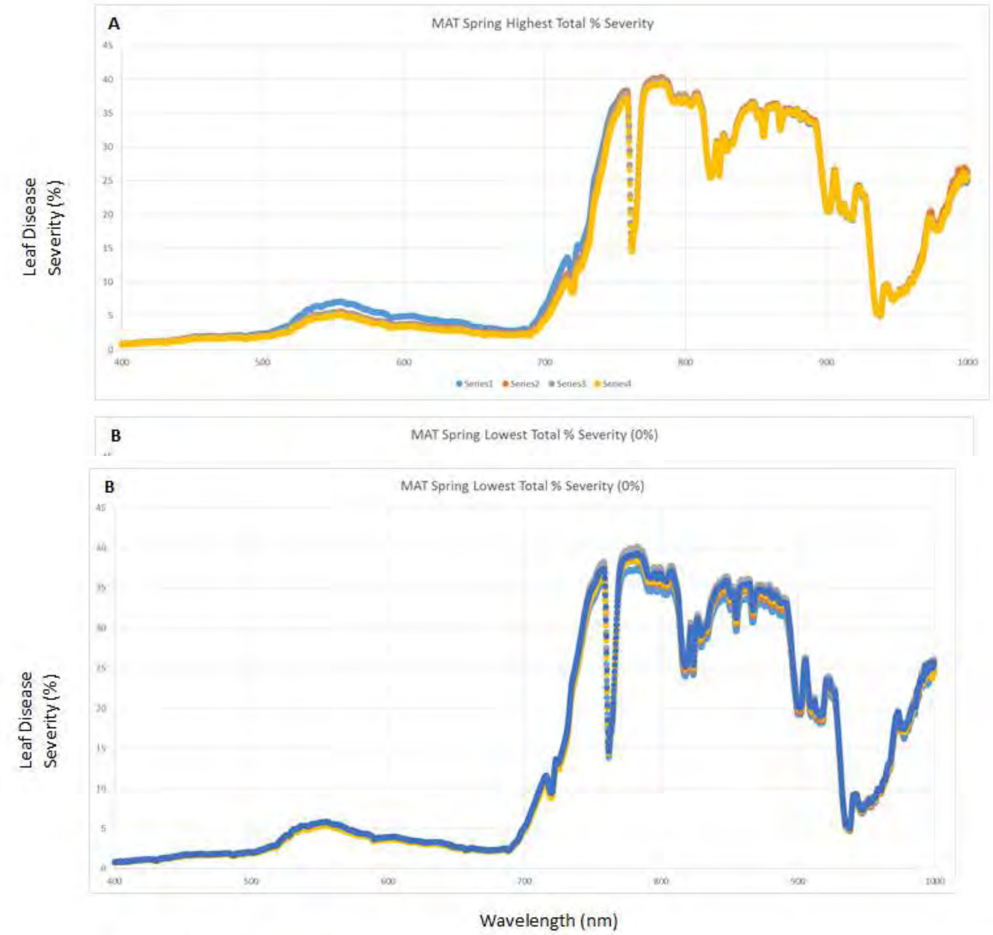


Fig. 1: % Reflectance against Wavelength from MAT Barley Variety Trial Plots* 2015



*Colors indicate individual trial plots.

Fig. 2: Reflectance data from plots* with the highest disease severities (2A) and the lowest disease severities (2B)

Dependent Variable	NDVI
N	108
Multiple R	0.087
Squared Multiple R	0.008
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	0.011

Analysis of Variance					
Source	SS	df	Mean Squares	F-Ratio	p-Value
Regression	0.000	1	0.000	0.804	0.372
Residual	0.014	106	0.000		

Durbin-Watson D-Statistic	1.003
First Order Autocorrelation	0.497

Regression Coefficients B = (X’X)-1X’Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	T	p-Value
CONSTANT	0.879	0.001	0.000	.	667.403	0.000
TOT_SEV	0.000	0.000	0.087	1.000	0.896	0.372

WARNING

Case	83	is an Outlier	(Studentized Residual	:	-5.093)
Case	88	has large Leverage	(Leverage	:	0.187)
Case	97	has large Leverage	(Leverage	:	0.294)
Case	99	has large Leverage	(Leverage	:	0.187)
Case	100	has large Leverage	(Leverage	:	0.187)

Information Criteria	
AIC	-656.701
AIC (Corrected)	-656.470
Schwarz’s BIC	-648.655

Fig. 3 Regression and ANOVA of NDVI vs Total % Disease Severity

Accelerated Breeding for Resistance to Fusarium Head Blight

Karl Glover, Plant Sciences, South Dakota State University

Research Questions

Complete resistance to Fusarium Head Blight (FHB) is unavailable, yet genetic variability for resistance is well documented. Steady progress toward increasing resistance levels has been demonstrated by breeding programs through the implementation of largely repeatable FHB screening procedures. Breeding programs must sustain efforts to simultaneously select resistant materials with desirable agronomic characteristics. The objective of this program is to use traditional plant breeding and selection techniques to develop hard spring wheat germplasm and cultivars that possess agronomic characteristics worthy of release in addition to acceptable levels of FHB resistance.

Results

Entries retained in the advanced yield trial (AYT) are thought to be at least moderately resistant to FHB. Those that do not perform adequately are generally discarded after the first year of AYT observation. 2015 AYT results are presented in the appendix. Thirty-five experimental breeding lines were tested along with thirteen check cultivars during the 2015 growing season. Of the thirty-five experimental lines, eighteen had FHB disease index (DIS) values that were less than the test average. Fifteen of these eighteen entries also had Fusarium damaged kernel (FDK) values that were below average. Among these fifteen, seven produced more grain than average and both test weight and protein content of six were also better than average. One of these six (SD4579) is presently under increase and may eventually be considered for release as a new cultivar. Although neither experimental line fell within the best group of six using the criteria specified above, both SD4299 and SD4383 will nonetheless be considered for release to Certified seed producers for the 2016 season. SD4299 possesses a high level of resistance to Bacterial leaf streak and may therefore still address grower concerns. SD4383 is characterized with above average FHB resistance, yield potential, and protein content, however, its test weight is slightly below average.

Application/Use

With the progression of time, increases in FHB resistance levels should help to prevent devastating loses to growers caused by severe FHB outbreaks.

Material and Methods

Focused efforts to increase resistance began within this program after the 1993 FHB epidemic in the spring wheat production region. Both mist-irrigated greenhouse and field screening nurseries were established and disease evaluation methods were developed. Breeding materials are evaluated for FHB resistance using three generations per year: two in the greenhouse and one in the field. We have the capacity to screen as many as 4,500 individual hills in the greenhouse. We also have 4 acres in the field under mist-irrigation. Both the field and greenhouse nurseries are inoculated with grain spawn (corn that is infested with the causal fungus) and spore suspensions. Mist-irrigation is used to provide a favorable environment for infection. Approximately 25 percent of the experimental populations possess Fhb1 as a source of resistance. Most of what remains are crosses with various “field resistant” advanced breeding lines. Experimental materials are advanced through the program in the following fashion;

Year 1	Field	Space planted F_2 populations
Year 1	Fall greenhouse	$F_{2:3}$ hills
Year 1	Spring greenhouse	$F_{3:4}$ hills
Year 2	Field	$F_{4:5}$ progeny rows
Year 2	Off-season Nursery	$F_{5:6}$ progeny rows
Year 3	Field	$F_{5:7}$ Yield Trials (1 replication, 2 locations)
Year 4	Field	$F_{5:8}$ Yield Trials (2 replications, 5 locations)
Year 5	Field	Advanced Yield Trials (3 reps, 8 locations)

F_2 populations are planted in the field and individual plants are selected. These are advanced to the fall greenhouse where seed from each plant is sown as individual $F_{2:3}$ hills and evaluated for FHB resistance. Four plants from each of the top 25% of the hills are advanced to the spring greenhouse. They are sown as individual $F_{3:4}$ hills and evaluated for FHB resistance. Those with FHB resistance nearly equal to or better than ‘Brick’ are advanced to the mist-irrigated field nursery as $F_{4:5}$ progeny rows. They are evaluated again for resistance and general agronomic performance. Plants are selected within the superior rows and sent to New Zealand as $F_{5:6}$ progeny rows for seed increase. A portion of seed from each selected plant is also grown in the fall greenhouse to confirm its resistance. If the FHB resistance of an $F_{5:6}$ line is confirmed, then the respective progeny row is harvested in New Zealand. In the following South Dakota field season, the selected lines are tested in a two replication, multi-location yield trial. Those that have agronomic performance and yield similar to current cultivars are included in more advanced, multi-location, replicated yield trials the following year. In year 5, lines advanced through this portion of the program are included in the AYT along with entries from the traditional portion of the program. Performance data with respect to DIS and FDK, along with agronomic potential from the 2015 AYT are presented in Table 1 of the appendix.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The presence of FHB inoculum within fields and favorable weather conditions are just two factors that heavily influence whether this disease becomes problematic. Immediate economic benefits are therefore difficult to assess. When conditions become favorable for disease presence, however, cultivars with elevated FHB resistance levels can help to reduce potentially serious grower losses.

12: APPENDIX

Table 1. South Dakota State University advanced yield trial spring wheat entries ranked according to FHB disease index values (lowest to highest – collected at Brookings) presented along with agronomic data obtained from three replication trials conducted at eight test environments in 2015.

ENTRY	FHB DIS INDEX	TOMB-STONE (%)	GRAIN YIELD (BU/AC)	TEST WEIGHT (LB/BU)	GRAIN PROTEIN (%)	HEAD DATE (D > 6/1)	PLANT HEIGHT (INCHES)
SD4580	16.28	10.83	43.37	61.05	15.37	20.44	38.75
SD4582	20.01	10.83	44.42	61.19	15.30	20.61	39.37
SD4559	20.98	15.00	38.15	60.54	15.20	19.67	36.22
BRICK	21.06	16.67	39.35	61.03	14.96	18.67	36.03
SD4606	21.79	26.67	37.33	59.91	14.60	21.89	39.45
SD4589	23.18	21.67	33.46	59.09	15.19	21.11	36.00
FOCUS	23.48	17.50	42.90	60.72	15.27	18.89	36.24
SD4472	23.78	33.33	42.52	59.30	15.07	23.94	34.06
SD4546	24.78	15.83	41.35	60.43	14.98	19.44	35.30
SD4587	25.47	20.83	42.09	60.80	15.45	20.56	38.32
FOREFRONT	26.13	23.33	40.69	60.20	14.95	21.33	38.58
SD4383	26.35	21.67	47.32	59.39	15.04	21.22	33.73
SD4576	26.45	30.83	37.09	58.88	15.15	20.11	37.07
SD4496	26.77	25.00	38.06	58.73	15.10	20.78	37.18
SD4579	26.80	9.17	44.53	60.29	15.10	20.61	35.89
SD4552	26.82	20.83	38.32	60.12	15.07	20.67	36.75
SD4595	27.04	21.67	42.32	61.36	15.62	22.50	36.83
SD4393	27.13	20.00	42.67	59.98	15.20	22.11	33.36
SD4492	27.63	25.83	39.88	60.20	14.76	22.11	36.31
SD4416	28.15	25.00	41.26	59.55	15.18	21.83	34.67
SD4451	28.53	48.33	40.98	59.68	14.98	21.61	34.82
SD4597	29.83	22.50	43.91	60.90	14.76	22.22	37.60
SD4514	29.83	20.00	44.67	60.19	15.22	21.22	39.82
SD4557	30.13	28.33	45.59	59.34	13.60	20.33	34.85
SD4299	30.33	25.00	45.44	59.59	15.22	24.61	34.50
SD4471	30.57	29.17	39.88	58.38	14.66	23.33	35.46
SD4493	30.83	26.67	40.23	60.39	15.01	22.61	32.77
TRAVERSE	30.89	48.33	46.59	56.91	14.17	22.11	36.27
SD4465	31.20	44.17	46.18	59.52	14.64	22.94	34.45
SELECT	31.39	31.67	38.20	60.34	14.82	20.78	35.92
KNUDSON	31.63	50.83	35.22	58.27	13.99	26.22	33.06
SD4529	31.89	29.17	37.61	59.66	15.63	21.00	36.37
SD4599	31.91	30.00	37.91	58.11	15.14	24.00	37.20
SD4575	32.07	33.33	43.55	59.14	14.53	20.06	38.16
SD4607	32.52	20.83	41.88	60.47	15.25	22.50	37.55
BRIGGS	32.61	33.33	41.47	58.76	15.10	21.44	34.89
PREVAIL	32.75	29.17	48.04	59.76	14.65	22.22	34.21
SD4543	33.22	26.67	40.22	60.84	15.17	20.61	39.08
SD4539	34.44	23.33	44.59	59.57	14.93	21.39	36.83
GRANGER	34.88	50.00	40.76	58.63	15.02	22.50	38.25
SD4584	35.44	30.00	38.37	59.41	14.33	19.56	35.94
FALLER	35.92	34.17	42.90	58.39	13.71	25.06	35.65
ADVANCE	36.73	32.50	43.17	59.59	14.12	23.22	33.89
SD4537	36.76	31.67	37.82	60.40	15.08	20.06	34.34
STEELE-ND	37.19	33.33	40.51	59.16	15.25	24.11	35.85
SD4403	39.75	35.83	43.57	59.06	14.93	22.72	35.96
SD4578	42.25	25.00	42.51	60.38	15.01	21.61	37.73
OXEN	46.15	67.50	42.53	57.50	14.93	22.78	33.73
MEAN	29.83	28.19	41.49	59.69	14.93	21.69	36.15
lsd (0.05)	6.87	9.29	1.89	0.39	0.22	0.98	0.67
cv (%)	19.55	39.92	7.67	1.64	2.93	7.38	4.97

Exploiting Genetic Variation for Wheat Improvement in the Northern Great Plains

Brian Steffenson, Dept. of Plant Pathology, U of M

Research Questions

Crop improvement is predicated on exploiting genetic variation. Without this variation, breeders cannot advance germplasm for any of the important traits of interest to growers. This project seeks to answer the question: what degree can we enhance economically important traits in wheat using diverse germplasm from the USDA Spring Wheat Core Collection.

This germplasm enhancement project is based on nested association mapping (NAM) and was initiated in 2013. It is a long-term and broad-based program that will provide a rich source of genetic diversity for many traits that are or may become important to wheat growers in the region. This includes, but is not limited to: yield, protein content, milling and baking quality, root growth, stand establishment, nitrogen use efficiency, water use efficiency, and disease and insect resistance.

Results

Population development. Based on single nucleotide polymorphism (SNP) marker data provided by the Triticeae Coordinated Agricultural Project (TCAP), the Spring Wheat Core Collection held by the USDA-ARS National Small Grains Collection was grouped into four subpopulations based on their degree of relatedness. We then selected 409 accessions that represent the greatest genetic and geographic diversity in the Spring Wheat Core Collection. These 409 accessions were designated as the "Spring Wheat Diversity Collection" (SWDC) and evaluated in the field for various traits.

As expected, a wide range of phenotypic diversity was observed for many traits in the SWDC. UM wheat breeder Jim Anderson selected 16 accessions from the St. Paul nursery exhibiting superior phenotypes, i.e. normal heading date, short-stature, good straw strength, disease resistance, etc. Phenotype data collected on the SWDC from the field were collated and analyzed. Twelve of the 16 accessions selected by Jim Anderson, plus 18 additional ones selected based on a) genetic diversity as assayed by SNP markers, b) phenotype data collected from the field, and c) geographic origin comprised the final set of select germplasm for development of NAM populations. These 30 (12 + 18) Nested Association Mapping Parental Selects (NAMPS) were sown in the 2013 fall greenhouse for crossing with cultivar RB07, selected by Jim Anderson as the recurrent parent. In December 2013, the first crosses of the NAMPS were made with RB07 in the greenhouse. All but five of these crosses were successful; thus, we are developing 25 NAM populations from the parents listed in Table 1. Crossed seed from these hybridizations were planted in the 2014 winter greenhouse for backcrossing to RB07. This was done to recover more of the superior genetic constitution of RB07 since some of the NAMPS are unadapted to the Midwest production region. About 100 BC_1 crossed seeds from each cross were obtained and planted in the 2014 fall greenhouse with harvest occurring at the end of December.

Activities in 2015. One arbitrarily selected seed (single seed descent) from each of ~2,500 BC_1F_2 plants was grown in the 2015 winter greenhouse and harvested as BC_1F_3 seed in April 2015. Another generation advance of this population (harvesting BC_1F_4 seed) was made during the 2015 spring greenhouse season. To further increase homozygosity in the NAM population and at the same time increase seed for the larger field plots slated for planting in 2016, we planted BC_IF_4 seed in the 2015 fall greenhouse. The BC_1F_5 seed from these BC_IF_4 plants will be harvested in December 2015 and planted in the 2016 spring greenhouse. The BC_1F_6 seed from these BC_1F_5 plants will be harvested in March 2015 and prepared for spring planting. In the field, we will assess yield, various agro-morphological characters, and disease resistance. Moreover, we will subject a subset of the NAM population to milling quality assays in collaboration with Senay Simsek.

