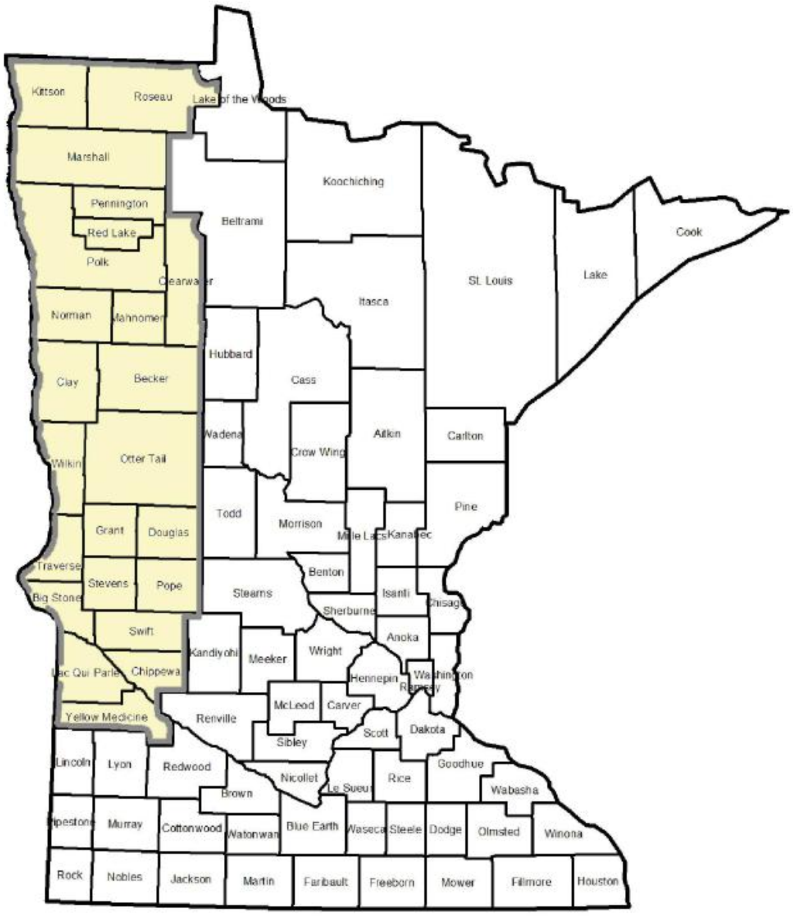
On-Farm Cropping Trials Northwest & West Central Minnesota and 2019 Minnesota Wheat Research Review



University of Minnesota Extension
Driven to Discover℠

Minnesota Wheat Research & Promotion Council

Minnesota Soybean Research & Promotion Council

2019 On-Farm Trials | UMN Extension 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: Dr. Angie Peltier, Extension Educator, Extension Regional Office, Crookston, apeltier@umn.edu; Dr. Jared Goplen, Extension Educator, Extension Regional Office, Morris, gople007@umn.edu; Dr. Seth Naeve, Associate Professor and Extension Agronomist, St. Paul, naeve002@umn.edu.

These projects were made possible thanks to the hard work of many people. This includes farmers, County and Regional Extension Educators, and specialists who conducted or cooperated with these trials.

Previous On-Farm Cropping Trials booklets can be found at:
http://www.extension.umn.edu/agriculture/crops-research/ and http://mnwheat.org/wheat-research-reports/

2019 Wheat Research Review

In 2019 the Minnesota Wheat Research and Promotion Council allocated about $804,151 of the total $1,676,764 check-off income to wheat research projects. The 2019 reports from these projects are printed in this book.

Wheat Research Project Funding Process:
Each year in September, the Minnesota Wheat Research and Promotion Council requests wheat research pre-proposals from researchers in Minnesota, North Dakota and South Dakota. Researchers are given an opportunity to meet with a small group of wheat growers to get feedback on project ideas. About 12 project pre-proposals are reviewed at the Prairie Grains Conference by the Research Committee of the Minnesota Wheat Council. This Committee listens to presentations from each researcher and then the Committee determines which ones should be asked to submit full proposals.

The proposals are evaluated on the following criteria: 1) Is it a priority for growers? 2) Impact on Profitability? 3) Probability of Success? 4) Cost v.s. Benefit?

At the end of January the committee meets once again to review the full proposals and make funding recommendations to the Minnesota Wheat Research and Promotion Council.

In addition to the projects reports being printed and distributed through this booklet, some of the project researchers give oral presentations at the Prairie Grains Conference, Best of the Best Workshops and Small Grains Updates - Wheat, Soybean and Corn. Also, some of the projects are reported in the Prairie Grains Magazine. The Minnesota Wheat Research Committee is made up of wheat growers, agronomists, unbias researchers and industry representatives.

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

Table of Contents

On-Farm Cropping Trials For Northwest & West Central Minnesota

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

2019 Statewide Soybean Crop & Pest Survey

Cooperators: Minnesota Soybean Research & Promotion Council, NDSU IPM Survey

Purpose of Study:
The soybean crop and pest survey was designed to provide in-season data about regional pest pressure to assist farmers and crop consultants in making pest management decisions. 2019 growing season was the fifth that UMN Extension undertook this MSR&PC-sponsored survey. The survey provided data about regional pest pressure. This data was shared with farmers to assist them in making pest management decisions. This project was coordinated with a similar survey undertaken by the

Results:
Field surveys of randomly selected Minnesota soybean fields were initiated on July 5. A total of 762 fields were surveyed from May 31 through August 5 in MN and ND (Fig 1).

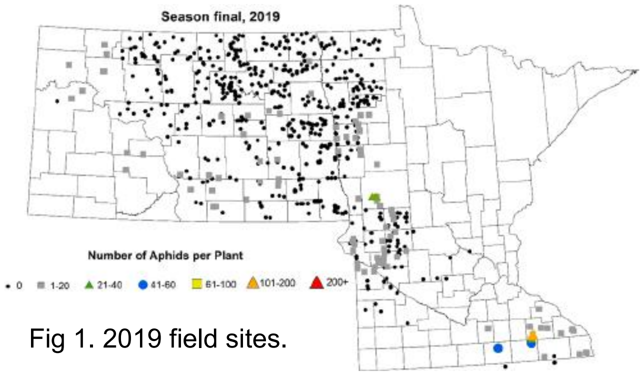


Fig 1. 2019 field sites.

While MN scouts informally visited random soybean fields starting in early June, later than typical planting and delayed crop development was common throughout the southern four-fifths of Minnesota (Fig 2).

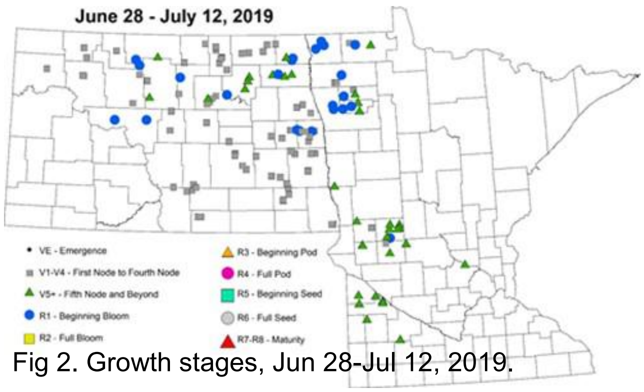


Fig 2. Growth stages, Jun 28-Jul 12, 2019.

Formal soybean field surveys in Minnesota were initiated after Independence Day, lasting until mid-August. A total of 267 formal field visits occurred in Minnesota in 2019.

Scouts also surveyed for both grasshopper and two-spotted spider mite infestations on the edge and inside of fields, periodically finding edge-of-field spider mite infestations (Fig 3).

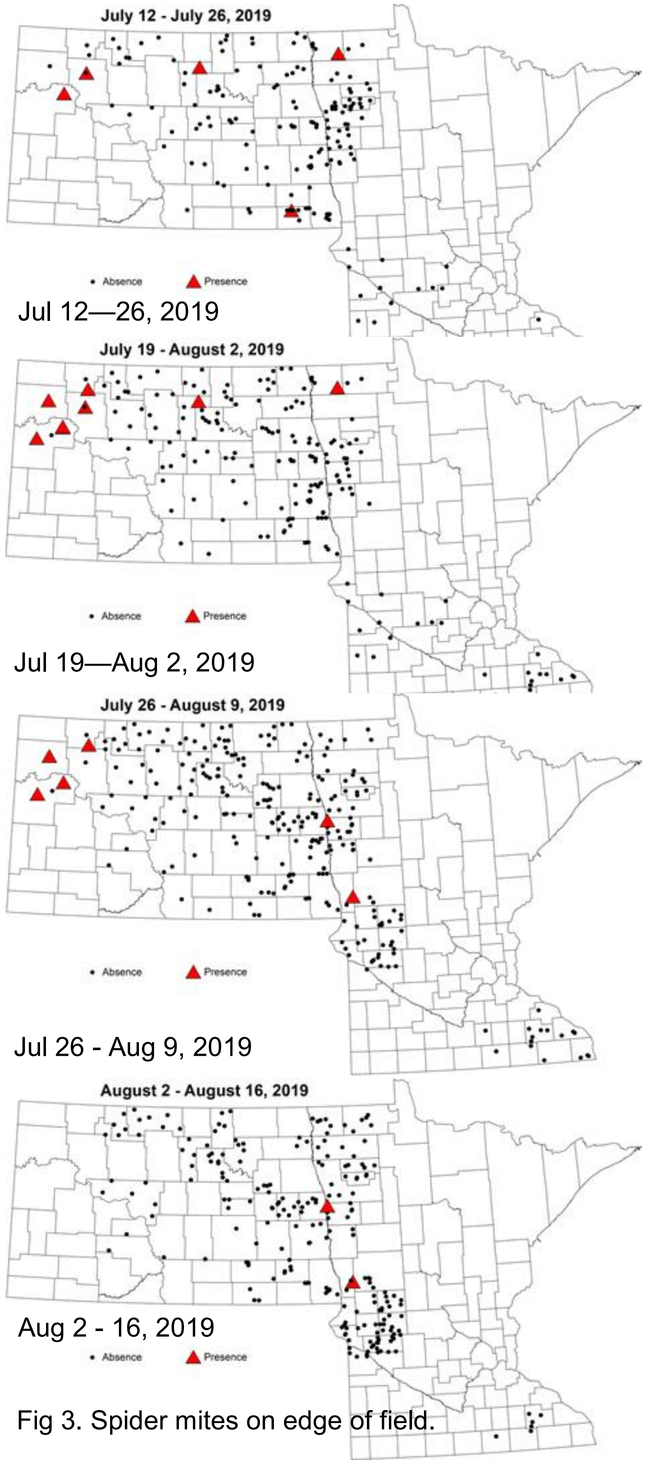


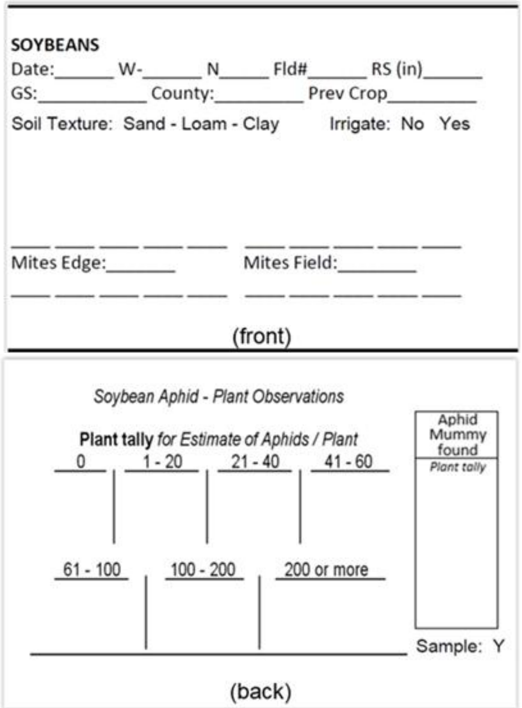
Fig 3. Spider mites on edge of field.

For Additional Information:
Angie Peltier, Jared Goplen

Funding Provided by:
Minnesota Soybean Research & Promotion Council

Soybean Crop Survey [continued] - statewide

A primary focus of the survey was documenting soybean aphid population dynamics. Surveys used a protocol based on the "Speed Scouting" procedure 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 from randomly selected soybean fields; plants with aphids were noted and used to determine the percentage of plants with at least one aphid. Aphid population densities on individual plants were visually estimated and tallied on field cards (Figure 4) by the numerical range estimated.


SOYBEANS
Date:______ W-______ N_____ Fld#______ RS (in)______
GS:___________ County:_________ Prev Crop_________
Soil Texture: Sand - Loam - Clay   Irrigate: No Yes

Mites Edge:_______   Mites Field:________

(front)

Soybean Aphid - Plant Observations

Plant tally *for Estimate of Aphids / Plant*

0 | 1 - 20 | 21 - 40 | 41 - 60

61 - 100 | 100 - 200 | 200 or more

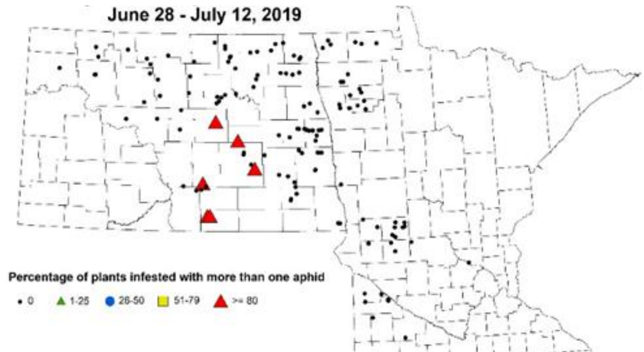
Aphid Mummy found
Plant tally

Sample: Y

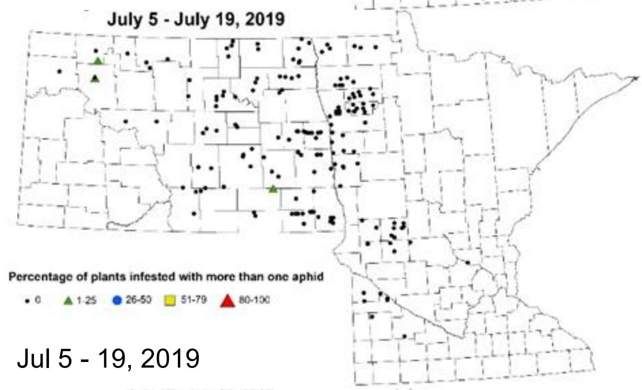
(back)

Figure 4. Pocket-sized card used to scout soybean fields for crop growth stage and spider mites and 31 plants within each field for soybean aphid population estimates.

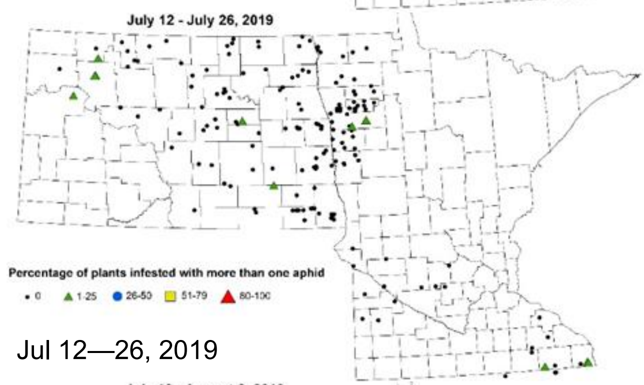
Although incidence and severity remained low, detectable aphid infestations were found in SE & S central (C) North Dakota beginning between June 28 and July 12 and in NW and SE Minnesota between July 19 and 26 (Figures 5 and 6). By August 9, individual fields with as high as 100% infested plants were found in WC and SE MN but densities averaged less than 20 aphids per plant. Aphid densities reached as high as 100 aphids per plant in a field in SE Minnesota by August 16 (Figure 5).



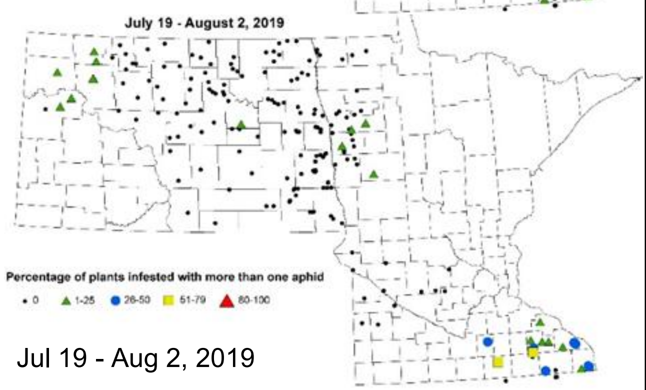
Jun 28 - Jul 12, 2019



Jul 5 - 19, 2019



Jul 12—26, 2019

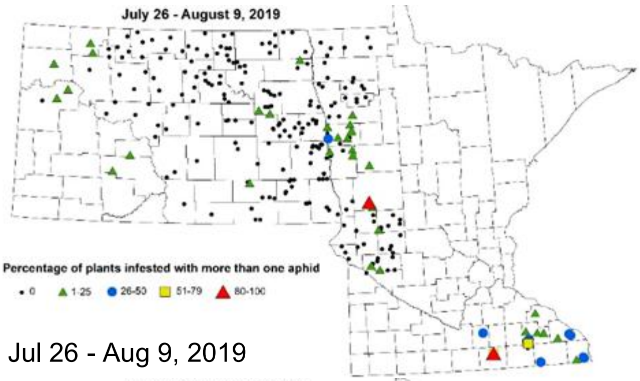


Jul 19 - Aug 2, 2019

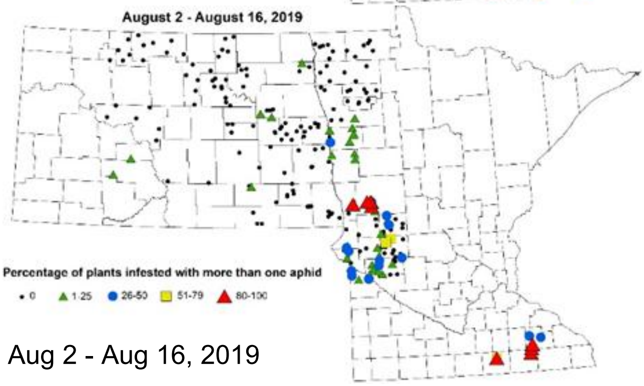
Figure 5. Percentage of surveyed soybean plants with at least one soybean aphid.

For Additional Information:
Angie Peltier, Jared Goplen

Funding Provided by:
Minnesota Soybean Research & Promotion Council

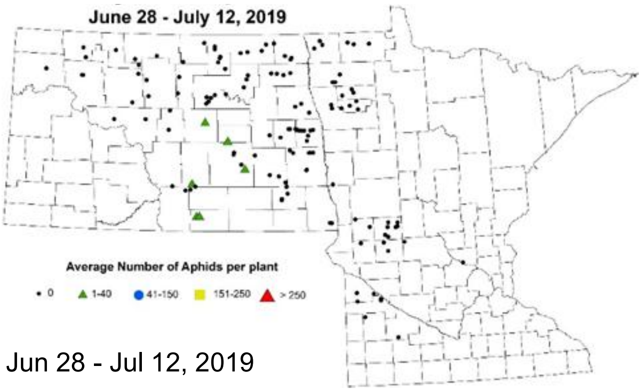


Jul 26 - Aug 9, 2019



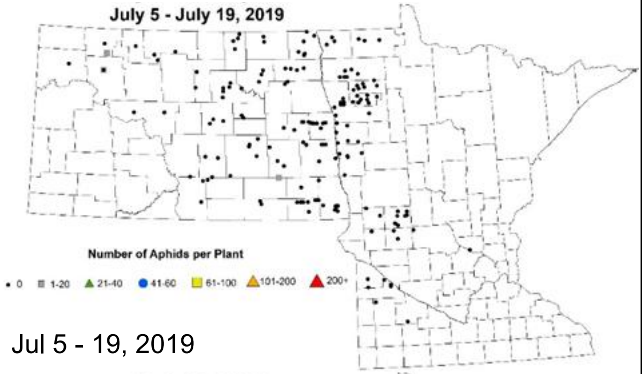
Aug 2 - Aug 16, 2019

Figure 5. Percentage of surveyed soybean plants with at least one soybean aphid.

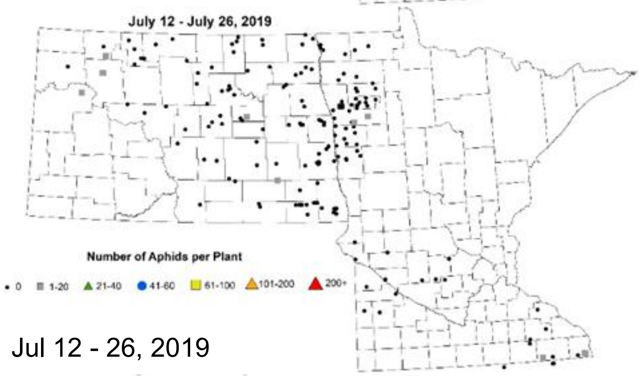


Jun 28 - Jul 12, 2019

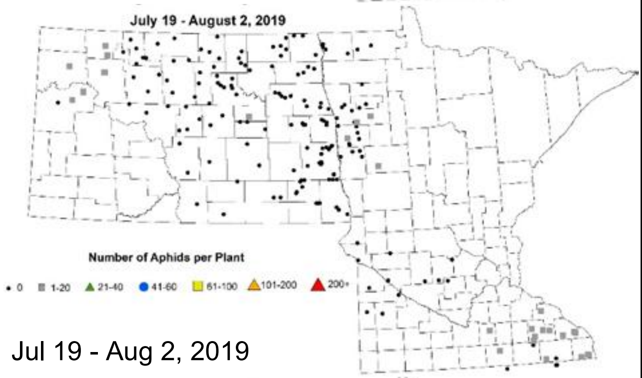
Figure 6. Average number of soybean aphids estimated per surveyed plant.



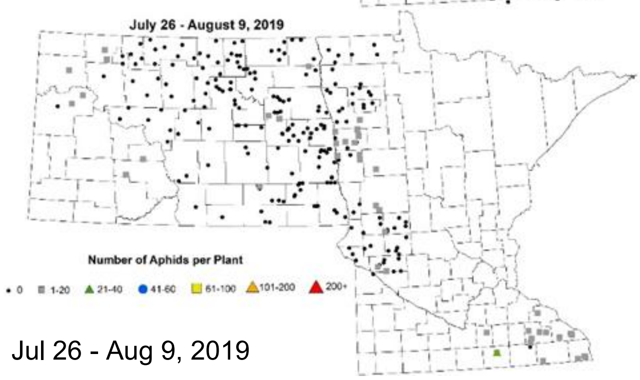
Jul 5 - 19, 2019



Jul 12 - 26, 2019



Jul 19 - Aug 2, 2019



Jul 26 - Aug 9, 2019

Figure 6. Average number of soybean aphids estimated per surveyed plant.

Insecticide costs can vary widely (Table 1). For example, per acre chemical costs for Warrior II (group 3A) costs between $2.37 and $4.74, while Sivanto Prime (group 4D) retails between $17.99 and $26.99. The economic benefit of scouting therefore cannot be overstated. Scouting can lead one to understand if aphid population densities in a field have reached all three aspects of the treatment threshold:

- More than 80% of plants are infested with aphids
- There is an average of 250 aphids per plant
- The aphid population is growing.

If plants have not yet reached the full seed or R6 growth stage and have met these three criteria, treatment prompt treatment with an insecticide can prevent economic injury. Conversely, understanding that aphids have not reached treatment thresholds can help to avoid unnecessary insecticide applications and preserve insecticide efficacy. Scouting and the use of economic thresholds can save a farmer between $9.12 and $35.49 per acre in insecticide and application costs.

The list of insecticides labeled for soybean aphid management have changed over time (Table 2). Insecticides have been widely used in soybean production, often without consideration of treatment thresholds, as ‘cheap and easy insurance’ when added to the spray tank when making post emergence herbicide or fungicide applications.

Soybean aphid populations resistant to insecticides in the pyrethroid class (3A) have rendered insecticides in this class largely ineffective. Others insecticides such as Transform, Sivanto and Sefina, in the 4C, 4D and 9D classes, respectively, have been labeled relatively recently. These three insecticides have a narrower control spectrum in that they only control insects with piercing/sucking mouthparts (hemipteran). This narrow spectrum can help preserve beneficial insects in treated fields but growers need to understand that they may also leave caterpillars, beetles and other defoliating insect pests untouched.

Additional information

- For additional information about biology, scouting and management of soybean aphid search “soybean aphid” on the University of Minnesota Extension website: https://extension.umn.edu/soybean-pest-management/soybean-aphid

- To download a paper speed scouting worksheet to print visit: https://www.ent.iastate.edu/soybeanresearch/content/extension

Alternatively, a smart phone app developed by University of Nebraska Extension is available free of charge on the Apple or Android app stores, by searching for “Aphid Speed Scout”.

Table 1. Insecticide products, groups, active ingredients, and per acre rates and prices at high and low application rates (Source: Robert Koch, UMN Extension entomologist)*

Product	Group(s)	Active ingredient(s)	Low rate (per acre)		High rate (per acre)	
			Rate	Price	Rate	Price
Chlorpyrofos 4E AG	1B	chlorpyrifos	8.0 oz	$2.48	32.0 oz	$9.92
Lorsban Advanced	1B	chlorpyrifos	8.0 oz	$2.88	32.0 oz	$11.52
Tundra EC	3A	bifenthrin	2.10 oz	$1.30	6.40 oz	$3.97
Warrior II	3A	lambda-cyhalothrin	0.96 oz	$2.37	1.92 oz	$4.74
Transform	4C	sulfoxaflor	0.75 oz	$5.53	1.0 oz	$7.37
Sivanto Prime	4D	flupyradifurone	7.0 oz	$17.99	10.5 oz	$26.99
Sefina	9D	pyropene	3.0 oz	$6.60	3.0 oz	$6.60
Endigo ZC	3A + 4A	lambda-cy + thiamethoxam	3.5 oz	$5.88	4.5 oz	$7.56
Cobalt Advanced	1B + 3A	chlorpyrifos + lambda-cy	6 oz	$2.34	38 oz	$14.82

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

For Additional Information:
Angie Peltier, Jared Goplen

Funding Provided by:
Minnesota Soybean Research & Promotion Council

Table 2. Insecticide groups, active ingredients and example products for management of soybean aphid (Source: Robert Koch, UMN Extension entomologist and Bruce Potter, Extension IPM specialist)*

Group	Common name	Individual a.i.	Formulated mixtures
1A=carbamate	Methomyl	Lannate	
1B=organophosphate	Acephate	Acephate	
1B=organophosphate	Chlorpyrofos	Chlorpyrofos, Govern, Hatchet, Lorsban Advanced, Nufos, Vulcan, Warhawk, Whirlwind, Yuma	Cobalt, Cobalt Advanced, Stallion, Match-Up, Tundra Supreme
1B=organophosphate	Dimethoate	Dimethoate	
3A=pyrethroid	Alpha-cypermethrin	Fastac	
3A=pyrethroid	Beta-cyflufthrin	Baythroid	Leverage
3A=pyrethroid	Bifentrin	Bifenture, Brigade, Discipline, Fanfare, Tundra, Sniper	Justice, Match-Up, Tundra Supreme, Brigadier, Swagger, Skyraider, Hero, Steed, Triple Crown
3A=pyrethroid	Cyflutrin	Tombstone	
3A=pyrethroid	Deltamethrin	Batallion, Delta Gold	
3A=pyrethroid	Esfenvalerate	Adjourn, Asana XL	
3A=pyrethroid	Gamma-cyhalothrin	Declare, Proaxis	Cobalt
3A=pyrethroid	Lambda-cyhalothrin	Grizzly Z, Lambda-Cy, LambdaStar, Lamcap, Province, Silencer VC, Taiga Z, Warrior II	Besiege, Cobalt Advanced, Double Take, Endigo, Seeker
3A=pyrethroid	Permethrin	Arctic	
3A=pyrethroid	Zeta-cypermethrin	Mustang Maxx, Respect	Hero, Stallion, Steed, Triple Crown
4A=neonicotinoid	Acetamiprid		Justice
4A=neonicotinoid	Chlothianidin	Belay	
4A=neonicotinoid	Imidocloprid	Admire Pro, Alias, Nuprid, Sherpa, Prey, Wrangler	Brigadier, Leverage, Skyraider, Swagger, Triple Crown
4A=neonicotinoid	Thiamethoxam		Endigo
4C=sulfoxamine	Sulfloxaflor	Closer, Transform	
4D=butenoloide	Flupyradifurone	Sivanto Prime	
9D=pyropene	afidopyropen	Sefina	

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

For Additional Information:
Angie Peltier, Jared Goplen

Funding Provided by:
Minnesota Soybean Research & Promotion Council

NOTES

2018 Soybean Cyst Nematode Survey — Minnesota

Cooperator: Multiple Minnesota farmers, crop advisors and land owners

Experimental Design: Fields were selected and samples were collected and submitted by participating farmers, crop advisors and land owners.