The NAMPS were again planted in the field in spring 2015 and assessed for the following traits: heading date, plant height, spike length, number of kernels per spike, and lodging. In addition, we assessed the field reaction of the NAMPS to bacterial leaf streak (BLS) (*Xanthomonas translucens*), and Fusarium head blight (FHB) (*Fusarium graminearum*). A moderate to high level of diversity was observed for most of the traits investigated in 2015. Heading date varied from 47 to 66 days in the NAMPS in comparison with 53 days for RB07. Heading dates within several days of RB07 are desirable for Minnesota production. Most of the NAMPS were taller than RB07 at 74.4 cm, but two were shorter at 62 (PI 519465) and 67 (PI 449298) cm. Shorter statured plants are desirable because they can be heavily fertilized without the risk of lodging. The potential for increasing yield from alleles derived from the NAMPS exist because many had longer spikes and higher numbers of kernels than RB07 (6.6 cm and 41 for the respective traits). With respect to BLS, none of the NAMPS exhibited a suitable level of resistance that could enhance that currently available in Minnesota wheat germplasm. The same was true for FHB. Finally, the mapping parents were evaluated to the widely virulent African stem rust races of TTKSK and TRTTF inside the Biosafety Level-3 (BSL-3) greenhouse in winter 2015. Significantly, several NAMPS were resistant to either race TTKSK or TRTTF, and one was resistant to both (PI 519465). These results hold great promise for enhancing the resistance of Minnesota wheat varieties to widely virulent African stem rust races. The NAMPS have been distributed to other researchers in the region so they can phenotype the germplasm for traits of interest to them. These cooperators include Ruth Dill-Macky and Madeleine Smith at the University of Minnesota; Mohamed Mergoum, Francois Marais, Shaobin Zhong & Senay Simsek at North Dakota State University and Karl Glover, Shaukat Ali, and Bill Berzonsky at South Dakota State University. We expect to receive phenotype data from their trials in the near future.

Application/Use

The germplasm developed from this project will serve as superior, adapted parental material for regional breeding programs aiming to enhance wheat for many different traits, including but not limited to yield, protein content, milling and baking quality, root growth, stand establishment, nitrogen use efficiency, water use efficiency, and disease and insect resistance. Our preliminary data show that useful genetic diversity exists in the NAMPS for the yield components of spike length and kernel number as well as resistance to the widely virulent African stem rust races.

Material and Methods

Population development. To start the project, nearly 2,200 accessions of the Spring Wheat Core Collection were genotyped with 90,000 SNP markers by TCAP and analyzed for their genetic relatedness using Principal Coordinate Analysis (PCA). Then, 409 accessions were selected that represent the greatest genetic and geographic diversity in the Spring Wheat Core Collection. These 409 accessions, designated as the "Spring Wheat Diversity Collection" (SWDC), were evaluated for various traits (i.e. heading date, height, awn length and lodging as well as general disease reactions to stem rust, leaf rust, bacterial leaf streak, and Fusarium head blight) in the field at Crookston and St. Paul in 2013. In the end, 30 accessions were selected for NAM population development based on: a) genetic diversity as assayed by SNP markers, b) phenotype data collected from the field, and c) geographic origin. NAM population development was started with the first cross of these 30 select lines to the recurrent parent RB07. All but five of these crosses were successful. Thus, the final project includes a 25 parent NAM population. F_1's from the first crosses were backcrossed to RB07 to recover more of the superior genetic constitution of recurrent parent since some of the NAMPS are unadapted to the Midwest production region. About 100 BC_1 crossed seeds from each cross were planted in the 2014 fall greenhouse and harvested in December. One arbitrarily selected seed (single seed descent) from each of ~2,500 BC_1F_2 plants was grown in the 2015 winter greenhouse and harvested as BC_1F_3 seed in April 2015. Another generation advance of this population (harvesting BC_1F_4 seed) was made during the 2015 spring greenhouse season. To further increase homozygosity in the NAM population and at the same time increase seed for the larger field plots slated for planting in 2016, we planted BC_lF_4 seed in the 2015 fall greenhouse. The BC_1F_5 seed from these BC_lF_4 plants will be harvested in December 2015 and planted in the 2016 spring greenhouse.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Cultivars bred with one or more of the enhanced traits derived from the NAM populations will increase profitability for wheat producers in the region. The level of economic benefit will depend on the trait considered. It is important to note that this pre-breeding project has a longer-term horizon for results. In this respect, it is similar to breeding programs since it will take several years before direct economic benefits will be realized by growers.

Related Research

As the NAM population is developed, we will evaluate it for many traits of importance to regional wheat producers, including agronomic traits (heading date, height, yield, lodging, etc.), milling and baking quality (flour yield, protein, absorption, mixing time, loaf volume, etc.), and disease resistance (rusts, root rots, bacterial leaf streak, etc.). Other colleagues in the region also have expressed a strong interest in evaluating the NAM population for specific traits of importance to their programs. They have been sent the NAMPS so they can chose which segregating components of the NAM to pursue in their research. Additionally, to effectively map and transfer genes controlling traits in the NAM population, genotyping must be done. Currently, genotyping by sequencing (GBS) is the best method for achieving a sufficiently large number of markers at a reasonable cost. I will request funds to conduct GBS on the NAM population in FY16.

Recommended Future Research

In order to fully realize the great potential of NAM populations for enhancing wheat germplasm in the northern Great Plains region, the full course of population development must be followed. The following scheme is being used to develop the NAM population before advanced homozygous seed stocks are available for multiple trait evaluation.

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Timetable for Nested Association Mapping Population Development of Wheat

2013 Fall GH:

--Plant NAMPS in August-September, make crosses to RB07 in November and harvest crossed (F_1) seed in December. *(Status: Completed)*

2014 Winter GH:

--Plant crossed seed in late December-early January, make backcrosses to RB07 in March, and harvest BC_1 crossed seed in April. *(Status: Completed)*

--Establish a genetically pure seed increase of the original 25 NAMPS. *(Status: Completed)*

2014 Summer field:

--Plant BC_1 crossed seed from each cross combination in the field at St. Paul in April. *(Status: Postponed until fall greenhouse season to ensure no populations are lost due to weather-related calamities).*

--Disease and agronomic trait assessments of original 25 NAMPS and RB07. *(Status: Completed)*

2014 Fall GH:

--BC_1 crossed seed (generating BC_1F_1 plants) was planted from each cross combination in the greenhouse and harvested in December (represents 1st selfed generation). *(Status: Completed)*

--Collate and analyze data taken on the NAMPS from the field. *(Status: Completed)*

2015 Spring GH:

--BC_1F_2 seed was planted (for single seed descent) and harvested in April (represents 2nd selfed generation). *(Status: Completed)*

--NAMPS were screened against African stem rust races TTKSK and TRTTF at the seedling stage. *(Status: completed)*

--Seed of NAMPS and RB07 were distributed to cooperators around the region so they can test them for traits of interest. Parents that differ from RB07 for a particular trait can be mapped in the derived NAM population. *(Status: Pending)*

2015 Late spring-Summer GH:

--BC_1F_3 seed planted in April and harvested in July and August (3rd selfed generation). *(Status: Completed)*

--Collate all data collected on the NAMPS and RB07 by our cooperators and by us. *(Status: pending)*

2015 Summer Field

--Disease and agronomic trait assessments of original 25 NAMPS and RB07. (Status: Completed)

2015 Fall GH:

--Plant BC_1F_4 seed in greenhouse in August-September and harvest in December. (4th selfed generation) (Status: pending)

--Test NAMPS and RB07 for leaf rust reaction at the seedling stage. (Status: pending)

To be completed in coming months:

2016 Winter GH:

--Plant BC_1F_5 seed in greenhouse in January and harvest in March (5th selfed generation).

--Distribute seed of populations of interest to cooperators for their field tests.

2016 Summer field:

--Plant BC_1F_6 NAM population (and parents) segregating for various traits and obtain year 1 phenotype data from the field.

--Collate all data collected on the NAM populations and parents by our cooperators and by us.

2016 Fall GH:

--Plant BC_1F_6 seed, extract DNA from seedlings, and perform genotype by sequencing (GBS) if funding can be procured.

--Plant NAM population (and parents) segregating for various traits and obtain first experiment phenotype data from the greenhouse.

2016 Winter GH:

--Analyze GBS data for the NAM population.

--Plant NAM population (and parents) segregating for various traits and obtain second experiment phenotype data from the greenhouse.

2017 Summer field:

--Plant NAM population (and parents) segregating for various traits and obtain year 2 phenotype data from the field.

--Collate all data collected on the NAM population (and parents) by our cooperators and by us.

2017 Fall:

--Analyze data.

--Identify and distribute advanced lines with enhanced traits to regional breeders for crossing in their programs.

--Write up manuscripts for publication.

--Continue evaluations of derived materials until variety candidates are identified.

Table 1. Spring wheat core collection accessions selected as parents for development of a nested association mapping population and selected phenotypic data from 2015 at St. Paul.

				St. Paul 2015				
LID	**ID1**	**ID2**	**Origin**	**Average plant height**	**Average spike length**	**No. kernels per spike**	**Lodging (0-9)**	**Days to heading**
3	CItr	14819	Eritrea	86.8	8.6	40	1	58
4	CItr	15006	Nepal	91.0	8.0	38	3	52
5	PI	62364	Venezuela	94.5	8.0	44	2	54
6	PI	153785	Brazil	95.5	9.5	45	1	59
8	PI	181458	Finland	89.9	8.9	59	1	65
9	PI	189771	Tunisia	98.3	9.3	42	1	50
10	PI	193938	Brazil	89.5	8.3	45	4	66
11	PI	199806	Peru	95.4	5.1	45	1	57
12	PI	205714	Peru	94.1	9.1	50	5	65
13	PI	213602	Argentina	92.5	8.5	44	0	66
14	PI	220455	Egypt	92.6	6.6	48	8	59
15	PI	278392	Palestine	88.1	8.8	46	9	59
16	PI	282922	Argentina	87.5	8.8	45	1	65
17	PI	344018	Angola	78.9	7.9	50	6	58
18	PI	345693	Belarus	101.4	11.6	54	3	60
19	PI	374254	Mali	86.4	7.9	44	0	48
21	PI	384403	Nigeria	78.5	7.3	44	6	47
22	PI	430750	Yemen	78.1	8.1	48	0	56
23	PI	449298	Spain	67.0	8.8	50	1	54
24	PI	519465	Zimbabwe	62.3	7.8	48	0	54
25	PI	519580	Chile	74.4	6.9	44	0	55
26	PI	520033	Kenya	78.5	7.0	42	5	58
27	PI	520371	Syria	78.8	10.5	54	0	58
29	PI	565238	Bolivia	79.4	7.9	42	2	47
30	PI	623147	Iran	73.0	8.0	38	4	56
P1	RB07	RB07	USA	74.4	6.6	41	0	53

LID=Lab ID number; ID1-ID2=Cereal Investigation number for Triticum or Plant Introduction number; Origin=Country of origin; plant height & spike length was calculated in cm; a 0 to 9 scale was used to score lodging where 1=standing upright and 9=completely flattened; and heading date was number of days from planting to when 50% of spikes in row were half-emerged from boot.

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Table 2. Spring wheat core collection accessions selected as parents for development of a nested association mapping population and selected disease reaction data from 2015 at St. Paul and Crookston, MN and Fargo, ND.

				Stem Rust		Bacterial Streak		Fusarium head blight	
LID	**ID1**	**ID2**	**Origin**	**Race TRTTF**	**Race TTKSK**	**St. Paul**	**Crookston**	**Fargo**	**Crookston**
3	CItr	14819	Eritrea	4	3+	6.0	7.3	56.6	72.0
4	CItr	15006	Nepal	4	4	4.8	6.5	49.6	37.6
5	PI	62364	Venezuela	4	4	6.0	6.5	50.4	75.3
6	PI	153785	Brazil	3+	4	6.8	7.0	61.2	28.6
8	PI	181458	Finland	4	3+	4.8	6.8	66.9	5.4
9	PI	189771	Tunisia	4	4	6.3	5.8	28.7	92.5
10	PI	193938	Brazil	1+,2	3+	5.0	5.3	94.8	12.6
11	PI	199806	Peru	4	1+,2	6.8	7.0	73.8	91.3
12	PI	205714	Peru	4	4	5.3	6.8	51.8	-
13	PI	213602	Argentina	3+	3+	5.3	6.0	-	-
14	PI	220455	Egypt	4	2+	4.8	6.3	72	45.0
15	PI	278392	Palestine	3+	4	6.3	7.0	31.4	65.1
16	PI	282922	Argentina	4	3+	6.0	6.0	-	-
17	PI	344018	Angola	2,1+	3,3-	5.5	7.5	-	56.3
18	PI	345693	Belarus	4	4	7.5	6.8	90.9	15.9
19	PI	374254	Mali	4	4	7.0	6.8	61.2	88.8
21	PI	384403	Nigeria	4	4	8.0	7.5	56.4	92.5
22	PI	430750	Yemen	4	3+	6.3	5.8	67.1	81.8
23	PI	449298	Spain	2+,3-	4	5.5	7.3	78.1	90.0
24	PI	519465	Zimbabwe	2	0;	7.0	6.8	69.4	93.8
25	PI	519580	Chile	2	3+	5.5	6.0	88.6	72.5
26	PI	520033	Kenya	2	3+	5.5	7.0	75.1	72.8
27	PI	520371	Syria	4	3+	6.0	6.3	54.9	63.6
29	PI	565238	Bolivia	4	3	6.3	7.0	58.9	90.0
30	PI	623147	Iran	4	2	5.0	7.0	16.3	42.8
P1	RB07	RB07	USA	4	3+	5.25	6.8	48.3	47.4

LID=Lab identification number; ID1-ID2=Cereal Investigation number for Triticum or Plant Introduction number; Origin=Country of origin; African stem rust races TTKSK and TRTTF (0-4 scale); Bacterial Leaf Streak (BLS) was assessed on a (0-9) scale; Fusarium head blight was assessed using (1-100) scale.

Southern Minnesota Small Grains Research and Outreach

Doug Holen, UM Extension Region Office, Morris

Research Questions

How to incorporate small grains into modern rotations of corn and soybeans to serve as an economically sustainable new rotation. What practices, approaches, genetics and technologies are available to assist in producing wheat yield and quality in central and southern Minnesota.

Objectives: 1. Improve variety selection and document demonstrative performance. 2. Alert producers to potential disease and pest problems while using sites as hands-on learning environments. 3. Develop best management practices specific to targeted regional agro-ecological zone.

Results

The outreach component: we worked with local educators, industry, and cooperating producers to conduct three field days. The research sites served as the backbone to the hands-on clinics in which we discussed genetics, agronomic practices, fertility, other small grain crops, insects, diseases, fungicides, weed control, and harvesting. Field days were held in LeCenter and Benson on June 19th and Kimball June 23rd. Attendance was very good at 105 participants for the three sites with hours of open discussion and field demonstrations. These field days led to many follow-up phone calls from producers and consultants as the season progressed. Another outcome of the effort will be small grain winter workshops at LeCenter, Benson, Morris, and Kimball to take 2015 efforts and learned information into practice for 2016. Our efforts in southern MN have also spun into new directions as industry has contacted us for information and direction as it pertains to working with local producers to grow malting barley, winter rye, and human consumption oats.

Application/Use

Hard red spring, winter wheat, rye, barley, and oats have been grown in central and southern Minnesota for decades but not in large acreages. Often small grains were grown in these regions on poor soils for reasons other than pure bushel production such as livestock manure applications, cover crop for forage establishment, straw production, and mid-season tiling projects. Producers in these regions are now incorporating more intense management systems to maximize yield and quality on their small grain acres with genetics, input products, and fertility systems on productive soils. The rising awareness of cover crops, crop rotation benefits, current economic markets and consecutive years with significant preventative plant acres in this half of the state have contributed to an increased awareness of the agronomic benefits and economic opportunities of small grains.

Nonetheless, producers do face added risks with small grain production as early season heat, late season heat and drought, and significant disease pressure can put the crop at risk and lower actual yields well below the attainable yields. Our goals are to assist southern small grains producers by outlining risk management strategies and identifying best practices to maximize yield and quality by:

1) Improve variety selection
2) Alert producers about potential disease and pest problems
3) Develop best management practices specific to their agro-ecological zone

To this end we:

1. Evaluated approx. 50 spring wheat cultivars for agronomic adaptation, grain yield and quality in southern MN environments.
2. Evaluated 24 winter wheat cultivars for agronomic adaptation, grain yield and quality in southern MN environments.
3. Co-located with additional small grain agronomic research including plant populations, oat, barley and winter rye genetic evaluations (not funded through this grant).
4. Used these sites as sentinels for production pest problem identification and reporting.
5. Coordinated sites as workshop locations for summer field days.

We have worked with core groups of producers in Morris, Dawson, Litchfield, Mora, Benson, Kimball and Montgomery for the past ten seasons to elevate small grain production with winter meetings, summer workshops, and one on one consultation. Adding genetic and agronomic research in these areas continues to be requested from producers and is an impactful component in growing small grains successfully in these regions. We continue to see small market (specialty) developments with wheat, barley, oats and rye with specific end uses. Sites have also proven effective in the tracking of pest incidence and severity specifically highlighted by bacterial leaf streak, Fusarium head blight, leaf and stem rust, armyworms and cereal aphids used by university researchers to forward management criteria to industry and producers. Our goal is to ensure producers growing small grains and connected consultants/industry in these regions are doing so with the genetics and management practices essential to success.

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Material and Methods

Cooperators were identified in Benson, (Scott Lee) Kimball (Dave Lochen) and LeCenter(Ron Pomije/Ruth Hoef) to host the wheat research sites and provide the initial fertility and seedbed preparations as well as host summer field days. A spring and winter wheat cultivar evaluation study were designed for the locations as duplicates of each other. The 51 cultivars were selected from private and public breeding programs in the Midwest region and identified as adapted to our environment. University of MN experimentals were also included for observation measurements. A 24 entry winter wheat cultivar evaluation study was also designed and replicated at two southern locations.

An open and windy winter put selection pressure on the winter cereals allowing good separation in survival ratings and emphasized critical spring stands for optimal yield. The winter wheat cultivar evaluation was seeded in LeCenter and Kimball. Kimball, LeCenter and Benson hosted the spring wheat cultivar evaluations with Kimball also having the seed treatment study. Planting conditions and dates for spring sites were as early as recent history recalls with adequate moisture throughout the growing season with light disease pressure. Lodging due to extended growing season and multiple heavy wind events resulted in some harvest difficulties.

The LeCenter site had a previous crop of peas, Benson was soybean and Kimball site was sweet corn. Winter wheat planting at LeCenter was 9-29-14 and Kimball 10-9-15. Spring grain seeding at LeCenter was 4-8-15 as was Kimball with Benson the 9th of April. All sites were sprayed during tillering with the herbicide Bison and fungicide Statego. The Benson site had an additional fungicide and insecticide applied in June. No grass control was needed at the sites.

Seeding equipment was used from the Northwest Research and Outreach Center to plant plots. Each of the cultivars was replicated four times. The weighing of thousand kernel weights of each seed lot ensured all seeding rates were constant with plots established and maintained at 15 feet in length and five feet in width with a targeted plant population of 1.3 million plants per acre. Row spacing was six inches with plots placed side by side and seven foot alleys between ranges.

Harvesting was done with a five foot wide Wintersteiger plot combine housed at the Northwest Research and Outreach Center. Variables measured included yield, test weight, moisture, lodging, plant height, and protein. Analysis was done by Dr. Jochum Wiersma in Crookston and represented by the research team.

Economic Benefit to a Typical
500 Acre Wheat Enterprise

Few if any of the producers we are working with in these regions have 500 or more wheat acres but rather something in the line of 40 to 200 acres. This research and outreach programming allows producers to identify the best genetics available for their operation. Our sites also serve as a model for plant populations, agronomic practices, pesticides, growth staging, and fertility approaches to assist economically sustainable production as discussed at growing season field days and winter workshops.

Related Research

This project ties into the St. Paul hard red spring wheat breeding program by adding three sites of representation and contributes strength to the data collected in southern MN. It also is connected to the University of MN small grain pathology partners as these locations were used as sources for pest collection and identification. Kimball site included an agronomic study looking at six seeding populations of six spring wheat cultivars to as part of a larger project in ND and MN. We had winter rye variety plots at LeCenter and Kimball working with three other locations to get statewide data. Lastly, we incorporated oats and barely variety evaluations at Kimball to work with the statewide programming efforts.

Publications

University of Minnesota Variety Trials 2015

Prairie Grains November/December 2015, Issue 144

On-Farm Cropping Trials Northwest and West Central Minnesota and 2015 Minnesota Wheat Research Review

2015 Research plot data:

Table 1. Winter Wheat performance data at LeCenter and Kimball locations combined with efforts in Lamberton and Crookston. 1-9 scales represent lower numbers as better.

Grain Yield	Lamberton	Crookston	LeCenter	Kimball	Combined	% of Mean	Test	Grain	Lodging	Winter
Bu/A					Bu/A	Yield	Weight	Protein	1-9 scale	Survival %
AAC Gateway	84.7	43.2	97.8	39.3	67.0	104.4	56.1	13.5	2.0	62.2
Arapahoe	73.1	36.6	75.1	33.3	57.4	89.4	55.3	12.5	3.7	63.2
Branson	59.6	38.3	113.5	18.7	58.9	91.8	54.9	12.2	1.5	47.5
Broadview	100.9	38.9	88.8	59.7	71.2	111.0	55.7	12.2	3.5	64.9
CDC Chase	93.9	46.5	84.2	59.6	71.6	111.6	57.9	13.2	3.8	72.7
CDC Falcon	86.1	39.7	101.6	58.4	71.8	111.8	55.9	12.7	2.2	68.2
Decade	95.6	40.3	87.2	38.5	67.1	104.5	54.7	12.4	2.8	68.0
Emerson	87.8	47.3	86.0	49.5	68.5	106.7	57.0	13.0	2.0	66.5
Expedition	63.4	35.8	97.3	40.7	60.2	93.8	56.9	12.2	3.2	69.2
Flourish	78.5	44.4	90.9	36.9	64.0	99.7	54.8	12.8	2.4	55.7
Freeman	77.7	34.1	100.7	34.3	63.3	98.6	55.3	12.1	4.4	62.5
Jerry	91.6	38.6	97.0	53.8	70.1	109.3	56.5	13.0	3.4	72.7
Millenium	91.0	43.8	103.3	32.6	67.9	105.8	57.3	12.8	3.1	62.8
Minter	66.7	35.8	59.1	47.8	51.1	79.6	57.1	13.3	5.4	72.0
Moats	86.4	45.5	93.6	46.1	70.2	109.4	56.3	13.7	3.1	60.2
NE10589	69.9	37.3	102.2	21.7	60.0	93.5	55.1	12.2	2.8	61.8
Overland	87.9	43.2	102.1	46.3	72.0	112.2	53.6	12.8	2.1	62.5
Redfield	90.1	42.0	95.6	38.5	68.6	106.9	56.5	12.5	2.4	65.3
Roughrider	76.3	36.7	74.0	41.6	58.6	91.3	60.3	13.4	4.1	76.7
SY Wolf	71.9	39.6	95.7	22.8	58.5	91.2	55.3	12.9	1.8	55.5
WB 4614	59.4	36.4	71.7	14.4	44.8	69.8	53.0	12.9	3.7	65.6
WB Grainfield	67.1	37.1	105.9	45.7	63.9	99.7	56.3	12.4	3.8	60.0
WB Matlock	86.6	43.7	96.9	61.9	74.1	115.5	58.1	12.9	2.8	70.7
Yellowstone	81.2	40.0	88.9	30.1	59.4	92.5	51.5	12.3	2.1	62.0
LSD (0.1)	8.7	5.5	9.6	11.0	7.2	11.2	2.2	0.5	1.0	6.4

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Table 2. Spring Wheat data from Benson and LeCenter location reporting yield in Bu/A, test weight, and grain protein. (Kimball data not shown)

Entry	Yield Benson	Yield LeCenter	TWT LeCenter	Prot LeCenter
Barlow	94.9	86.2	60.8	14.7
Bolles	98.7	75.7	58.4	17.0
Chevelle	116.5	90.1	58.7	13.1
Elgin-ND	104.2	80.2	59.7	14.5
Faller	105.5	91.8	59.5	13.6
Focus	98.9	80.7	61.1	15.4
Forefront	97.0	93.0	61.8	14.2
Glenn	95.8	72.2	61.8	15.0
HRS3361	93.1	91.0	59.5	13.7
HRS3419	109.7	102.9	57.9	13.1
HRS3504	113.5	95.6	59.2	13.6
HRS3530	108.9	93.5	61.3	13.9
Knudson	97.3	88.0	59.5	13.2
LCS Albany	115.2	92.1	60.3	13.4
LCS Breakaway	105.6	84.3	59.3	14.5
LCS Iguaca	100.9	84.5	59.7	12.7
LCS Nitro	108.7	95.0	58.5	13.1
Linkert	97.7	90.2	60.2	14.9
Linkert 1.3X	97.4	85.4	59.0	14.6
LNR-0311	112.3	88.0	60.8	13.4
Marshall	102.0	60.2	55.6	13.7
MN07098-6-Lr34	98.1	83.6	59.8	13.8
MN07098-6-no Lr	92.5	80.7	60.2	13.8
MN10201-4-A	105.3	85.1	61.0	13.7
MN10201-4-B	97.5	84.1	60.7	14.3
MN10261-1	99.0	96.4	62.5	15.1
MN10281-1-1-98	108.9	91.8	59.5	13.7
MN11325-7	112.1	78.7	57.9	14.3
MN11394-6	99.3	98.6	61.0	13.7
MN11492-6	106.6	83.0	59.3	14.0
MN12119-3	101.8	88.1	61.0	13.7
MS Stingray	111.2	87.3	56.1	10.9
NDSU1	90.6	87.2	59.2	14.7
NDSU2	93.8	83.2	59.7	15.1
NDSU3	90.4	74.2	57.4	15.8
Norden	95.5	82.9	61.2	14.2
Prevail	99.4	91.9	59.5	14.2
Prosper	117.8	86.6	60.8	13.7
RB07	102.9	76.7	60.3	14.6

Entry	Yield Benson	Yield LeCenter	TWT LeCenter	Prot LeCenter
Rollag	103.9	78.8	60.7	14.5
Samson	101.9	93.7	57.6	13.6
SD4299	98.0	78.8	59.7	14.9
SD4383	101.7	86.8	60.8	15.0
SD4393	101.0	92.5	59.9	14.1
SY Ingmar	103.2	94.8	60.2	14.9
SY Rowyn	109.3	84.9	61.2	13.6
SY Soren	97.9	74.6	57.2	15.2
SY Valda	112.9	100.1	60.6	13.7
WB 9507	107.3	97.7	59.6	13.3
WB 9653	114.3	94.0	60.5	13.7
WB Mayville	100.9	92.4	59.6	13.9
LSD(0.05)	**7.2**	**12.2**	**1.9**	**1.0**

NOTES

2015 Wheat, Barley, and Oats Variety Performance in Minnesota

- Preliminary Report

Both the cash prices and futures for all commodities continued their decline that started in second half of 2013. Consequently, producers weighed their options. The relatively dry and early spring may have helped contribute to an increase of spring wheat acreage by 25% to 1.6 million acres. Barley and oats also enjoyed a renaissance as acreage increased by nearly 40% for both. As a whole, the 2015 growing season was probably one of the most ideal for the cool season grasses that are wheat, barley, oats, and rye. Consequently, the state has new record averages of 78, 77 and 60 bushels per acre for oats, barley, and spring wheat, respectively. Winter wheat did not break a record but ended up with a 58 bushels per acre average across the state, the second highest ever recorded.

Planting progress followed a pace much like the 2012 season. Already a fifth of the spring wheat, oats, and barley acreage had been seeded by the middle of April. Very cool and dry conditions, however, delayed emergence. Planting had progressed to over 90% for spring wheat, barley and oats by the end of April. Over half of the acreage had emerged by that time; a pace three weeks ahead of the five-year average and nearly a month ahead of the 2014 growing season. Cooler than average conditions prevailed once again for much of the month of May and June across many parts of Minnesota. But unlike the 2012 and 2013 seasons, the topsoil and subsoil moistures were rated adequate for nearly 90% of the state and only a few percentage points were rated as being short. USDA's July 1 yield forecast, therefore, had the state average spring wheat yield pegged as 62 bushel per acre. By August 1, USDA had even adjusted the estimate upwards to 64 bushel per acre, a more that 10% increase over the previous record set in 2003.

Disease problems centered around tan spot and stripe rust. The first reports of stripe rust in spring wheat came in mid-June followed quickly by crown rust in oats. Later in the season bacterial leaf streak and infections of barley yellow dwarf were quite common. The use of fungicides at the five leaf stage and at anthesis, a common practice for much of the spring wheat acres and being adopted by oat producers, reduced both incidence and severity of the fungal pathogens and reduced economic losses substantially, especially when compared to the losses caused by crown rust in 2014. Damages due to Fusarium head blight were generally light across the state and only in the southeastern part of the state was testing for DON at the time of delivery common.

By August 9, about half of the state's barley and oats and about one-third of the state's spring wheat acreage had been harvested. A pace nearly equal to the 5-year average and again a testament to the excellent growing conditions for small grains. Growers' expectations for yield were generally exceeded in the southern one-third of the state, about met in the central one-third of the state and only in the northern one-third of the state were growers disappointed. Much of this disappointment can be explained by the observed abortion of developing kernels in the lower and upper quarters of heads. The likely cause of these abortions were not disease or insect problems but rather the interplay of a relatively shallow rooted crop and a sudden increase in day time temperatures during the grain fill period that was one to two weeks later. The overall quality of the wheat, barley and oats is excellent. Preliminary reports from US Wheat Associates indicate that grain protein is approximately a half point higher than the 2014 crop with high falling numbers, excellent test weight and vitreous kernel count, resulting in an overall grade of No. 1 DNS (Dark Northern Spring).

Introduction

Successful small grain production begins with selection of the best varieties for a particular farm or field. For that reason, varieties are compared in trial plots on the Minnesota Agricultural Experiment Station (MAES) sites at St. Paul, Rosemount, Waseca, Lamberton, Morris, and Crookston. In addition to the six MAES locations, trials are also planted with a number of farmer cooperators. The cooperator plots are handled so factors affecting yield and performance are as close to uniform for all entries at each location as possible.

The MAES 2015 Wheat, Barley, and Oat Variety Performance in Minnesota Preliminary Report 24 is presented under authority granted by the Hatch Act of 1887 to the Minnesota Agricultural Experiment Station to conduct performance trials on farm crops and interpret data for the public.

Variety Classifications

Varieties are listed in the tables alphabetically. No other distinction or classification is used to group varieties. Seed of tested varieties can be eligible for certification, and use of certified seed is encouraged. However, certification does not imply a recommendation. Registered and certified seed is available from seed dealers or from growers listed in the ‘Minnesota Crop Improvement Association 2016 Directory’, available through the Minnesota Crop Improvement Association office in St. Paul or online at http://www.mncia.org

Interpretation of the Data

The presented data are the preliminary variety trial information for single (2015) and multiple years (2013-2015) comparisons in Minnesota. The yields are reported as a percentage of the location mean, with the overall mean (bu/acre) listed below. Two-year and especially one-year data are less reliable and should be interpreted with caution. In contrast, averages across multiple environments, whether they are different years and/or locations, provide a more reliable estimate of mean performance and are more predictive of what you may expect from the variety the next growing season. The least significant difference or LSD is a statistical method to determine whether the observed yield difference between any two varieties is due to true, genetic differences between the varieties or due to experimental error. If the difference in yield between two varieties equals or exceeds the LSD value, the higher yielding one was indeed superior in yield. If the difference is less, the yield difference may have been due to chance rather than genetic differences, and we are unable to differentiate the two varieties. The 10% unit indicates that, with 90% confidence, the observed difference is indeed a true difference in performance. Lowering this confidence level will allow more varieties to appear different from each other, but also increases the chances that false conclusions are drawn.

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SPRING WHEAT

James Anderson, Jochum Wiersma, Susan Reynolds, Lance Miller, Chris Olson, Ruth Dill-Macky, James Kolmer, Matt Rouse, and Yue Jin.

The lower grain protein and higher incidence of FHB in the 2014 crop combined with steep discounts over the course of the marketing year made producers re-evaluate their variety selection. Consequently acreages of two varieties in particular - LCS Albany and WB Mayville - decreased in favor of Linkert, the 2013 release of the University of Minnesota. Faller and Prosper’s combined acreage declined to 29% of the total acreage, representing over 460,000 acres. Two public varieties, namely Bolles and Focus, and LCS Nitro were released in 2015 and their single and multi-year data has been added to the tables. First-time entrants in the 2015 trials were SY Valda (Syngenta), WB9653 (WestBred), while Croplan Genetics added HRS 3504 and HRS 3530 to their line-up. Meridian Seed of Casselton, ND, entered MS Stingray and Chevelle for the first time. Testing of Advance, Breaker, HRS 3378, Jenna, LCS Powerplay, Vantage and WB-Digger was discontinued.

The results of the variety performance evaluations are summarized in Tables 1 through 7. The average yield across the six southern testing locations was 81 bu/acre in 2015. This compares to an average of 75 bu/acre in 2014 and a three-year average of 74 bu/acre. The eight northern locations averaged 91 bu/acre in 2015 compared to 84 bu/acre last year and 88 bu/acre for the three-year average. Four of the fourteen locations exceeded 100 bu/acre averages, further evidence of the favorable growing conditions across the state this past growing season.

Tables 4, 5, and 6 present the relative grain yield of tested varieties in 1, 2, and 3-year comparisons. LCS Albany no longer had the monopoly on the highest grain yield. SY Valda, MS Stingray, HRS 3530, and HRS 3419 all yielded as much if not more in the single year comparison across locations. Faller, Prosper, LCS Albany, and LCS Iguacu maintained - at least for now – their high yield rankings in both the south as well as the northern half of the state in multi-year comparisons. Higher yielding cultivars tend to be lower in grain protein as is the case with these three varieties. Variety selection is one approach to avoid discounts for low protein, but N fertility management remains paramount to maximize grain yield and grain protein. Ultimately, however, Mother Nature has the final word as she eloquently demonstrated this past season with high grain yield and high to very high grain protein percentages.

The varietal characteristics are presented in Tables 1, 2, and 3. Table 3 summarizes all the disease reactions for individual varieties. Varieties that are rated 4 or better are considered the best defense against a particular

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disease. Varieties that are rated 7 or higher are likely to suffer significant economic losses under even moderate disease pressure. Table 7 provides insight of how varieties respond to the use of fungicides. In Lamberton, Morris, Crookston, and Roseau the State Variety Trials are grown in duplicate. The duplicate trial is treated with fungicides at Feekes 5, 9, and 10.51 to eliminate, to the extent possible, any fungal pathogens that potentially can reduce grain yield and quality. Averaged across varieties, the use of fungicide increased grain yield by 13 bu/acre in the northern locations and 5 bu/acre in southern locations in 2015. Much of the losses in the north can be attributed to tan spot and Septoria species, while in the southern locations stripe rust was slightly more prevalent in 2015. Overall losses due to either leaf rust or FHB were minimal. Individual varieties may have very different responses to fungicide, depending on their level of susceptibility to and intensity of fungal diseases. Use the information in Tables 3 and 7 to gain an understanding of how individual varieties should be managed to reduce the yield losses caused by fungal pathogens such as tan spot, leaf and stripe rust, and FHB. For example, WB9507 yielded 32% more with fungicide protection, largely due to its high susceptibility to stripe rust.