Purpose of Study: Soybean cyst nematode (SCN) is the most yield limiting pathogen in Minnesota and the U.S. SCN is responsible for an estimated 95.9 million bushel yield loss in the north central region (Bradley et al., 2017). Despite only recent infestations in NW MN counties, the northern Red River Valley is at risk for yield-damaging SCN populations for multiple reasons, including:

- SCN can complete several generations per year without causing overt above-ground symptoms.
- There were 3,564 more soybean fields and 328,964 more soybean acres in NW MN counties in 2016 than in 2012 (USDA-FSA, 2017).
- Growing soybean after soybean is has come into practice.
- Alkaline soils can support 3.8-fold higher SCN populations than more acidic soils (Pedersen et al., 2010).

Monitoring SCN population densities through periodic soil sampling is the best way to determine both whether a field is infested and how well SCN is being managed (Chen, 2011).

This project aimed to:

- educate regarding the importance of soil sampling for SCN detection and monitoring,
- encourage sampling by providing sample bags and complimentary sample analysis,
- create a geo-referenced map of sample results to better understand incidence and severity of SCN infestations and
- provide farmers with management recommendations based on SCN egg counts.

References

- Bradley, C. et al. 2015. Crop Protection Network. CPN-1018-15-W.
- Chen, S. (ed.) 2011. Soybean cyst nematode management guide. Regents of the University of Minnesota. Online.
- Pedersen, P. et al. 2010. Crop Science. 50: 1458-1464.
- USDA-FSA. 2017. FOIA request regarding soybean parcels and acreage in Clearwater, Kittson, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake and Roseau Counties enrolled in federal programs in 2012 and 2016.

Results: A total of 1,807 people were reached with 32 educational SCN programs (27 of which were in NW MN) during the duration of this project. Information about SCN and this sampling program were shared in eighteen newspapers and fifteen radio programs.

Samples submitted through this program originated from 28 Minnesota counties, with the majority of the 363 samples coming from the most newly infested northwest region (Figure 1). One sample submitted through this survey included the first infestation documented in Beltrami County. Fewer than half of the samples, concentrated in the northwest counties, had SCN population densities lower than the limit of detection of 50 eggs per 100 cubic centimeters of soil (small black circle, Figure 1).

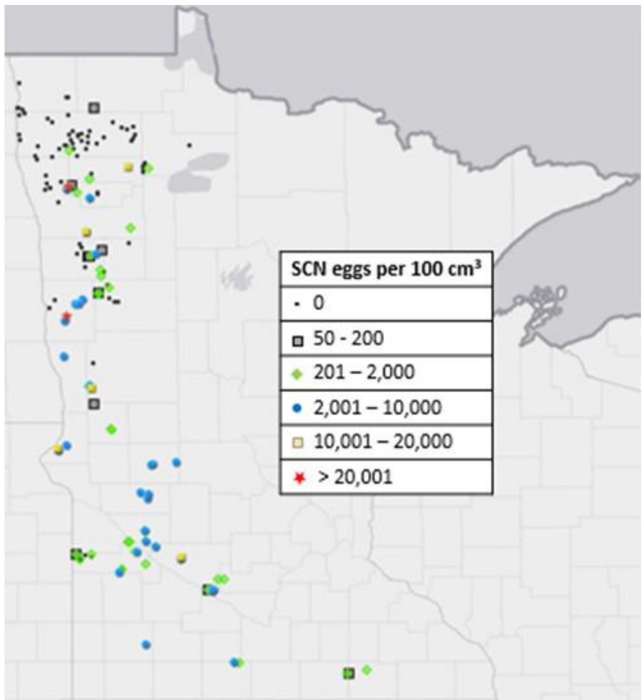


Figure 1. SCN population densities at locations sampled as part of the 2018 MSR&PC-sponsored SCN sampling program.

For Additional Information:
Angie Peltier, Jared Goplen, Seth Naeve

Project Funding Provided by:
Minnesota Soybean Research and Promotion Council

Among samples testing positive, 43% had population densities high enough to cause yield loss on SCN susceptible soybean varieties (diamond), 38% had densities high enough to cause yield loss on SCN resistant soybean varieties (outlined square), and 7% had densities so high that yields would be impacted enough that soybeans would not be recommended (square with shadow, Chen, 2011).

What program participants are saying: In a follow-up survey of those who submitted soil samples, only 8% of respondents had previously routinely submitted soil samples for SCN analysis and 44% had never done so. Twenty-six percent of respondents were not previously aware that their field(s) were infested with SCN and for 21% the SCN population density was much higher than anticipated. As a result of this SCN sampling program, 91% indicated that they were likely or extremely likely to continue to periodically collect SCN soil samples. As a result of learning their sample's SCN egg counts respondents plan to actively manage SCN, with 47% planning to plant an SCN resistant soybean variety and 29% planning to plant a crop that is not a host of SCN.

To see a larger, more detailed, color version of the sample results, visit:
https://blog-nwcrops.extension.umn.edu/2019/04/farmers-sampling-for-soybean-cyst.html

For additional information about soybean cyst nematode, visit University of Minnesota Extension's Soybean cyst nematode management guide online:
https://extension.umn.edu/soybean-pest-management/soybean-cyst-nematode-management-guide

For Additional Information:
Angie Peltier, Jared Goplen, Seth Naeve

Project Funding Provided by:
Minnesota Soybean Research and Promotion Council

PPO Inhibitor Effects on Soybean Canopy — NW MN

Cooperator: David Swanson; Bill Zurn; Corey Hanson; UMN Soybean Breeding Project (Lorenz)
Nearest Town: Kragnes, MN; Callaway, MN; Gary, MN
Soil Type: Wahpeton Silty Clay
Tillage: Conventional
Previous Crop: Corn (Kragnes and Gary), Soybean (Callaway)
Planting Date: May 18, 2019 (Callaway), May 31, 2019 (Gary), June 1 (Kragnes)
Spray Dates: June 26 (POST); July 18 (POST)
Row Width: 30 inch
Experimental Design: RCB, 10 treatments, 3 replications

Purpose of Study:

The use of PPO-inhibitor herbicides (Cobra, Flexstar, etc.) has increased in recent years as herbicide resistant weeds have become more problematic in NW Minnesota. One of the issues associated with the use of PPO-inhibitor herbicides is the level of soybean injury that can result from herbicide applications. University of Minnesota research in southern Minnesota has shown that soybean yields are not typically affected by PPO-inhibitor herbicides, especially with early-season applications. There has not been research determining the effect that PPO-inhibitor herbicides have when applied to plants suffering from the iron deficiency chlorosis (IDC) symptoms prevalent in NW Minnesota.

We established three sites to evaluate the effect that PPO-inhibitor herbicides have on soybean yield and injury at sites where soybeans may be stressed by IDC and SCN pressure. Early POST applications were made on June 26 and late POST applications on July 18 (Table 1).

Table 1. Herbicide treatment, groups, rate and application timing for 2019 PPO-inhibitor herbicide trials in farm fields near Callaway, Gary and Moorhead

#	Herbicide treatment	Herbicide Group	Application rate (per acre)	Application timing
1	Roundup PowerMax[vx]	9	32 fl oz	Early POST
	Roundup PowerMax[vx]	9	32 fl oz	Late POST
2	Cobra[vy]	14	12.5 fl oz	Early POST
	Roundup PowerMax	9	32 fl oz	Early POST
3	Flexstar GT 3.5[vz]	14, 9	2.68 pt	Early POST
4	Cobra[vy]	14	12.5 fl oz	Late POST
	Roundup PowerMax	9	32 fl oz	Late POST
5	Flexstar GT 3.5[vz]	14, 9	2.68 pt	Late POST
6	Cobra[vy]	14	12.5 fl oz	Early POST
	Roundup PowerMax	9	32 fl oz	Early POST
	Cobra[vy]	14	12.5 fl oz	Late POST
	Roundup PowerMax	9	32 fl oz	Late POST
7	Flexstar GT 3.5[vz]	14, 9	2.68 pt	Early POST
	Cobra[vy]	14	12.5 fl oz	Late POST
	Roundup PowerMax	9	32 fl oz	Late POST

[v] 3 qt/A N-Pak AMS added as adjuvant.
[x] 6.4 oz/A Preference added as adjuvant.
[y] 1 pt/A Crop oil concentrate added as adjuvant.
[z] 1.6 pt/A MSO added as adjuvant.

For Additional Information:
Jared Goplen and Angie Peltier

Project Funding Provided by:
Minnesota Soybean Research & Promotion Council

Results:

Plots were visually rated for percent crop injury on July 18 and July 25. Data among different locations are combined in Table 2. On July 18, following the early PPO-inhibitor application, crop injury ratings were not different among treatments. However, on July 25, one week following the late applications, plots that received late Cobra treatments had significantly higher levels of crop injury compared to those receiving only early PPO inhibitor treatments, or the Roundup only treatment (Figure 1). Injury ratings from plots receiving the late POST Flexstar GT treatment were statistically indistinguishable from all other treatments. Although plots were unable to be harvested for yield, the crop injury observed in this study is comparable to results found previously, where crop injury is minimized with early-season applications.

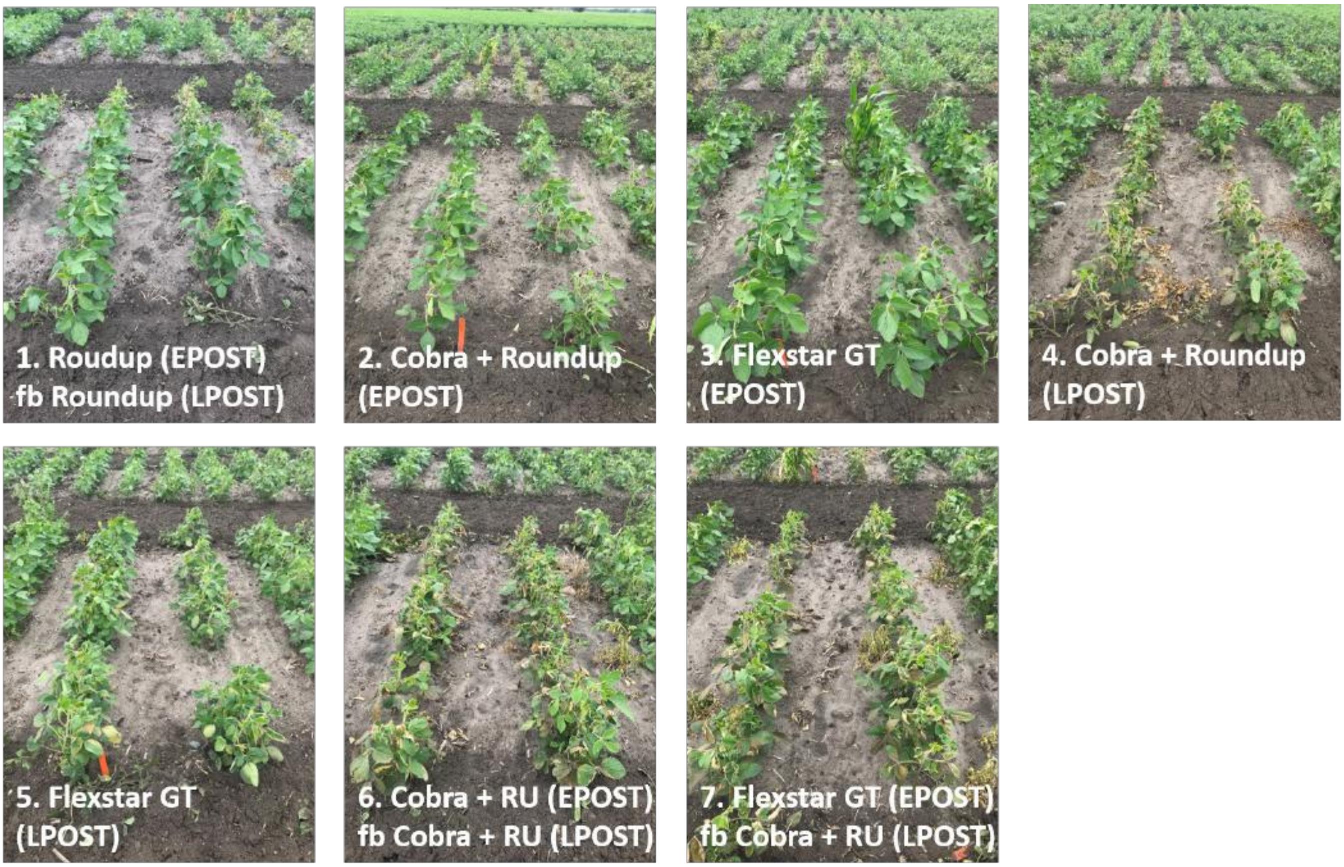


Figure 1. Photos of plot appearance for the PPO-inhibitor herbicide study. Photos were taken on 7/25/19, approximately one week following POST herbicide application

For Additional Information:
Jared Goplen and Angie Peltier

Table 2. Herbicide treatments, rates, application timing, percent crop injury, and crop yield.

Herbicide treatment	Rate (per acre)	Application timing	Crop injury on 7/18 (%)	Crop injury on 7/25 (%)
Roundup PowerMax[vx] Roundup PowerMax[vx]	32 fl oz 32 fl oz	Early POST Late POST	0 a	6.6 b*
Cobra[vy] Roundup PowerMax	12.5 fl oz 32 fl oz	Early POST Early POST	3.3 a	2.5 b
Flexstar GT 3.5[vz]	2.68 pt	Early POST	0.8 a	1.3 b
Cobra[vy] Roundup PowerMax	12.5 fl oz 32 fl oz	Late POST Late POST	0 a	28.3 a
Flexstar GT 3.5[vz]	2.68 pt	Late POST	0.8 a	18.3 ab
Cobra[vy] Roundup PowerMax Cobra[vy] Roundup PowerMax	12.5 fl oz 32 fl oz 12.5 fl oz 32 fl oz	Early POST Early POST Late POST Late POST	2.5 a	33.3 a
Flexstar GT 3.5[vz] Cobra[vy] Roundup PowerMax	2.68 pt 12.5 fl oz 32 fl oz	Early POST Late POST Late POST	0.8 a	30.0 a

* Percent crop injury ratings followed by the same letter are not statistically different at P = 0.05.
[v] 3 qt/A N-Pak AMS added as adjuvant.
[x] 6.4 oz/A Preference added as adjuvant.
[y] 1 pt/A Crop oil concentrate added as adjuvant.
[z] 1.6 pt/A MSO added as adjuvant.

For Additional Information:
Jared Goplen and Angie Peltier

Pre + Post Herbicide Demonstration — NW MN

Cooperator:	David Swanson; Bill Zurn; Corey Hanson; UMN Soybean Breeding Project (Lorenz)
Nearest Town:	Kragnes, MN; Callaway, MN; Gary, MN
Soil Type:	Wahpeton Silty Clay
Tillage:	Conventional
Previous Crop:	Corn (Kragnes and Gary), Soybean (Callaway)
Planting Date:	May 18, 2019 (Callaway), May 31, 2019 (Gary), June 1 (Kragnes)
Spray Dates:	May 20 (PRE, Callaway), June 3 (PRE, Gary, Kragnes), June 26 (POST)
Row Width:	30 inch
Experimental Design:	RCB, 10 treatments, 3 replications

Purpose of Study:

As herbicide resistant weeds have become more problematic in NW Minnesota, more robust weed management programs are needed. In an effort to demonstrate efficacy of weed control programs, several POST-emergence or combination PRE/POST programs were evaluated on-farm near Moorhead, Callaway and Gary in Clay, Becker and Norman Counties, respectively.

Treatments included:

1) Weedy Control
2) Dual + Valor
3) Authority First
4) Authority MTZ
5) Outlook
6) Flexstar GT (fomesafen + glyphosate)
7) Roundup only
8) Authority First + Flexstar GT
9) Authority First + (Flexstar GT + Warrant)
10) Dual + Valor + Flexstar GT

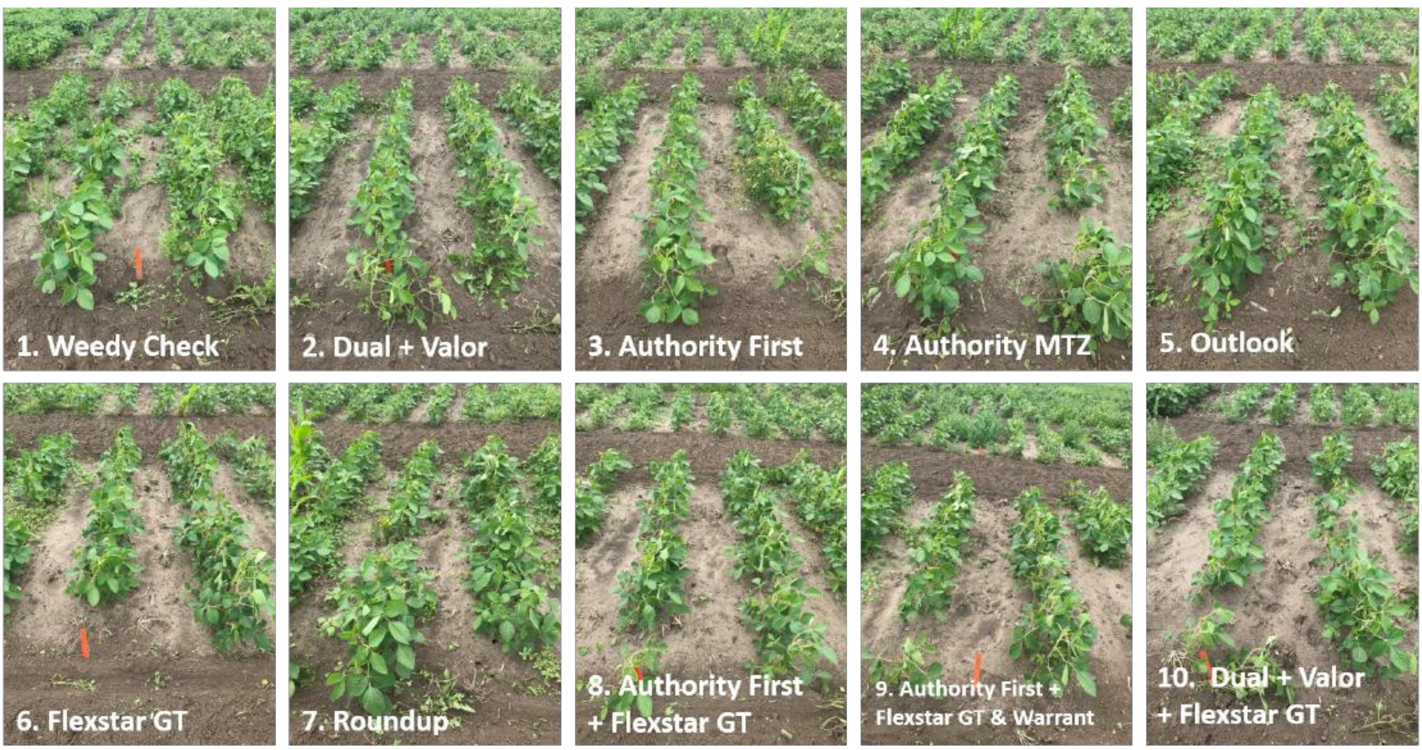


Figure 1. Photos of plot appearance for the PRE / POST herbicide study. Photos were taken on 7/25/19, approximately one month following POST herbicide application

For Additional Information:
Jared Goplen and Angie Peltier

Project Funding Provided by:
Minnesota Soybean Research & Promotion Council »

Results:

Plots were visually rated for percent weed control on July 18. Since weed pressure at Kragnes and Callaway was low, data is presented in Table 1 combined across locations as well as with Gary presented separately. When data was combined across locations, all PRE, POST and PRE+POST treatments had significantly better weed control than the weedy check except Outlook applied pre-emergence. Other treatment differences were not detected. The lack of treatment separation was largely influenced by the low weed pressure at trial locations, as well as the late planting dates which provided weed control via preplant tillage.

At Gary, where weed pressure was greater, all herbicide treatments provided significantly greater weed control than the weedy check. In general, the PRE + POST herbicide programs provided the greatest

Table 1. Herbicide treatment, application rate and timing and percent weed control at the Gary location or the Gary, Callaway and Moorhead trial locations combined

Herbicide treatment (Herbicide group #)	Application rate (per acre)	Application timing	All locations	Gary
			Percent control	
Weedy check	NA	NA	64.4 b*	41.6 c
Valor SX (14) Dual II Magnum (15)	3 fl oz 1.67 pt	PRE POST	89.5 a	89.3 ab
Authority First (14, 2)	6 oz	PRE	95.6 a	95.3 a
Authority MTZ (14, 5)	15 oz	PRE	91.1 a	88.0 ab
Outlook (15)	18 fl oz	PRE	80.6 ab	71.6 b
Flexstar GT 3.5[xy] (14, 9)	2.68 pt	POST	93.5 a	91.3 ab
Roundup PowerMax[xz] (9)	32 fl oz	POST	89.2 a	83.3 ab
Authority First (14, 2) Flexstar GT 3.5[xy] (14, 9)	6 oz 2.68 pt	PRE POST	96.7 a	98.0 a
Authority First (14, 2) Warrant (15) Flexstar GT 3.5 [xy] (14, 9)	6 oz 1.5 qt 2.68 pt	PRE POST POST	96.4 a	94.3 a
Valor SX (14) Dual II Magnum (15) Flexstar GT 3.5 [xy] (14, 9)	3 fl oz 1.67 pt 2.68 pt	PRE POST POST	95.7 a	97.0 a

[x] 3 qt/A N-Pak AMS added as adjuvant.
[y] 1.6 pt/A MSO added as adjuvant.
[z] 6.4 oz/A Preference added as adjuvant.
* Values within a column followed by the same letter are not significantly different at $P \leq 0.05$.

For Additional Information:
Jared Goplen and Angie Peltier

level of weed control. These treatments included Authority First + Flexstar GT, Authority First + Flexstar GT + Warrant, and Valor SX + Flexstar GT + Dual II Magnum. There were no differences among PRE products used aside from all other PRE products outperforming Outlook.

While the pre-emergence only treatments (Authority First, Authority MTZ), as well as post-emergence only treatments (Roundup, Flexstar GT) provided acceptable weed control in this trial, these programs are not recommended as full-season weed control programs. It is likely that if herbicide-resistant common ragweed and waterhemp were present at these locations, weed control would have been much poorer with these programs. A combination of cultural weed management strategies (pre-plant tillage, cultivation, a plant population and row-spacing that promotes canopy closure and crop rotation) and diverse pre and post-emergence herbicide treatments are needed to maintain soybean yield potential and reduce weed seed additions to the soil seed bank.

For Additional Information:
Jared Goplen and Angie Peltier

Prairie Talk
For the Red River Valley and Surrounding Areas

The 2019 On-Farm Research Network reports are available online at mnwheat.org

Tough Times Don't Last but Tough People Do

By Lauren Proulx
MN Wheat, Agronomist, CCA and On-Farm Research Coordinator

2019 has been a year to remember for all the wrong reasons. Even in the some of the worst conditions, we were blown away by the support we received from producers. Together, our determination and downright stubbornness resulted in another successful year of on-farm research!

BACKGROUND
Minnesota Wheat's On-Farm Research Network (OFRN) is producer focused. Wheat producers choose trials that interest them and work with research coordinators to conduct replicated, randomized, multi-year strip trials. Producers can see how the crop responds to a new practice on their own farm, across the region and over time.

Funding for the OFRN is provided by Minnesota Wheat through the Wheat Check-off and also through grants awarded by the Minnesota Department of Agriculture's Agricultural Growth, Research, and Innovation Program (MDA-AGRI), the Agriculture Fertilizer Research and Education Council (AFREC) and the Minnesota Soybean Research and Promotion Council (MSR&PC).

LOOKING AHEAD
We all know how daunting this spring will be but just as with the difficult obstacles that 2019 brought we will push forward. The 2020 season will see a few more staffing changes but the OFRN will continue conducting impactful research for wheat producers to find answers to your crop production questions. Feel free to give Melissa Geiszler a call at (952) 738-2000 or send her an email at mgeiszler@mnwheat.com to learn more.

THANK YOU
Thank you, Minnesota Wheat Producers, for your continued support. Thank you, On-Farm Research Advisory Committee and the Minnesota Wheat Council and Grower boards for your dedication to the OFRN. Thank you, Minnesota Department of Agriculture, the Agriculture Fertilizer Research and Education Council, and the Minnesota Soybean Research and Promotion Council for additional funding for the OFRN. Thank you, BASF and CHS Ag Services for donating Priaxor. Thank you, Koch Agronomic Services for donating Centuro. Thank you, Encirca-Granular for donating access to their online services for each of the trials. Thank you, West Central Ag Services, Gary Purath and the University of Minnesota for letting us use your weigh wagons. Thank you, CHS Northland Grain in St. Hilaire for helping us calibrate weigh wagons this fall. Lastly, thank you to the many unnamed contributors who help make our work possible!

MINNESOTA WHEAT 2019 ON-FARM RESEARCH NETWORK TRIALS

35 Wheat Production Research Trials

- Variable Rate Nitrogen, comparing variable rate to flat rate N application
- Seeding Rate, comparing rates of 1, 1.5, and 2 million plants per acre on 6 varieties
- Flag-leaf Fungicide, testing a 3rd fungicide application during flag leaf emergence in addition to applications at the 4-5 leaf and flowering stages
- N-stabilizer, first year results of fall and spring anhydrous ammonia applied with and without a new nitrification inhibitor formulation (CENTUROTM)
- Sulfur, testing the addition of 100 lbs/acre AMS to increase yield and protein content
- Elevated P and K Fertility, first year results of increasing P and K fertility over four years in a wheat-soybean rotation
- Within-Field Protein Variability, using on-combine analyzers to map spatial variability of protein on farms in Roseau and Thief River Falls, MN

3 Soybean Production Research Trials

- Soybean Seeding Rate, comparing yield of soybean populations ranging from 50-180k plants per acre

5 Cover Crops & Tillage Trials

- Vertical vs Conventional Tillage, three years of data for one field in a wheat-soybean rotation
- Green seeding soybean into rye, first year observations planting rye after wheat
- Oats to Reduce IDC, preliminary results from one year of data

MINNESOTA WHEAT 2020 ON-FARM RESEARCH NETWORK TRIALS

- Within-Field Protein Variability
- N-stabilizer
- Seeding Rate
- Flag-leaf Fungicide
- Elevated P and K Fertility
- Oats to Reduce IDC
- ‘Green seeding’ soybean into rye

Identifying Causes of Within-Field Protein Variability in Spring Wheat using Precision Field Mapping and Aerial Imagery

Joel Ransom, Dept. of Plant Sciences, NDSU, Fargo
Melissia Geisler, MN Wheat, On-Farm Research, Red Lake Falls

Research Questions

Spring wheat profitability is influenced by grain protein content premiums or discounts when sold at the elevator. Wheat protein content can vary greatly across a field, and is influenced by many environmental factors, most importantly N and water availability. Protein maps created using combine-mounted protein analyzers can guide efforts to identify the underlying causes of protein variability within a field. Understanding these relationships could improve protein management practices, such as using a pre-plant or in-season variable rate N application to allocate fertilizer where it is most likely to increase grain protein content and profitability.

The objectives of this research are i) identify the most influential factors affecting within-field protein variability, ii) develop a model to predict protein content during the growing season using the identified influential factors and in-season UAV and satellite vegetation indices, and iii) identify a cost-effective approach to site-specific N management that maximizes both wheat yield and protein content to increase the overall profitability of wheat in MN, while also reducing fertilizer inputs and environmental loss.