The foliar disease rating represents the total complex of leaf diseases other than the rusts, and includes the Septoria complex and tan spot. Although varieties may differ from their response to each of those diseases, the rating does not differentiate among them. Therefore, the rating should be used as a general indication and only for varietal selection in areas where these diseases historically have been a problem or if the previous crop is wheat or barley. Tan spot was again widespread in 2015 and likely caused significant yield reduction in susceptible varieties. Control of leaf diseases with fungicides may be warranted, even for those varieties with an above average rating. Leaf rust was not a problem in 2015. However, growers should consider a variety's rating for leaf rust, and plan to use a fungicide if a variety is rated 5 or higher for leaf, stem, or stripe rust and disease levels warrant treatment.

Bacterial Leaf Streak cannot be controlled with fungicides. Variety selection of more resistant varieties is the only recommended practice at this time if you have a history of problems with this disease. Focus, Forefront, LCS Breakaway, Prevail, SY Ingmar, and SY Rowyn offer the best resistance while varieties like HRS 3419, LCS Albany, RB07, Samson, WB-Mayville, WB9507 have a rating of 6, indicating that they are the most consistently affected by the disease.

Variety selection for 2016 continues to be a balance between yield potential, disease responses, and grain quality. Vigilance against FHB remains paramount as economic losses can quickly add up with varieties rated 6 or higher. Forefront, and Rollag provide the best resistance against FHB. Forefront has good adaptation to southern locations and both Forefront and Rollag are competitive varieties for the northern locations. Barlow, Bolles, Faller, LCS Albany, LCS Iguacu, Norden, Prevail, RB07, and SY Rowyn are all varieties with a rating of 4 for FHB. Combined, this group of varieties includes some of the top yielders (LCS Albany, Faller) and varieties with higher grain protein content such as Bolles, Rollag, and Barlow. The extensive lodging encountered in some parts of the state will put more emphasis on straw strength in the variety selection process for next year. The University of Minnesota's releases Linkert, Norden, and Rollag together with the Croplan Genetics line-up provide some of the best straw strength ever available in adapted HRSW cultivars. Use of growth regulators, a common practice in winter wheat production across much of Europe, is another way to reduce lodging and allows for other varieties to be considered if straw strength is paramount for next years' variety selection.

BARLEY

Kevin Smith, Ruth Dill-Macky, Jochum Wiersma, Brian Steffenson, and Ed Schiefelbein

The results of the state yield trials are summarized in Table 8. The average yield across the four testing locations (Crookston, Morris, Stephen, and Roseau) was 116 bu/acre in 2015. This is 13 bushels higher than the state average in 2014. The highest yields were in Roseau and the lowest in Morris.

The yield data in Table 8 were collected from advanced yield trials that contain the important varieties for the region planted in five locations in the state. Yield data is presented as percent of the mean of the varieties listed in the table. The mean of the varieties is presented in bushels per acre. Rasmusson was the highest yielding variety followed by Innovation and Pinnacle based on the 3 year state averages (Table 8). Innovation and Pinnacle are the most lodging resistant lines and Robust and Quest are the least (Table 9). The two-rowed varieties Conlon and Pinnacle had the plumpest grain while Celebration was thinner than the other varieties. Grain proteins for the six-rowed varieties ran from 13.0% (Innovation and Rasmusson) to 13.9% (Robust). While the two-rowed varieties had 12.0% (Pinnacle) and 13.1% (Conlon) protein.

Table 10 describes the reaction of the currently grown varieties to the six major diseases in the region. Disease reaction is based on at least two years of data and scored from 1–9 where 1 is most resistant and 9 is most susceptible. Bacterial Leaf Streak (BLS) cannot be controlled by fungicides and there are only minimal differences in resistance among the current varieties. Conlon and Celebration have the best net blotch resistance while Quest and Conlon have the best FHB resistance among the varieties presented. The two-rowed varieties are more susceptible to spot blotch.

OATS

As of press time, the variety performance data for oats was not completed.

Table 1. Origin and agronomic characteristics of hard red spring wheat varieties in Minnesota in single-year (2015) and multiple-year comparisons.

			Days to	Height	Straw
Entry	**Origin[1]**	**PVP Status**	**Heading[2]**	**Inches[2]**	**Strength[3]**
Barlow	2009 NDSU	PVP (94)	64.8	35.3	7
Bolles	2015 MN	PVP (pending)	68.9	33.0	4
Chevelle	2014 Meridian Seeds	PVP (94)	64.9	31.2	4
Elgin-ND	2013 NDSU	PVP (94)	65.7	37.4	6
Faller	2007 NDSU	PVP (94)	67.6	34.2	5
Focus	2015 SDSU	PVP (pending)	62.8	36.9	7
Forefront	2012 SDSU	PVP (94)	63.6	38.9	6
Glenn	2005 NDSU	PVP (94)	63.8	36.5	5
HRS 3361	2013 CROPLAN by WinField	PVP (94)	66.8	32.2	3
HRS 3419	2014 CROPLAN by WinField	PVP (pending)	69.5	32.2	3
HRS 3504	2015 CROPLAN by WinField	PVP (pending)	67.4	30.5	3
HRS 3530	2015 CROPLAN by WinField	PVP (pending)	67.7	35.8	5
Knudson	2001 Syngenta	PVP (94)	66.3	31.6	5
LCS Albany	2009 Limagrain Cereal Seeds	PVP (94)	69.2	32.6	5
LCS Breakaway	2012 Limagrain Cereal Seeds	PVP (94)	64.3	31.0	4
LCS Iguacu	2014 Limagrain Cereal Seeds	PVP (94)	68.8	32.7	4
LCS Nitro	2015 Limagrain Cereal Seeds	PVP (pending)	68.9	31.8	5
Linkert	2013 MN	PVP (94)	65.4	29.2	2
Linkert 1.3X	30% higher seeding rate of Linkert	PVP (94)	65.5	30.1	2
Marshall	1982 MN	None	70.8	32.4	4
MS Stingray	2013 Meridian Seeds	PVP (94)	71.6	34.0	4
Norden	2012 MN	PVP (94)	67.0	32.7	3
Prevail	2014 SDSU	PVP (pending)	64.2	33.0	4
Prosper	2011 NDSU	PVP (94)	67.0	35.2	6
RB07	2007 MN	PVP (94)	65.0	32.2	5
Rollag	2011 MN	PVP (94)	65.4	30.6	3
Samson	2007 WestBred	PVP (94)	65.8	30.9	3
SY Ingmar	2014 Syngenta	PVP (94)	68.1	31.9	4
SY Rowyn	2013 Syngenta	PVP (94)	65.4	30.7	5
SY Soren	2011 Syngenta	PVP (94)	65.6	30.3	4
SY Valda	2015 Syngenta	PVP (pending)	66.2	31.4	4
WB-Mayville	2011 WestBred	PVP (94)	65.2	29.9	3
WB9507	2013 Westbred	PVP (pending)	65.3	34.1	6
WB9653	2015 Westbred	PVP (pending)	67.3	30.9	4
Mean			66.5	32.7	

[1] Abbreviations: MN = Minnesota Agricultural Experiment Station; NDSU = North Dakota State University Research foundation; SDSU = South Dakota Agricultural Experiment Station

[2] 2015 data.

[3] 1-9 scale in which 1 is the strongest straw and 9 is the weakest. Based on 2009-2015 data. The rating of newer entries may change by as much as one rating point as more data are collected.

Table 2. Grain quality of hard red spring wheat varieties in Minnesota in single-year (2015) and multiple-year comparisons.

	Test Weight (Lb/Bu)			Protein (%)[1]			Baking	Pre-Harvest
Entry	**2015**	**2-Year**		**2015**	**2-Year**		**Quality[2]**	**Sprouting[3]**
Barlow	61.7	61.1		14.9	14.7		3	2
Bolles	60.3	60.1		15.9	15.8		1	1
Chevelle	61.0	–		13.4	–		–	–
Elgin-ND	60.0	60.0		14.7	14.6		3	2
Faller	60.4	60.3		13.6	13.5		4	2
Focus	62.2	61.9		14.9	14.9		–	–
Forefront	61.3	61.1		14.6	14.6		4	4
Glenn	62.8	62.3		15.1	14.9		1	1
HRS 3361	60.2	59.8		14.0	13.9		–	–
HRS 3419	59.1	59.5		13.4	13.1		–	–
HRS 3504	59.0	–		14.0	–		–	–
HRS 3530	60.8	–		14.4	–		–	–
Knudson	60.5	60.1		13.6	13.5		3	2
LCS Albany	60.5	60.5		13.4	13.2		6	5
LCS Breakaway	61.5	61.5		14.7	14.5		4	3
LCS Iguacu	61.3	61.2		13.2	12.9		7	2
LCS Nitro	60.5	60.3		13.3	13.0		–	–
Linkert	61.1	60.7		15.0	15.0		1	2
Linkert 1.3X	61.0	–		14.9	–		1	–
Marshall	58.8	59.1		13.7	13.5		7	2
MS Stingray	58.7	–		12.2	–		–	–
Norden	62.1	61.8		14.2	14.0		4	1
Prevail	60.9	60.7		14.1	13.9		4	5
Prosper	60.7	60.5		13.8	13.6		4	2
RB07	60.8	60.5		14.5	14.3		3	2
Rollag	61.6	61.4		15.0	14.9		6	1
Samson	59.9	59.0		13.9	14.1		4	5
SY Ingmar	61.3	61.1		14.9	14.7		–	–
SY Rowyn	60.7	60.9		13.8	13.8		4	4
SY Soren	59.8	60.2		14.7	14.6		4	1
SY Valda	60.7	–		13.9	–		–	–
WB-Mayville	60.4	59.6		14.6	14.6		3	4
WB9507	59.4	59.1		13.6	13.7		–	–
WB9653	60.2	–		13.7	–		–	–
Mean	60.6	60.5		14.2	14.1			
No. Environments	11	23		11	23			

[1] 12% moisture basis.

[2] 2012-2014 crop years.

[3] 1-9 scale in which 1 is best and 9 is worst. Values of 1-3 should be considered as resistant.

Table 3. Disease reactions[1] of hard red spring wheat varieties in Minnesota in multiple-year comparisons (2011-2015).

Entry	Leaf Rust	Stripe Rust[2]	Stem Rust[3]	Bacterial Leaf Streak[4]	Other Leaf Diseases[5]	Scab
Barlow	4	1	1	4	4	4
Bolles	1	1	2	4	4	4
Chevelle	–	1	1	–	–	–
Elgin-ND	2	2	2	5	5	5
Faller	5	5	2	4	4	4
Focus	3	3	3	3	7	–
Forefront	2	2	4	3	4	3
Glenn	5	1	1	4	5	3
HRS 3361	3	3	3	4	4	–
HRS 3419	4	1	1	6	3	–
HRS 3504	–	2	1	–	–	–
HRS 3530	–	3	1	–	–	–
Knudson	2	4	3	4	3	6
LCS Albany	2	3	3	6	5	4
LCS Breakaway	3	2	2	3	5	5
LCS Iguacu	4	5	2	4	4	4
LCS Nitro	4	2	2	5	7	–
Linkert	4	1	1	4	4	5
Linkert 1.3X	4	1	1	4	4	5
Marshall	8	–	1	6	7	7
MS Stingray	–	7	2	–	–	–
Norden	2	1	1	4	4	4
Prevail	2	1	5	2	6	4
Prosper	5	5	2	4	4	5
RB07	2	2	2	6	6	4
Rollag	4	1	2	4	5	3
Samson	5	2	1	6	6	8
SY Ingmar	3	2	1	3	6	–
SY Rowyn	3	1	1	2	6	4
SY Soren	2	2	1	4	4	5
SY Valda	–	2	1	–	–	–
WB-Mayville	3	3	2	6	7	7
WB9507	8	8	3	6	3	–
WB9653	–	2	2	–	–	–

[1] 1-9 scale where 1=most resistant, 9=most susceptible.

[2] Based on natural infections in 2015 at Kimball, Lamberton, and Waseca.

[3] Stem rust levels have been very low in production fields in recent years, even on susceptible varieties.

[4] Bacterial leaf streak symptoms are highly variable from one environment to the next. The rating of newer entries may change by as much as one rating point as more data is collected.

[5] Combined rating of tan spot and septoria.

Table 4. Relative grain yield of hard red spring wheat varieties in northern Minnesota locations in single-year (2015) and multiple-year comparisons (2013-2015).

	Crookston			Fergus Falls			Hallock			Oklee
Entry	**2015**	**2-Year**	**3-Year**	**2015**	**2-Year**	**3-Year**	**2015**	**2-Year**	**3-Year**	**2015**
Barlow	94	89	89	97	89	91	96	98	102	100
Bolles	93	98	99	99	100	104	95	94	100	97
Chevelle	102			100			94			110
Elgin-ND	100	100	99	99	99	100	86	95	101	95
Faller	93	109	109	115	115	116	110	112	116	97
Focus	101	97		94	94		95	97		109
Forefront	102	103	101	93	101	102	102	103	102	101
Glenn	90	87	86	93	88	91	89	94	95	103
HRS 3361	100	100		105	106		96	97		104
HRS 3419	115	111		107	118		115	111		99
HRS 3504	102			106			97			100
HRS 3530	108			112			114			103
Knudson	96	101	100	100	100	103	98	102	106	102
LCS Albany	103	110	108	111	113	119	109	108	115	103
LCS Breakaway	104	94	93	102	91	94	91	95	101	99
LCS Iguacu	101	106	105	94	105	110	103	101	106	100
LCS Nitro	105	104		104	114		99	99		102
Linkert	108	101	99	95	90	92	101	99	104	103
Linkert 1.3X	104			91			91			95
Marshall	88	90	92	92	91	96	92	95	101	103
MS Stingray	103			110			120			99
Norden	98	97	97	100	98	99	97	98	102	99
Prevail	103	100	99	100	108	107	102	101	107	108
Prosper	100	108	107	110	113	114	109	110	114	105
RB07	100	101	99	97	97	99	93	95	103	106
Rollag	108	105	99	101	99	101	101	100	104	109
Samson	110	98	97	100	93	98	109	105	110	104
SY Ingmar	95	100		100	100		99	98		100
SY Rowyn	102	107	103	108	110	109	104	103	107	95
SY Soren	104	103	99	91	96	98	92	95	99	101
SY Valda	107			110			118			98
WB-Mayville	97	91	93	97	91	92	98	98	103	97
WB9507	94	103		112	113		110	111		92
WB9653	97			110			87			100
Mean (Bu/Acre)	82.3	88.5	89.4	108.2	93.3	89.7	90.9	89.4	93.2	103.1
LSD (0.10)	6.6	11.4	7.9	7.5	11.3	7.8	11.4	6.3	5.3	11.2

Table 4. *continued*

Oklee (continued)		Perley			Roseau			Stephen			Strathcona	
2-Year	3-Year	2015	2-Year	3-Year	2015	2-Year	3-Year	2015	2-Year	3-Year	2015	2-Year
100	97	93	93	96	98	100	97	97	98	108	99	99
99	96	95	97	99	101	102	94	94	94	104	108	104
		96			84			102			94	
95	95	89	93	97	83	90	92	89	95	108	95	94
103	102	102	104	105	104	104	104	105	107	117	101	105
99		97	97		109	109		97	95		102	95
100	98	104	103	103	94	98	92	91	98	105	103	101
100	96	91	92	94	106	102	95	99	98	105	101	101
103		96	97		92	99		91	93		105	99
105		105	106		112	111		113	108		110	111
		100			94			109			98	
		113			102			113			114	
100	98	94	96	99	88	92	91	97	99	107	109	100
109	106	105	104	103	103	104	105	102	106	115	101	106
101	96	107	103	104	103	100	93	104	101	105	105	101
107	103	111	107	110	111	110	106	111	109	112	104	106
104		99	101		98	103		100	100		114	106
99	95	95	95	98	100	102	96	105	101	106	107	103
		95			111			103			94	
93	93	85	91	95	71	81	84	95	95	106	87	89
		115			131			109			126	
100	98	96	97	99	114	102	99	97	98	107	84	93
104	98	103	101	102	108	106	100	97	99	104	99	101
108	107	104	106	108	105	106	103	105	105	119	106	107
102	98	95	98	100	91	96	92	96	99	106	97	98
103	98	103	100	101	87	90	87	88	92	100	100	97
105	102	111	107	108	104	108	101	102	103	110	123	113
97		100	100		102	98		104	101		100	101
99	96	97	98	98	90	95	90	102	100	104	110	102
100	98	95	95	99	110	108	100	99	99	104	105	103
		110			98			110			105	
99	96	96	97	96	95	101	93	94	94	100	89	95
100		106	106		92	98		98	104		110	104
		92			95			114			106	
98.3	94.2	108.8	95.5	92.6	84.5	86.1	83.9	85.4	72.9	74.9	64.7	77.3
8.7	6.7	7.4	5.9	5.3	12.2	8.5	8.7	10.7	8.4	7.6	14.1	9.4

Table 5. Relative grain yield of hard red spring wheat varieties in southern Minnesota locations in single-year (2015) and multiple-year comparisons (2013-2015).

	Benson				LeCenter			Lamberton			
Entry	**2015**	**2-Year**	**3-Year**		**2015**	**2-Year**		**2015**	**2-Year**	**3-Year**	
Barlow	94	91	90		100	84		97	98	89	
Bolles	101	98	93		88	77		92	97	91	
Chevelle	117	–	–		104	–		105	–	–	
Elgin-ND	105	97	94		93	79		97	99	91	
Faller	105	106	103		106	104		111	108	99	
Focus	96	99	–		94	91		110	106	–	
Forefront	95	95	94		108	100		108	103	95	
Glenn	87	92	87		84	80		102	97	89	
HRS 3361	88	94	–		106	97		101	100	–	
HRS 3419	99	100	–		119	117		114	115	–	
HRS 3504	108	–	–		111	–		112	–	–	
HRS3530	115	–	–		108	–		106	–	–	
Knudson	100	96	94		102	93		102	103	94	
LCS Albany	113	110	106		107	96		104	110	105	
LCS Breakaway	98	99	96		98	91		93	93	86	
LCS Iguacu	101	103	101		98	99		103	102	97	
LCS Nitro	107	110	–		110	110		106	107	–	
Linkert	93	93	89		104	94		93	92	86	
Linkert 1.3X	92	–	–		99	–		93	–	–	
Marshall	101	102	95		70	67		75	82	77	
MS Stingray	103	–	–		101	–		89	–	–	
Norden	95	98	94		96	87		100	100	90	
Prevail	93	100	97		106	103		105	101	94	
Prosper	116	114	106		100	96		104	105	95	
RB07	102	98	94		89	85		99	101	92	
Rollag	101	100	93		91	83		94	94	84	
Samson	96	94	93		109	94		106	99	93	
SY Ingmar	103	108	–		110	109		103	103	–	
SY Rowyn	102	105	100		98	99		109	106	96	
SY Soren	95	97	93		86	83		93	100	92	
SY Valda	110	–	–		116	–		113	–	–	
WB-Mayville	92	96	95		107	99		95	91	85	
WB9507	110	107	–		113	108		97	101	–	
WB9653	112	–	–		109	–		109	–	–	
Mean (Bu/Acre)	102.6	107.8	105.1		86.3	75.6		94.5	88.0	81.9	
LSD (0.10)	10.2	8.2	5.9		10.8	11.0		7.1	8.1	7.2	

Table 5. *continued*

Morris			St. Paul			Waseca		
2015	2-Year	3-Year	2015	2-Year	3-Year	2015	2-Year	3-Year
99	98	95	93	92	100	94	89	93
98	101	92	103	105	106	100	109	113
110	–	–	103	–	–	93	–	–
101	101	96	99	99	101	81	79	89
96	102	97	98	103	106	109	104	106
93	105	–	95	98	–	96	94	–
106	108	99	86	96	100	102	107	116
87	95	90	75	78	85	103	92	94
105	101	–	99	101	–	116	113	–
114	108	–	116	113	–	117	116	–
116	–	–	102	–	–	101	–	–
88	–	–	104	–	–	141	–	–
100	99	94	101	98	102	82	88	97
101	107	102	115	117	118	112	121	131
85	92	89	99	93	101	100	93	100
98	100	97	118	118	120	77	89	110
113	109	–	120	117	–	98	110	–
99	93	88	102	96	97	103	102	102
96	–	–	105	–	–	109	–	–
97	92	86	75	80	82	40	56	70
98	–	–	122	–	–	88	–	–
102	96	91	101	99	100	103	107	109
101	108	102	105	109	111	122	124	136
90	103	100	98	103	109	106	112	117
95	94	93	99	94	96	104	94	98
104	98	92	92	94	92	88	85	89
106	96	92	114	105	104	105	103	110
94	101	–	90	95	–	80	86	–
112	116	108	100	101	106	101	109	109
83	95	90	99	99	100	78	85	93
112	–	–	107	–	–	98	–	–
114	96	89	106	103	103	110	97	101
86	97	–	114	114	–	87	102	–
123	–	–	108	–	–	111	–	–
64.9	72.7	71.6	88.7	77.9	76.4	47.7	42.7	43.1
9.4	14.2	9.4	7.2	11.4	10.1	16.8	23.9	17.9

Table 6. Relative grain yield of hard red spring wheat varieties in Minnesota in single-year (2015) and multiple-year comparisons (2013-2015).

	State				North				South		
Entry	**2015**	**2-Year**	**3-Year**		**2015**	**2-Year**	**3-Year**		**2015**	**2-Year**	**3-Year**
Barlow	96	94	96		96	95	96		96	93	96
Bolles	97	98	99		97	98	99		97	97	100
Chevelle	101	–	–		98	–	–		106	–	–
Elgin-ND	94	94	97		92	95	97		97	94	97
Faller	104	106	107		103	107	108		104	105	105
Focus	99	98	–		100	97	–		97	100	–
Forefront	99	101	100		98	100	99		100	101	102
Glenn	93	92	93		96	95	94		89	89	91
HRS 3361	99	99	–		98	99	–		101	100	–
HRS 3419	110	110	–		109	110	–		112	111	–
HRS 3504	103	–	–		100	–	–		108	–	–
HRS3530	109	–	–		109	–	–		109	–	–
Knudson	98	98	99		97	98	99		99	97	98
LCS Albany	106	108	111		105	107	109		109	110	113
LCS Breakaway	99	96	97		101	98	97		95	94	97
LCS Iguacu	103	105	106		104	106	106		101	103	107
LCS Nitro	105	106	–		102	103	–		109	111	–
Linkert	100	97	96		101	98	97		98	94	94
Linkert 1.3X	98	–	–		97	–	–		98	–	–
Marshall	85	87	91		89	90	94		79	83	86
MS Stingray	108	–	–		113	–	–		101	–	–
Norden	98	98	98		98	98	98		99	98	98
Prevail	103	104	104		102	102	101		103	106	108
Prosper	104	107	108		105	107	109		103	106	107
RB07	97	97	98		97	98	98		97	95	97
Rollag	98	96	95		99	98	97		95	94	93
Samson	106	101	102		107	103	103		105	98	99
SY Ingmar	99	100	–		100	99	–		98	102	–
SY Rowyn	101	103	102		100	101	100		103	106	106
SY Soren	95	97	98		99	99	98		90	94	96
SY Valda	108	–	–		107	–	–		110	–	–
WB-Mayville	98	96	96		95	95	95		102	97	97
WB9507	102	105	–		101	104	–		103	106	–
WB9653	104	–	–		99	–	–		111	–	–
Mean (Bu/Acre)	86.9	83.2	81.7		91.4	88.1	88.4		81.0	77.2	73.6
LSD (0.10)	4.0	2.7	2.2		4.7	3.2	2.5		7.0	4.7	3.8
No. Environments	14	29	42		8	16	23		6	13	19

Table 7. Grain yield (bushels per acre) of hard red spring wheat varieties grown under conventional and intensive management.

	North						South						State					
	2015		2-year		3-year		2015		2-year		3-year		2015		2-year		3-year	
Entry	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int
Barlow	80.2	91.7	82.3	96.5	80.7	93.6	77.9	82.5	78.7	82.7	73.1	72.5	79.1	87.1	80.5	89.6	76.9	83.0
Bolles	81.0	92.4	87.5	97.0	83.7	93.3	75.3	79.7	79.2	83.4	70.1	71.8	78.2	86.0	83.3	90.2	76.9	82.5
Chevelle	77.5	100.5					85.1	89.4					81.3	94.9				
Elgin-ND	76.2	90.5	82.9	96.5	82.8	94.7	78.4	82.3	80.4	84.3	73.3	73.1	77.3	86.4	81.7	90.4	78.1	83.9
Faller	82.4	105.1	92.8	111.1	92.2	106.3	83.6	92.5	85.0	91.4	76.6	78.1	83.0	98.8	88.9	101.3	84.4	92.2
Focus	87.6	96.5	89.6	100.2			86.5	78.6	86.9	83.0			87.1	88.4	88.3	92.0		
Forefront	82.1	83.1	87.9	94.6	83.9	90.9	93.4	85.8	88.9	85.3	77.8	74.1	86.6	84.5	87.8	89.9	80.5	82.5
Glenn	81.9	88.9	82.5	94.2	78.6	90.1	86.5	75.6	82.5	80.5	73.2	69.8	83.7	82.2	82.3	87.4	75.8	80.0
HRS 3361	79.9	91.8	86.5	100.9			88.9	79.4	84.1	81.7			83.5	85.6	84.8	91.3		
HRS 3419	94.6	98.3	96.9	108.2			91.0	98.8	89.9	96.4			92.8	98.5	93.4	102.3		
HRS 3504	81.6	102.5					93.6	91.0					87.1	96.7				
HRS3530	87.5	99.3					78.7	88.0					83.1	93.6				
Knudson	76.7	95.4	84.6	100.6	83.0	96.6	83.6	90.1	82.9	86.3	74.1	75.2	79.8	93.0	83.6	93.6	78.4	86.0
LCS Albany	85.9	101.2	93.3	106.1	92.5	104.2	85.2	95.4	89.0	91.2	80.9	79.9	85.6	98.3	91.2	98.7	86.7	92.1
LCS Breakaway	86.2	100.4	84.7	102.4	80.5	95.5	79.8	86.3	78.3	87.1	71.6	75.3	83.6	94.0	81.8	95.1	76.3	85.6
LCS Iguacu	88.8	92.8	94.2	102.4	91.5	99.3	80.4	90.2	81.4	89.3	74.9	77.4	84.6	91.5	87.8	95.9	83.2	88.4
LCS Nitro	84.6	91.1	90.2	101.9			86.7	85.6	86.6	90.9			85.6	88.4	88.4	96.4		
Linkert	86.7	98.0	88.6	100.8	84.3	94.6	75.8	81.2	74.5	79.9	67.7	69.3	81.3	89.6	81.6	90.4	76.0	81.9
Linkert 1.3X	89.9	93.5					75.0	85.8					82.4	90.0				
Marshall	66.5	89.6	74.8	97.6	76.4	94.3	67.4	80.4	69.8	81.3	63.6	69.7	66.9	85.0	72.3	89.5	70.0	82.0
MS Stingray	97.9	107.9					74.1	91.5					86.0	99.7				
Norden	88.5	94.2	87.1	98.6	85.0	96.0	83.1	82.9	80.1	83.4	72.4	72.1	86.1	88.5	83.7	91.0	78.8	84.0
Prevail	87.7	101.6	90.0	102.4	86.1	97.1	82.4	91.7	83.6	87.2	76.6	75.6	85.1	97.1	86.8	95.0	81.3	86.5
Prosper	85.3	98.2	93.5	106.8	90.8	102.6	78.0	91.3	83.4	90.6	77.4	78.8	81.6	94.7	88.5	98.7	84.1	90.7
RB07	79.9	100.5	86.1	104.7	83.1	98.9	77.5	87.3	78.9	85.7	73.5	74.2	78.7	93.9	82.5	95.2	78.3	86.6
Rollag	81.2	98.7	85.2	101.2	80.8	95.4	78.5	80.8	77.4	80.2	69.4	68.4	79.8	89.7	81.3	90.7	75.1	81.9
Samson	89.4	105.9	90.0	104.9	85.9	98.2	84.5	88.3	78.5	87.2	71.9	77.0	86.9	97.9	84.2	96.5	78.9	87.9
SY Ingmar	82.1	100.2	86.4	101.6			75.5	83.6	80.0	86.1			79.1	91.9	83.3	93.9		
SY Rowyn	80.1	100.1	88.0	103.5	83.8	97.3	95.1	86.9	92.4	89.4	83.1	76.7	86.1	93.5	89.5	96.5	82.9	87.0
SY Soren	89.4	97.1	91.9	102.1	86.7	95.9	71.0	83.7	78.5	85.0	70.4	73.7	80.2	90.4	85.2	93.6	78.5	84.8
SY Valda	85.6	99.5					89.5	93.0					87.5	96.3				
WB-Mayville	80.4	102.5	83.8	103.8	80.4	97.2	83.7	90.4	76.1	85.5	67.9	73.7	81.9	96.5	79.9	94.7	74.1	85.5
WB9507	77.8	104.0	87.7	107.2			73.5	96.3	79.8	94.6			75.6	100.2	83.8	100.9		
WB9653	79.9	101.6					91.3	80.4					86.1	91.0				
Mean (Bu/Acre)	83.8	97.2	87.7	101.8	84.7	96.9	81.4	86.5	81.8	86.2	73.5	74.3	82.5	91.9	84.7	94.0	79.1	85.6
LSD (0.10)	7.1	6.3	3.7	3.4	3.0	2.8	5.4	5.9	3.4	3.2	2.4	2.2	4.7	4.4	4.6	4.4	1.9	1.8
No. Environments	2	2	4	4	6	6	2	2	4	4	6	6	4	4	8	8	12	12

Table 8. Relative grain yield (percent of the mean of the trial) of barley varieties at several locations in Minnesota in single-year (2015) and multiple-year comparisons (2013-2015).

	Crookston		Morris		Stephen		St. Paul	Roseau		State Mean	
Variety	2015	2-Year [1]	2015	3-Year	2015	3-Year	2-Year [2]	2015	3-Year	**2015**	**3 year**
Celebration	96	103	87	95	94	101	103	85	96	**90**	**99**
Conlon	91	93	87	92	88	98	91	96	89	**90**	**93**
Innovation	108	105	105	105	112	103	119	108	104	**108**	**106**
Lacey	106	100	108	104	113	104	96	97	101	**105**	**101**
Pinnacle	97	105	105	103	103	103	100	112	113	**104**	**105**
Quest	103	99	107	105	94	95	111	95	102	**99**	**102**
Rasmusson	110	104	106	112	123	114	109	109	104	**111**	**109**
Robust	97	99	93	89	73	88	91	99	100	**90**	**93**
Stellar-ND	99	99	99	93	101	98	89	105	95	**101**	**95**
Tradition	94	92	103	99	98	97	90	94	95	**97**	**95**
Mean, (bu/acre)	103	95	90	88	124	113	126	145	126	**116**	**110**
LSD (0.05)	**7**	**6**	**16**	**9**	**19**	**10**	**11**	**12**	**8**	**7**	**4**

[1] Only two years of data, 2013 and 2015.

[2] Only two years of data, 2013 and 2014.

Table 9. Agronomic characteristics of barley varieties, 2008-2015.

Variety	**Type**	**Use**	**Heading (DAP)**	**Height (inches)**	**Lodging (1-9)**	**Plump (%)**	**Protein (%)**
Celebration	6-row	Malt	59	34	4.8	85	13.6
Conlon	2-row	Malt	57	31	4.3	95	13.1
Innovation	6-row	Malt	59	31	3.4	94	13.0
Lacey	6-row	Malt	59	32	3.8	94	13.3
Pinnacle	2-row	Malt	60	32	3.0	97	12.0
Quest	6-row	Malt	59	33	5.4	91	13.2
Rasmusson	6-row	Malt	59	30	3.8	91	13.0
Robust	6-row	Malt	59	34	5.4	92	13.9
Stellar ND	6-row	Malt	59	32	3.9	94	13.4
Tradition	6-row	Malt	59	32	3.9	92	13.5
No. Environments			**24**	**20**	**10**	**17**	**17**

Table 10. Disease reactions of barley varieties in multiple year comparisons1.

Variety	Fusarium Head Blight	Net Blotch	Speckled Leaf Blotch	Spot Blotch	Stem Rust [2]	Bacterial Leaf Streak
Celebration	7	3	9	4	1	5
Conlon	6	3	9	5	1	5
Innovation	8	4	9	2	1	6
Lacey	8	6	9	2	1	6
Pinnacle	9	6	9	4	1	6
Quest	5	5	9	3	1	6
Rasmusson	9	5	9	2	1	6
Robust	8	5	9	2	1	6
Stellar-ND	9	6	9	2	1	7
Tradition	8	4	9	2	1	7

[1] 1-9 scale where 1=most resistant, 9=most susceptible.

[2] Reaction to the dominant strain of the stem rust pathogen.

North Dakota Hard Red Spring Wheat Variety Trial Results for 2015 and Selection Guide ~ Preliminary Results

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Hard red spring (HRS) wheat was harvested from 6.2 million acres in 2015, up slightly from 2014. The average yield of spring wheat was 48 bushels/acre (bu/a), up slightly from last year.

Barlow was the most popular HRS wheat variety again in 2015, occupying 12.6 percent of the planted acreage, followed by SY Soren (12.1), Elgin-ND (10.8), Prosper (10.5) and Faller (8.3). SY Soren was released by Syngenta/AgriPro. All other varieties are NDSU releases.

Spring wheat was generally planted early this year due to an early spring. Temperatures were moderate during much of the growing season which helped the development of relatively high yield potential even in the late plantings. Stripe rust, also referred to as yellow rust, was problematic in some locations in the state. Scab caused elevated levels of DON in a few regions, but generally the crop was free from scab damage this year.

Successful wheat production depends on numerous factors, including selecting the right variety for a particular area. The information included in this publication is meant to aid in selecting that variety or group of varieties. Characteristics to consider in selecting a variety may include yield potential, protein content when grown with proper fertility, straw strength, plant height, reaction to problematic pests (diseases, insects, etc.) and maturity. Every growing season differs; therefore, when selecting a variety, we recommend using data that summarize several years and locations. Choose the variety that, on average, performs the best at multiple locations near your farm during several years.

Selecting varieties with good milling and baking quality also is important to maintain market recognition and avoid discounts. Hard red spring wheat from the northern Great Plains is known around the world for its excellent end-use quality. Millers and bakers consider many factors in determining the quality and value of wheat they purchase. Several key parameters are: high test weight (for optimum milling yield and flour color), high falling number (greater than 300 seconds indicates minimal sprout damage), high protein content (the majority of HRS wheat export markets want at least 14 percent protein) and excellent protein quality (for superior bread-making quality as indicated by traditional strong gluten proteins, high baking absorption and large bread loaf volume).

Gluten strength, and milling and baking quality ratings, are provided for individual varieties based on the results from the NDSU field plot variety trials. These ratings are applied to varieties grown for multiple years at seven NDSU Research Extension Centers across the state to provide producers and end users with end-use performance data. The wheat protein data often are higher than obtained in actual production fields but can be used to compare differences among varieties.