Results

Wheat yield and protein maps, and UAV imagery were collected during the 2019 season. Protein appears to be inversely related to yield, and also appears to vary along with yield according to soil type within the field. Preliminary analysis showed a moderate correlation between yield and soil organic matter (r=0.47). Contrary to the original hypothesis, protein content was not correlated to yield (r=0.08), and very weakly correlated to percent sand in the soil (r=0.21), and soil organic matter (-0.19). Further spatial analysis in 2020 and beyond will help to elucidate the relationships between protein content and the environment.

Application and Use

Identifying the underlying factors affecting the spatial variability of protein within a field may help guide decisions related to managing protein content. In the future, we hope this research can be used to direct variable rate in-season N applications.

Materials and Methods

Two CropScan 3300H protein analyzers manufactured by Next Instruments are currently in operation near Roseau and Thief River Falls, MN. The CropScan analyzes and records protein data every 7-11 seconds to create a georeferenced map of wheat protein while harvesting.

As we move forward, protein data will continue to be mapped on each of the cooperating producer’s wheat fields, however intensive data collection will be limited to 2-4 fields to minimize cost and keep the volume of data to be analyzed at a manageable level. Nitrogen-rich and N-deficient strips will be established in these fields to aid yield and protein prediction using in-season NDVI/NDRE imagery obtained via satellite and a Matrice M-100 UAV equipped with a MicaSense RedEdge-M sensor. Fields will be flown with the UAV at the 4-5 leaf, boot, flag-leaf, and flowering stages. Satellite images nearest to these timings will be used for analysis. After harvest, fields will be zone soil sampled for texture, OM, and N. ArcGIS and R mapping and statistical software will be used to spatially analyze the relationships between these data to identify which factors are the most influential on protein content within a field, and if these factors can be used to predict protein content during the growing season.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

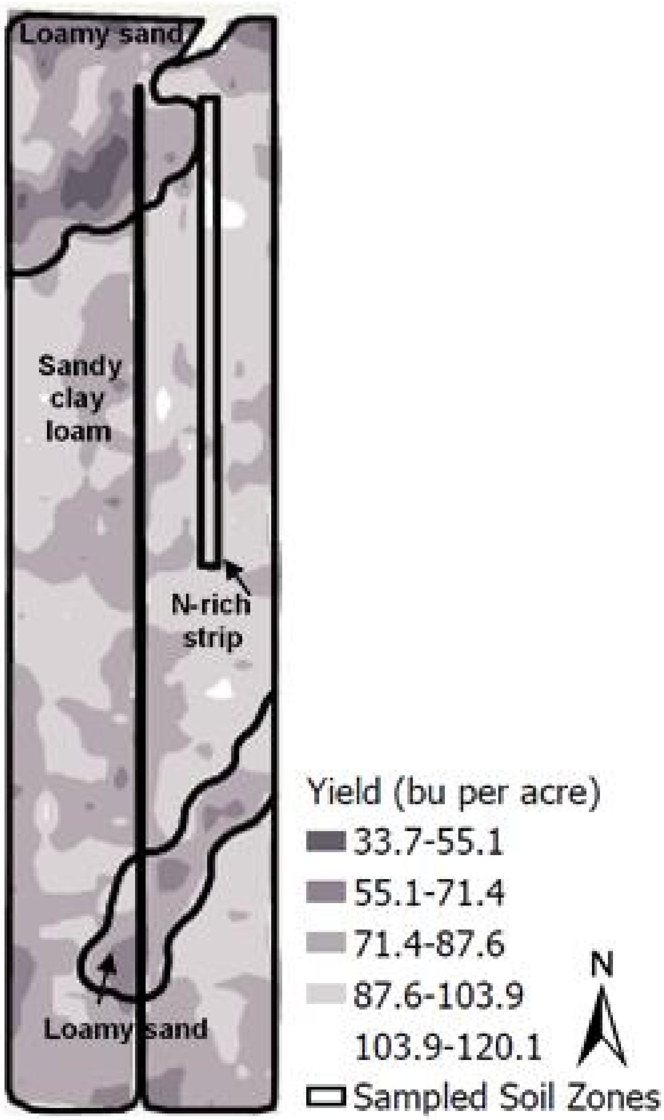
Potential economic benefits are unknown at this time but will hopefully become clear as we continue to collect and explore the data.

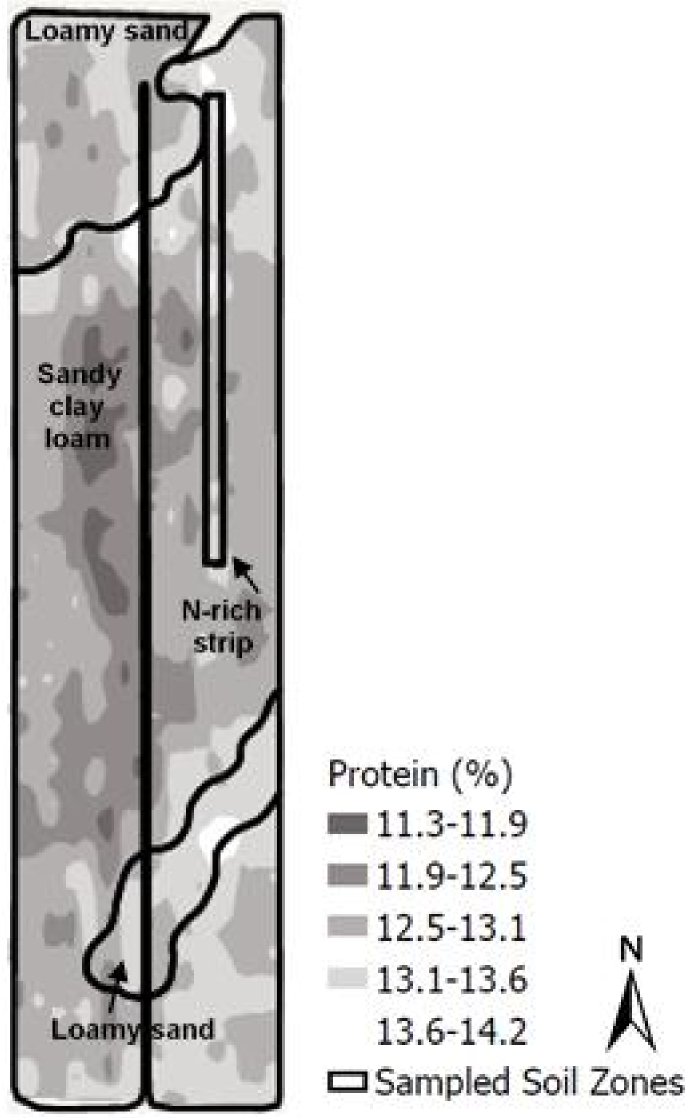
Related Research

Mapping protein variability in a field has been researched previously in Montana and Washington to map the variability of spring wheat protein within fields using hand-sampling approaches.

A related project conducted at NDSU is collecting in-season imagery with drone-mounted sensors from fields of wheat and corn that have a nitrogen rich strip in order to determine if these data can be used in developing prescription fertilizer maps. Though there will be limited data collected on protein in this project, some of the procedures used may apply to the MN-funded project to monitor N sufficiency.

This research is also being conducted in partnership with the Minnesota Wheat Research & Promotion Council's On-Farm Research Network.





University of Minnesota Wheat Breeding Program

Jim Anderson, Dept. of Agronomy & Plant Genetics, U of M, St Paul

Research Questions

This is a continuation of the U of MN spring wheat breeding program with the objectives: 1) Develop improved varieties and germplasm combining high grain yield, disease resistance, and end-use quality; and 2) Provide performance data on wheat varieties adapted to the state of Minnesota.

Results

During the 2018/2019 crossing cycle, 250 crosses were made. The 2019 State Variety Trial, which contained 36 released varieties, 16 University of Minnesota experimental lines, 5 experimental lines from other programs, and 3 long term checks was grown at 15 locations. Another 187 advanced experimental lines were evaluated in advanced yield trials at 10-11 locations and 363 lines were evaluated in preliminary yield trials at 3 locations. A total of 6,978 yield plots were harvested in 2019. Fusarium-inoculated, misted nurseries were established at Crookston and St. Paul. An inoculated leaf and stem rust nursery was 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 USDA-ARS. DNA sequence information was obtained from 2,533 pre-yield trial lines and their FHB resistance and dough mixing properties were predicted based on a training set of 499 lines. Data from the yield and disease nurseries are summarized and published in Prairie Grains and the MAES's 2019 Minnesota Field Crop Trials bulletin.

MN-Washburn spring wheat was released January 2019. Tested as MN10201-4-A (MN97695-BYDV/Sabin), MN-Washburn has shown stable yields over 6 years of statewide testing. It has good straw strength (3 on 1-9 scale), and overall good disease resistance. MN-Washburn has better straw strength than our recent releases Bolles (4), Shelly (5), and Lang-MN (5) and the high yielding SY Valda (5). Importantly, MN-Washburn contains the bdv2 gene for resistance to Barley Yellow Dwarf Virus (BYDV) – to our knowledge, it is the only variety in the region containing this gene. The grain protein of MN-Washburn is lower than average, but its overall baking quality is acceptable and better than other lower protein varieties. Data is summarized in Table 1.

Table 1. Comparison of MN-Washburn and experimental line MN1405-7 with recent MN releases and other popular spring wheat cultivars, based on 2019 MN acreage. Entries are sorted by 3 Yr grain yield from 43 environments.

			Grain Yield					Straw	Test Wt.	Protein	Baking
	Release	% M	% of mean			Heading	Height	Str.	(lbs/bu)	%	Quality
Variety [1]	Yr.	Acreage	2019	2 Yr	3 Yr	d	in.	1-9	2 yr	2 yr	1-9
SY-Valda	2015	15.5	109	109	111	54.6	31.3	5	60.0	14.0	6
Prosper	2011	1.9	104	107	108	56.5	33.1	6	59.7	13.7	5
Shelly	2016	7.1	106	106	107	57.4	29.5	5	59.4	14.1	5
TCG-Spitfire	2016	3.9	107	106	107	57.9	31.3	3	58.7	13.9	2
MN14105-7	-	-	106	105	105	56.2	31.3	4	59.9	14.8	5
MN-Washburn	2019	0.3	101	100	103	56.8	30.0	3	59.8	14.0	3
Lang-MN	2018	1.9	102	102	101	57.3	32.7	5	60.6	14.8	3
SY Ingmar	2014	2.8	99	100	99	55.8	29.2	4	60.1	15.1	2
WB-Mayville	2011	5.4	97	96	98	52.7	28.0	3	59.8	15.4	2
Bolles	2015	4.4	96	94	95	57.8	32.3	4	59.2	16.1	1
Linkert	2013	22.3	93	92	95	55.2	28.5	2	59.9	15.4	1

[1] WB9590 (13.8% of MN acreage) and WB9479 (9.2%) are not included in this table because they were not tested in 2019.

MN14105-7 (Sabin/01S0377-6//Linkert) was increased at two MN locations in 2019. MN14105-7 has grain yield between Shelly and MN-Washburn but has higher grain protein than both and also better straw strength and bacterial leaf streak resistance compared with Shelly. In both 2017 and 2018 Uniform Regional Nurseries that are grown in Minnesota, North Dakota, South Dakota and one location each in Montana, Manitoba, and Saskatchewan, MN14105-7 ranked no. 3 for yield out of >30 test entries (data not shown). Of the 3 entries with the highest grain yield in those nurseries, MN14105-7 had the highest protein. MN14105-7 has acceptable baking quality (5) and good disease resistance, among the best for bacterial leaf streak (3) and moderately resistant to scab (4).

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

Approximately 300 crosses are made per year. A winter nursery is used to advance early generation material when appropriate, saving 1-2 years during the process from crossing to variety release. Early generation selection for plant height and leaf rust and stem rust resistance is practiced in nurseries in St. Paul and Crookston. Approximately 400 new lines are evaluated in preliminary yield trials annually at 2 or 3 locations. Advanced yield trials - containing 180-200 experimental lines – are evaluated at 10-11 locations. All yield nurseries are grown as 50-80 sq. ft. plots. Misted, inoculated Fusarium head blight nurseries are grown in Crookston and St. Paul and an inoculated leaf and stem rust nursery is grown at St. Paul. We are implementing genomic selection in the breeding program. This involves predicting the performance of experimental lines based on DNA sequence information of related lines. This allows us to screen a larger number of potential varieties that we can't accommodate in our field trials, and can help us find the rare genotypes that combine all the necessary traits in a high yielding line.

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. As an example, a new variety that yields 4% higher will produce 3 extra bushels in a field that averages 75 bu/A. At current market prices that equates to approximately an additional $7,500 in gross revenue for a 500 acre wheat enterprise.

Related Research

These funds provide general support for our breeding/genetics program. Additional monetary support for breeding activities in 2019 came from the MN Small Grains Initiative via the Minnesota Agricultural Experiment Station, and the U.S. Wheat and Barley Scab Initiative via USDA-ARS.

Publications

1. Anderson, J.A., J.J. Wiersma, S.K. Reynolds, G.L. Linkert, R. Caspers, J.A. Kolmer, Y. Jin, M.N. Rouse, R. Dill-Macky, M.J. Smith, L. Dykes, and J.-B. Ohm. 2019. Registration of 'Shelly' hard red spring wheat. J. Plant Registrations, doi:10.3198/jpr2018.07.0049crc

2. Anderson J.A, J.J. Wiersma, S. Reynolds, N. Stuart, H. Lindell, R. Dill-Macky, J. Kolmer, M. Rouse, Y. Jin, and L. Dykes. 2019. 2019 Hard Red Spring Wheat Field Crop Trials Results. *In*: 2019 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN. (available at https://www.maes.umn.edu/publications/field-crop-trials by Dec. 2019)

	Leaf	Stripe	Bact	
PHS	Rust	Rust	Leaf Str.	Scab
1-9	1-9	1-9	1-9	1-9
2	1	2	3	4
1	6	5	4	4
1	3	1	6	4
3	5	-	3	5
2	3	-	3	4
1	1	2	3	4
1	1	1	3	3
2	2	2	3	4
3	3	3	7	8
1	2	1	5	4
1	3	1	5	5

Maximizing Canopy Conductance to Enhance Spring Wheat Yield Potential in the Upper Midwest

M. Walid Sadok, Dept. of Agronomy & Plant Genetics, U of M, St. Paul

Research Questions

During the day, wheat canopy continuously 'transpires', releasing water vapor into the atmosphere through microscopic pores on the leaves, called stomates. This process is critical to crop production as it allows for bringing water and nutrients -particularly nitrogen- from the soil into the plant. When these stomates open to release water vapor, they also allow for carbon dioxide (CO_2) to diffuse from the atmosphere into the plant to be used in photosynthesis. Both processes (transpiration & CO_2 fixation) are critical for productivity as they enable entrance into the plants of carbon and nitrogen that enable filling the seed with carbohydrates and protein. In crop physiology, this ability to keep stomata open is called **canopy conductance.** Previously, we have shown in three different production environments (Australia, North Africa and Minnesota) that increasing canopy conductance is a promising breeding target to increase yields (Schoppach et al. 2017; Sadok et al. 2019; Tamang et al. 2019).

How to maximize canopy conductance in MN wheat? The medium-term objective of this research is to identify major genetic loci associated with this complex trait and pyramid them in the pipeline of the University of Minnesota wheat breeding program to deliver MN growers varieties with higher yield potential. Thanks to a 'precision-phenotyping' system (the GraPh platform, Tamang and Sadok, 2018) enabling 'high-fidelity' screening of whole-plant canopy conductance, we are the first group in the U.S. and one of the very few worldwide who have the capacity to achieve this goal, potentially giving MN growers a major competitive advantage. Using our system, and in the first 3 years of this research, we were able to: 1) Adapt the GraPh platform to enable high throughput phenotyping of wheat mapping populations, 2) Screen (twice) the parents of the Minnesota Nested Association Mapping Population (MNAMP) to identify parents with contrasted canopy conductance, 3) Phenotype (twice) families from the MNAMP which parents exhibited the greatest contrast in canopy conductance from the recurrent parent RB07, 4) Identify several quantitative trait loci (QTL) controlling canopy conductance in those families, and 5) Initiate an effort to confirm those QTL in a breeding population developed by wheat breeder Jim Anderson (145 recombinant inbred lines from a cross between MN-adapted parental lines MN99394-1-2 and MN99550-5-2). **Goals:** In this year, our goals were to replicate phenotyping experiments to 1) capture and confirm all of the large- effect QTL available in the MNAMP population and 2) initiate validation of the detected QTL in the independent genetic background of the breeding population.

Results

This third year, we have successfully conducted a third replication of the phenotyping effort on the MNAMP families developed by Brian Steffenson and a second replication of the phenotyping of the bi-parental mapping population developed by Jim Anderson. In addition, we undertook a multi-population QTL analysis of canopy conductance on the MNAMP families and the breeding population. To the best of our knowledge, this is the first time that such a large number of genotypes is screened for canopy conductance in a single year. While the analysis of this large dataset is on-going, it is clear that we have identified a number of large-effect QTL for canopy conductance, which -when confirmed across populations and experimental replications (see recommended future research), will be prime candidates to design MN wheat cultivars with enhanced canopy conductance. Analysis is already underway to not only identify the most robust and stable QTL across all the populations but also to identify genotypes to be deployed in the field for multi-location confirmation of QTL effects in the field, a key step for a breeding program (see recommendations for future research). Our research methodology presents the unique advantage of substantially speeding up the phenotyping pipeline, as standard approaches would require double the time needed (i.e., 7-8 years) to assemble such datasets. As a result, this physiological phenotyping methodology developed through the support of the MWR&PC has attracted global, international attention as attested by invitations to present research findings as talks in international conferences, including the largest wheat conference ever organized (attended by 900+ wheat researchers from the all over the world, see publications).

Application and Use

Increasing canopy conductance can lead to numerous yield-related benefits for Minnesota-grown wheat. Higher canopy conductance is associated with higher yield, likely due to an increased ability of the plant for water and nitrogen uptake from the soil. This in turn may decrease risks of nitrogen leaching and waterlogging. In addition, higher canopy conductance is linked to increased fixation of CO_2 and other mobile nutrients needed for filling the grain and to protecting the canopy from heat stress during the summer, via evaporative cooling. However, until very recently, breeders were unable to select for higher canopy conductance, because of the lack of technologies available. With the new physiological phenotyping approach we have developed, we have an untapped opportunity to breed for next-generation, MN-adapted wheat, equipped with genes maximizing yield potential by enhancing canopy conductance.

Materials and Methods

For this research, the plants were grown under naturally fluctuating conditions in a well-maintained greenhouse at the University of Minnesota. Plants were grown in a setting that mimic field conditions (large pots, fertilized top soil, high density) where key environmental conditions were carefully monitored (light, temperature, relative humidity, watering regime). After 4-5 weeks, plants were transferred inside the GraPh precision-phenotyping platform. This platform tracks canopy conductance as a function of whole-plant transpiration response –measured using weighing lysimeters– to increasing atmospheric vapor pressure deficit. This allows for a very precise estimation of whole-plant canopy conductance which is very difficult to accurately measure in the field because of the confounding influence of uncontrollable variations in light, temperature and wind speed.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Based on computer-based simulation modelling taking into account weather data, soil type and crop management, our work on a similar context in north Africa projected a yield increase by 15-20% in well-watered environments as a result of increasing canopy conductance to values that are within the range observed in our MN experiments (Sadok et al. 2019). Therefore, such numbers could be used as a baseline for estimating the expected yield benefits that would result from this trait modification in the more favorable environments of Minnesota. Other benefits could add to such baseline number, such as reducing risks of N leaching enabled by high-conductance genotypes which have a higher ability to remove water from the soil, therefore enhancing N-use efficiency, while reducing environmental footprint.

Related Research

Dr. Sadok is currently participating in an international, collaborative effort to help breeders develop wheat cultivars equipped with canopy conductance traits that maximize yield gains under different water availability regimes in collaboration with colleagues in the Middle-East and Australia (Schoppach et al. 2017; Sadok et al. 2019; Tamang et al. 2019; Sadok and Schoppach 2020). For instance, in well-watered environments with deep, moisture-holding soils such as most of Minnesota, breeders should favor genotypes with high canopy conductance. However, in MN environments with sandy soils with low moisture holding capacity or more broadly the western part of the U.S. spring wheat region, our research showed that genotypes that decrease their canopy conductance at midday would increase yields through a water-saving strategy. This research has been leveraged as USDA NIFA proposal (still pending as of this writing).

Recommended Future Research

Our goals for the next year are to: i) phenotype one last (3rd) time the bi-parental breeding population ii) finalize the genetic analysis to confirm robust, large-effect QTL controlling canopy conductance, iii) recommend, based on ii) genotypes harboring contrasting alleles at those major loci to be deployed in field yield trials and iv) initiate confirmation of the effects of such QTL in multi-location yield trials where yields and yield component traits will be measured to validate the beneficial effects of canopy conductance.

References

Sadok, W. and R. Schoppach. 2020. Potential involvement of root auxins in drought tolerance by modulating nocturnal and daytime water use in wheat. Annals of Botany (in press).

Sadok, W., R. Schoppach, M.E. Ghanem, C. Zucca, and T.R. Sinclair. 2019. Wheat drought-tolerance to enhance food security in Tunisia, birthplace of the Arab Spring. European Journal of Agronomy, 107: 1–9.

Tamang, B.G., R. Schoppach, D. Monnens, B.J. Steffenson, J.A. Anderson, and W. Sadok. 2019. Variability in temperature-independent transpiration responses to evaporative demand correlate with nighttime water use and its circadian control across diverse wheat populations. Planta, 250: 115–127.

Tamang, B.G., and W. Sadok. 2018. Nightly business: links between daytime canopy conductance, nocturnal transpiration and its circadian control illuminate physiological trade-offs in maize. Environmental and Experimental Botany, 148: 192–202.

Schoppach R, Fleury D, Sinclair TR, Sadok W. 2017. Transpiration sensitivity to evaporative demand across 120 years of breeding of Australian wheat cultivars. Journal of Agronomy and Crop Science 203: 219-226.

Publications

[Support of MWR&PC acknowledged in the paper/oral presentation]

Peer-reviewed publication in international scientific journal:

1. Tamang, B.G., R. Schoppach, D. Monnens, B.J. Steffenson, J.A. Anderson, and W. Sadok. 2019. Variability in temperature-independent transpiration responses to evaporative demand correlate with nighttime water use and its circadian control across diverse wheat populations. Planta, 250: 115–127.

»

» **Oral presentation in international conference: (speaker name underlined)**

2. Sadok W., R. Schoppach, M.E. Ghanem, C. Zucca, T.R. Sinclair. 2019. Crop simulation modeling informed by physiological phenotyping illuminate context-dependencies for enhancing wheat drought tolerance in Tunisia. Talk presented at the ASA-CSSA Meeting, San Antonio, TX, USA, 11 November 2019.

3. Sadok W., B.G. Tamang, R. Schoppach, B.J. Steffenson, J.A. Anderson. 2019. Out of darkness: nocturnal transpiration and its circadian control as contributors of drought tolerance in crops. Talk presented at the ASA-CSSA Meeting, San Antonio, TX, USA, 12 November 2019.

4. Sadok W., R. Schoppach, U. Baumann, D. Fleury, M.E. Ghanem, J.D. Taylor, T.R. Sinclair, C. Zucca. 2019. Root-shoot hydraulic and hormonal traits shape a whole-plant water use strategy enabling drought tolerance in wheat under a Mediterranean environment. International Conference on Integrative Plant Physiology 2019, Melia Sitges, Spain, 27 October 2019.

5. Sadok W., J.A. Anderson, U. Baumann, D. Fleury, M.E. Ghanem, D. Monnens, R. Schoppach, T.R. Sinclair, B.J. Steffenson, B.G. Tamang, J.D. Taylor, C. Zucca. 2019. Combining eco-physiology, genetics and crop modeling to enhance wheat yields under variable water availability regimes. Talk presented at the main session of the 1st International Wheat Congress, Saskatoon, SK, Canada, 26 July 2019. **[**According to organizers, this was the largest wheat conference ever organized, with an attendance of over 900 from 51 countries]**

Providing Rapid End-use Quality Characterization Services to the University of Minnesota Breeding Program

George A. Annor, Dept. of Food Science & Nutrition, U of M, St Paul

Research Questions

How do breeding activities by the University of Minnesota Breeding Program affect end-use Quality of Wheat?

Results

About 400 wheat samples consisting of lines to be entered in Preliminary yield trials and the repeated checks Lang-MN and Linkert were screened for their protein aggregation kinetics. Samples were first milled and their protein aggregation kinetics determined using the Brabender gluten peak tester. The parameters determined were peak maximum time, torque maximum, Torque before maximum, torque after maximum, startup energy, plateau energy and aggregation energy. These parameters were used in an earlier study to develop models to rapidly predict water absorption and other dough parameters. Based on regression equations developed earlier, the water absorption of the samples was calculated and presented in **Figure 1**. The water absorption of the samples ranged from about 45% to 78%. The mean water absorption was 64%. The calculated water absorption for the check varieties Linkert was 69% and Lang -MN was 65%. Based on these results, samples with water absorptions between 57 to 72% should be advanced for further testing.

Application and Use

This data, along with grain protein and test weight data from three 2019 Preliminary yield trials, is the only end-use quality data the breeding program will have to help decide which of these entries (about 140 of the 363) will be advanced for Advanced yield trials in 2020. These results are also being used by the breeding program to develop models that will be used to improve selection for end-use quality parameters of future breeding lines.

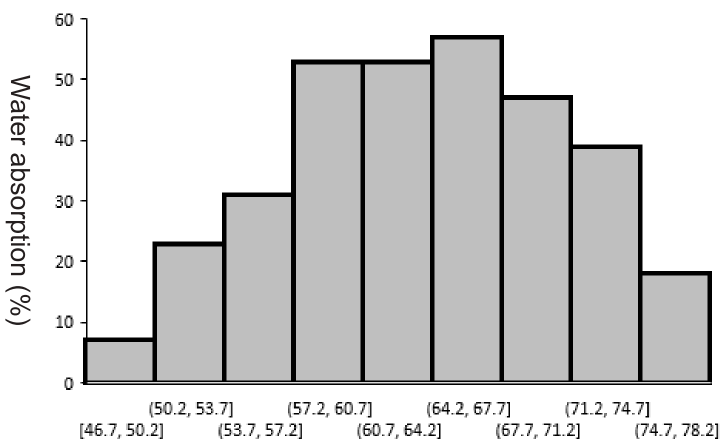


Figure 1: Calculated water absorption wheat samples

Materials and Methods

Grain from 363 2019 Preliminary yield trial lines harvested in New Zealand and 14 replications of the checks Lang-MN and Linkert were milled into flour and their protein aggregation kinetics determined using the Brabender Gluten Peak tester.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Results from this study enables the University of Minnesota Wheat breeding program to incorporate selection for good end-use quality earlier in the breeding efforts, thus avoiding the continued testing poor quality lines. The results of this research will be used to develop models that can be used to select for varieties with end-use quality parameters that are valued by our hard-red spring wheat customers. Such varieties will help to maintain the price premium of hard red spring wheat.

Figure 2 shows the aggregation energy of the samples. Aggregation energy indicates how much energy is needed to aggregate the gluten proteins in the samples. High aggregation energies are required for the aggregation of strong gluten proteins.

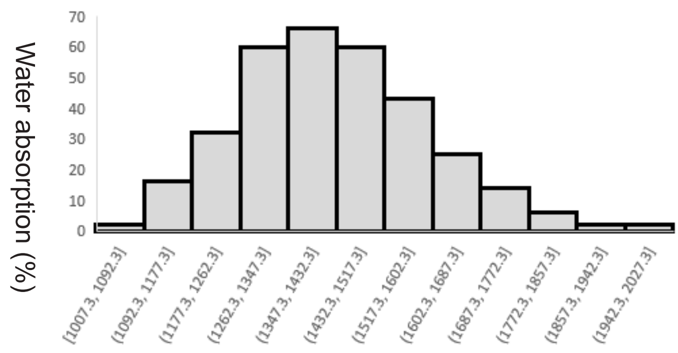


Figure 2: Aggregation energy of wheat samples

Combining Key Resistance and Agrotype Genes for the Improvement of Hard Red Winter Wheat Germplasm

G. Francois Marais, Dept. of Plant Services, NDSU, Fargo

Research Questions

Recently, NDSU introduced many FHB and rust resistance genes from hard red spring wheat (HRSW) into our newly developed hard red winter wheat (HRWW) breeding program. This project facilitates further integration of this valuable resistance into the broader breeding population. Presently, the newly transferred genes occur (mostly singly) in highly related, lower yielding winter wheat backgrounds and need to be systematically combined into more diverse, higher yielding combinations that will improve multi-pathogen resistance. The purpose of this project is to:

- Hasten the dissipation of FHB resistance genes within the breeding population and integrate it with improved yield plus resistance to other prevailing diseases such as leaf, stem and stripe rust, bacterial leaf streak (BLS), tan spot and Septoria nodorum blotch (SNB).
- Simultaneously develop sub-populations of hard white wheat germplasm with the same attributes.

Results

In January 2019, eight crosses outlined in Table 1 were made and the F_1 planted for seed increase. Approximately 150-200 F_2 seedlings per cross were re-planted in September 2019. Following vernalization, these will be infected with mixed leaf rust (six races) and stem rust (four races) spores in November 2019. The most severely infected seedlings will be removed and the remaining plants raised to maturity when plants that are too tall will also be discarded. The most productive plants of semi-dwarf height (approximately 90% of the height of cultivar Jerry) will be harvested for continued pre-selection and inbreeding according to the scheme in Fig. 1.

In parallel to the crosses, DNA extraction and genotyping by sequencing utilized 380 advanced breeding lines from the routine breeding program. Study of the genotypic data will aim to find single nucleotide polymorphism (SNP) markers that map close to significant rust resistance (particularly stripe rust) genes within the population. Rust resistance data gathered in 2019 will be analyzed in the attempt to identify chromosome regions that harbor rust resistance genes. These will be evaluated to determine whether it could provide additional markers that might improve marker-aided selection for rust resistance in the segregating progenies.

Application and Use

The introduction of FHB resistance from spring wheat produced promising resistance phenotypes in winter wheat; however, the newly selected, FHB resistant inbred lines appeared to be lower yielding than their susceptible counterparts were. This raised the possibility that yield-detrimental genetic effects were co-introduced.This project aims to develop FHB resistant lines that are simultaneously high yielding, and possibly also resistant to other major diseases. Such material will greatly aid the breeding program. The accumulation of multiple favorable genes for disease resistance, yield, adaptation and processing quality in a breeding population is a formidable task achieved through numerous cycles of un-interrupted, meticulous crosses; strict phenotypic and statistical evaluation and selection. This will be easier to achieve through targeted pre-breeding projects utilizing accelerated pure line development and marker-facilitated selection. The genetic material and gene pyramids developed in the course of this project will however, not only ensure that the breeding program reach maximum productivity sooner; it also has commercial potential and we will continue to evaluate it in yield trials.

Materials and Methods

The project utilizes crosses among eight winter wheat parents (Table 1). Each parent contributes either a good plant type or resistance. Inbreeding and selection within these crosses will attempt to develop new high yielding inbred lines with notable winter hardiness, FHB and rust resistance utilizing the selection scheme outlined in Fig. 1.

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.

Related Research

The project supports the NDSU hard red winter wheat pedigree-breeding program. 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 and that are useful as breeding parents. 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 aims to directly supplement and facilitate the main pedigree breeding effort.

Recommended Future Research

a. Acquire and establish additional FHB resistance genes that supplement the *Fhb1* and *Qfhs.ifa-5A* resistance in the main breeding program.
b. Develop genetically diverse, high yielding inbred lines with significant FHB resistance and employ these as breeding parents.

References

Bakhsh A., N. Mengistu, P.S. Baenziger et. al. 2013. Effect of Fusarium head blight resistance gene *Fhb1* on agronomic and end-use quality traits of hard red winter wheat. Crop Sci. 53:793-801.
Bai G., Z. Su, and J. Cai. 2018. Wheat resistance to Fusarium head blight. Canadian Journal of Plant Pathology, 40:3, 336-346, DOI: 10.1080/07060661.2018.1476411.
Gupta P.K., R.K. Varshney, P.C. Sharma, and B. Ramesh. 1999. Molecular markers and their applications in wheat breeding. Plant Breeding. 118: 369-390.
Poehlman J.M. and D.A. Sleper 1995. Breeding Field Crops. Iowa State University Press.
Steiner B., M. Buerstmayr, S. Michel, et al. 2017. Breeding strategies and advances in line selection for Fusarium head blight resistance in wheat. Trop. Plant pathol. 42: 165-174.
USDA-ARS Cereal Disease Lab. 2017. Resistance Genes. St. Paul, MN. https://www.ars.usda.gov/midwest-area/stpaul/cereal-disease-lab/docs/resistance-genes/resistance-genes/.

Table 1. Hard red winter wheat parents and cross combinations used for initiating the study.

Parent/ Cross number	Traits[1],[2]	Pedigree	Resistance genes[3]
1	T; CH	CM82036/Jerry//Jerry-*Lr56*	*Lr34; Lr56;* 1B1R
2	SD; CH; W	Broadview/SD07W083-4	*Fhb1; Qfhs.ifa-5A; Lr34; Lr46; Yr17; tsn1*
3	TSD; NH	Radiant/RCATL33//Ideal	*Sr24;* unknown FHB resistance
4	T; CH	Norstar-*Fhb1*/Jerry//TX09D1119/Buteo	*Fhb1; Lr46;* 1B1R; *Yr17*
5	T; CH	Norstar-*Fhb1, Sr39*	*Fhb1; Sr39/Lr35; Lr34; Lr46; Lr68;* 1BL.1RS
6	SD; MH	Monument	Lr34; Sr24;Yr17
7	SSD; MH	Keldin	
8	TSD; NH	CM82036/Jerry/3/*Lr50*//Jerry//Falcon/3/Moats	*Fhb1; Qfhs.ifa-5A; Lr46; Yr17*
19K331		1 X 2	
19K438		2 X 3	
19K89		4 X 2	
19K365		5 X 6	
19K94		4 X 6	
19K368		5 X 7	
19K97		4 X 7	
19K132		4 X 8	

[1] T = tall, SD= semi-dwarf; TSD = tall semi-dwarf; SSD = short semi-dwarf; CH = cold-hardy, MH = moderately cold-hardy, NH = non cold-hardy; W = white seed.
[2] Parents 3, 6 and 7 have inadequate bacterial leaf streak resistance.
[3] *Lr* = leaf rust resistance locus, *Sr* = stem rust resistance locus; *Yr* = stripe rust resistance locus; *Fhb* = *FHB* resistance QTL; *Qfhs.ifa-5A* = FHB resistance QTL; 1BL.1RS = wheat rye translocation; *tsn1* = tan spot insensitivity allele. »

F_1: Produce and plant 8 crosses by Feb 2019

% Hetero-zygosity	
50.0	F_2: Plant in Sept 2019. Vernalize about 150-200 F_2 of each cross in planting trays. Screen with mixed LR and SR inoculum. Remove plants that are too tall. Keep about 50% (**75-100**) of the seedlings per cross for SSD.
25.0	F_3: Re-plant in Feb 2020 (greenhouse pots - 3 lineages per pot; 200-266 total pots) and select for vigor, seed set and semi-dwarf plant height (include a height control).
12.5	F_4: Select the best 50% of the F_3-derived F_4 families and plant (in an un-replicated field nursery; 300-400 single plots plus controls, Casselton) to allow winter-kill of sensitive plants/families. Evaluate plots for winter survival, FHB resistance, agrotype and yield in summer 2021 and also identify lines that breed true for white kernel color (based on F_5 seed). Identify the best families (approximately 8 per cross).
6.25	F_5: <u>Select single F_5 plants from within the best yielding F_3-derived F_5 families.</u> Identify the 8 very best F_3-derived F_5 families within each cross based on the 2021 agronomic data. Plant 10 F_5 seeds per selected family and do a marker screen to identify families segregating for either or both of *Fhb1* and *Qfhs.ifa-5A*, and to characterize these for the presence/absence of *Lr34, Lr46, Lr67, Lr56, Sr24, Lr35/Sr39, Yr17* and the 1RS translocation. Increase seeds of the best single plants for continued testing in replicated trials.

Fig. 1. Outline of the proposed selection scheme.

Nitrogen Losses Under Spring Wheat Production System in Minnesota

Amitava Chatterjee, Dept. of Soil Science, NDSU, Fargo

Research Questions

The overarching research question of the project is ‘what are the ranges of nitrogen losses, soil nitrogen availability, and grain yield and protein content under spring wheat production systems across the Red River Valley of Minnesota?

Results

Grain yield, protein content and nitrogen use efficiency (%) of eight sites are presented in Figure 1. The highest average yield was observed at Dorothy site (97.9 Bu/ac) and the lowest yield was observed at the Red Lake Falls site (61.5 Bu/ac). The highest protein content was observed at Rustad (15.8%) and the lowest protein content was at Mahnomen (10.3%). Dorothy site received anhydrous ammonia at the rate of 135 lb nitrogen per acre in fall, and the Linkert was the cultivar. At Rustad, high protein cultivar, ‘Bolles’ was planted and received 110 lb nitrogen per acre in fall. Nitrogen use efficiency was calculated by dividing the nitrogen removal by grain with nitrogen applied through fertilizer. The highest nitrogen use efficiency was found at the Thief River Falls site and the lowest was observed at Gentilly. Initial (24th June) growing season and post-harvest deep soil (2 ft) nitrate content were presented in Figure 2. Initial deep soil nitrate content ranged between 5.66 (Thief River Falls) to 9.99 (Argyle) lb nitrogen per acre. Post-harvest deep soil nitrate content ranged between 17.4 (Thief River Falls) to 30.1 (Argyle) lb nitrogen per acre. Low soil nitrogen content at Thief River Falls might be due to fast water movement through profile under sandy loam textured soils. On the other hand, high soil nitrogen content at Argyle might be resulted from slow water movement (sandy clay loam soils) and high nitrogen mineralization (5.2% organic matter). Cumulative ammonia volatilization losses observed at eight sites during the growing season are presented in Figure 3. The lowest ammonia volatilization was observed at Gentilly and the highest value was observed at Mahnomen site.

Application and Use

This study provides growers information about the nitrogen use efficiency of their practices. Interactions of soil types, cultivar and fertilizer management practices on grain yield, protein content and nitrogen losses were evaluated for eight sites.

Materials and Methods

During spring of 2019, eight spring wheat field located across the Red River Valley of MN were selected for this study (Table 1). Soon after planting, four collar for headspace air sampling to determine nitrous oxide flux, four suction cup lysimeter to collect soil solution at 2 ft depth for below-root-zone-nitrate concentration, and four open static chamber with ammonia trap to determine volatilization loss, were installed at 10 ft interval at each field (Figure 1). On a weekly basis, four soil samples from 0-6” soil depth were collected from each field and analyzed for inorganic nitrogen (ammonium and nitrate) concentration using 2M KCl extraction and TL2800 Timberline Ammonia Analyzer. Soil N_2O-N efflux will be measured every week interval using static chamber installed at each plot after planting. Headspace air samples of chamber was collected using a syringe at 0, 15, 30 min interval at each observation and air samples was analyzed using a Shimadzu gas chromatograph equipped with an electron capture detector. For volatilization, foam strips and the acid solution was collected. The sampled traps was transferred to the laboratory, where they was immediately extracted with 250 mL of 2 M KCl solution. The extracts were analyzed for NH_3 concentration using the ammonia analyzer. Soil water samples below the rooting zone was collected at a depth of 2’ using a suction cup lysimeter consisting a sealed plastic tube that was equipped with a 100-kPa high flow porous ceramic cup. A slight vacuum in the tube draws soil water through porous ceramic tip and water sample was collected by a syringe to the suction line extending past the top seal and a clamp to seal it off. Sample water from lysimeters was be analyzed for NO_3-N using an automated Timberline TL2800 Ammonia Analyzer. For harvesting, five-feet long four-rows were harvested to determine grain yield and protein content.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Information about nitrogen use efficiency can facilitate growers to save the cost of fertilizers. Growers can compare the potentials of different practices to improve their yield.

Cover Crop Management in a Wheat-Soybean System in Northwest Minnesota

Joel Ransom, Dept. of Plant Sciences, NDSU, Fargo

Research Questions

There is increasing interest in the use of cover crops, primarily for their benefits in protecting the soil from erosion and improving soil health. Given the limited time between the harvest of a crop and the end of the growing season in northern Minnesota, the establishment of cover crops into most farming systems can be challenging. Within the rotation sequences in northwestern Minnesota, cover crops will most likely establish best and provide the greatest environmental benefits when planted after harvesting wheat in fields where soybeans will be grown the following spring. When incorporated into the current wheat-soybean cropping system in NW Minnesota, cover crops have the potential of protecting the soil for several weeks, grow sufficiently to scavenge much of the residual soil nitrate, thereby reducing its loss through leaching and runoff and establish enough biomass to reduce soil blowing in the winter. This project will seek to answer questions related to how to manage cover crops after wheat to maximize their environmental benefits while minimizing any detrimental impacts on the productivity of the cash crops grown. Specifically, we hope to answer the questions of what cover crops are the most effective to plant after wheat if soybean is planted the following spring, and if planting rye after wheat, when is the best time to terminate it, relative to when soybean is planted the following spring

Results

We are still early the research process, with cover crops in one of the experiments planted only a few weeks ago because of late spring wheat harvest. In the rye termination timing experiments, we found that delaying the termination of rye (with glyphosate) until 2 weeks after planting (the latest termination date in the experiment) did not significantly reduce soybean emergence or soybean yield at harvest when compared to earlier termination timings (the earliest timing was two weeks before planting which was about as early as one could enter the field this year due to the late spring. The later termination dates resulted in greater rye biomass at the time of termination, greater weed suppression, and more ground cover during the early stages of soybean development. Rye terminated before planting soybeans had developed little biomass and this biomass was largely gone with a week or two of planting soybeans.

Application and Use

The data collected so far are from a single year, one which was abnormally wet in the spring. Therefore, the results should be viewed in the context of a wet spring. They do suggest that when rye is planted as a cover crop after wheat that delaying its termination beyond the planting of the soybean crop, will not have a detrimental impact on soybean establishment and yield, and will provide very good cover while the soybean crop is developing. This can reduce weed pressure, in addition to reducing the potential for erosion during the time that soybean is still developing.

Materials and Methods

We established the rye termination trial in fields of rye that had been planted the fall before, one in east of RLF in Red Lake County Minnesota and the other in Steele County in North Dakota. We superimpose the following treatments in a uniform area of the field (time of termination of rye in the spring): a) early spring (2 weeks before planting), b) 1 week prior to planting; c) at planting, d) 1 week after planting; and e) 2 weeks after planting. Rye was terminated by applying glyphosate at the recommended rate. Soybeans were planted with a no-till drill about May 20th. Rye biomass at the time of termination, stand establishment of soybeans; observations on early weed suppression, vigor and iron chlorosis scores on soybeans, and yield were obtained from these plots. This experiment will be repeated in 2019/20.

A second experiment was established in two location in September. In this experiment, a range of commonly recommended cover crops were planted in September (largely due to the wet fall, which precluded earlier planting). Cover crop biomass, in both the fall and winter will be measured and the effect of cover crops on the yield of soybeans in 2020 will be quantified. There are no data from this experiment yet as it was just established. Measurements that will be taken include: cover and biomass in the fall (after freeze-up and at the time of termination in the spring); nitrogen content of cover crops; stand establishment of soybeans; observations on early weed suppression, yield of the soybeans, vigor and iron chlorosis scores on soybeans as well as soil moisture and observations on soil tilth. Check plots where no cover crops will be planted will be included.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Potential economic benefits are unknown at this time but will hopefully become clear as we explore and analyze the data moving forward. Preliminary data suggests that there will be weed suppression when rye is terminated after planting soybeans. This could potentially translate into an economic benefit for farmers, particularly if there are weeds in the field that are difficult to control due to herbicide resistance.

Related Research

Funding for this project is provided by the MN Wheat Research and Promotion Council and the MN Soybean Research and Promotion Council. The goal of this project is to improve the sustainability of the wheat-soybean rotation as a whole by evaluating cover crops from a systems perspective, rather than focusing on a single year or crop.

Recommended Future Research

None yet.

Publications

None. The plots from the first year of the research were just harvested.

Figure 1. Photo of plots showing the differing levels of rye biomass in mid-June.

Breeding Wheat for Intensive Management in Western Minnesota and Eastern North Dakota-II

Andrew Green, Dept. of Plant Sciences, NDSU, Fargo

Research Questions

Continue to identify and select genotypes which perform well for producers in eastern North Dakota and western Minnesota.

Gather agronomic, grain quality, and end-use data regarding genotypic response to intensive management for aid in breeding selection.

Evaluate elite breeding lines in target environments of western Minnesota.

Results

Tables 1 - 4 present results from 2017-2019. Some interesting findings are summarized here.
Fungicide significantly increased yield at both Wolverton and Fisher in 2019. The yield protection at Wolverton was notable (11.6 bu/ac), due to the severe Fusarium Head Blight (FHB) at that location.There was significant Bacterial leaf streak (BLS) at Fisher, which was higher in the intensive management block (data not shown). This likely masked some yield protection from the fungicide since it won’t affect bacteria.

Table 2 presents means by management treatment, analyzed by individual location. Baking data from 2018 is included, but samples are still being processed for 2019 locations. There were no differences for loaf volume in 2018 with addition of UAN, but baking absorption did increase at East Grand Forks in 2018. Overall, there were inconsistent results for end-use quality differences under intensive management. At every location from 2017-19, grain protein increased with post-anthesis UAN, as expected.

Because this experiment involved breeding program lines, the entries changed each year. However, nine genotypes were tested in all six environments. These results (Table 3&4) allow for deeper conclusions, across years. Yield and grain protein content were consistently different between management treatments. Because quality data are from unreplicated composite samples, these data cannot be analyzed in the same manner. The means of the nine genotypes that appeared in every environment are shown in Table 4. Interestingly, all of the varieties on this list are at least moderately resistant to Fusarium head blight, which was the primary disease we observed in these trials. Despite this, notable improvements were still found for yield across years with addition of fungicide. As noted from Table 2, results of quality data were inconsistent. This suggests that an integrated management approach of varietal resistance and chemical protection offers the best yield protection.

Application and Use

We hope to use this research in the breeding program to identify new varieties that will perform well in these management practices. If we are able to help quantify how different varieties and their end-use quality perform under the two management programs, this information could also be used for making economically sound decisions on the farm.

Materials and Methods

The study was a split-plot trial at Fisher and Wolverton, MN in 2019. There were three replicates per management treatment, for a total of six plots per genotype at each location. In 2019 there were 45 entries in the trial, ten of which were check varieties, with 35 experimental lines. Over the three years of the project, nine genotypes were tested in each year, which allowed for analysis across years. The whole plot factor was management, with standard (no foliar fungicide, no post-anthesis UAN) and intensive (foliar fungicide at flag leaf emergence and 20 gal/acre of 28-0-0, post-anthesis). All other management was consistent, and conducted by farmer cooperators. Since real breeding data was used for the experiment, individual years were analyzed separately, as experimental genotypes changed from year to year. We would like to thank Jay Nord, K&D Krueger Farms & Sons, and AgriMAX for their valued cooperation.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The primary objective of this research was to screen potential new varieties in productive environments in western Minnesota. In addition to conducting elite breeding trials at these locations, this project addressed two main academic questions.
1) Fungicide application in wheat has become a routine management technique, whether the variety and environment needs it or not. Monitoring yield differences under intensive management from modern genetics can help

breeders and producers make the best decisions to maximize economic gains. Our results showed that potential yield gains vary a great deal from year to year, and may not even be significant in some years (Wolverton 2017, East Grand Forks 2018). However, when disease pressure is exceptionally high, yield improved by an average of 11 bushels per acre from fungicide application (Wolverton, 2019). These gains varied a great deal by genotype, which is information that needs to be collected, for best management.

2) Spring wheat is valued for its superior milling and baking qualities. A low grain protein content can compromise this quality, and subject producers to cash discounts. While available N for grain protein is not always limiting, it may be possible to manage high yielding varieties with post-anthesis UAN to supplement N for protein content. This management can also be useful for selection. In the breeding program, we may not want to discard a line because the grain protein percentage was low if it had a high yield and could be managed differently. Rather, we would prefer to test for protein functionality through milling and baking where protein was not limiting. This should lead to more productive variety options for farmers that also possess good end-use quality.

Publications

We intend to submit this work for publication when the baking analysis is complete for 2019. MNWRPC will be credited with funding for this study in that manuscript.

Table 1. Analysis of Variance for Agronomic Traits, by Location in 2019

Wolverton 2019					
	df	Yield	Protein	Test Weight	Harvest Moisture %
Management Treatment	1	**<.0001**	**0.0002**	**<.0001**	**<.0001**
Genotype	44	**<.0001**	**<0.0001**	**<.0001**	**<.0001**
Management Treatment *Genotype	44	0.9947	0.8637	0.2406	0.4688
Effect of Intensive Management		+11.6 bu/ac	+.27%	+.82 lb/bu	-.65%
Fisher 2019					
	df	Yield	Protein	Test Weight	Harvest Moisture %
Management Treatment	1	**<.0001**	**<.0001**	**<.0001**	**<.0001**
Genotype	44	**<.0001**	**<.0001**	**<.0001**	**<.0001**
Management Treatment *Genotype	44	0.7435	**0.0117**	0.2265	0.9928
Effect of Intensive Management		+5.7bu/ac	+.51%	+.90 lb/bu	-.91%

Statistically significant data are noted with **bold** text.

»

Table 2. Mean of all genotypes for select traits, by Management Treatment within Environment.

	Mixograph Score (1-9)*		Loaf Volume (cc)		Flour Extraction %		
	Standard	Intensive	Standard	Intensive	Standard	Intensive	
EAST GRAND FORKS 2017	4.4	4.8	**202**	**213**	53.2	533	
WOLVERTON 2017	3.8	4.0	**188**	**206**	51.0	50.2	
EAST GRAND FORKS 2018	4.1	4.3	222	214	51.4	51.2	
BARNESVILLE 2018	4.6	4.6	184	188	*48.9*	*47.9*	
FISHER 2019	4.0	3.9	-	-	*40.1*	*41.7*	
WOLVERTON 2019	3.1	2.5	-	-	41.6	42.4	

#	p<0.01
#	p<0.05

* Genotype means by Management Treatment were compared across years using a t-test and not found to significantly differ.

Table 3. Analysis of Variance probability values for nine check varieties appearing in all six environments, 2017-2019

	df	Yield	Lodging	Protein	Test Weight	Harvest Moisture
Management Treatment	1	**<.0001**	0.76	**<.0001**	0.39	0.8583
Genotype	8	**<.0001**	**0.0232**	**<.0001**	**0.0005**	**<.0001**
Management Treatment*Genotype	8	0.9864	0.97	0.811	0.36	0.9786
Effect of Intensive Management		+5.9 bu/ac	NS	+.52%	NS	NS

Statistically significant data are noted with **bold** text.

	Baking Absorption %		Test Weight (lb/bu)		Grain Protein %		Yield (bu/ac)	
	Standard	Intensive	Standard	Intensive	Standard	Intensive	Standard	Intensive
	60.1	59.8	**62.2**	**62.9**	**14.8**	**15.1**	**97.1**	**102.7**
	59.8	59.9	**60.1**	**60.6**	**14.4**	**15.2**	75.5	76.9
	66	**69**	**61.8**	**62.2**	**15.3**	**16.2**	73.7	74.2
	70	69	60.0	60.1	**15.2**	**15.7**	**51.1**	**57.0**
	-	-	58.5	59.0	**14.9**	**15.4**	**78.1**	**83.8**
	-	-	58.3	59.0	**15.0**	**15.2**	**62.64**	**74.8**

Table 4. Mean of agronomic and baking traits for nine check varieties tested across all environments, 2017-2019.

Variety	Management	Yield (bu/ac)	Protein %	Test Weight (lb/bu)	Flour Extraction %	Baking Absorption %	Loaf Volume (cc)	Mixograph (1-9)
Barlow	Standard	74.7	14.9	60.4	50.3	65.5	202.0	4.0
	Intensive	82.9	15.5	61.1	48.9	63.5	206.0	4.3
Elgin-ND	Standard	82.0	14.6	59.0	49.4	60.0	206.5	3.8
	Intensive	86.6	15.0	60.0	49.3	60.0	200.0	3.8
Faller	Standard	81.0	14.1	60.6	54.1	58.0	203.0	3.1
	Intensive	87.3	14.8	61.0	51.1	58.0	206.0	3.1
Glenn	Standard	73.7	15.2	61.5	47.6	64.0	206.8	4.8
	Intensive	79.5	15.9	62.2	47.5	64.5	205.0	4.7
NDExp1	Standard	72.5	15.4	61.2	47.4	65.0	206.0	3.3
	Intensive	75.8	16.0	61.7	48.8	66.0	208.0	3.2
NDExp2	Standard	81.1	14.4	60.5	47.6	64.0	176.3	4.0
	Intensive	83.8	14.9	58.1	48.7	64.0	204.8	4.5
ND Vitpro	Standard	76.4	15.3	61.2	49.8	63.5	195.5	4.3
	Intensive	81.8	15.8	61.8	49.3	64.0	215.8	4.3
SY Ingmar	Standard	81.7	15.0	60.6	51.2	62.5	194.3	4.2
	Intensive	89.7	15.3	60.9	50.7	63.0	197.3	4.3
SY Valda	Standard	79.8	14.3	60.2	48.9	62.5	184.8	2.8
	Intensive	87.6	14.6	60.5	48.4	62.5	176.8	2.5

Accelerated Breeding for Resistance to Fusarium Head Blight

Karl Glover, Plant Science Dept., SDSU, Brookings

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 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 project is to use traditional plant breeding and selection techniques to develop hard red 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 generally at least moderately resistant to FHB. Those that do not perform adequately are discarded after the first year of AYT observation. 2019 AYT results are presented in the appendix. Thirty-four experimental breeding lines were tested along with fourteen check cultivars during the 2019 growing season. Of the thirty-four experimental lines, twenty-one had FHB disease index (DIS) values that were less than the test average. Among these entries, seventeen produced more grain than average. Among these seventeen, test weight of fourteen entries was higher than average, and protein content of eight (SD4625, SD4848, SD4852, SD4855, SD4873, SD4874, SD4879, and SD4885) were also greater than average. SD4625 may be released in November 2019 for Certified seed production in 2020.

Application and Use

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

Materials 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 (over two winter seasons). 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 50 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, 10 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 Disease Index, along with agronomic potential from the 2019 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 development, however, cultivars with elevated FHB resistance levels can help to reduce potentially serious grower losses.

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 ten test environments in 2019.