The agronomic data presented in this publication are from replicated research plots using experimental designs that enable the use of statistical analysis. These analyses enable the reader to determine, at a predetermined level of confidence, if the differences observed among varieties are reliable or if they might be due to error inherent in the experimental process.

The LSD (Least Significant Difference) values beneath the columns in the tables are derived from these statistical analyses and apply only to the numbers in the column in which they appear. If the difference between two varieties exceeds the LSD value, it means that with 95 percent confidence (LSD probability 0.05), the higher-yielding variety has a significant yield advantage. When the difference between two varieties is less than the LSD value, no significant difference was found between those two varieties under those growing conditions.

NS is used to indicate no significant difference for that trait among any of the varieties at the 95 percent level of confidence. The CV stands for coefficient of variation and is expressed as a percentage. The CV is a measure of variability in the trial. Large CVs mean a large amount of variation that could not be attributed to differences in the varieties. Yield is reported at 13.5% moisture while protein content is reported at 12% moisture content.

Presentation of data for the entries tested does not imply approval or endorsement by the authors or agencies conducting the test. North Dakota State University approves the reproduction of any table in the publication only if no portion is deleted, appropriate footnotes are given and the order of the data is not rearranged. Additional data from county sites are available from each Research Extension Center at www.ag.ndsu.edu/varietytrials/spring-wheat.

Table 1. North Dakota hard red spring wheat variety descriptions, agronomic traits, 2015.

						Reaction to Disease[4]				
Variety	**Agent or Origin[1]**	**Year Re-leased**	**Height (inches)**	**Straw Strength[2]**	**Days to Head[3]**	**Stem Rust[5]**	**Leaf Rust**	**Leaf Spot[6]**	**Bact. Leaf Streak**	**Head Scab**
Advance	SD	2012	32	6	64	R	MR/MS	M	MS	MS
Alpine[7]	AgriPro	2008	34	6	62	MS	S	MS	S	MS
Barlow	ND	2009	35	6	62	R	MS	MR	MS/S	M
Bolles	**MN**	**2015**	**32**	**4**	**66**				**NA**	
Brennan	AgriPro	2009	30	4	62	R	MR	M	MS	MS
Brick	SD	2009	35	5	60	R	MS	MS/S	NA	MR
Duclair[8]	MT	2011	31	4	65	R	NA	NA	NA	NA
Elgin-ND	ND	2012	36	5	65	R	MS	M	MS/S	M
Faller	ND	2007	35	5	65	R	S	MR	MS	M
Focus	**SD**	**2015**	**35**	**5**	**60**				**S**	**MR**
Forefront	SD	2012	37	5	61	R/MR	MR	MR	M/MS	MR
Glenn	ND	2005	37	4	61	R	MS	M	M/MS	MR
HRS 3361	Croplan	2013	33	3	65	NA	MS/MR	MR	NA	M
HRS 3378	Croplan	2013	32	4	64	NA	MR	M	NA	M
HRS 3419	Croplan	2014	32	2	68	NA	MR	MR	NA	MR
HRS 3530	**Croplan**	**2015**	**36**	**4**	**68**				**NA**	
Jenna	AgriPro	2009	32	4	66	R	MR	M	M/MS	M
Kelby	AgriPro	2006	30	4	62	R/MR	MR/MS	M	S	M
LCS Albany	Limagrain	2008	32	5	67	NA	MR	MS	M	M
LCS Breakaway	Limagrain	2011	32	5	63	R	R	MS	MS	M
LCS Iguacu	Limagrain	2014	33	3	66	NA	MS	M	M/MS	MR
LCS Nitro	**Limagrain**	**2015**	**32**	**4**	**65**				**NA**	
LCS Powerplay	Limagrain	2011	33	5	65	R	MS	MS	S	M
LCS Pro	**Limagrain**	**2015**								
Linkert	MN	2013	31	2	63	R	MR/MS	M	MS	M
Mott[7]	ND	2009	36	3	66	R	MS	MS	MS	MS
MS Chevelle	Meridian	2014	30	5	63	NA	R	NA	NA	M
MS Stingray	Meridian	2013	35	3	67	NA	MS	NA	NA	NA
ND901CL Plus[9]	ND	2010	36	4	60	MR	MS/MR	NA	NA	M
Norden	MN	2012	32	3	62	R	MR/MS	M	S	M
Prestige	**Pulse-USA**	**2015**	**31**	**3**	**62**				**NA**	
Prevail	SD	2014	31	4	64	NA	MR	MS	NA	M
Prosper	NDSU	2011	35	5	65	R	MS	M	MS	M
RB07	MN	2007	32	5	62	R	MS	MS	MS/S	MR
Redstone	Pulse-USA	2014	32	3	67					
Rollag	MN	2011	32	3	63	R	MR/MS	MR	M	MR
Sabin	MN	2009	33	6	65	R	MR/MS	MS	NA	M
Samson	WestBred	2007	31	2	63		MR/MS	MS	MS	S
Select	SD	2010	35	6	60	R	MS	R/MR	S	MR

Table 1 *continued*

						Reaction to Disease[4]				
Variety	Agent or Origin[1]	Year Re-leased	Height (inches)	Straw Strength[2]	Days to Head[3]	Stem Rust[5]	Leaf Rust	Leaf Spot[6]	Bact. Leaf Streak	Head Scab
SY Ingmar	Syngenta/ AgriPro	2014	31	4	64	NA	MR	M	M	M
SY Rowyn	Syngenta/ AgriPro	2013	31	4	62	R	R	M	M	M
SY Soren	Syngenta/ AgriPro	2011	30	4	63	R	R	M	S	M
SY Tyra[8]	Syngenta/ AgriPro	2011	31	5	62	R	R	MS	S	S
SY Valda	**Syngenta/ AgriPro**	**2015**	**31**	**4**	**64**				**MS**	
Vantage	WestBred	2007	32	2	67	MR	R	MS	MS/S	MS
Velva	NDSU	2011	35	4	63	R	R	M	S	MS
WB9507	WestBred	2013	32	5	61	NA	MR	R	NA	MR
WB9653	**WestBred**	**2015**	**31**	**4**	**65**		**R**	**M**	**NA**	**M**
WB9879CLP[9]	WestBred	2012	33	4	64	NA	MS	MR	NA	MS
WB-Digger	WestBred	2009	34	6	63	MR	R	M	NA	MS
WB-Gunnison	WestBred	2013	31	5	65	NA	MS	MS	M	MS
WB-Mayville	WestBred	2011	30	4	63	R	R	MS	S	S

[1] Refers to agent or developer: MN = University of Minnesota; MT = Montana State University; ND = North Dakota State University; SD = South Dakota State University; **Bold** varieties are those recently released, so data is limited and rating values may change. NA indicates insufficient information is available to make an accurate assessment.
[2] Straw Strength = 1 to 9 scale, with 1 the strongest and 9 the weakest. These values are based on recent data and may change as more data become available.
[3] Days to Head = the number of days from planting to head emergence from the boot averaged from several locations in 2010 and 2011.
[4] R = resistant; MR = moderately resistant; M = intermediate; MS = moderately susceptible; NA = Not adequately tested; S = susceptible.
[5] Fargo stem rust nursery inoculated with Puccinia graminis f. sp. Tritici races TPMK, TMLK, RTQQ, QFCQ and QTHJ.
[6] Leaf spot refers to the leaf fungal diseases such as tan spot and septoria. It does not include bacterial leaf streak.
[7] Hard white wheat.
[8] Solid stemmed or semisolid stem, imparting resistance to sawfly.
[9] CL = refers to a Clearfield variety, with tolerance to the Beyond™ family of herbicides.

Table 2. Analytical milling and baking data from field plot variety trials at Carrington, Casselton, Dickinson, Hettinger, Langdon, Minot and Williston, 2013 and 2014 (unless otherwise noted).

Variety	2015 N.D. Planted (% area)	OBS[1]	Test Weight (lb/bu)	Protein 12% MB (%)	Vitreous Kernels (%)	Falling Number (sec)	Farinograph Stability (min)	Farinograph Absorption (%)	Loaf Volume (cc)	Mill and Bake Quality Rating (1-5 Stars)[2]
Advance	--	14	62.8	13.1	53	384	9.4	59.6	949	**
Barlow	12.6	14	62.6	14.0	65	357	8.5	65.1	936	***
Bolles	--	14	61.5	15.1	70	401	19.1	62.7	982	****
Brennan	2.9	14	62.0	14.3	52	392	7.6	63.7	942	*
Elgin-ND	10.8	14	61.8	13.6	64	385	9.0	63.2	921	***
Faller	8.3	14	61.5	13.0	60	390	8.7	62.3	911	***
Forefront	--	14	62.2	13.8	51	401	10.1	61.3	995	**
Glenn[3]	6.5	14	63.9	14.3	74	363	10.4	64.2	948	*****
Jenna	0.9	14	61.1	13.3	44	357	7.3	61.9	943	**
Kelby	1.2	10	61.7	14.5	51	378	7.4	62.5	946	**
LCS Albany	--	10	61.5	12.6	45	373	7.0	57.6	918	**
LCS Breakaway	--	13	63.3	14.0	66	413	6.1	63.5	917	*
LCS Powerplay	--	13	62.5	13.2	54	395	7.0	63.9	930	*
Linkert	1.0	14	62.0	14.3	58	414	16.2	62.5	952	****
Mott	1.1	11	62.2	14.1	63	352	9.0	61.1	904	***
Norden	--	14	63.3	13.5	77	394	8.9	63.4	922	**
Prevail	--	14	61.3	13.2	45	342	7.9	60.0	923	**
Prosper	10.5	14	61.9	13.1	55	378	8.6	62.8	918	***
RB07	1.9	11	62.0	13.9	65	378	10.9	61.6	967	***
Rollag	1.5	13	62.8	14.4	67	465	6.4	66.7	882	*
Select	--	12	62.7	13.6	67	411	7.3	62.6	932	*
Steele-ND	0.9	11	63.0	14.4	70	389	8.5	64.2	970	***
SY Rowyn	1.9	13	62.2	13.3	54	426	17.5	60.5	938	****
SY Soren	12.1	13	62.7	14.0	55	404	8.6	62.9	970	***
SY Tyra	--	11	62.1	13.0	64	372	7.3	62.3	901	***
Vantage	1.3	13	63.4	15.0	81	321	10.4	63.7	953	***
Velva	1.2	13	61.5	13.6	66	393	9.1	63.2	928	**
WB-Mayville	4.6	11	61.7	14.1	56	394	9.8	63.9	946	***

Analyses conducted at the NDSU Hard Red Spring Wheat Quality Laboratory in Fargo, N.D.

[1] Observations

[2] Mill and Bake Quality Rating scale 1 to 5, with 1 being low and 5 being superior.

[3] Glenn is the current Wheat Quality Council check variety for comparing new experimental lines and newly released varieties.

Table 3. Analytical milling and baking data from field plot variety trials at Carrington, Casselton, Dickinson, Hettinger, Langdon, Minot and Williston, 2014 (unless otherwise noted).

Variety	2015 N.D. Planted	OBS[1]	Test Weight	Protein 12% MB	Vitreous Kernels	Falling Number	Farinograph Stability	Farinograph Absorption	Loaf Volume	Mill and Bake Quality Rating
	(% area)		(lb/bu)	(%)	(%)	(sec-onds)	(minutes)	(%)	(cc)	(1-5)[2]
Advance	--	7	61.9	13.2	42	342	9.3	59.1	989	**
Alpine	--	3	59.7	12.9	0	219	6.5	60.7	923	**
Barlow	12.6	7	61.7	13.4	47	324	7.9	63.5	917	***
Bolles	--	7	60.6	14.4	57	357	20.0	60.5	969	****
Brennan	2.9	7	61.2	14.0	38	352	7.4	63.1	989	*
DuClair	--	4	60.3	12.5	37	328	9.2	57.4	981	**
Elgin-ND	10.8	7	61.0	12.7	37	351	9.7	61.1	882	***
Faller	8.3	7	60.8	12.3	47	357	7.2	60.6	870	***
Focus	--	2	61.8	14.6	64	372	6.1	61.4	915	**
Forefront	--	7	61.5	13.4	40	378	9.8	60.5	1033	**
Glenn[3]	6.5	7	63.2	13.7	56	339	9.0	62.7	915	*****
Jenna	0.9	7	60.1	13.0	35	278	6.1	60.4	973	**
Kelby	1.2	5	60.8	13.9	39	342	6.9	61.4	970	**
LCS Albany	--	5	60.3	12.1	28	312	6.4	56.0	960	**
LCS Breakaway	--	7	62.7	13.5	54	381	6.0	62.8	924	*
LCS Iguacu	--	7	60.9	12.3	29	363	9.6	58.8	842	***
LCS Powerplay	--	7	61.6	12.7	38	374	7.1	62.3	944	*
Linkert	1.0	7	61.0	13.7	42	378	15.2	61.1	945	****
Mott	1.1	5	61.3	13.7	44	310	8.7	59.6	905	***
Norden	--	7	62.3	13.4	70	368	9.1	62.4	942	**
Prevail	--	7	60.8	12.7	28	296	7.9	58.6	931	**
Prosper	10.5	7	61.1	12.4	36	340	7.5	61.0	882	***
RB 07	1.9	6	61.3	13.6	57	350	11.3	60.8	964	***
Rollag	1.5	6	62.1	14.0	58	400	6.2	66.3	905	*
Samson	--	3	58.2	13.0	29	277	7.1	57.4	1012	***
Select	--	5	61.8	13.1	55	388	7.3	61.8	973	*
Steele-ND	0.9	5	62.2	14.3	67	367	8.9	63.4	984	***
SY Ingmar	--	5	61.9	14.0	62	393	9.0	61.1	1001	***
SY Rowyn	1.9	6	61.6	12.9	44	407	12.5	59.8	948	****
SY Soren	12.1	6	62.4	13.6	42	380	7.6	62.6	1005	***
SY Tyra	--	5	60.5	12.6	42	313	7.0	61.1	903	***
Vantage	1.3	6	63.1	14.9	79	298	9.7	63.1	972	***
Velva	1.2	6	60.7	12.8	57	366	8.8	61.7	943	**
WB-Digger	--	4	60.5	12.9	49	314	7.3	61.0	986	**
WB-Gunnison	--	3	60.5	13.2	33	321	9.5	60.5	945	***
WB-Mayville	4.6	6	61.0	13.5	48	328	8.9	62.4	949	***

Analyses conducted at the NDSU Hard Red Spring Wheat Quality Laboratory in Fargo, N.D.
[1] Observations [2] Mill and Bake Quality Rating scale 1 to 5, with 1 being low and 5 being superior. [3] Glenn is the current Wheat Quality Council check variety for comparing new experimental lines and newly released varieties.

Table 4. Yield of hard red spring wheat varieties grown at four locations in eastern North Dakota, 2013-2015.

	Carrington		Casselton		Prosper		Langdon		Avg. eastern N.D.	
Variety	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**2 Yr.**	**2015**	**3 Yr.**	**2015**	**2/3 Yr.**
	---(bu/a)---									
Advance	59.7	66.3	60.3	76.5	62.2	73.0	74.6	85.3	64.2	75.3
Alpine	54.4	64.9	--	--	--	--	72.6	87.7	--	--
Alsen	56.8	65.6	63.7	70.3	59.4	65.7	--	--	--	--
Barlow	56.6	67.0	63.6	68.7	63.5	70.4	73.5	84.2	64.3	72.6
Bolles	50.0	--	64.1	--	60.7	--	73.0	84.3	62.0	--
Brennan	62.3	66.3	58.9	72.2	56.1	66.7	--	--	--	--
Duclair	--	--	61.4	--	52.2	63.6	--	--	--	--
Elgin-ND	59.6	69.4	64.3	75.4	57.1	68.0	72.9	87.4	63.5	75.1
Faller	56.2	74.9	60.6	81.0	49.7	70.9	74.1	93.8	60.2	80.2
Focus	56.6	--	64.1	--	72.3	--	72.5	--	66.4	--
Forefront	55.6	68.6	69.3	80.4	70.7	77.0	71.6	78.2	66.8	76.1
Glenn	57.9	65.3	58.8	70.1	64.9	71.1	74.8	80.5	64.1	71.8
HRS 3361	53.3	72.1	--	--	--	--	66.4	82.9	--	--
HRS 3378	51.2	64.4	--	--	--	--	71.6	82.8	--	--
HRS 3419	51.9	--	--	--	--	--	82.7	--	--	--
HRS 3530	62.9	--	--	--	--	--	77.0	--	--	--
LCS Albany	63.3	74.3	58.0	--	68.2	73.1	68.2	89.5	64.4	--
LCS Breakaway	55.4	65.9	65.4	75.6	62.0	72.6	73.6	79.6	64.1	73.4
LCS Iguacu	53.2	69.0	68.0	--	63.1	74.2	73.3	--	64.4	--
LCS Nitro	50.5	--	58.9	--	60.2	--	75.0	--	61.2	--
LCS Powerplay	63.8	73.8	62.5	72.2	62.2	70.8	70.9	86.6	64.9	75.9
LCS Pro	--	--	62.5	--	60.0	--	75.6	--	--	--
Linkert	58.4	67.6	69.0	74.2	66.7	72.1	76.1	79.7	67.6	73.4
Mott	60.0	71.2	62.1	74.7	57.2	68.7	--	--	--	--
MS Chevelle	53.0	--	61.4	--	66.5	74.1	80.1	--	65.3	--
MS Stingray	61.5	75.9	58.5	--	53.4	65.7	62.0	91.1	58.9	--
ND901CL Plus	56.6	64.4	66.8	71.9	62.4	69.4	--	--	--	--
Norden	61.9	69.6	70.9	75.4	61.9	70.2	72.9	81.0	66.9	74.1
Prestige	55.7	--	--	--	--	--	77.7	--	--	--
Prevail	63.0	70.1	74.3	--	72.4	--	73.6	82.3	70.8	--
Prosper	56.0	73.0	62.2	75.2	52.1	71.1	70.8	91.1	60.3	77.6
RB07	55.5	66.1	65.5	77.1	57.2	68.2	74.3	86.3	63.1	74.4
Redstone	54.8	--	--	--	--	--	79.1	--	--	--
Rollag	56.7	70.0	78.7	78.3	65.5	73.2	75.0	81.0	69.0	75.6
Samson	53.7	60.2	62.0	72.3	54.5	68.6	79.4	85.7	62.4	71.7
Select	61.7	70.2	69.2	73.2	50.0	66.5	--	--	--	--

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Table 4 *continued*

	Carrington		Casselton		Prosper		Langdon		Avg. eastern N.D.	
Variety	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**2 Yr.**	**2015**	**3 Yr.**	**2015**	**2/3 Yr.**
	(bu/a)									
Steele-ND	66.5	69.8	63.7	73.7	67.2	71.8	--	--	--	--
SY605 CL	59.4	66.3	71.6	76.4	74.3	79.9	--	--	--	--
SY Ingmar	57.7	--	68.5	--	61.6	68.9	74.2	--	65.5	--
SY Rowyn	65.9	71.7	64.2	75.5	56.6	71.8	77.6	86.4	66.1	76.4
SY Soren	50.4	64.2	56.4	69.5	55.9	65.1	74.0	81.7	59.2	70.1
SY Tyra	--	--	49.0	65.4	49.5	56.4	--	--	--	--
SY Valda	56.5	--	70.3	--	66.1	--	79.3	--	68.1	--
Vantage	60.9	67.2	67.1	73.2	65.2	67.6	67.8	78.4	65.3	71.6
Velva	55.4	65.0	50.8	70.8	49.1	59.8	--	--	--	--
WB-Digger	--	--	61.5	--	54.2	--	--	--	--	--
WB-Mayville	53.5	62.3	59.3	68.6	57.6	69.2	65.9	77.8	59.1	69.5
WB9507	45.0	--	52.3	--	54.6	--	60.8	--	53.2	--
WB9653	68.1	--	66.1	--	67.8	--	73.8	--	69.0	--
Mean	57.4	68.0	63.6	73.6	60.5	69.6	73.3	84.2	64.0	74.1
CV%	11.2	--	9.3	--	15.7	--	5.8	--	--	--
LSD 0.05	8.9	--		--		--	5.9	--	--	--
LSD 0.10	7.4	--	6.9	--	11.1	--	5.0	--	--	--

Table 5. Yield of hard red spring wheat varieties grown at four locations in western North Dakota, 2013-2015.

	Dickinson		Hettinger		Minot		Williston		Avg. western N.D.	
Variety	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**
	(bu/a)									
Advance	66.8	66.0	79.1	78.6	80.4	68.9	33.1	33.1	64.9	61.7
Alpine	--	--	--	--	65.5	57.5	--	--	--	--
Barlow	69.1	66.1	65.2	71.2	68.5	61.7	26.3	31.7	57.3	57.7
Bolles	68.9	67.7	70.5	71.8	68.6	60.8	33.5	--	60.4	--
Brennan	--	--	--	--	73.3	57.6	32.6	36.0	--	--
Duclair	63.9	65.1	64.5	--	72.5	65.1	32.9	35.6	58.5	--
Elgin-ND	71.4	69.6	74.5	76.6	72.5	64.4	30.8	36.0	62.3	61.7
Faller	68.1	70.4	79.5	76.0	82.4	74.1	31.4	34.7	65.4	63.8
Forefront	52.3	58.8	64.8	71.6	72.9	59.0	34.6	38.9	56.2	57.1
Glenn	67.8	64.5	63.1	66.8	68.0	58.0	28.4	33.7	56.8	55.8
HRS 3361	64.1	--	65.5	--	70.6	61.5	32.9	--	58.3	--
HRS 3378	74.6	--	73.1	--	69.2	60.3	36.4	--	63.3	--
HRS 3419	76.6	--	86.8	--	82.2	--	28.9	--	68.6	--
HRS 3530	72.2	--	79.6	--	90.2	--	35.5	--	69.4	--
LCS Albany	--	--	82.3	84.5	--	--	32.2	35.0	--	--
LCS Breakaway	77.6	69.1	64.1	73.4	70.2	62.1	26.9	34.4	59.7	59.8
LCS Iguacu	80.9	68.3	72.9	76.7	78.6	64.7	34.0	34.8	66.6	61.1
LCS Nitro	85.2	--	82.6	--	83.3	--	32.1	--	70.8	--
LCS Powerplay	73.2	71.8	68.6	73.8	76.5	66.6	36.2	40.6	63.6	63.2
LCS Pro	77.7	--	60.4	--	69.1	--	35.5	--	60.7	--
Linkert	71.2	66.5	63.7	68.4	68.6	59.7	32.9	36.1	59.1	57.7
Mott	64.1	65.8	66.4	70.1	78.0	65.1	35.7	35.6	61.1	59.2
MS Chevelle	75.9	--	76.1	--	68.8	--	35.1	--	64.0	--
MS Stingray	68.8	--	73.8	80.2	84.9	73.9	34.4	--	65.5	--
ND901CL Plus	67.1	63.0	59.2	62.8	74.7	62.5	31.7	32.7	58.2	55.3
Norden	70.5	67.6	70.0	73.1	73.4	60.4	30.4	34.7	61.1	59.0
Prestige	77.1	--	72.6	--	71.6	--	--	--	--	--
Prevail	53.4	60.4	75.2	76.3	76.5	66.0	35.3	41.0	60.1	60.9
Prosper	71.1	68.8	70.4	73.2	78.8	73.2	31.7	35.3	63.0	62.6
RB07	73.7	58.1	70.2	72.3	73.5	62.0	30.6	35.6	62.0	57.0
Redstone	71.0	--	80.2	--	--	--	--	--	--	--
Rollag	75.4	68.0	71.8	73.3	81.8	66.4	29.3	--	64.6	--
Select	74.5	67.1	--	--	--	--	35.2	36.2	--	--
Steele-ND	64.1	61.6	--	--	67.2	63.8	29.1	32.7	--	--
SY605 CL	72.0	65.8	71.5	75.5	78.3	64.8	31.8	33.7	63.4	60.0
SY Ingmar	75.7	--	67.0	--	81.3	--	32.3	--	64.1	--
SY Rowyn	72.4	66.2	74.3	76.3	80.3	67.4	30.6	34.2	64.4	61.0
SY Soren	70.6	67.4	71.9	76.8	74.1	63.2	30.4	33.2	61.8	60.2
SY Tyra	73.1	69.6	66.5	72.7	--	--	31.9	35.6	--	--
SY Valda	78.3	--	71.5	--	88.3	--	37.5	--	68.9	--
Vantage	62.7	61.7	--	--	67.6	58.5	26.6	32.1	--	--
Velva	67.0	69.6	61.5	71.7	65.7	62.1	34.7	39.4	57.2	60.7
WB-Digger	71.8	72.1	--	--	--	--	--	--	--	--
WB-Mayville	73.5	68.6	60.1	67.5	66.2	60.7	34.2	34.4	58.5	57.8
WB9507	71.3	--	65.6	--	74.0	--	31.0	--	60.5	--
WB9653	69.5	--	77.9	--	--	--	--	--	--	--
Mean	70.8	66.4	70.9	73.5	74.7	63.6	32.4	35.3	62.3	59.7
CV %	5.9	--	4.8	--	7.4	--	12.4	--	--	--
LSD 0.05	5.9	--	4.7	--	7.5	--	5.6	--	--	--
LSD 0.10	4.9	--	4.0	--	6.2	--	4.7	--	--	--

Table 6. Protein at 12 percent moisture of hard red spring wheat varieties grown at eight locations in North Dakota, 2015.

Variety	Carrington	Casselton	Prosper	Dickinson	Hettinger	Langdon	Minot	Williston	State Avg.
	(%)								
Advance	13.6	13.5	13.9	14.9	13.3	12.5	14.0	14.2	13.7
Alpine	14.3	--	--	--	--	13.3	15.8	--	--
Alsen	15.5	14.6	15.3	--	--	--	--	14.0	--
Barlow	16.0	14.3	14.6	16.0	15.2	14.1	15.5	14.8	15.1
Bolles	17.4	15.4	16.1	17.7	15.3	15.1	16.0	17.2	16.3
Brennan	15.4	14.8	14.9	--	--	--	14.5	16.2	--
Duclair	--	14.5	14.4	15.8	14.0	--	14.0	14.1	--
Elgin-ND	15.4	14.5	14.7	16.0	14.6	13.6	15.1	15.5	14.9
Faller	13.9	14.2	14.2	14.8	12.4	12.3	13.7	13.8	13.7
Focus	15.0	14.9	14.5	--	14.9	13.2	--	14.3	--
Forefront	14.9	13.9	14.3	16.0	14.5	13.6	15.0	15.3	14.7
Glenn	16.0	14.6	14.9	16.2	15.6	14.3	15.9	15.3	15.4
HRS 3361	14.8	--	--	15.4	14.0	12.5	13.7	15.2	--
HRS 3378	14.1	--	--	14.8	13.3	12.4	13.3	13.9	--
HRS 3419	13.3	--	--	15.1	13.3	12.5	13.1	14.6	--
HRS 3530	14.8	--	--	16.3	14.3	12.8	14.2	15.3	--
LCS Albany	13.5	14.3	13.0	--	13.0	12.3	--	13.0	--
LCS Breakaway	16.2	14.7	14.6	16.1	14.7	13.7	15.1	15.1	15.0
LCS Iguacu	12.7	13.5	12.2	13.4	12.2	11.3	12.5	14.2	12.8
LCS Nitro	14.2	13.0	13.3	14.3	12.6	12.0	12.8	14.9	13.4
LCS Powerplay	14.3	14.2	14.1	15.4	13.4	12.9	14.5	14.8	14.2
LCS Pro	--	14.9	14.7	16.0	15.3	13.5	15.6	14.5	--
Linkert	16.7	14.8	15.5	16.9	15.6	14.5	15.1	16.1	15.7
Mott	14.5	14.3	14.2	16.0	14.3	--	14.9	16.2	--
MS Chevelle	14.3	13.8	14.1	14.6	12.8	12.5	14.1	13.6	13.7
MS Stingray	11.6	13.6	12.0	13.6	10.9	10.9	11.4	12.7	12.1
ND901CL Plus	13.4	14.2	15.0	16.8	15.3	--	16.2	15.4	--
Norden	14.7	14.5	14.8	15.3	14.4	13.5	14.3	14.2	14.5
Prestige	15.0	--	--	15.0	14.1	12.9	14.2	--	--
Prevail	14.9	14.1	13.7	15.5	14.0	13.0	13.7	14.1	14.1
Prosper	14.4	13.8	13.9	14.4	12.8	12.6	13.9	13.9	13.7
RB07	15.4	14.0	14.4	15.7	14.6	13.5	14.0	14.8	14.6
Redstone	13.4	--	--	15.4	13.9	12.7	13.7	--	--
Rollag	16.2	13.8	15.4	16.4	14.7	14.0	15.4	14.9	15.1
Samson	14.7	14.0	14.1	--	--	12.5	--	--	--
Select	14.7	14.0	14.2	16.3	--	--	--	14.5	--
Steele-ND	15.6	14.6	14.8	16.6	--	--	15.3	14.8	--
SY605 CL	15.4	13.5	15.0	16.8	14.5	--	--	15.7	--
SY Ingmar	15.0	14.4	14.8	16.3	15.3	13.9	14.9	15.1	15.0
SY Rowyn	14.3	14.4	13.7	15.1	14.0	12.7	13.6	14.6	14.1

Table 6 *continued*

Variety	Carrington	Casselton	Prosper	Dickinson	Hettinger	Langdon	Minot	Williston	State Avg.
	--(%)--								
SY Soren	15.1	14.4	15.0	16.1	15.1	13.8	14.8	15.4	15.0
SY Tyra	--	15.0	14.7	15.1	13.3	--	--	14.6	--
SY Valda	14.8	13.9	14.1	15.9	13.5	13.0	13.7	15.8	14.3
Vantage	15.4	14.2	15.8	--	--	14.7	15.9	16.8	--
Velva	14.0	13.8	14.7	15.2	13.6	--	14.6	14.7	14.4
WB-Digger	--	14.4	13.6	15.6	--	--	--	--	--
WB-Mayville	16.0	14.3	15.1	15.5	14.7	13.9	14.3	15.9	15.0
WB9507	14.0	13.8	13.7	15.2	12.4	11.9	14.1	14.2	13.7
WB9653	14.9	13.7	13.5	15.2	13.1	12.5	--	--	--
Mean	14.7	14.2	14.4	15.6	14.0	13.1	14.4	14.8	14.4
CV %	3.1	6.2	1.8	1.7	3.9	2.4	3.6	7.2	--
LSD 0.05	0.6			0.5	0.8	0.4	0.7	1.5	--
LSD 0.10	0.5	1.0	3.2	0.5	0.6	0.4	0.6	1.2	--

Table 7. Test weight of hard red spring wheat varieties grown at eight locations in North Dakota, 2015.

Variety	Carrington	Casselton	Prosper	Dickinson	Hettinger	Langdon	Minot	Williston	State Avg.
	---(lb/bu)---								
Advance	62.7	60.0	58.2	57.0	62.5	61.9	60.1	59.2	60.2
Alpine	62.0	--	--	--	--	61.0	57.5	--	--
Alsen	62.4	61.0	58.5	--	--	--	--	59.7	--
Barlow	62.5	61.0	58.7	58.4	63.1	62.1	57.5	60.1	60.4
Bolles	61.3	60.2	58.4	55.5	60.8	60.9	59.1	57.4	59.2
Brennan	62.3	59.4	57.5	--	--	--	59.5	58.5	--
Duclair	--	58.4	56.3	54.1	59.6	--	56.9	56.9	--
Elgin-ND	61.2	59.8	57.2	55.4	61.8	60.8	57.5	58.5	59.0
Faller	61.0	59.2	56.8	52.8	61.6	60.5	58.9	57.7	58.6
Focus	62.8	61.4	59.5	--	62.3	62.4	--	59.1	--
Forefront	62.2	61.2	59.8	54.5	61.6	62.7	60.3	57.9	60.0
Glenn	63.3	63.3	60.9	57.3	63.5	64.5	58.4	61.0	61.5
HRS 3361	61.5	--	--	55.7	60.7	58.6	58.9	57.3	--
HRS 3378	62.3	--	--	60.1	63.1	61.7	58.9	58.8	--
HRS 3419	60.8	--	--	56.1	60.9	60.6	59.5	56.2	--
HRS 3530	61.6	--	--	53.1	61.8	60.3	59.1	57.9	--
LCS Albany	60.7	58.4	57.3	--	61.1	60.0	--	57.2	--
LCS Breakaway	62.7	61.0	59.6	59.6	62.3	62.2	58.4	59.6	60.7
LCS Iguacu	62.0	60.5	58.7	60.0	61.8	61.9	61.1	58.2	60.5
LCS Nitro	60.4	57.9	56.1	56.8	60.8	60.5	59.8	56.1	58.6
LCS Powerplay	62.9	60.1	57.9	58.3	61.9	61.2	59.4	59.0	60.1
LCS Pro	--	60.6	57.9	59.7	62.6	62.0	--	58.7	--

Table 7 *continued*

Variety	Carrington	Casselton	Prosper	Dickinson	Hettinger	Langdon	Minot	Williston	State Avg.
	--(lb/bu)--								
Linkert	61.6	59.5	58.1	58.6	61.5	61.1	59.9	58.1	59.8
Mott	61.8	60.7	58.2	55.9	61.5	--	59.9	58.0	--
MS Chevelle	61.7	58.2	56.3	57.1	61.4	60.5	57.5	58.6	58.9
MS Stingray	59.9	56.9	54.7	51.7	60.0	56.6	58.0	57.2	56.9
ND901CL Plus	60.8	60.2	58.3	59.2	60.8	--	58.3	59.4	--
Norden	63.1	62.0	59.3	58.9	62.6	61.7	59.7	59.8	60.9
Prestige	61.4	--	--	56.5	60.1	61.2	58.3	--	--
Prevail	61.9	60.0	57.9	55.3	61.1	61.7	59.5	57.3	59.3
Prosper	61.4	59.5	57.2	54.7	61.2	60.4	58.7	58.0	58.9
RB07	62.0	59.8	56.9	57.7	60.4	61.5	59.1	58.2	59.5
Redstone	60.6	--	--	57.1	61.0	61.2	58.9	--	--
Rollag	62.2	61.5	59.2	59.4	62.3	61.5	60.1	58.7	60.6
Samson	60.9	57.5	55.7	--	--	60.4	--	--	--
Select	63.1	61.2	56.9	61.1	--	--	--	59.6	--
Steele-ND	62.9	60.2	59.1	59.1	--	--	59.0	58.4	--
SY605 CL	62.3	60.9	59.2	59.5	62.2	--	59.9	59.0	--
SY Ingmar	62.2	61.1	58.2	59.2	62.5	61.5	58.6	59.4	60.3
SY Rowyn	61.7	59.1	57.2	55.9	61.3	61.8	60.0	57.8	59.4
SY Soren	61.3	59.2	57.3	58.6	62.3	61.8	60.4	58.3	59.9
SY Tyra	--	--	--	57.5	60.8	--	--	60.0	--
SY Valda	61.7	60.1	57.9	58.1	62.3	60.7	59.8	58.3	59.9
Vantage	61.7	62.1	60.6	60.2	--	63.1	60.4	59.3	61.1
Velva	59.9	58.9	54.3	54.0	60.0	--	56.5	58.9	--
WB Digger	--	58.6	56.2	57.0	--	--	--	--	--
WB Mayville	61.3	59.5	57.4	58.1	60.7	60.3	58.2	58.9	59.3
WB9507	59.1	56.9	53.9	54.6	59.1	57.7	58.1	57.0	57.1
WB9653	62.2	58.0	56.2	54.6	61.9	58.1	--	--	--
Mean	61.7	59.9	57.7	57.1	61.5	61.2	58.9	58.4	58.7
CV %	1.0	1.0	1.2	2.4	0.7	0.9	1.4	1.0	--
LSD 0.05	0.9			1.9	0.6	0.8	1.1	0.8	--
LSD 0.10	0.7	0.7	0.8	1.6	0.5	0.6	0.9	0.7	--

North Dakota Durum Wheat Variety Trial Results for 2015 and Selection Guide

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Durum was planted on 1.1 million acres in North Dakota in 2015, up slightly from the 820,000 acres planted in 2014. The average yield is estimated at 36 bushels per acre, down slightly from last year. The most commonly grown varieties in 2015 and the percent of the acreage they occupied were Divide (29.5), Alkabo (20.9), Tioga (10.1), Mountrail (7.6), Lebsock (4.9), Grenora (4.3) and Carpio (2.2).