ENTRY	DIS	YIELD	TW	PROTEIN	HEADING	HEIGHT
	INDEX	(BU/AC)	(LB/BU)	(%)	(D > 6/1)	(INCHES)
BRICK	17.3	35.3	58.8	16	32.7	32.1
BOOST	18.2	36.5	57.4	16	39.5	32
SD4870	18.3	40.6	57	16.1	38.3	31.9
SD4848	18.6	38.1	58.6	16.8	38.5	30.3
SD4773	18.7	40.8	56.9	15.7	39.9	31.2
LCS-TRIGGER	18.8	45	57.7	13.9	42.7	31.5
SD4879	18.8	38.2	58.3	16.4	38.7	33.9
SD4873	19.3	48	58.1	16.1	39.3	33
SD4885	19.4	38.5	58.8	15.9	35.1	32
FOCUS	19.6	36	58.5	16.3	33	33.7
SD4775	19.6	38.3	56.5	15.7	41.7	31.9
SD4840	19.6	40.6	57.7	15.5	33.7	30.5
SD4871	19.8	42	59	15.5	37.4	29.1
SD4855	19.9	41.3	58.7	16.1	37.7	31.7
SD4874	19.9	40.5	58	16.3	39.9	31.6
SD4625	20.1	40.9	57.6	15.9	38.2	31.7
SD4852	20.2	41.3	58.4	16.1	35.2	30.4
PREVAIL	20.3	39.7	57.1	15.1	37.1	30.5
SY-VALDA	20.3	39.9	57.2	15.8	37	29.4
SD4849	20.5	37.7	57.5	15.8	36.2	31.1
SD4844	20.6	36.3	57.1	16.1	38	32.1
ADVANCE	20.7	37	57.1	15.3	38	30.4
SD4878	20.7	40.2	58.3	15.7	39.6	32.4
FOREFRONT	21	37.9	58	15.9	34.2	34.2
SD4843	21.3	40.5	58.3	15.2	37.7	31.4
SD4866	21.6	34.9	58.6	16.2	41.4	31.7
SD4708	21.7	39.1	57.9	15.8	36.7	32.5
SD4868	21.9	32.8	57.7	16	38.6	29
SD4719	22	40.1	57.7	15.2	39.1	33.4
SURPASS	22.1	35.4	56.6	16.2	34.3	31.3

»

» **Table 1** *continued.*

ENTRY	DIS INDEX	YIELD (BU/AC)	TW (LB/BU)	PROTEIN (%)	HEADING (D > 6/1)	HEIGHT (INCHES)
SD4816	22.8	35.4	56.8	15.8	41.9	30.4
FALLER	22.8	37.8	57	15.1	38.7	32.5
SD4891	22.9	37.6	58.5	16	36.3	32.1
SD4881	23.3	35.8	56.7	16.4	37.3	33
SD4842	23.6	36.1	58.7	16.4	36.6	32.6
SD4854	23.8	39.8	58.3	16.5	37.7	31.9
SD4765	24.6	36.1	57.1	16.4	34.8	32.3
TRAVERSE	24.7	35.1	54.4	15.7	36.1	34.3
SD4859	24.9	34	56	16.1	35.5	30.4
SD4876	25.3	39.5	56.7	15.5	36.4	29
SD4771	26.2	31.6	54.5	16.2	34.4	26.6
BRIGGS	26.3	33	56.5	16.3	35	31.3
SD4772	26.3	38	56.8	15.8	35.6	30.3
SELECT	27.1	34	57.6	16	33.1	31.7
SD4846	27.3	36	56.9	15.9	33.8	30.3
SD4814	27.7	36.4	55.5	15.9	40.2	31.5
SD4869	28.6	31.6	55.6	15.7	36.5	25.6
OXEN	34.5	32.5	54.4	15.9	36.3	29.2
MEAN	22.16	37.79	57.36	15.88	37.2	31.31
LSD (0.05)	3.17	1.37	0.29	0.14	0.67	0.72
cv	15.34	8.75	2.00	2.98	6.55	5.46

Research on Bacterial Leaf Streak and the Root and Crown Rots of Wheat

Ruth Dill-Macky, Dept. of Plant Pathology, U of M, St. Paul

Research Questions

This project aimed to seek control measures for two diseases that are important to wheat production in Minnesota; bacterial leaf streak (BLS) and Fusarium root and crown rot. The ultimate goal of the project is to deliver economic disease control measures for these diseases, largely through the development of germplasm with improved resistance. The work completed in this project is of benefit to wheat production in Minnesota through the development of adapted wheat varieties with improved resistances to two economically significant diseases.

Specific Objectives of the project included:
Bacterial Leaf Streak
1.1. Co-ordinate the BSL cooperative nursery (BLSCN) testing commercial cultivars from all wheat breeding programs in the region - we anticipate that financial support of the BLSCN will transfer to our MN Small Grains Initiative project at the start of the next MN-SGI funding cycle.
1.2. Identify additional sources of resistance to BLS using field and greenhouse screens
1.3. Complete studies conducted in the previous project examining the host range of the BLS pathogen and examining variation in pathogen populations
1.4. Examine the diversity and structure of TAL effectors produced by the *Xtu* population associated with wheat in Minnesota with the goal of identifying host resistance that negates the impact of these pathogen proteins
1.5. Disseminate information to wheat growers

Fusarium Root and Crown Rot Disease
2.1. Utilize the greenhouse methods we have developed for determining the reaction to root rot pathogens in the greenhouse screenings to screen commercial cultivars and advanced breeding lines for reaction to Fusarium crown rot
2.2. Screen wheat populations for response to crown rot
2.3. Identify sources of resistance to FCR with the goal of generating additional wheat populations
2.4. Disseminate information in FCR control to wheat growers

Results

Bacterial Leaf Streak: In 2019 we tested released varieties and advanced lines in a regional cooperative nursery (BLSCN). The 92 entries came from eight wheat breeding programs (3 public [UMN, NDSU, SDSU] and 5 private [BASF, Dyna-Gro, Meridian Seeds, Syngenta, 21st Century Genetics) in the Upper Great Plains. The BLSCN was established at four locations; St Paul, Crookston, Fargo, ND and Brookings, SD. The data from all four locations indicate that significant differences were observed in these materials for their reaction to BLS under field conditions (Table 1). The information obtained on the response of released varieties and elite germplasm has been provided to the regional wheat breeding programs to the benefit of growers. Information on the response of released germplasm to BLS collected in the 2019 BLSCN will be combined with previous data sets and the overall evaluations will be disseminated to Minnesota growers through the MN variety trials bulletin and other publications.

In 2019 we continued our work examining the role that wild grasses and other grass hosts play in the epidemiology of BLS in Minnesota. We utilized a collection of *Xanthomonas translucens* isolates collected from weed hosts to conduct a molecular analysis of the diversity of the pathogen.
The objectives of this study were to isolate *X. translucens* from poaceous weeds in Minnesota, determine pathogenicity of these strains on wheat and barley, assess phylogenetic relationships and genetic diversity of strains using multilocus sequence analysis (MLSA) and typing (MLST) of four housekeeping genes (*rpoD, dnaK, fyuA,* and *gyrB*), and evaluate the efficacy of loop-mediated isothermal amplification (LAMP) assays designed to identify *X. translucens* pathovars that cause BLS on small grains. Bacteria were isolated from 157 plant samples, representing 12 poaceous hosts collected in and around commercial fields of wheat. Strains exhibiting characteristic colony morphology on Wilbrink's medium were purified and evaluated further. The majority (87/134) of strains were predicted to be *X. translucens* by DNA (16S rDNA) sequencing. A subset (51) of the strains predicted to be *X. translucens* were infiltrated into leaves of wheat and barley seedlings and found to cause disease. Eight of these strains were also tested in the field and likewise caused disease on wheat and barley. Phylogenies from MLSA show that strains from weedy grasses and wild rice are closely related to known *X. translucens* pathovars, most commonly *X. translucens* pv. *undulosa.* The findings demonstrate that poaceous weeds serve as reservoirs of inoculum for the bacterial pathogen inciting BLS of wheat.

In a previous project we had demonstrated that strains of *Xtu* produce TAL effectors, small proteins that impact the host-pathogen interaction. In 2019 we started to examine the diversity of these TAL effectors, specifically to examine their diversity using molecular tools. The collection of *Xtu* isolates we developed and characterized in the previous projects were utilized in this project. Our results show » evidence that multiple TALEs are present in *X. translucens* and there is diversity among isolates and pathovars. This work, though preliminary, may provide avenues or research to provide additional tools and show promise to inform future breeding efforts for host resistance.

Root and Crown Diseases:
In the 2019 spring greenhouse season we tested a new protocol for inoculating wheat seedlings and tested a number of wheat populations that appear to be segregating for reaction to crown rot. We have made progress in refining our methods of greenhouse screening and have continued our efforts to identify sources of resistance to *Fusarium* crown rot (FCR). As is the case for Fusarium head blight (FHB or scab), resistance to FCR is partial in nature and appears to be conferred by multiple small effect QTL. The ultimate goal of this work is to identify progeny with improved resistance that can serve as adapted donors of resistance in the hard red spring wheat breeding programs in the Upper Great Plains.

Application and Use

Developing effective and durable resistant germplasm to the diseases of economic importance to wheat in Minnesota relies in the development of effective screening methods to identify sources of resistance and to introgress the resistance into adapted germplasm, along with an understanding of the epidemiology and biology of the pathogens.

In 2019 we have continued our screening efforts in field nurseries for BLS and greenhouse screening for crown rot of wheat. We have also made significant progress in understanding the diversity of the pathogen populations that inform future breeding efforts and the development of other disease control practices.

Materials and Methods

<u>Bacterial leaf streak:</u> In 2019 we coordinated a cooperative regional nursery (BLSCN) in which released cultivars and advanced lines from wheat breeding programs (public and private) in the Upper Great Plains are screened for resistance to BLS. Screening nurseries were also used to identify additional sources of resistance. Annual field screening nurseries are critical to the ultimate goals of the research - host resistance - and this work is being done cooperatively with Dr Shaukat Ali (South Dakota State University) and Dr Zhaohui Liu (North Dakota State University).

<u>Wheat Root and Crown Diseases:</u> We have developed a better understanding of the root and crown rots in wheat and identified Fusarium crown rot as a prevalent and underrecognized pathogen of wheat in Minnesota. Field surveys, conducted collaboratively with pathologists and breeders have examined the distribution and prevalence of root rot pathogens. We have established laboratory methods for working with the root rot pathogens and have developed greenhouse methods for inoculating the roots and stem bases of wheat plants with *Fusarium* spp. These efforts continued in 2019 and have facilitated our ability to screen germplasm for reaction to the Fusarium root rot.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

We have demonstrated that bacterial leaf streak (BLS) is of economic importance to the wheat industry and data has been generated that a grower can use to select wheat varieties for production that are less susceptible to BLS. The data gathered from this project demonstrate that root rots are prevalent in commercial wheat fields in Minnesota. Two root rot pathogens in particular, *Fusarium* and *Bipolaris*, are abundant and likely contribute significantly to yield losses, particularly in years when moisture is limiting in the latter part of the growing season. Information on the prevalence of these diseases is of immediate benefit to the grower by increasing an awareness of disease problems impacting wheat production. The development and introgression of host resistance provides economic and environmentally sustainable control of wheat diseases. The work in this project has contributed to the development of wheat varieties with improved resistance to diseases with economic impact.

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 private) in Minnesota and with our neighboring states. Regional wheat breeding programs have benefited by our ability to provide field observations of the distribution of diseases and in evaluating wheat germplasm. The wheat breeding programs in the region (public and private) have especially benefitted from information on the reaction of released and advanced breeding lines to BLS.

Recommended Future Research

Bacterial leaf streak: Our collaborative screening efforts have provided robust data on the reaction of commercial what cultivars to BLS. The majority of our wheat cultivars, and many advanced lines from the regional breeding programs, are at least moderately susceptible to BLS thus additional efforts to identify source of resistance are warranted. We plan to continue using screening nurseries to test wheat lines for their response to BLS and identifying additional and improved sources of resistance. BLS resistance appears to be governed by multiple genes and quantitatively inherited. We have completed our studies examining the pathogen population to determine the host range of the *X. translucens* pv. *undulosa* pathovars associated with BLS of wheat, other crops and grassy weeds and this work is in preparation for publication. We are pursuing a collaboration with researchers at Cornell and The Ohio State University to examine the survival of BLS from one season to the next on wheat seed and to develop a PCR and genomics based pipeline for sensitive, specific and affordable BLS diagnostics and surveillance.

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 have made good progress in developing testing methods suitable for inoculating plants with *Fusarium* spp. in the field and greenhouse. As was anticipated from the start from this project, the root diseases have proven challenging host-pathogen interactions to understand and manipulate. We have continued to make steady progress in our understanding of the root rots in 2019 having continued our efforts in developing greenhouse protocols that are of value to breeding efforts. In 2020 we plan to continue our efforts and plan to test additional materials in our efforts to identify additional and adapted spring wheat sources of resistance to FCR.

Publications

Curland, R., Gao, L., Bull, C., Vinatzer, B., Dill-Macky, R., van Eck, L., and Ishimaru, C. 2018. Genetic diversity and virulence of wheat and barley strains of *Xanthomonas translucens* from the Upper Midwestern United States. *Phytopathology* 108:443-453.

Ledman, K. E., Curland R. D., Ishimaru C. A., and Dill-Macky, R. 2019. Weedy grasses as a potential reservoir of the pathogen causing bacterial leaf streak of wheat. *Phytopathology* (abstract) *In press*.

Winter, M., Samuels, P.L., Dong, Y., and Dill-Macky, R. (2019). Trichothecene production is detrimental to early root colonisation by *Fusarium culmorum* and *F. graminearum* in Fusarium crown and root rot of wheat. *Plant Pathology*, 68 (https://doi-org.ezp2.lib.umn.edu/10.1111/ppa.12929).

Table 1: Response to bacterial leaf streak rated on a 1-9 scale (1= no disease and 9 = severe disease) for the forty-four named varieties, of the ninety-two entries, included in the 2019 Bacterial Leaf Streak Cooperative Nursery.

	Location				4 Location Mean
Variety	St Paul - MN	Crookston - MN	Fargo - ND	Brookings - SD	
Boost	3.0	2.8	4.3	3.7	**3.4**
TCG-Spitfire	2.5	2.8	5.5	5.7	**4.1**
Blade	3.3	3.3	6.0	4.3	**4.2**
Lang-MN	3.5	2.8	6.0	4.7	**4.2**
Surpass	2.3	3.0	6.5	5.3	**4.3**
Advance	2.8	3.3	6.0	5.7	**4.4**
TCG-Wildfire	3.8	3.0	5.8	5.3	**4.5**
Faller	3.0	3.0	5.8	6.3	**4.5**
Prevail	3.5	3.3	6.5	5.0	**4.6**
Rollag	2.8	2.5	6.8	6.3	**4.6**
Prosper	3.0	3.0	6.3	6.3	**4.6**
SY Valda	3.3	3.3	6.5	5.7	**4.7**
Dyna-Gro Ballistic	3.0	3.0	7.0	6.0	**4.8**
MN-Wasburn	3.0	4.0	5.8	6.3	**4.8**
Shelly	3.0	3.5	6.0	6.7	**4.8**
Cromwell	3.5	3.5	5.8	6.7	**4.9**
ND VitPro	3.5	3.0	7.3	5.7	**4.9**
SY Rustler	3.3	3.5	7.0	5.7	**4.9**

»

Table 1. *continued*

	Location				4 Location Mean
Variety	**St Paul - MN**	**Crookston - MN**	**Fargo - ND**	**Brookings - SD**	
Focus	3.8	3.0	7.5	5.3	**4.9**
TCG-Climax	3.0	4.3	5.8	6.7	**4.9**
MS Chevelle	3.8	3.0	7.0	6.0	**4.9**
Dyna-Gro Caliber	3.3	3.0	7.3	6.3	**5.0**
TCG-Cornerstone	4.5	3.3	6.5	5.7	**5.0**
Knudson	3.3	4.0	6.8	6.0	**5.0**
Bolles	3.8	4.5	7.3	4.7	**5.0**
Dyna-Gro Ambush	3.8	4.5	7.3	4.7	**5.0**
Linkert	4.3	3.5	6.5	6.0	**5.1**
SY Ingmar	4.0	3.0	6.8	6.7	**5.1**
RB07	3.5	4.3	7.5	5.7	**5.2**
SY Longmire	4.0	3.5	7.8	5.7	**5.2**
Forefront	3.8	3.5	7.5	6.3	**5.3**
SY Soren	4.3	3.3	7.3	6.3	**5.3**
SY Rowyn	4.3	3.0	6.8	7.3	**5.3**
TCG-Glennville	4.0	3.3	7.8	6.3	**5.3**
MS Camaro	3.8	3.3	7.8	6.7	**5.4**
SY Rockford	4.3	5.3	6.5	6.3	**5.6**
TCG-Heartland	4.8	3.3	7.5	7.0	**5.6**
Dyna-Gro Commander	5.0	3.3	7.8	6.7	**5.7**
Hattrick	3.5	4.3	7.8	7.3	**5.7**
Samson	4.5	5.0	8.0	5.7	**5.8**
SY McCloud	5.0	3.3	7.8	7.3	**5.8**
Select	5.3	5.0	7.3	6.3	**6.0**
MS Barracuda	4.5	4.8	8.0	6.7	**6.0**
TCG-Stalwart	4.8	6.5	7.8	7.7	**6.7**

The data provided are based on four replicate plots at each location, except Brookings where the data are from three replicates. Varieties are listed in rank order of the four-location mean.

Southern Minnesota Small Grains Research and Outreach Project

Jared Goplen, Morris Regional Extension Office

Research Questions

The objectives of this grant were to:

1. Evaluate variety performance for Hard Red Spring Wheat (HRSW) and Hard Red Winter Wheat (HRWW) varieties across southern Minnesota with locations at Benson, Kimball, and Le Center.
2. Organize extension programming for small grain production and management in southern Minnesota using summer field days and winter meetings.

Results

The "Southern Wheat Tour" characterized the winter extension programming for small grains production and management in central and southern Minnesota. Meetings were held in Benson, Cold Spring, Mora, New Prague, Rochester, and Slayton, MN. Attendance has been strong in recent years, with 157 farmers and crop consultants attending these six meetings in 2019 despite blizzards affecting attendance at several locations (Figure 1). The meetings were well received, with 99% of attendees responding that they would recommend the program to others. Over 95% of workshop attendees planned to change production practices at least somewhat by attending a workshop, with a 22% increase in attendees planning to increase scouting efforts for small grain insects and diseases. Additionally, there was a 27% increase in attendees who plan to seed some acres to a cover crop following small grain harvest to utilize as forage-capturing additional value from small grain production.

The summer field days were held the last week of June at Benson, Kimball, Le Center, New Ulm and Rochester to showcase variety trials. A summary of the attained grain yield and grain quality of the HRSW and HRWW variety trial results can be found in tables 1 and 2 (Appendix I). The average yield across all southern Minnesota locations was 69 bu/ac for HRWW and 77 bu/ac for HRSW. Plots were also used as sentinel plots for summer scouts to monitor disease and insect pests during the growing season (In conjunction with the Minnesota Small Grains Pest Survey) and were also used for pest identification and demonstration during summer field days.

Application and Use

Central and southern Minnesota have not had large small grain acreages in recent decades. Small grains have often been grown in this region for reasons other than maximized production, such as manure applications, straw production, forage/cover-crop establishment, or tiling projects. The combination of low commodity crop prices, weed and insect resistance issues, and interest in diversifying crop rotations to improve soil health has inspired more farmers in these regions to consider growing small grains. Our research and demonstration plots have documented the ability to grow small grains in central and southern Minnesota with high yield and quality that can maximize profitability. Our results have been echoed by reports from farmers in these regions who utilize advanced management tools and genetics despite the added production risks of heat and disease stressors that are more prevalent in southern Minnesota.

Materials and Methods

The winter wheat and rye variety trials had 24 and 18 entries, respectively. Plots were seeded on October 1, 2018 at Kimball, MN and on 10/7/2018 at Le Center, MN. The spring wheat, oats, and barley variety trials had 37, 25, and 10 entries, respectively. Trials at Rochester, Le Center, Kimball, and Benson were seeded from 4/23/2019 – 4/26/2019. New Ulm was not seeded due to unsuitable planting conditions. Trials were all a randomized complete block design with 3 replications. Field preparations and fertility management were completed by plot cooperators. Planting, weed control, data collection, and harvest were completed by the research group.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Variety selection is one of the most critical decisions made on a wheat enterprise. A well-adapted versus a poorly-adapted variety can be the difference in farm profitability. In the 2019 on-farm trials, there was a 20 bu/ac difference between the highest-yielding 10% of varieties and the lowest-yielding 10% of varieties. This 20 bu/ac difference in yield could increase returns by over $100 per acre, or over $50,000 in gross returns for a 500 acre wheat enterprise. All with only changing variety selection. Even just increasing yield by 10% can increase gross returns by nearly $40 per acre. Variety trials are especially valuable in southern Minnesota, where variety trial information is otherwise limited. The ability to recommend varieties adapted to southern Minnesota as well as for farmers to see varieties firsthand before planting them has an invaluable impact on current and future wheat farmers in southern Minnesota.

»

» These trials also influence the spring wheat, barley, and oat breeding programs at the University of Minnesota, by allowing on-farm assessments of yield, disease, lodging and other agronomic characteristics that are used to influence future varietal releases and agronomic ratings. These factors further add to the long-term impact that this project has on a typical wheat farm in Minnesota.

Related Research

This research is integrally linked with the small grain breeding programs at the University of Minnesota. The spring wheat, barley, and oat breeding programs utilize the data generated in these trials as part of their southern small grain variety performance evaluations, which expands the geographical coverage of small grain variety trials as well as provides on-farm credibility to the variety evaluations. The rye variety trials also link with this project with funding from other sources.

Recommended Future Research

Variety trial data is much more valuable when it is aggregated with ongoing variety trials. Just because a variety performed well one year does not mean it will repeat the same trend in the future. Variety selections should be based on multiple years of data from multiple locations. This is why these variety trials should be continued into the future so that farmers can continue to refine their variety selections as new genetics become available.

Publications

Results of yield trials for spring and winter wheat, barley, oats, and winter rye are part of the variety trial results that will be published in the on-line publication '2019 Minnesota Field Crop Trials' (Also available at https://www.maes.umn.edu/publications/field-crop-trials). The 2018 trial results were published in:

1. Anderson J.A, J.J. Wiersma, S. Reynolds, N. Stuart, H. Lindell, R. Dill-Macky, J. Kolmer, M. Rouse, Y. Jin, M. Smith, and L. Dykes. 2018. 2018 Hard Red Spring Wheat Field Crop Trials Results. *In*: 2018 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.
2. Smith, K., R. Dill-Macky, J.J. Wiersma, M. Smith, B. Steffenson, and E. Schiefelbein. 2018. 2018 Barley Field Crop Trials Results. *In*: 2018 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.
3. Heuschele, J., R. Dill-Macky, D. von Ruckert, J.J Wiersma, and K. Smith. 2018. 2018 Oat Field Crop Trials Results. *In*: 2018 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.
4. Wiersma, J.J. and J.A. Anderson. 2018. 2018 Winter Wheat Field Crop Trials Results. *In*: 2018 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.
5. Wiersma, J.J., S. Wells, and A. Garcia y Garcia. 2018. 2018 Winter Rye Field Crop Trials Results. *In*: 2018 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.

Appendix

Table 2 – Grain yield (% of mean) of Hard Red Winter Wheat varieties at two on-farm trial locations in southern Minnesota in 2019.

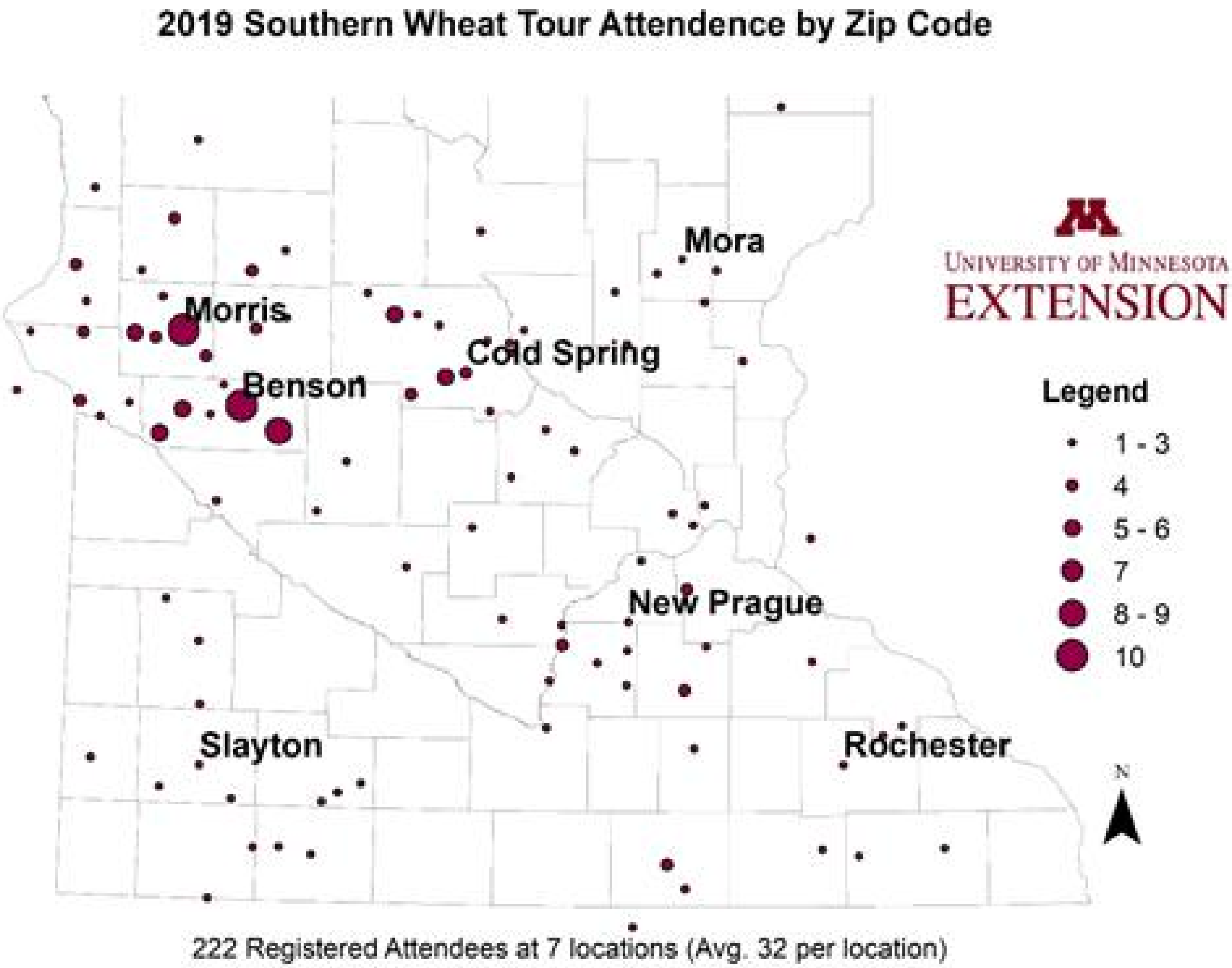
Variety	Kimball Grain Yield (% of Mean)	LeCenter Grain Yield (% of Mean)
AAC Goldrush	100	83
AC Emerson	111	86
DynaGro 9242W	98	109
FourOSix	107	105
Freeman	108	129
Ideal	89	96
Jerry	127	101
Jupiter	80	103
Keldin	103	121
LCS Chrome	94	88
LCS Link	93	102
LCS Mint	94	92
Loma	100	99
Minter	92	60
Northern	114	91
Oahe	102	120
Redfield	111	107
Ruth	88	96
SY Wolf	121	120
Thompson	106	110
Warhorse	88	73
WB4418	127	123
WB4462	102	102
Whitetail	49	103
Mean bu/acre)	**65**	**74**
LSD (0.1)	**12**	**NS**

Table 1 – Grain yield (% of mean), grain protein (%), and test weight (lbs/bu) of Hard Red Spring Wheat varieties at three on-farm trial locations in southern Minnesota in 2019.

	Benson			Kimball			LeCenter		
Entry	**Grain Yield (% of Mean)**	**Test Weight (lbs/bu)**	**Grain Protein (%)**	**Grain Yield (% of Mean)**	**Test Weight (lbs/bu)**	**Grain Protein (%)**	**Grain Yield (% of Mean)**	**Test Weight (lbs/bu)**	**Grain Protein (%)**
Bolles	103	61.8	15.9	87	60.6	16.3	91	59.1	14.9
Boost	99	59.6	14.3	94	60.3	14.8	102	58.7	13.2
CP3530	121	61.9	13.8	108	61.1	13.9	124	59.7	12.9
CP3888	101	61.3	13.7	106	60.7	14.8	97	58.3	13.3
CP3910	99	63.1	14.7	106	62.8	14.6	98	59.6	13.1
CP3915	108	62.9	14.4	99	62.1	14.7	96	59.1	13.4
CP3939	96	62.2	14.6	105	62.4	15.0	87	59.8	13.8
Dyna-Gro Ambush	93	61.9	15.2	111	62.0	15.8	120	60.9	14.0
Dyna-Gro Ballistic	107	60.9	14.5	109	60.9	14.7	103	58.9	12.7
Dyna-Gro Caliber	85	61.8	15.8	92	61.8	15.3	99	60.6	14.1
Dyna-Gro Commander	97	62.0	15.3	108	62.9	14.7	101	59.5	13.7
Dyna-Gro Velocity	97	62.8	15.3	98	62.8	16.3	106	60.8	13.5
Lang-MN	98	62.4	14.8	103	62.9	15.4	108	61.4	13.3
Lang-MN (0.7X)	98	62.8	14.7	100	62.7	15.5	104	60.5	14.4
LCS Breakaway	92	63.2	15.4	100	62.8	15.9	110	60.9	14.1
LCS Cannon	91	63.8	15.0	118	63.4	14.4	111	60.6	12.8
LCS Rebel	101	61.8	15.4	104	63.5	14.9	98	61.2	13.4
LCS Trigger	122	61.4	12.2	110	60.0	12.6	121	60.0	11.2
Linkert	89	62.5	15.5	102	62.2	16.0	86	60.1	14.4
MN-Washburn	96	61.4	14.3	92	61.2	14.9	97	59.9	12.8
MS Barracuda	94	62.6	15.2	115	63.0	15.5	106	60.1	14.1
MS Camaro	78	61.8	15.6	100	62.1	15.3	90	59.4	13.7
MS Chevelle	91	61.5	14.2	102	61.2	13.6	98	59.1	12.7
ND-VitPro	96	63.2	15.4	110	63.7	16.0	86	60.8	14.3
Prosper	104	61.6	13.2	100	61.5	12.9	105	59.5	12.4
Rollag	95	62.5	15.3	98	62.6	15.5	76	59.6	14.9
Shelly	100	61.6	14.1	103	62.5	14.4	99	59.2	13.2
Surpass	103	62.2	14.1	97	61.5	15.0	104	58.6	13.4
SY 611 CL2	111	62.8	14.6	107	61.6	14.9	100	60.1	13.7
SY Ingmar	100	62.1	15.4	100	62.8	15.8	91	60.2	14.9
SY Longmire	103	60.6	14.8	81	60.7	15.1	89	58.8	14.5
SY McCloud	91	63.5	15.7	97	63.5	15.6	89	61.5	13.8
SY Valda	114	60.9	13.6	107	61.4	14.5	125	59.7	12.6
TCG-Climax	97	63.1	15.0	89	62.4	16.5	90	60.4	14.6
TCG-Heartland	101	62.5	15.1	106	63.2	15.9	89	60.2	14.8
TCG-Spitfire	124	59.9	13.8	102	59.6	13.9	113	58.0	13.3
WB-Mayville	92	62.5	16.1	103	62.5	15.5	90	60.6	13.7
Mean (Bu/Acre)	**96**	**62.1**	**14.8**	**77**	**62.0**	**15.0**	**58**	**59.9**	**13.6**
LSD (0.10)	**8**			**9**			**7**		

»

» **Figure 1** – Map of Southern Wheat Tour winter workshop attendees by zip code across the 7 locations in southern Minnesota in January - February 2019.



Minnesota Small Grains Pest Survey and Wheat Stem Sawfly Surveillance

Jochum Wiersma, Dept. of Agronomy and Plant Genetics, NWROC, Crookston

Research Question

1) Provide timely alerts about pest and disease issues in small grains for small grains producers so that sound economic control options can be implemented.
2) Gain insight into the prevalence of the wheat stem sawfly (Cephus cinctus Norton) in northwest Minnesota.
3) Gain insight in emergence patterns of wheat stem sawfly in northwest Minnesota.
4) Evaluate current, adapted HRSW varieties for resistance to stem cutting by wheat stem sawfly.

Results

Pest and Disease Survey
The 2019 pest and disease survey was conducted differently than in previous years, where a call went out to small grain growers in early April to volunteer their fields for the small grains disease and pest survey. Approximately 80 fields were selected from the one hundred individual small grain fields in Minnesota submitted via the call for submissions (Figure 1). The three field scouts sampled these fields weekly and the data was shared with the NDSU IPM program to produce the regional IPM maps (https://www.ag.ndsu.edu/ndipm/wheat). The collected data was also used for ten small grains disease and pest updates that were published in in the months of June and July in the Minnesota Crop News blog (https://blog-crop-news.extension.umn.edu/) as well as on the Minnesota Association of Wheat Growers disease-forecasting website (http://mawg.cropdisease.com/) and the national Fusarium Head Blight Prediction Center (http://www.wheatscab.psu.edu/).

The Season Summary maps by disease or insect are provided as a reference in Appendix I at the end of the report (Appendix 1)

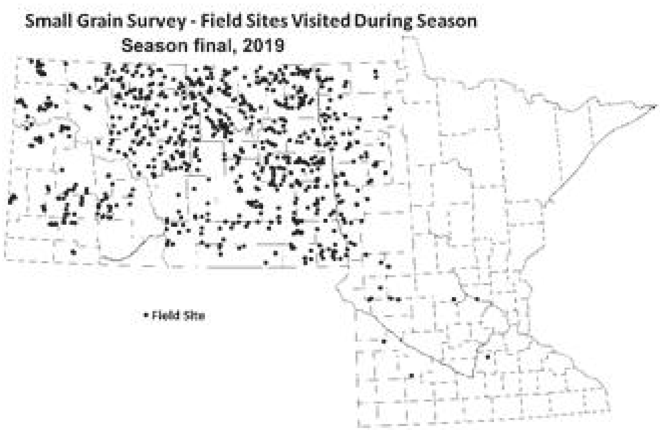


Figure 1 – Locations of wheat fields surveyed during the 2019 field season.

Wheat Stem Sawfly Surveillance
Adults of wheat stem sawfly (WSS) and subsequent stem clipping appears to have spread further from the Crookston area where it was first found several years ago. Stem clipping from WSS was reported in Norman, Polk, Red Lake, Pennington, and Marshall counties in 2019. The highest levels of clipping reported were nearly 50% of stems clipped per unit area. The highest levels of clipping were present in field borders near fields that had wheat grown in them last year. This leading edge effect is generally very noticeable when evaluating WSS damage just prior to harvest. It remains unclear whether WSS is increasing in population densities or if stem lodging/cutting is being noticed due to increased awareness of WSS. Survey for adults by sweep net were conducted, but the survey results suggest that this method does not provide a lot of information on level of activity in NW MN (Figure 2).

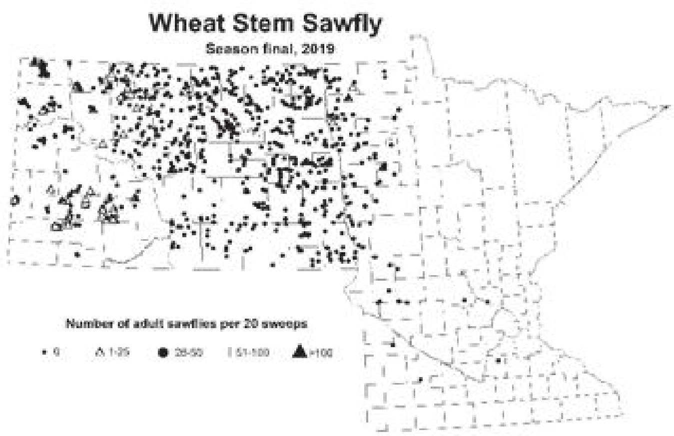


Figure 2 – Sweep net catches of adult wheat stem sawfly in Minnesota and North Dakota in 2019.

Emergence of WSS adults of monitored using forty-two emergence cages at twenty-one sampling sites in six different fields at the Northwest Research and Outreach Center in 2019. The emergence cages were placed on 6/4/2019 and monitoring started 2 days later. After the initial sampling date on 06/06/19, cages were sampled every Monday, Wednesday, and Friday throughout the month of June and the first week of July (Figure 3). Emergence of the adult males stared prior to first sampling date and likely already peaked in two of the six fields sampled. Peak emergence of adults in the other fields was on 06/10/2019. Emergence of female adults peaked approximately 10 after the peak emergence of male adults in individual fields. The highest counts encountered in a single cage on any of »

»

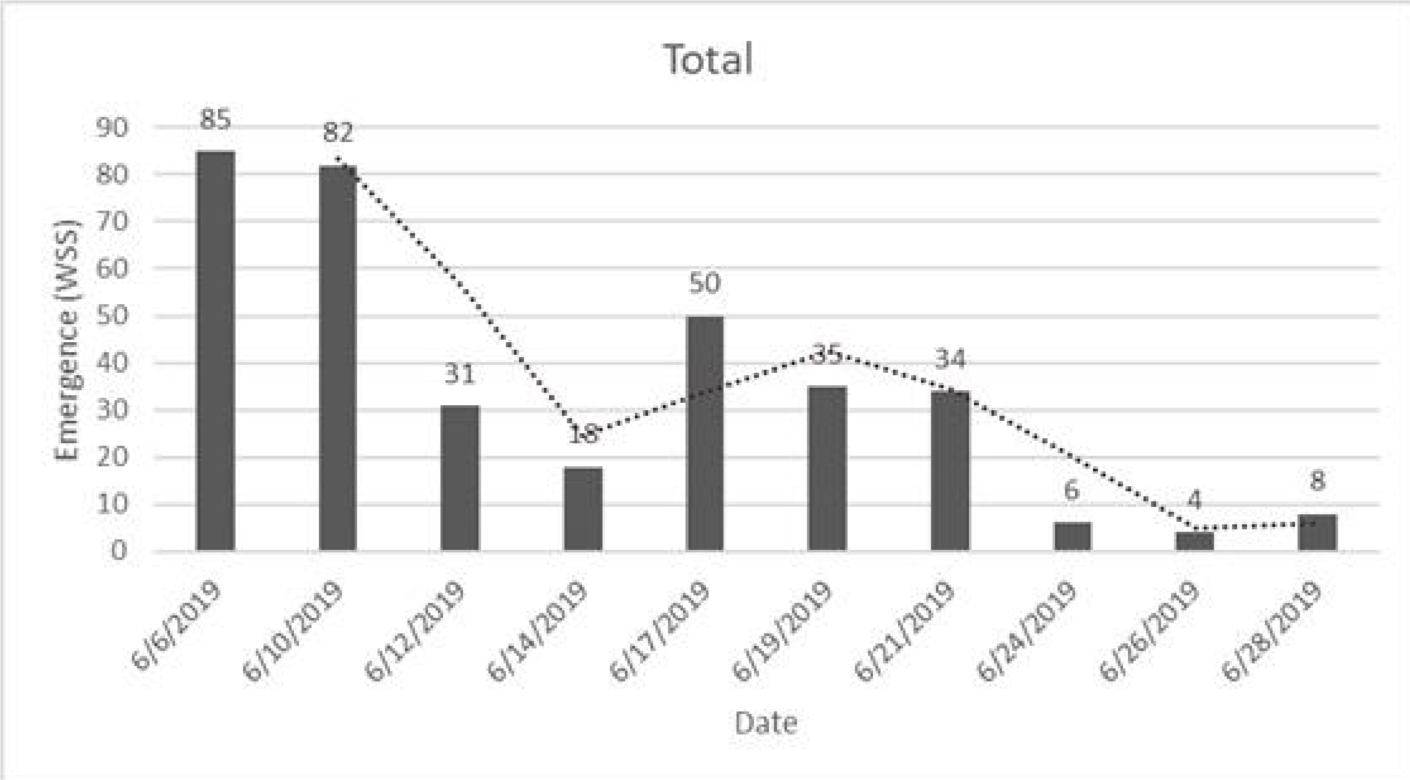


Figure 3 - Number of adult wheat stem sawfly (*Cephus cintus* Norton) that emerged in 42 emergence cages located across 6 fields at the Northwest Research and Outreach Center between June 6th and July 28th, 2019.

the sampling dates equaled to a density of approximately 25,000 adult WSS flies emerging per acre per day.

Little to no stem clipping was observed in the dedicated WSS screening nursery. Preliminary results of the stem dissection indicate that, on average, nearly 40% of the stems show evidence of wheat stem sawfly feeding and thus successful oviposition.

Materials and Methods

The three survey scouts were assigned routes to score each selected HRSW field once per week. Scouts also visited the on-farm small grains yield trials across the state. Collected data was collated each Friday and forwarded to NDSU for processing. A qualitative interpretation of the data was used for the commentaries posted to the Minnesota Crop News blog, Minnesota Association of Wheat Growers disease forecasting site, and the national Fusarium Head Blight Prediction Center.

Wheat Stem Sawfly emergence was monitored using soil emergence traps (BugDorm Model BT2003, BioQuip Products, CA 90220). The collection bottle was filled with approximately 50 ml of pre-diluted automotive antifreeze/coolant solution (SuperTech Extended Life Antifreeze/Coolant, WalMart, AR). Emergence traps were placed in pairs on bare soil and secured to the soil surface using tent stakes in six fields on the Northwest Research and Outreach Center in Crookston, MN. Each of the fields selected had wheat grown on them at least once in the previous two years.

The number of adult male or female WSS were counted every Monday, Wednesday and Friday for six weeks starting on June 3, 2019. To aid identification and counting of WSS males and female specimens, the collection bottle was removed from individual emergence traps and the contents were emptied on a piece of white cheesecloth held over a 200 ml glass beaker with a sink strainer. The collected antifreeze solution was recycled and poured back into the sample collection bottle. Additional antifreeze solution was added to the bottles when necessary before sample collection bottles were placed back in the emergence trap. The insects caught on the cheesecloth were separated and individual WSS were identified and counted.

A duplicate of the HRSW variety performance evaluation trial was seeded on May 15th, 2019 near Crookston, MN in a field that has been continuous wheat for the past three years. Stem clipping was scored just prior to the trial being harvest ripe. All stems from three linear feet of row were harvested by hand and fifty randomly selected stems from each hand-harvested sample were dissected longitudinally to determine presence of frass on or near the nodes to evaluate whether WSS oviposition was successful. The incidence of parasitism by Bracon cephi (Gahan) and other parasitoids was scored by determining the percent of WSS infected stems that had an emergence hole or a parasitoid cocoon.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

A follow-up survey to the users of the Minnesota Crop News blog and the disease risk assessment websites is necessary to fully assess whether the timely disease and pest updates and commentary altered producer decisions for their disease and pest management in 2019. Each update posted to the Minnesota Crop News Blog had an average of 434 page visits, indicating a large potential impact with this scouting program as a majority of Minnesota Crop News blog subscribers are farmers or crop consultants. On an aggregate level, the US Wheat Associates' 2019 US Hard Red Spring Wheat Regional Quality Report reported an average DON content of 0.7 ppm. This DON level is equal to the 2018 average, even while 2019 had more cumulative days favorable for Fusarium Head Blight (FHB) infection than in 2018. This indicates that increased management took place in 2019 to manage FHB, which may have been a result of a reinstituted scouting program in 2019. Even small impacts on a typical wheat enterprise have the potential for large economic benefits, as informed pest management decisions can easily provide impacts of more than $10 per acre.

Finding WSS across a wider area is concerning. The absence of any substantial stem clipping in the variety evaluation trial, however, provides some optimism for this situation. Preliminary results of the stem dissections suggest that WSS were present in large enough numbers to result in 40% of the stems having WSS larvae present. However, substantial parasitism was observed, resulting in few WSS larvae that were able to complete their life cycle. If an increase in parasitoid populations is indeed occurring, then the wheat production ecosystem in the Red River Valley may self-correct to the point that WSS is no longer an economic pest.

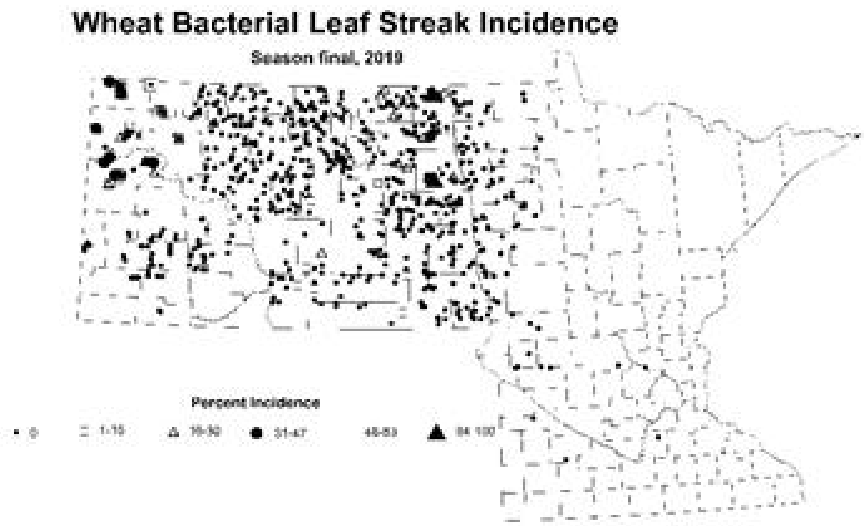
Recommended Future Research

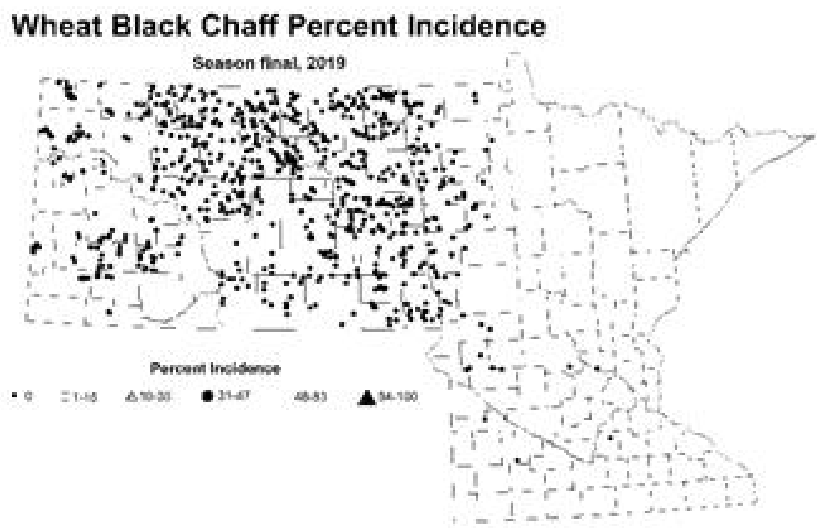
The PIs would like to continue both the general crop pest survey across the state as well as the surveillance of WSS. In addition, the screening of modern HRSW varieties should be continued for the near future until it becomes clear that WSS will not be an economic pest going forward.

Publications

10 Minnesota Crop News submissions (https://blog-crop-news.extension.umn.edu/)

Appendix 1 :

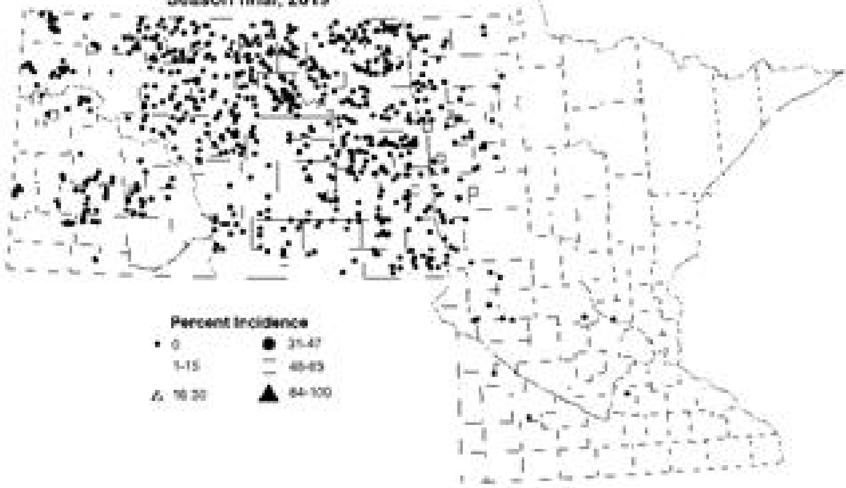




»

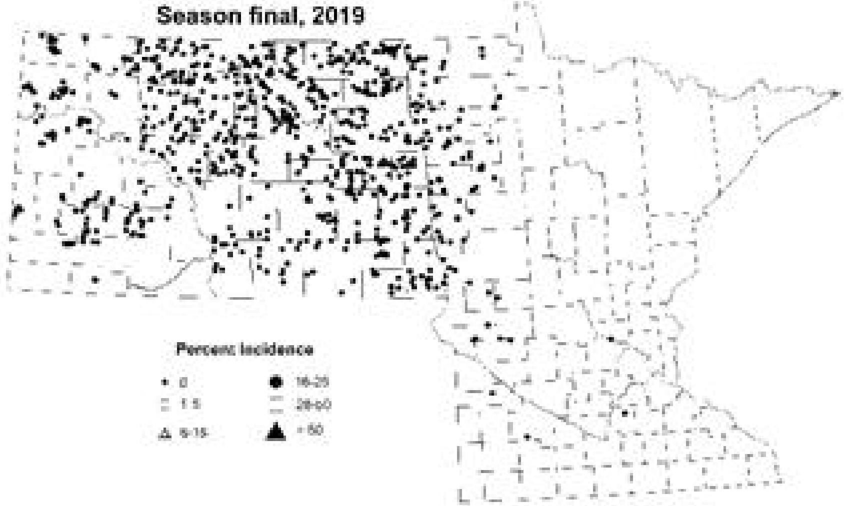
Wheat Ergot Percent Incidence

Season final, 2019



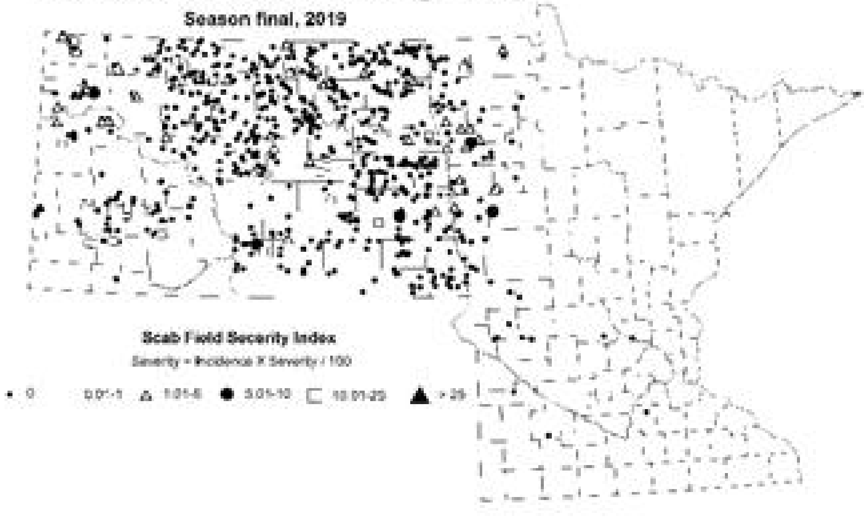
Wheat Stripe Rust Incidence

Season final, 2019

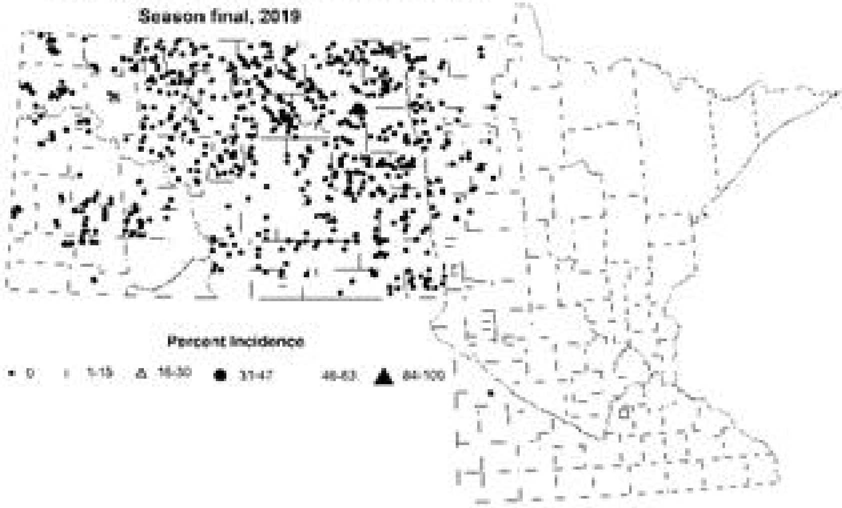


Wheat Scab Field Severity Index

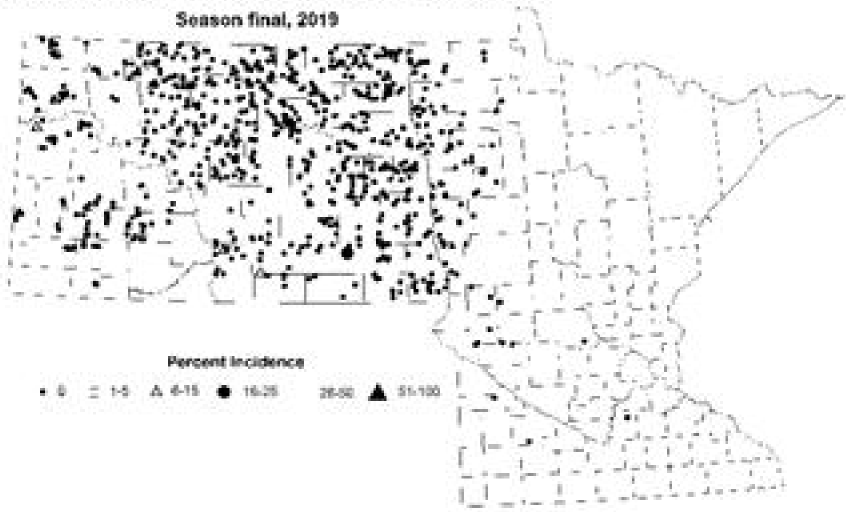
Season final, 2019



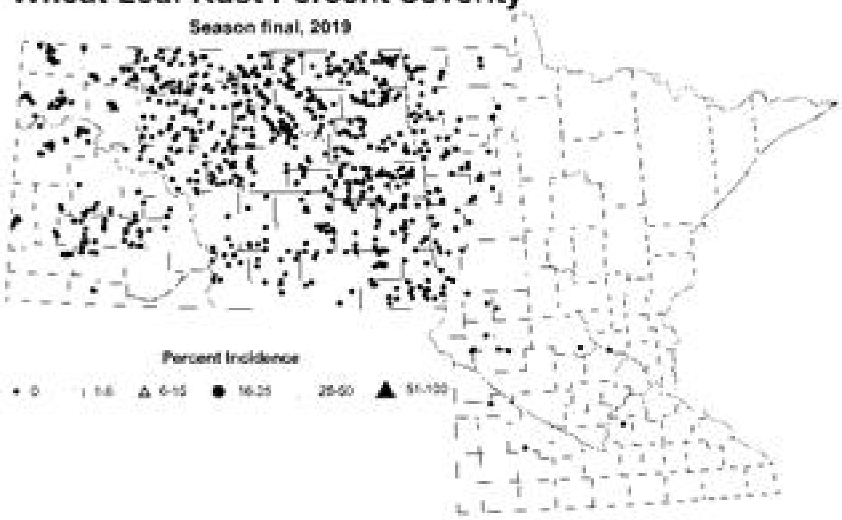
Wheat Loose Smut Incidence



Wheat Leaf Rust Percent Incidence



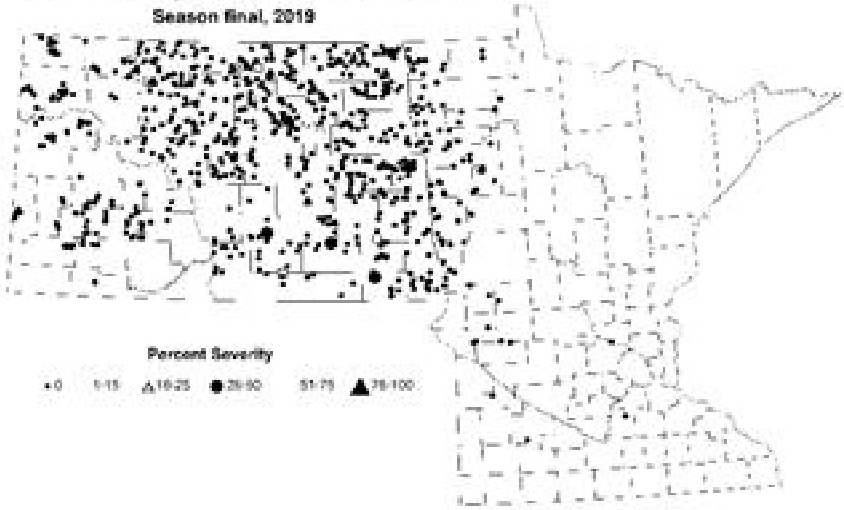
Wheat Leaf Rust Percent Severity



»