Durum varieties are tested each year at multiple sites throughout North Dakota. The relative performance of these varieties is presented in table form. Variety performance data are used to provide recommendations to producers. Some varieties may not be included in the tables due to insufficient testing or lack of seed availability, or they offer no yield or disease advantage over similar varieties. Yield is reported at 13.5 percent moisture, while protein content is reported at 12 percent moisture.

The agronomic data presented in this publication are from replicated research plots using experimental designs that enable the use of statistical analysis. These analyses enable the reader to determine, at a predetermined level of confidence, if the differences observed among varieties are reliable or if they might be due to error inherent in the experimental process. The LSD (least significant difference) numbers beneath the columns in tables are derived from these statistical analyses and only apply to the numbers in the column in which they appear. If the difference between two varieties exceeds the LSD value, it means that with 95 or 90 percent confidence (LSD probability 0.05 or 0.10), the higher-yielding variety has a significant yield advantage. When the difference between two varieties is less than the LSD value, no significant difference occurs between those two varieties under those growing conditions.

The abbreviation NS is used to indicate no significant difference for that trait among any of the varieties at the 95 or 90 percent level of confidence. The CV is a measure of variability in the trial. The CV stands for coefficient of variation and is expressed as a percentage. Large CVs mean a large amount of variation that could not be attributed to differences in the varieties.

Presentation of data for the entries tested does not imply approval or endorsement by the authors or agencies conducting the test. North Dakota State University approves the reproduction of any table in the publication only if no portion is deleted, appropriate footnotes are given and the order of the data is not rearranged. Additional data from county sites are available from each Research Extension Center at www.ag.ndsu.edu/varietytrials/durum. Use data from multiple locations and years when selecting a variety.

Table 1. Descriptions and agronomic traits of durum wheat varieties grown in North Dakota, 2015.

						Reaction to Disease[4]				
Variety	Agent or Origin[1]	Year Released	Height (inches)	Straw Strength[2]	Days to Heading[3]	Stem Rust	Leaf Rust	Foliar Disease	Bact. Leaf Streak	Head Scab
AC Commander	Can.	2002	32	5	68	R	R	MS	NA	NA
AC Napoleon	Can.	2001	40	5	68	R	R	S	NA	NA
AC Navigator	Can.	1999	32	5	66	R	R	M	NA	S
Alkabo	ND	2005	36	2	67	R	R	M	MS	MS
Alzada[5]	WB	2004	30	6	63	R	R	S	NA	VS
Belzer	ND	1997	39	5	66	R	R	M	NA	MR
Ben	ND	1996	39	3	67	R	R	MR	MS	S[6]
Carpio	ND	2012	37	5	69	R	R	M	MS/S	M
CDC Verona	Can.	2010	38	4	69	R	R	MR	NA	S
DG Max	DGP	2008	38	5	66	R	MR	MR	NA	MS
DG Star	DGP	2007	37	4	64	R	R	M	NA	NA
Dilse	ND	2002	37	5	68	R	R	M	M	MS
Divide	ND	2005	38	5	68	R	R	M	MS/S	MR
Grande D'Oro	WB/DGP	2005	37	4	68	R	R	M	NA	NA
Grenora	ND	2005	35	5	67	R	R	M	MS/S	MS
Joppa	ND	2013	39	5	68	R	R	M	MS	MS
Kyle	Can.	1984	39	7	68	R	MR	M	NA	NA
Lebsock	ND	1999	37	3	67	R	R	M	MS	MS
Maier	ND	1998	37	5	67	R	R	M	NA	S[6]
Mountrail	ND	1998	37	5	68	R	R	M	MS	S[6]
MS-Dart[7]	**Meridian**	**2015**	**37**	**5**	**68**	**NA**	**NA**	**NA**	**NA**	**NA**
Pierce	ND	2001	38	5	67	R	R	MS	MS	S
Plaza	ND	1999	29	7	68	R	R	M	NA	MS
Rugby	ND	1973	38	5	64	R	R	MR	NA	S[6]
Silver	MT	2012	31	5	62	NA	NA	NA	NA	NA
Strongfield	Can.	2004	37	6	68	R	R	MS	NA	S
Tioga	ND	2010	39	4	68	R	R	M	MS	MS
VT Peak	Viterra	2010	37	6	68	NA	NA	NA	NA	NA
Wales	WB	2008	36	3	67	R	R	M	NA	S[6]
WB-Belfield	WB	2011	30	2	62	R	R	S	NA	S
Westhope	WB	2009	36	3	67	R	R	MS	NA	S

[1] Refers to agent or developer: Can. = Agriculture Canada, WB = Westbred, ND = North Dakota State University, DGP = Dakota Growers Pasta, Montana State = MT.

[2] Straw Strength = 1-9 scale, with 1 the strongest and 9 the weakest. Based on recent data. These values may change as more data become available.

[3] Days to Heading = the number of days from planting to head emergence from the boot. Averaged from several locations and years.

[4] R = resistant; MR = moderately resistant; M = intermediate; MS = moderately susceptible; S = susceptible; VS = very susceptible; NA = Not adequately tested. Foliar Disease = reaction to tan spot and septoria leaf spot complex.

[5] Alzada has a disease-resistance package that makes it more adapted to drier growing conditions (for example, western North Dakota).

[6] Indicates yields and/or quality often have been higher than would be expected based on visual symptoms. NA = Not adequately tested.

[7] Bold indicates newly released in 2015.

Table 2. Durum wheat variety quality descriptions, milling and processing data averaged for five years (2009-2014) from drill strips (33 locations/year).

Variety	Test Weight (lb/bu)	Vitreous Kernels (%)	Large Kernels (%)	Falling Number (sec)	Wheat Protein[1] (%)	Gluten Index[2]	Pasta Color[3] (1-12)	Spaghetti Firmness (g-cm)	Overall Quality[4]
AC Commander	59.5	94	52	477	14.0	90	9.0	5.7	Good
AC Navigator	60.0	95	50	462	14.3	69	8.8	5.8	Good
Alkabo	60.8	88	51	385	13.8	51	8.9	5.1	Good
Alzada[5]	59.1	93	62	451	14.2	90	8.5	5.7	Good
Carpio	60.9	83	58	433	13.8	92	8.9	5.5	Good
Divide	60.5	89	52	428	14.1	76	8.7	5.2	Good
Grenora	60.1	93	51	404	13.8	67	8.8	5.4	Good
Joppa	60.5	88	44	391	13.5	84	9.1	5.1	Good
Lebsock[6]	60.3	93	42	411	14.5	42	8.5	5.5	Good
Maier	60.0	93	46	380	14.7	55	8.7	5.5	Good
Mountrail	59.7	91	42	396	14.0	22	8.2	4.7	Average
Pierce	60.7	95	42	391	14.2	63	8.7	5.4	Good
Strongfield	60.1	89	52	406	14.7	67	8.6	5.5	Good
Tioga	60.5	89	57	389	13.8	77	8.6	5.4	Good
Average	60.2	91	50	415	14.1	68	8.7	5.4	
For all numbered footnotes, refer to bottom of Table 3.									

Table 3. Durum wheat variety quality descriptions, milling and processing data for 2014 at seven locations in the drill strips.

Variety	Test Weight (lb/bu)	Vitreous Kernels (%)	Large Kernels (%)	Falling Number (sec)	Wheat Protein[1] (%)	Gluten Index[2]	Pasta Color[3] (1-12)	Spaghetti Firmness (g-cm)	Overall Quality[4]
AC Commander	60.1	88	73	354	12.4	87	8.5	4.0	Good
AC Navigator	60.7	89	69	347	12.9	60	8.4	4.0	Good
Alkabo	60.9	74	68	266	12.7	38	8.4	3.4	Average
Alzada[5]	59.5	86	81	330	12.7	82	7.9	3.7	Average
Carpio	60.9	65	72	335	12.1	91	8.4	3.6	Good
Divide	60.7	76	67	320	12.4	70	8.4	3.4	Good
Grenora	60.4	87	64	282	12.8	66	8.4	3.9	Good
Joppa	60.9	72	60	270	12.0	77	8.6	3.4	Good
Maier	60.7	85	66	253	13.0	41	8.3	3.6	Good
Mountrail	60.7	77	61	297	12.4	4	7.7	3.2	Fair
Pierce	61.2	90	59	281	12.8	51	8.2	3.5	Good
Strongfield	60.0	77	73	254	12.6	56	7.8	3.5	Average
Tioga	59.9	78	66	274	12.8	72	8.1	3.8	Good
Average	60.5	80	68	297	12.6	61	8.2	3.6	

[1] Wheat protein is reported on a 12 percent moisture basis.
[2] Gluten index is unitless. Numbers less than 15 = very weak and greater than 80 = very strong gluten proteins.
[3] Pasta Color Score: Higher number indicates better color, with 8.5+ typically considered good.
[4] Overall Quality is determined based on agronomic, milling and spaghetti processing performance.
[5] Alzada has good quality when grown in environments where it is adapted. Low test weight can affect quality in some environments.
[6] Average of 30 drill strips instead of 33 for other varieties in Table 1. Average of four locations instead of seven for other varieties in Table 2.

Table 4. Yield of durum wheat varieties at six Research Extension Centers in North Dakota, 2013-2015.

	Carrington		Langdon		Dickinson		Hettinger		Minot		Williston*		Average	
Variety	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**	**2015**	**3 Yr.**
	(bu/a)													
AC Commander	44.3	53.7	58.7	80.5	63.5	57.2	59.7	57.7	71.0	64.8	24.7	36.4	53.7	58.4
AC Navigator	43.6	53.4	52.0	74.9	61.4	54.8	56.2	54.5	52.3	54.1	27.4	35.5	48.8	54.5
Alkabo	41.6	54.7	70.0	84.2	68.2	60.8	70.0	67.7	80.8	71.2	28.1	36.7	59.8	62.6
Alzada	41.9	52.5	60.7	71.2	59.6	50.5	41.7	44.5	46.4	52.8	26.5	34.1	46.1	50.9
Ben	46.1	53.3	71.8	80.6	68.1	58.8	60.5	62.2	70.7	66.6	23.7	35.2	56.8	59.5
Carpio	52.4	59.6	84.8	89.7	67.4	59.4	71.6	67.5	74.3	69.1	29.9	36.3	63.4	63.6
CDC Verona	50.8	56.9	69.8	83.0	59.0	56.4	66.5	67.1	62.1	61.5	28.7	32.9	56.2	59.6
Divide	48.6	54.9	77.5	85.2	73.7	63.8	82.6	73.1	77.3	68.3	27.2	35.0	64.5	63.4
Grenora	50.9	59.1	76.6	86.8	75.0	62.7	76.3	65.7	74.0	67.9	32.2	37.3	64.2	63.3
Joppa	46.1	58.1	82.1	90.0	69.1	63.5	78.8	71.9	77.3	69.6	26.8	39.9	63.4	65.5
Lebsock	47.2	58.0	72.3	80.4	68.2	57.7	60.6	60.6	77.4	68.8	24.0	32.5	58.3	59.7
Maier	39.6	54.6	73.7	82.5	72.0	61.3	59.3	56.0	72.8	65.9	--	--	--	--
Mountrail	50.5	58.2	80.3	90.0	68.4	65.4	76.6	71.7	78.1	70.0	28.2	37.0	63.7	65.4
MS-Dart	51.0	--	--	--	--	--	73.5	--	64.1	--	--	--	--	--
Pierce	46.8	55.4	73.1	85.4	71.4	59.1	55.3	55.6	79.4	69.0	26.0	36.4	58.7	60.2
Rugby	40.8	52.0	66.1	75.3	66.3	56.5	59.3	61.8	63.9	62.6	22.1	32.0	53.1	56.7
Silver	36.2	--	--	--	--	--		--	--	--	22.9	--	--	--
Strongfield	46.6	51.1	64.9	84.1	63.9	57.9	70.7	66.3	65.5	63.3	25.3	33.7	56.2	59.4
Tioga	45.6	57.6	75.5	84.8	74.7	63.5	81.5	73.7	73.3	69.2	28.5	39.8	63.2	64.8
VT Peak	48.8	55.7	75.3	84.3	--	--	79.2	74.3	73.4	67.8	29.9	38.7	--	--
Mean	46.0	55.5	71.4	82.9	67.6	59.4	67.4	64.0	70.2	65.7	26.8	35.8	58.2	60.6
CV %	10.4	--	7.5	--	6.3	--	6.2	--	9.0	--	18.7	--	--	--
LSD 0.05	8.1	--	7.6	--	6.1	--	6.4	--	10.3	--	7.1	--	--	--
LSD 0.10	6.8	--	6.4	--	5.1	--	5.3	--	8.8	--	6.0	--	--	--

* Plots with 30 percent stress or higher were averaged from other plots within the same variety. Yields were adjusted to stands of 100 percent.

Table 5. Test weight and protein of durum wheat varieties at six Research Extension Centers in North Dakota, 2015.

	Carrington		Langdon		Dickinson		Hettinger		Minot		Williston		Average	
Variety	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein
	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%
AC Commander	58.1	14.3	57.7	13.4	54.4	15.9	56.3	13.7	58.9	14.1	58.5	19.7	57.3	15.2
AC Navigator	59.6	14.2	58.0	13.5	56.1	16.1	57.3	14.0	58.6	14.4	59.8	17.7	58.2	15.0
Alkabo	60.9	13.2	61.6	12.3	57.0	16.0	59.2	13.0	62.3	12.7	59.5	17.6	60.1	14.1
Alzada	59.0	14.9	57.6	13.7	54.8	16.3	53.9	14.1	57.9	14.4	58.4	18.1	56.9	15.3
Ben	61.6	13.8	61.7	12.9	56.8	16.3	58.0	13.6	61.3	13.8	59.2	19.8	59.8	15.0
Carpio	60.8	13.8	61.3	12.4	57.4	16.8	59.3	13.8	62.5	12.2	58.3	19.1	59.9	14.7
CDC Verona	59.5	14.8	59.8	14.2	53.9	17.8	57.2	14.5	59.0	15.3	58.8	19.9	58.0	16.1
Divide	60.5	14.5	61.0	13.6	56.9	17.0	59.5	13.2	61.8	13.8	59.1	17.5	59.8	14.9
Grenora	61.1	14.0	61.3	13.2	57.1	16.0	57.7	13.8	61.9	12.5	58.6	17.6	59.6	14.5
Joppa	60.9	13.6	61.3	12.2	55.7	16.3	58.1	12.7	61.8	13.0	59.1	19.6	59.5	14.6
Lebsock	61.8	13.7	61.7	13.2	56.1	16.4	58.7	14.0	62.5	14.1	58.7	18.3	59.9	15.0
Maier	60.2	13.1	61.5	13.9	56.2	16.9	57.6	14.7	61.5	14.9	--	--	--	--
Mountrail	60.6	13.4	60.7	12.0	54.7	16.5	57.4	13.1	61.2	12.5	58.0	18.0	58.8	14.3
MS-Dart	60.5	13.4	--	--	--	--	58.9	12.4	61.1	13.6	--	--	--	--
Pierce	61.7	13.2	61.9	12.7	57.1	16.2	57.8	13.5	62.3	13.3	58.9	18.7	60.0	14.6
Rugby	61.6	13.4	61.4	12.7	57.5	16.7	57.6	13.6	62.0	13.6	58.4	20.5	59.8	15.1
Silver	59.9	14.8	--	--	--	--	--	--	--	--	57.6	18.0	--	--
Strongfield	59.7	15.4	59.6	14.9	52.9	17.8	59.1	14.7	59.7	15.0	59.1	18.4	58.4	16.0
Tioga	60.8	14.5	61.5	13.0	57.4	16.2	59.0	13.6	61.6	13.8	59.2	16.6	59.9	14.6
VT Peak	61.9	14.0	62.5	13.1	--	--	60.5	13.1	62.6	13.3	59.4	19.1	--	--
Mean	60.5	14.0	60.7	13.2	56.0	16.5	58.1	13.6	61.1	13.7	58.8	18.6	59.2	14.9
CV %	0.8	3.2	1.0	3.8	2.0	2.3	0.9	3.2	1.1	5.0	1.0	7.2	--	--
LSD 0.05	0.7	0.6	0.9	0.7	1.6	0.8	0.7	0.6	1.1	1.1	0.8	1.9	--	--
LSD 0.10	0.6	0.5	0.7	0.6	1.3	0.6	0.6	0.5	0.9	0.9	0.7	1.6	--	--

NOTES

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