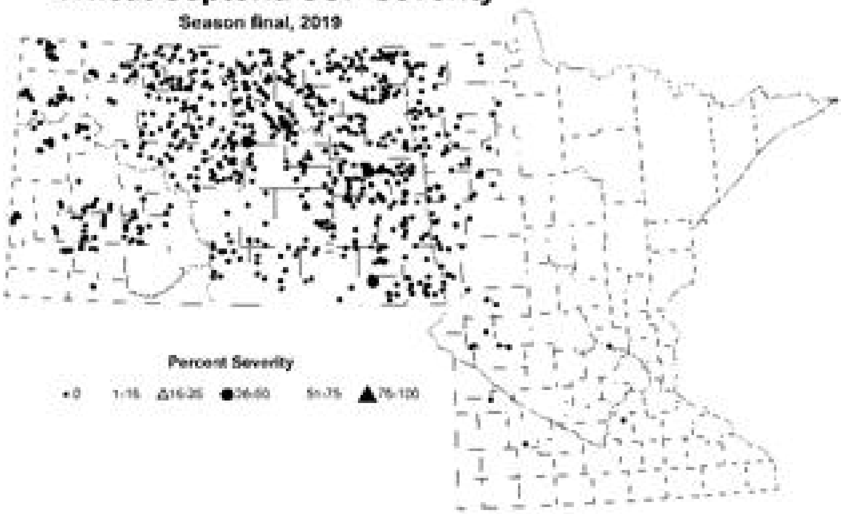
Wheat Septoria SSP Incidence

Season final, 2019



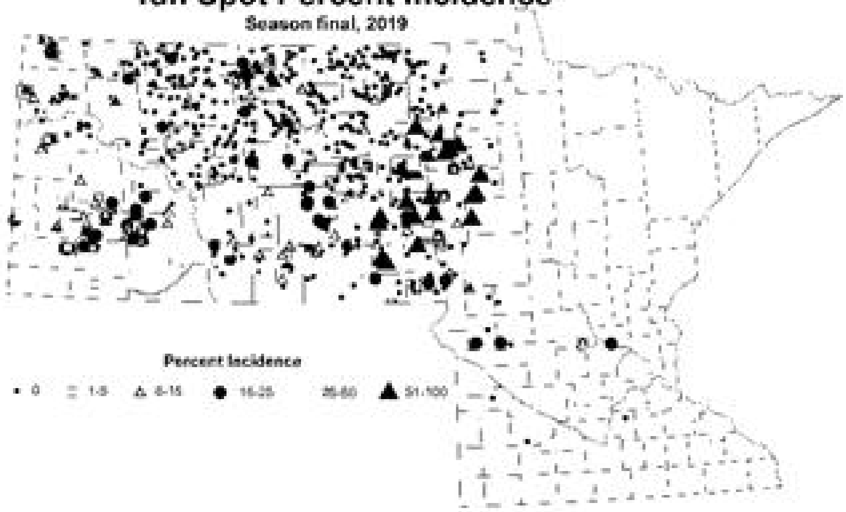
Wheat Septoria SSP Severity

Season final, 2019



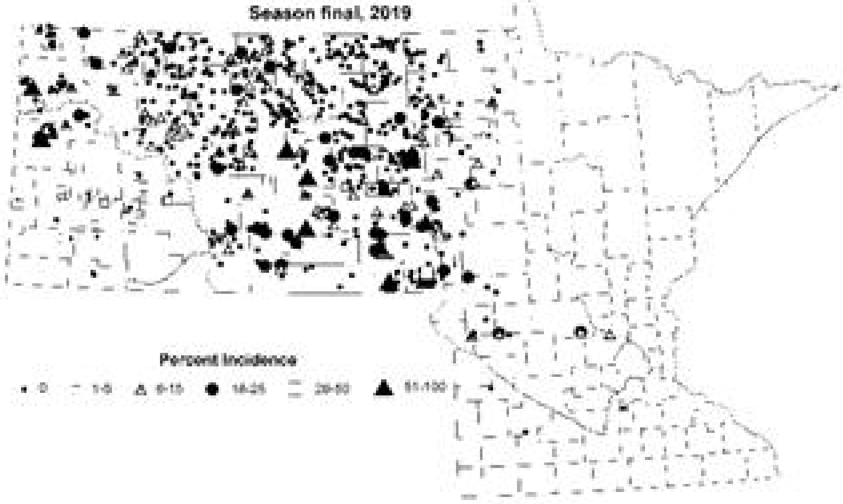
Tan Spot Percent Incidence

Season final, 2019



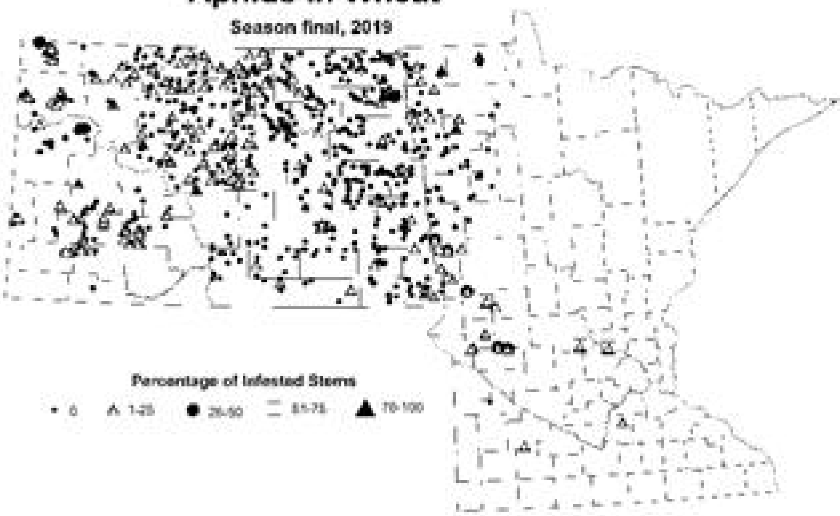
Tan Spot Percent Severity

Season final, 2019



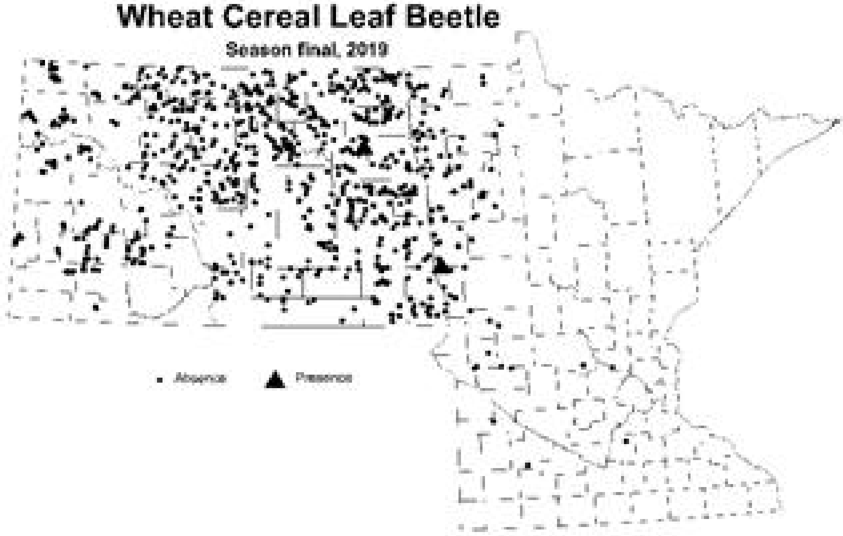
Aphids in Wheat

Season final, 2019

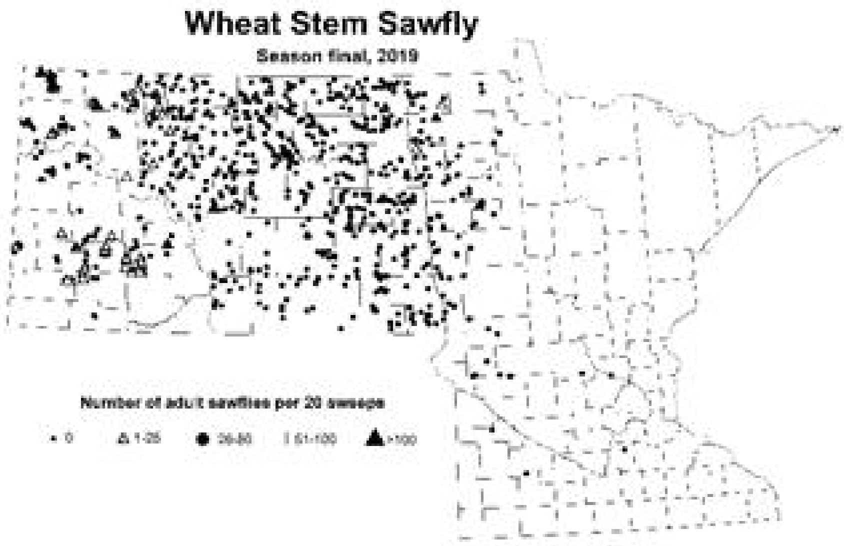


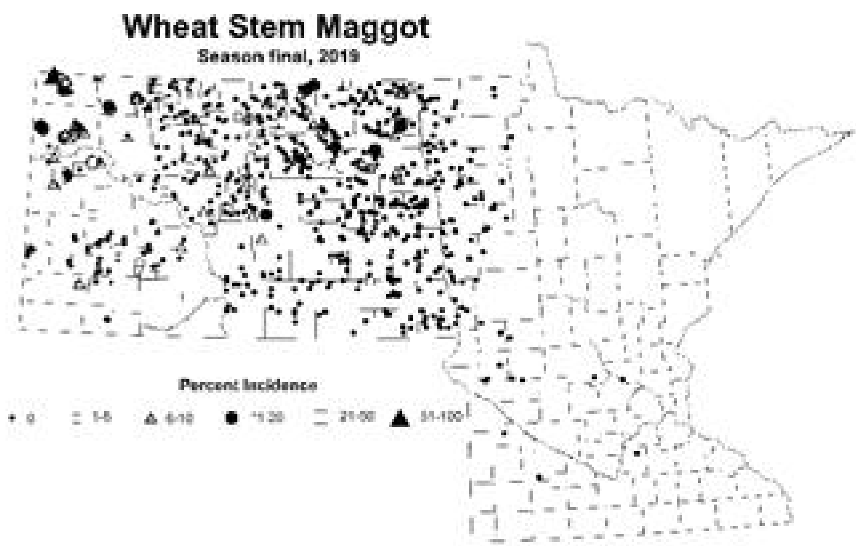
Wheat Cereal Leaf Beetle

Season final, 2019



»


Wheat Stem Sawfly
Season final, 2019
Number of adult sawflies per 20 sweeps


Wheat Stem Maggot
Season final, 2019
Percent Incidence

2019 Wheat, Barley, and Oats Variety Performance in Minnesota
- Preliminary Report 24

'Worst ever' and 'Never ever' are two adverbs have I learned not to use when describing (growing) seasons in Minnesota; average is merely a mathematical concept when you talk weather or growing conditions in Minnesota. The weather challenges of the 2018 growing season were, as it turned out, only a prelude to this year; As of the first of November there is still spring wheat left unharvested across Minnesota and North Dakota, sugar beet harvest in the Red River Valley are barely past the midpoint, and corn and soybean harvest has just started in earnest now that water has started to recede and ground has frozen hard enough to carry combines across much of the western half of the State.

It started much the same as 2018, with a late season blizzard and cold snap delaying the start of the season by about three weeks. By the end of the month of April only 2% and 10% of the wheat and oats had been seeded, respectively. The pace in the first half of May remained well behind the 5-year average and even last season progress. It wasn't until the third week of May that producers got a break and catching up to the 5-year average with about three quarters of the barley, oat, and spring wheat getting into the ground. Eventually 70,000 acres of barley, 250,000 acres of oats, and nearly one and half million acres of spring wheat were seeded. The 33% jump in acres seeded to oats is deceiving as only 100,000 acres were harvested. The requirement to seed a cover crop on prevented plant acres likely explains the large discrepancy between seeded and harvested acres.

The remainder of May and the month of June were largely favorable for small grains development with the crop advancing as expected and slowly caught up in development to the 5-year average. This all changed after the Fourth of July holiday when temperatures and dew points increased enough for the crop to be adversely impacted. By the middle of July small grain crop development had sped up to the point that it was ahead by nearly a week compared to both 2018 and the 5-year average. The high dew points, and with it the higher nighttime temperatures, also meant that the risk of Fusarium Head Blight (FHB) was high across much of the State during anthesis and much of the grain fill period.

Consequently, incidence of FHB was, like the previous season, not limited to the southern half of the state. Likewise, the incidence of Bacterial Leaf Streak (BLS) was much higher and more widespread across the state when compared to recent years. In contrast, stripe rust, leaf rust, and stem rust were largely absent. Crown rust, however, was rampant in the late seeded oat cover crop acreage.

USDA-NASS estimated MN's HRSW crop to average 62 bu/acre in their July forecast. This remained unchanged in their August forecast. In the September Small Grains Summary, with still plenty of spring wheat left in the field, MN average yield was estimated at 57 bu/acre, 2 and 10 bushels less per acre when compared to 2018 and 2017, respectively.

The lower yields, however, are not what will be remembered. requent rains throughout August not only delayed harvest repeaαtedly but ultimately led to declines in test weight and eventually breaking of the post-harvest dormancy. This led elevators to refuse grain due to visible sprout damage and low Hagberg Falling Numbers (HFN) and producers being forced to sell their spring wheat as a feed grain at steeply discounted prices.To complicate things further, a few cool nights in the first and second week of August may have resulted in a phenomenon called Late Maturity ạ-Amylase (LMA) rarely if ever encountered in Minnesota and North Dakota. LMA yields low HFN test result even if the dormancy of the grain has not been broken and the grain has not sprouted.

The quality of the wheat, barley, and oats was, like last year, much more variable than most years. The US Hard Red Spring Wheat Regional Quality Report from US Wheat Associates indicates that MN's crop had, on average, about a 2 lbs/bu lower test weight, with a nearly 40% drop in % vitreous kernels, and doubling of the % damaged kernels, resulting in an overall grade of #1 Northern Spring (NS). The average HFN test score of 271 seconds is well below the market's minimum threshold of 300 seconds and nearly a 140 seconds lower than the 2018 crop.

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 2019 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.

The MAES and the College of Food, Agricultural and Natural Resource Sciences (CFANS) grants permission to » reproduce, print, and distribute the data in this publication - via the tables - only in their entirety, without rearrangement, manipulation, or reinterpretation. Permission is also granted to reproduce a maturity group sub-table provided the complete table headings and table notes are included. Use and reproduction of any material from this publication must credit the MAES and the CFANS as its source.

VARIETY CLASSIFICATIONS

Varieties are listed in the tables alphabetically. Seed of tested varieties can be eligible for certification, and use of certified seed is encouraged. However, certification does not imply a recommendation. The intellectual property rights of the breeders or owners of the variety are listed as either PVP, PVP(pending), PVP(94), patent, or none. PVP protection means that the a variety is protected under the Plant Variety Protection Act for a period of 20 years, while PVP(94) means that the variety is protected for 20 years with the additional stipulation that seed of the variety can only be sold as registered and certified classes of seed. PVP(pending) indicates that the PVP application has been made and that you should consider the variety to have the same intellectual property rights as those provided by PVP(94). The designation of 'Patent' means that the variety is protected by a utility patent and that farm-saved seed may be prohibited by the patent holder. The designation 'None' means that the breeder or owner never requested any intellectual property protection or that legal protection has expired. Registered and certified seed is available from seed dealers or from growers listed in the 'Minnesota Crop Improvement Association 2019 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 preliminary variety trial information for single (2019) and multiple year (2017-2019) 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.

THE AUTHORS AND CONTRIBUTORS

This report is written, compiled, and edited by Dr. Jochum Wiersma, Small Grains Specialist. The contributing authors/principal investigators are:

Dr. James Anderson, Wheat Breeder, Department of Agronomy & Plant Genetics, St. Paul. Dr. Kevin Smith, Barley Breeder, Department of Agronomy & Plant Genetics, St. Paul. Dr. Jo Heuschele, Post-doctoral fellow oat breeding, Department of Agronomy & Plant Genetics, St. Paul. Dr. Ruth Dill-Macky, Plant Pathologist, Department of Plant Pathology, St. Paul. Dr. James Kolmer, USDA-ARS, Cereal Disease Laboratory, St. Paul. Dr. Matt Rouse, USDA-ARS, Cereal Disease Laboratory, St. Paul. Dr. Brian Steffenson, Plant Pathologist, Department of Plant Pathology, St. Paul. Dr. Yue Jin, USDA-ARS, Cereal Disease Laboratory,St. Paul.

Matt Bickell, Robert Bouvette, Dave Grafstrom, Mark Hanson, Tom Hoverstad, Michael Leiseth, Houston Lindell, Steve Quiring, Curt Reese, Susan Reynolds, Dimitri von Ruckert, Edward Schiefelbein, Nathan Stuart, Donn Vellekson, and Joe Wodarek supervised fieldwork at the various sites. Special thanks are also due to all cooperating producers.

SPRING WHEAT

James Anderson, Jochum Wiersma, Susan Reynolds, Nathan Stuart,Houston Lindell, Ruth Dill-Macky, James Kolmer, Matt Rouse, and Yue Jin

For a third year in a row University of Minnesota varieties accounted for more than half of the state's HRSW acreage. Linkert maintained its top ranking with about 28% of the acreage, while Bolles and WB Mayville stayed in second and third place, respectively. Acreage of both Bolles and WB-Mayville have declined a few percentage points further in favor of SY Valda, Shelly, and Lang-MN. First-time entrants in the 2019 trials were 4 new CROPLAN varieties, 2 entries from Dyna-Gro, SY Longmire, SY 611 CL2, and TCG Heartland. Testing of CP3419, CP3504, Faller, Forefront, Prevail, SY Rowyn, and SY Soren was discontinued. WestBred opted to not submit any HRSW varieties for testing. WB Mayville, however, was included in the testing as it occupied more than 5% of the acreage in 2018.

The results of the variety performance evaluations for spring wheat are summarized in Tables 1 through 7. The varietal characteristics are presented in Tables 1 through 3. Tables 4, 5, and 6 present the relative grain yield of tested varieties in 1, 2, and 3-year comparisons. Table 7 presents the grain yield when fungal pathogens are controlled to the maximum extent possible compared to the same trials without the use of fungicides. The average yield across the six southern testing locations was 63 bu/acre in 2018. This compares to an average of 65 bu/acre in 2018 and a three-year average of 70 bu/acre. The eight northern locations averaged 77 bu/acre in 2019 compared to 88 bu/acre last year and 87 bu/acre for the three-year average. Prosper, Shelly, and SY Valda together with LCS Trigger and TCG Spitfire were the highest yielding varieties in both the south as well as the northern half of the state in both single year and multiyear comparisons. Higher yielding cultivars tend to be lower in grain protein. Variety selection is one approach to avoid discounts for low protein, but N fertility management remains paramount to maximize grain yield and grain protein.

Lodging is a serious production risk. Varieties with a lodging score of 2 and 3 are considered exceptionally good and will only lodge in extreme cases, while varieties with a rating of 4 or 5 have adequate straw strength most years. Increasing seeding rates generally increases the risk of lodging for all but the strongest and shortest semi-dwarf HRSW varieties. Conversely, lower seeding rates will lower the risk of lodging, but commonly will results in lower grain yield potential. Producers had observed that a lower seeding rate for Lang-MN didn’t cause a substantive yield penalty in both 2017 and 2018. This past season, Lang-MN was included at the standard and a 30% below standard seeding rate. The lodging score, as expected, improved while no yield penalty was observed across either southern or the northern locations.

Varieties that are rated 4 or lower are considered the best defense against a particular disease. Varieties that are rated 7 or higher are likely to suffer significant economic losses under even moderate disease pressure. 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. Control of leaf diseases with fungicides may be warranted, even for those varieties with an above average rating.

Bacterial leaf streak (BLS) 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. Boost, Dyna-Gro Ballistic, Lang-MN, LCS Rebel, LCS Trigger, ND-VitPro, Surpass, SY Ingmar, SY Valda, and TCG-Spitfire provide the best resistance against BLS. Lang-MN, ND-VitPro, and Rollag provide the best resistance against FHB while another twelve varieties have a rating of 4 for FHB. Combined, this group of varieties includes some of the top yielders and varieties with higher grain protein content such as Bolles and Rollag.

BARLEY

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

The results of the variety performance evaluations for spring barley are summarized in Tables 8 through 12. The varietal characteristics are presented in Tables 8 and 9. Tables 10 through 12 present the relative grain yield of the tested varieties in 1 and 3-year comparisons. The average yield across the twelve testing locations was 83 bu/acre in 2019. The highest yields were recorded in Crookston (127 bu/A) while the lowest grain yields were recorded in Fergus Falls (41 bu/A).

Fewer varieties were tested in 2019 as the malting and brewing industries increasingly favor two-row varieties. ND Genesis was the highest yielding variety based on the 2019 state average (Table 12). The six-row varieties were more lodging resistant while Conlon was the most prone to lodging. Grain protein content varied between 11.5% and 13.9%. Brewers in general require low grain protein with all-malt brewers desiring less protein then adjunct brewers. The two-row varieties ND-Genesis and Pinnacle have the lowest grain protein.

Table 9 describes the reaction of the currently grown varieties to the five 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. Net blotch can be an important disease, however we have not obtained reliable data in the past few years to score the varieties. The best resistance to Fusarium head blight, expressed as lower concentrations of vomitoxin or DON, was Conlon. Bacterial Leaf Streak (BLS) cannot be controlled by fungicides and there are only minor differences in resistance among the current varieties. All listed varieties carry stem rust resistance to the predominate *Puccinia graminis* f. sp. *tritici* race (MCCF). They do not, however, carry resistance to African stem rust races in the Ug99 lineage or the virulent domestic race QCCJ. Most varieties possess pre-heading resistance to stem rust; thus, they will not likely incur much damage unless the disease epidemic is severe.

OATS

Jo Heuschele, Ruth Dill-Macky, Dimitri von Ruckert, Karen Beaubien, Jochum Wiersma, Kevin Smith

This past growing season was both wet and cool, which caused delayed oat growth. Uniform replicated trials tested across Minnesota included Lamberton, Le Center, Kimball, Rochester, Morris and Waseca in Southern Minnesota (south of I-94). In Northern Minnesota (north of I-94) trials were conducted in Crookston, Fergus Falls, Roseau, and Stephen. In addition, entries were evaluated for disease resistance to crown rust, barley yellow dwarf virus (BYDV), and smut in specific inoculated nurseries. Damage from multiple storm events caused yield trials near Fergus Falls to be abandoned. »

The results of the variety evaluations are summarized in Tables 13 to 17. The greatest challenges in oat production and performance evaluation continue to be lodging and crown rust. All yield performance trials were treated with a propiconazole based fungicide when the flag leaf was fully extended (Feekes 9) to evaluate the yield potential without disease infection.

The origin and agronomic characteristics of oat varieties tested are listed in Table 13. The U.S. Plant Variety Protection Act (PVP) status is also listed. PVP(94) notation indicates that seed of that variety may not be sold by a grower without the permission of the variety's owner. If the PVP is pending consider the variety as having PVP(94) protection. Maturity, height and test weight data are presented as statewide averages from 2017-2019 except where noted. Lodging data is also a statewide average from the same period, but only from locations where lodging was present. Maturity, height, and lodging are important considerations for variety selection based on the intended location and expected end use of the crop. In general, earlier maturing varieties perform better in Southern Minnesota so flowering can occur during cooler periods. In these locations, a variety maturing similar to Sumo or Reins may be a good choice. In Northern locations varieties that mature later such as Hayden or Deon may be prudent.

For grain production, lodging and grain quality traits should be considered when choosing a variety (Table 13). For the human food market, oat varieties with high protein and low oil may be desirable. High test weight may carry equal consideration to yield if the crop is intended for food or feed market. Hull color may also need to be taken into account. Contact your local elevator or buyer whether processors have a preferred or (recommended) varieties for milling.

Crown rust and other disease resistance ratings are listed in Table 14. All disease scores were converted to a "0-9" scale. Where "0" is very resistant and "9" is very susceptible. Crown rust continues to be a major limiting factor to oat production in Minnesota that must be managed to achieve optimal yield. Buckthorn, the alternate host of crown rust is widespread in Minnesota, allowing the pathogen population to be present annually and particularly aggressive. Crown rust resistance was evaluated in the Buckthorn Nursery in St. Paul by the USDA-ARS, and represents an exceptionally aggressive crown rust population. The most economical way of controlling crown rust is the use of a resistant variety. However, application of fungicide to a variety with rating of "4" or greater is prudent if crown rust is present in the lower canopy at Feekes 9.

Deon continues to be one of the best varieties for crown rust resistance. In addition, the new variety Warrior also shows good resistance, however it has only been tested one year. Crown rust is a rapidly evolving disease; the rust ratings taken this year compared to last year's numbers are the same indicating that the pathogen has not overcome current genetics. Other important diseases include BYDV and smut which were evaluated in inoculated nurseries at the University of Illinois and the University of Minnesota, respectively. Varieties susceptible to BYDV (>3) should be selected with caution particularly in the Southern Minnesota, where infected aphids are more common early in the season. A seed treatment and certified seed should be utilized to manage smut. Disease resistance may be a driving factor if pesticides are not economical or intended production is an organic system.

The regional yield performance evaluation in 2019 and 3-year averages are listed in Table 15. In addition, the statewide averages are listed. Table 16 and 17 contain the year and 3-year averages for each location. To standardize the data across locations the yield is expressed as percent of the trial mean. MN-Pearl continues to be the top yielding line in statewide averages for 2019 and in multi-year comparisons. However, Deon and Horsepower surpassed MN Pearl in yield in some locations this year.

The newest variety this year is Warrior. Warrior has good crown rust resistance, maturity similar to Deon and high lodging resistance. In general, yield performance from single years should be viewed cautiously as environmental variability may significantly affect the yields in single locations or years. From this year's trials MN-Pearl, Deon and Horsepower are recommend in northern Minnesota and MN-Pearl, Saddle, Antigo, and Deon in southern Minnesota.

University of Minnesota Tables #1 - 17
can be found on pages 61-77.

Table 1. Origin and agronomic characteristics of hard red spring wheat varieties in Minnesota in single-year (2019) and multiple-year comparisons.

Entry	Origin[1]	Legal Status	Desired Stand (Plants/Acre)[2]	Days to Heading[3]	Height Inches[3]	Straw Strength[4]
Bolles	2015 MN	PVP (94)	1.3	57.8	32.3	4
Boost	2016 SDSU	PVP (94)	1.3	58.0	32.7	5
CP3530	2015 CROPLAN by WinField	Patended	1.3	56.7	34.4	5
CP3888	2018 CROPLAN by WinField	Patended	1.3	56.0	31.3	3–4
CP3910	2019 CROPLAN by WinField	Patend pending	1.3	52.8	30.2	3
CP3915	2019 CROPLAN by WinField	Patend pending	1.3	54.9	30.8	4
CP3939	2019 CROPLAN by WinField	Patend pending	1.3	54.9	31.0	3–4
Dyna-Gro Ambush	2016 Dyna-Gro	PVP (94)	1.4	53.8	30.9	4
Dyna-Gro Ballistic	2018 Dyna-Gro	PVP (94)	1.1	56.1	33.0	5
Dyna-Gro Caliber	2017 Dyna-Gro	PVP (94) (pending)	1.8	55.4	26.4	2
Dyna-Gro Commander	2019 Dyna-Gro	PVP (94) (pending)	1.4	53.1	30.7	4–5
Dyna-Gro Velocity	2019 Dyna-Gro	PVP (94) (pending)	1.4	55.0	30.2	3
Lang-MN	2017 MN	PVP (94) (pending)	1.3	57.3	32.7	5
Lang-MN (0.7X)[5]	2017 MN	PVP (94) (pending)	0.9	56.5	32.0	4
LCS Breakaway	2012 Limagrain Cereal Seeds	PVP (94)	1.3	52.8	29.5	4
LCS Cannon	2018 Limagrain Cereal Seeds	PVP (94) (pending)	1.3	52.0	29.3	4
LCS Rebel	2017 Limagrain Cereal Seeds	PVP (94) (pending)	1.3	53.4	33.1	6
LCS Trigger	2016 Limagrain Cereal Seeds	PVP (94)	1.3	60.0	33.1	5
Linkert	2013 MN	PVP (94)	1.3	55.2	28.5	2
MN-Washburn	2019 MN	PVP (94) (pending)	1.3	56.8	30.0	3
MS Barracuda	2018 Meridian Seeds	PVP (94) (pending)	1.3	52.3	28.1	3
MS Camaro	2017 Meridian Seeds	PVP (94) (pending)	1.3	53.4	27.4	5
MS Chevelle	2014 Meridian Seeds	PVP (94)	1.3	53.9	30.1	5
ND-VitPro	2017 NDSU	PVP (94) (pending)	1.3	54.2	32.2	4
Prosper	2011 NDSU	PVP (94)	1.3	56.5	33.1	6
Rollag	2011 MN	PVP (94)	1.3	55.2	29.8	3
Shelly	2016 MN	PVP (94)	1.3	57.4	29.5	5
Surpass	2016 SDSU	PVP (94)	1.3	52.4	32.5	7
SY 611 CL2	2019 AgriPro/Syngenta	PVP (94) (pending)	1.3	54.5	29.4	5
SY Ingmar	2014 AgriPro/Syngenta	PVP (94)	1.3	55.8	29.2	4
SY Longmire	2019 AgriPro/Syngenta	PVP (94) (pending)	1.3	56.1	30.2	3
SY McCloud	2019 AgriPro/Syngenta	PVP (94) (pending)	1.3	53.8	30.7	4
SY Valda	2015 AgriPro/Syngenta	PVP (94)	1.3	54.6	31.3	5
TCG-Climax	2017 21st Century Genetics	PVP (94)	1.5	60.0	31.6	3
TCG-Heartland	2019 21st Century Genetics	PVP (94) (patent pending)	1.5	53.8	29.7	3
TCG-Spitfire	2016 21st Century Genetics	PVP (94)	1.5	57.9	31.3	3
WB-Mayville	2011 WestBred	PVP (94)	1.3	52.7	28.0	3
Mean				55.2	30.7	

[1] Abbreviations: MN = Minnesota Agricultural Experiment Station; NDSU = North Dakota State University Research Foundation; SDSU = South Dakota Agricultural Experiment Station [2] Our standard seeding rate is designed to achieve a desired stand of 1.3 million plants/acre, assuming a 20% stand loss and adjusting for the germination percentage and seed weight of each variety. [3] 2019 data [4] 1-9 scale in which 1 is the strongest straw and 9 is the weakest. Based on 2013-2019 data. The rating of newer entries may change by as much as one rating point as more data are collected. [5] Lang-MN (0.7X) is a 30% lower seeding rate to achieve a stand of 0.9 million plants per acre vs. 1.3 million plants per acre.

Table 2. Grain quality of hard red spring wheat varieties in Minnesota in single-year (2019) and multiple-year comparisons.

	Test Weight (Lb/Bu)			Protein (%)[1]			Baking	Pre-Harvest
Entry	**2019**	**2 yr**		**2019**	**2 yr**		**Quality[2]**	**Sprouting[3]**
Bolles	59.6	59.2		15.5	16.1		1	1
Boost	59.3	59.2		14.1	14.6		2	5
CP3530	60.0	59.5		13.8	14.6		3	2
CP3888	59.0	–		14.1	–		–	2
CP3910	60.3	–		13.9	–		–	3
CP3915	60.2	–		14.0	–		–	1
CP3939	59.9	–		14.5	–		–	2*
Dyna-Gro Ambush	61.3	60.5		14.4	14.9		2	3*
Dyna-Gro Ballistic	59.3	58.9		13.6	13.9		–	3*
Dyna-Gro Caliber	60.2	59.6		14.9	15.5		2	3*
Dyna-Gro Commander	60.3	–		14.2	–		–	1
Dyna-Gro Velocity	61.1	–		14.6	–		–	2
Lang-MN	61.0	60.6		14.3	14.8		3	1
Lang-MN 0.7X	61.1	–		14.4	–		–	–
LCS Breakaway	61.4	61.0		14.6	15.0		5	2
LCS Cannon	61.5	61.2		13.7	14.2		–	3
LCS Rebel	61.3	61.0		14.4	14.9		3	5
LCS Trigger	60.0	59.9		11.9	12.4		–	2
Linkert	60.5	59.9		14.9	15.4		1	1
MN-Washburn	60.1	59.8		13.6	14.0		3	1
MS Barracuda	60.4	60.0		14.5	15.0		–	3
MS Camaro	59.6	59.3		14.7	15.1		–	2
MS Chevelle	59.6	59.5		13.2	13.6		5	4
ND-VitPro	61.8	61.4		14.8	15.2		2	1
Prosper	59.9	59.7		13.1	13.7		5	1
Rollag	60.8	60.2		14.9	15.6		6	2
Shelly	59.4	59.4		13.5	14.1		5	1
Surpass	59.4	59.0		14.3	14.7		3	1
SY 611 CL2	60.9	–		14.1	–		–	2*
SY Ingmar	60.1	60.1		14.8	15.1		2	2
SY Longmire	59.2	–		14.3	–		–	2*
SY McCloud	61.5	61.1		14.6	15.0		–	2*
SY Valda	60.3	60.0		13.6	14.0		6	2
TCG-Climax	61.5	61.4		15.1	15.6		3	3
TCG-Heartland	60.9	–		14.9	–		–	2
TCG-Spitfire	58.3	58.7		13.5	13.9		2	3*
WB-Mayville	60.4	59.8		14.8	15.4		2	3
Mean	60.2	60.0		14.1	14.6			
No. Environments	11	27		12	29			

[1] 12% moisture basis. [2] 2014-2018 crop years, where applicable [3] 1-9 scale in which 1 is best and 9 is worst. Values of 1-2 should be considered as resistant. Falling number data was collected from four 2019 locations. Varieties with an * following their pre-harvest sprouting rating had lower than expected falling numbers based on their rating.

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

Variety	Leaf Rust	Stripe Rust[2]	Stem Rust[3]	Bacterial Leaf Streak[4]	Other Leaf Diseases[5]	Fusarium Head Blight
	(1-9)					
Bolles	2	1	2	5	3	4
Boost	2	2	4	2	4	4
CP3530	3	3	1	4	4	4
CP3888	5	–	1–2	5–6	5	5–6
CP3910	3	–	1–2	6–7	5	4–6
CP3915	–	–	1–2	2–3	5	4–6
CP3939	–	–	1–2	4–5	5	4–5
Dyna-Gro Ambush	2	–	2	5	4	4
Dyna-Gro Ballistic	4	–	1–2	3	5	4–5
Dyna-Gro Caliber	3	–	2	4	3	7
Dyna-Gro Commander	–	–	1–2	4	6	4–6
Dyna-Gro Velocity	–	–	1–2	6–7	7	5–6
Lang-MN	1	1	2	3	4	3
LCS Breakaway	3	2	2	6	5	5
LCS Cannon	3	–	2	6	7	4–6
LCS Rebel	6	–	2	3	4	4
LCS Trigger	1	–	1–2	2	3	3–4
Linkert	3	1	1	5	4	5
MN-Washburn	1	2	1	3	3	4
MS Barracuda	5	–	2	7	5	5–6
MS Camaro	2	–	1–2	7	5	7
MS Chevelle	3	1	1	6	6	5
ND-VitPro	3	–	1	3	5	3
Prosper	6	5	2	4	4	4
Rollag	4	1	2	7	5	3
Shelly	3	1	2	6	3	4
Surpass	3	2	5	3	6	4
SY 611 CL2	3	–	4–5	4	3–4	3–4
SY Ingmar	2	2	2	3	5	4
SY Longmire	4	–	1–2	2–4	5	7–8
SY McCloud	3	–	1	5	5	4–5
SY Valda	1	2	1	3	4	4
TCG-Climax	4	–	5	6	4	4
TCG-Heartland	2	–	1–2	5–6	3–4	5–6
TCG-Spitfire	5	–	3	3	4	5
WB-Mayville	3	3	3	7	7	8

[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 (2019)

Variety	Crookston			Fergus Falls			Hallock		
	2019	2 yr	3 yr	2019	2 yr	3 yr	2019	2 yr	3 yr

Bolles	101	99	100	93	93	92	99	94	93
Boost	96	98	104	99	95	96	88	97	98
CP3530	101	98	102	104	104	105	103	101	102
CP3888	95			105			100		
CP3910	108			102			109		
CP3915	107			108			100		
CP3939	98			102			100		
Dyna-Gro Ambush	103	98	99	103	100	99	99	101	102
Dyna-Gro Ballistic	109	104		114	114		110	108	
Dyna-Gro Caliber	92	91	96	98	93	94	82	84	88
Dyna-Gro Commander	101			103			106		
Dyna-Gro Velocity	91			95			97		
Lang-MN	95	97	97	102	101	100	95	97	100
Lang-MN (0.7X)	97			98			96		
LCS Breakaway	96	97	92	95	98	103	104	105	103
LCS Cannon	102	102		105	105		106	106	
LCS Rebel	105	102	104	93	95	97	99	99	102
LCS Trigger	119	114		112	112		112	106	
Linkert	92	91	94	90	92	94	100	99	100
MN-Washburn	100	99	98	105	105	105	101	99	103
MS Barracuda	101	100		93	97		97	100	
MS Camaro	91	94		93	96		103	100	
MS Chevelle	108	105	107	103	102	105	105	109	108
ND-VitPro	98	96	95	91	94	92	94	97	97
Prosper	110	104	109	109	108	109	102	106	109
Rollag	96	89	93	93	89	92	103	99	97
Shelly	107	106	109	115	113	115	111	107	106
Surpass	100	102	101	95	94	98	100	105	106
SY 611 CL2	103			105			106		
SY Ingmar	95	98	95	95	98	99	96	99	98
SY Longmire	103			106			101		
SY McCloud	94	97		95	99		94	97	
SY Valda	106	110	114	96	101	106	111	113	112
TCG-Climax	93	97	103	96	100	100	80	84	85
TCG-Heartland	97			93			91		
TCG-Spitfire	104	109	107	104	105	108	98	99	99
WB-Mayville	92	90	89	90	95	97	91	93	95
Mean (bu/acre)	78.8	72.1	83.2	82.8	90.8	89.6	84.8	91.0	92.2
LSD (0.10)	7.8	5.6	7.0	10.3	5.3	5.4	9.4	6.4	5.2

[1] Strathcona was abandoned in 2017 due to poor growing conditions

and multiple-year comparisons (2017-2019).

Oklee			Perley			Roseau			Stephen			Strasthcona [1]	
2019	**2 yr**	**3 yr**	**2019**	**2 yr**	**3 yr**	**2019**	**2 yr**	**3 yr**	**2019**	**2 yr**	**3 yr**	**2019**	**2 yr**
----------------(% of mean)----------------													
92	91	96	92	91	97	86	91	96	97	91	95	94	93
100	102	103	101	102	101	103	101	103	95	94	96	97	97
95	96	96	111	108	109	101	99	103	99	97	106	98	98
106			81			101			99			99	
112			104			113			101			101	
106			97			109			111			101	
92			91			83			97			94	
105	106	106	87	92	97	87	93	94	94	100	100	103	103
115	108		104	107		110	109		107	108		105	103
97	97	95	85	84	86	95	90	90	96	93	94	96	97
101			121			108			101			100	
87			89			101			94			90	
105	98	98	104	99	96	104	106	104	104	100	98	104	98
100			102			97			98			106	
96	94	96	79	86	94	113	104	99	101	101	99	99	95
106	104		121	112		104	102		109	108		101	107
102	101	103	110	110	104	104	101	101	102	102	102	104	99
122	114		117	118		118	115		111	111		118	109
93	92	93	88	91	94	88	90	93	94	92	92	91	96
104	98	102	105	108	106	97	100	106	100	100	101	101	99
107	104		107	97		98	101		100	101		105	109
88	90		95	88		77	79		104	102		93	98
100	103	105	93	99	104	105	103	103	103	107	108	94	101
87	94	92	95	100	98	89	91	93	93	92	92	90	91
105	108	109	93	104	107	101	106	109	103	107	109	111	105
92	91	93	100	95	97	80	83	86	94	94	97	87	91
107	105	106	100	98	103	113	109	111	107	108	110	107	104
106	100	100	105	112	107	92	97	99	106	105	105	100	97
102			95			98			111			108	
97	98	101	111	102	100	100	95	94	99	98	98	96	100
106			78			94			107			100	
94	96		98	93		96	96		103	100		98	102
106	111	114	99	103	106	120	111	110	117	115	115	110	105
88	93	99	95	98	95	92	91	94	94	92	94	88	89
94			110			88			96			93	
103	104	109	115	108	106	113	106	106	101	103	104	100	100
92	95	95	114	106	102	100	96	95	86	92	96	90	96
64.4	80.7	79.7	66.3	70.6	84.8	86.4	88.0	91.2	81.9	89.8	94.5	72.1	82.7
9.2	6.1	5.3	7.0	7.8	7.5	10.3	7.7	6.7	8.8	5.2	6.2	6.6	8.0

Table 5. Relative grain yield of hard red spring wheat varieties in southern Minnesota locations in single-year (2019) and

Variety	Benson			Kimball			LeCenter		
	2019	**2 yr**	**3 yr**	**2019**	**2 yr**	**3 yr**	**2019**	**2 yr**	**3 yr**
			----------	----------	----------	----------	----------	----------	----------
Bolles	103	98	91	87	91	96	91	79	84
Boost	99	99	95	94	85	93	102	104	101
CP3530	121	114	112	108	103	103	124	125	122
CP3888	101			106			97		
CP3910	99			106			98		
CP3915	108			99			96		
CP3939	96			105			87		
Dyna-Gro Ambush	93	94	98	111	110	106	120	109	106
Dyna-Gro Ballistic	107	107		109	107		103	101	
Dyna-Gro Caliber	85	83	90	92	95	96	99	92	92
Dyna-Gro Commander	97			108			101		
Dyna-Gro Velocity	97			98			106		
Lang-MN	98	103	101	103	104	106	108	104	98
Lang-MN (0.7X)	98			100			104		
LCS Breakaway	92	93	96	100	105	105	110	93	93
LCS Cannon	91	91		118	115		111	111	
LCS Rebel	101	98	97	104	94	95	98	92	93
LCS Trigger	122	118		110	98		121	120	
Linkert	89	88	92	102	102	99	86	86	93
MN-Washburn	96	97	96	92	92	97	97	100	106
MS Barracuda	94	93		115	110		106	109	
MS Camaro	78	82		100	97		90	95	
MS Chevelle	91	94	90	102	95	97	98	95	102
ND-VitPro	96	96	93	110	102	103	86	89	88
Prosper	104	109	111	100	103	106	105	100	103
Rollag	95	93	95	98	97	98	76	70	84
Shelly	100	106	102	103	99	103	99	106	107
Surpass	103	99	103	97	97	102	104	94	93
SY 611 CL2	111			107			100		
SY Ingmar	100	101	100	100	101	97	91	98	102
SY Longmire	103			81			89		
SY McCloud	91	97		97	103		89	90	
SY Valda	114	116	117	107	107	105	125	111	116
TCG-Climax	97	97	95	89	96	96	90	101	93
TCG-Heartland	101			106			89		
TCG-Spitfire	124	117	112	102	102	103	113	117	115
WB-Mayville	92	90	101	103	99	104	90	95	100
Mean (bu/acre)	95.8	86.5	88.8	77.0	72.7	79.3	58.3	57.7	67.8
LSD (0.1)	7.8	8.3	9.2	8.6	8.5	7.2	7.4	8.8	8.5

[1] 2018 Morris was discarded due to excessive rainfall and abnormally low grain yields. 2 yr data is from 2017 & 2019.

multiple-year comparisons (2017-2019).

Lamberton				Morris[1]			St. Paul				Waseca		
2019	2 yr	3 yr		2019	2 yr		2019	2 yr	3 yr		2019	2 yr	3 yr
---(% of mean)---													
87	95	91		102	102		102	98	100		104	108	102
123	118	102		104	99		93	93	93		99	109	105
113	115	110		113	104		115	110	108		112	115	114
86				107			99				105		
101				109			98				98		
101				95			96				79		
96				104			93				87		
102	101	100		105	107		117	104	103		117	108	109
111	111			117			101	103			112	109	
90	86	87		101	95		108	97	100		97	81	80
103				112			110				107		
93				92			86				94		
106	108	105		107	109		88	98	102		116	126	115
108				103			103				109		
66	88	93		102	103		84	89	93		101	87	98
101	94			99			110	112			112	110	
103	107	103		100	99		92	94	97		104	100	96
122	119			108			106	110			103	118	
86	75	88		90	96		98	100	103		100	82	91
113	110	107		102	98		111	105	107		95	98	106
69	73			88			115	108			97	88	
65	77			79			92	96			98	70	
97	86	99		110	112		99	97	97		100	91	100
101	105	96		88	86		105	101	102		93	99	98
121	128	118		116	106		98	105	107		91	106	101
82	82	89		77	85		78	80	85		89	78	85
88	97	103		105	108		111	109	109		108	107	106
105	108	104		94	94		79	88	96		104	104	110
87				107			87				105		
115	111	104		85	87		108	107	103		105	108	105
94				91			89				66		
103	98			95			100	102			98	90	
114	119	116		102	105		102	102	103		113	109	111
82	84	91		97	104		95	95	95		101	101	98
83				97			109				98		
120	116	116		111	111		107	105	108		96	102	103
97	82	92		104	108		110	107	105		109	94	96
31.8	36.4	52.3		65.3	61.9		70.6	70.1	70.2		42.0	42.9	59.5
5.4	5.5	6.5		10.1	7.2		7.1	8.6	6.6		6.5	10.7	8.7

Table 6. Relative grain yield of hard red spring wheat varieties in Minnesota in single-year (2019) and multiple-year comparisons (2017-2019).

Variety	State			North			South		
	2019	2 yr	3 yr	2019	2 yr	3 yr	2019	2 yr	3 yr
	--(% of mean)--------------------------------------								
Bolles	96	94	95	94	93	95	97	95	95
Boost	98	99	99	97	99	100	100	99	97
CP3530	107	105	106	101	100	103	115	112	110
CP3888	100			99			101		
CP3910	104			106			101		
CP3915	102			105			98		
CP3939	95			95			96		
Dyna-Gro Ambush	102	101	102	98	99	100	108	103	104
Dyna-Gro Ballistic	109	107		109	107		108	108	
Dyna-Gro Caliber	94	91	92	93	92	93	96	91	91
Dyna-Gro Commander	105			105			105		
Dyna-Gro Velocity	94			93			95		
Lang-MN	102	102	101	102	99	99	102	105	104
Lang-MN (0.7X)	101			99			103		
LCS Breakaway	97	96	98	98	98	98	95	95	98
LCS Cannon	106	105		107	106		105	105	
LCS Rebel	101	99	100	102	101	102	100	97	97
LCS Trigger	115	112		116	112		113	113	
Linkert	93	92	95	92	93	94	93	91	95
MN-Washburn	101	100	103	102	101	103	100	100	102
MS Barracuda	100	100		101	101		100	99	
MS Camaro	90	91		93	93		87	88	
MS Chevelle	101	101	103	102	104	106	99	96	99
ND-VitPro	94	95	95	92	94	94	98	97	96
Prosper	104	107	108	104	106	109	104	108	107
Rollag	90	89	92	93	92	94	86	84	89
Shelly	106	106	107	109	106	108	103	105	106
Surpass	99	100	101	100	102	102	97	96	100
SY 611 CL2	103			103			102		
SY Ingmar	99	100	99	98	98	98	100	102	100
SY Longmire	95			100			89		
SY McCloud	96	97		97	97		96	98	
SY Valda	109	109	111	108	109	111	111	109	110
TCG-Climax	92	94	95	91	92	95	94	97	96
TCG-Heartland	97			95			99		
TCG-Spitfire	107	106	107	105	104	105	111	110	109
WB-Mayville	97	96	98	94	95	95	100	96	101
Mean (bu/acre)	70.6	73.4	78.7	77.2	82.2	86.9	63.0	64.0	70.2
LSD (0.1)	3.0	2.2	1.9	3.5	2.5	2.3	4.6	3.5	3.1
No. Environments	15	29	43	8	16	23	7	13	20

NOTES

Table 7. Grain yield (bushel per acre) of hard red spring wheat varieties grown under conventional

	North										
	2019			2-year			3-year			2019	
	Conv	Int		Conv	Int		Conv	Int		Conv	Int
Bolles	77.1	76.8		75.8	74.9		85.3	86.6		47.0	53.3
Boost	82.4	84.9		79.8	83.3		90.2	93.5		53.5	57.1
CP3530	83.4	90.6		78.9	86.0		89.5	95.4		54.7	60.9
CP3888	81.1	85.0								48.6	52.5
CP3910	91.0	91.9								51.6	53.1
CP3915	89.1	88.0								47.0	56.0
CP3939	74.4	84.0								49.4	53.0
Dyna-Gro Ambush	78.0	74.8		76.1	76.8		83.9	87.0		50.5	61.3
Dyna-Gro Ballistic	90.5	98.0		85.5	92.6					55.9	64.5
Dyna-Gro Caliber	77.5	81.5		72.4	76.5		81.2	84.2		47.3	51.3
Dyna-Gro Commander	86.4	88.8								52.8	55.7
Dyna-Gro Velocity	79.7	91.3								44.9	51.7
Lang-MN	82.6	84.0		81.6	83.6		87.9	91.4		51.7	63.4
Lang-MN (0.7X)	80.5	86.6								50.8	59.4
LCS Breakaway	86.7	86.5		80.6	83.8		83.5	88.4		43.9	49.9
LCS Cannon	85.4	87.9		81.8	84.8					48.4	53.9
LCS Rebel	86.0	81.0		81.1	80.1		89.6	92.3		49.0	58.5
LCS Trigger	97.5	103.1		91.8	99.0					54.7	66.0
Linkert	74.2	80.9		72.4	78.4		81.4	87.1		43.2	46.8
MN-Washburn	81.4	86.5		79.8	86.2		89.0	93.5		51.2	59.0
MS Barracuda	82.4	83.7		80.3	81.2					39.8	48.5
MS Camaro	69.4	78.0		68.4	75.8					36.0	42.9
MS Chevelle	88.0	94.8		83.4	89.6		91.6	100.6		51.4	53.3
ND-VitPro	77.1	79.3		74.6	76.4		81.8	83.3		44.7	49.0
Prosper	86.7	96.8		84.4	91.4		95.1	105.2		57.2	65.5
Rollag	72.5	78.9		68.7	74.3		77.6	82.7		38.3	49.1
Shelly	90.8	91.8		86.2	87.3		95.6	98.0		48.1	59.2
Surpass	79.0	82.0		79.4	81.8		87.2	91.4		47.2	52.2
SY 611 CL2	82.8	95.7								48.8	52.6
SY Ingmar	80.6	82.2		77.0	81.4		82.4	86.0		45.9	54.6
SY Longmire	81.2	87.0								44.6	52.0
SY McCloud	78.7	84.3		77.2	81.8					47.6	51.1
SY Valda	93.8	96.3		88.5	92.0		97.7	101.8		51.4	57.2
TCG-Climax	76.4	82.5		75.2	83.5		85.7	93.5		44.7	53.9
TCG-Heartland	76.2	83.7								44.8	52.7
TCG-Spitfire	89.7	93.7		85.7	89.9		92.9	96.9		55.3	60.3
WB-Mayville	79.3	84.9		74.8	81.0		80.4	88.7		49.6	53.6
Mean (bu/acre)	**82.4**	**86.7**		**79.3**	**83.5**		**87.1**	**91.8**		**48.4**	**55.0**
LSD (0.10)	**8.0**	**8.4**		**4.9**	**5.2**		**5.7**	**7.0**		**7.2**	**7.8**
No. Environments	**2**	**2**		**4**	**4**		**6**	**6**		**2**	**2**

and intensive management.

South						State							
2-year			**3-year**			**2019**			**2-year**			**3-year**	
Conv	**Int**		**Conv**	**Int**		**Conv**	**Int**		**Conv**	**Int**		**Conv**	**Int**
45.2	49.3		53.9	56.6		62.1	65.0		62.7	63.9		71.0	73.0
51.2	54.5		56.7	61.1		68.0	71.0		67.5	71.0		75.0	78.8
52.4	56.4		60.1	66.2		69.1	75.7		67.5	73.4		76.2	82.1
						64.9	68.8						
						71.3	72.5						
						68.0	72.0						
						61.9	68.5						
47.4	54.6		57.9	64.1		64.3	68.0		63.8	67.3		72.1	76.6
52.5	59.9					73.2	81.3		71.4	78.6			
42.9	45.9		50.7	52.8		62.4	66.4		59.8	63.4		67.4	69.9
						69.6	72.2						
						62.3	71.5						
49.4	58.7		60.0	66.9		67.2	73.7		67.8	72.9		75.2	80.2
						65.7	73.0						
43.7	45.3		54.9	57.9		65.3	68.2		64.8	67.3		70.5	74.6
44.4	49.0					66.9	70.9		65.8	69.5			
47.7	54.1		56.7	62.6		67.5	69.8		66.8	69.0		74.7	78.8
52.5	62.3					76.1	84.5		74.9	83.3			
37.9	43.8		51.3	55.6		58.7	63.9		57.6	63.6		67.7	72.8
48.8	55.8		57.8	64.4		66.3	72.7		66.6	73.2		74.8	80.3
37.0	45.5					61.1	66.1		61.7	65.9			
35.8	40.4					52.7	60.4		54.4	60.6			
44.8	50.2		59.0	62.2		69.7	74.0		66.9	72.7		76.8	83.1
44.7	48.3		51.5	55.2		60.9	64.1		61.8	64.4		68.0	70.6
56.3	62.9		63.1	71.3		71.9	81.2		72.4	79.2		80.5	89.8
36.7	45.9		48.9	54.4		55.4	64.0		55.0	62.1		64.6	69.8
46.4	55.2		59.1	66.3		69.4	75.5		69.1	73.6		79.0	83.6
46.5	50.2		55.7	58.2		63.1	67.1		65.3	68.3		72.9	76.3
						65.8	74.2						
45.3	51.5		54.3	60.0		63.3	68.4		63.4	68.6		69.6	74.2
						62.9	69.5						
44.4	48.7					63.1	67.7		63.1	67.6			
51.0	54.5		62.4	66.2		72.6	76.7		72.4	75.9		81.7	85.6
41.4	50.1		54.3	59.7		60.5	68.2		60.7	69.2		71.5	78.1
						60.5	68.2						
52.2	57.1		63.8	66.7		72.5	77.0		71.4	75.9		79.7	83.2
42.6	45.8		55.9	58.1		64.4	69.3		61.0	65.9		69.2	74.8
46.0	**51.7**		**56.6**	**61.2**		**65.4**	**70.8**		**65.0**	**69.8**		**73.2**	**77.9**
5.3	**6.2**		**4.2**	**4.7**		**5.5**	**6.0**		**3.8**	**4.1**		**3.9**	**4.5**
3	**3**		**5**	**5**		**4**	**4**		**7**	**7**		**11**	**11**

Table 8. Origin and agronomic characteristics of barley varieties in multiple-year comparisons (2017-2019).

Variety	Origin[1]	Year of Release	Legal Status	Days to Heading	Plant Height	Straw Strength[2]	Plump (%)	Protein (%)
				(days)	(inches)	(1-9)	(%)	(%)
2-row								
AAC Synergy[1]	AAFC	2012	PVP(94)	56	33	5	94	12.2
AC Metcalfe[1]	AC	1997		56	33	6	87	13.9
Conlon	ND	1996	PVP(94)	51	31	7	94	13.4
ND Genesis	ND	2015	PVP(94)	55	34	5	95	11.5
Pinnacle	ND	2007	PVP(94)	55	33	5	95	11.5
6-row								
Lacey	MN	2000	PVP(94)	53	35	3	96	12.5
Tradition	ABI	2003	PVP(94)	54	37	3	92	13.4
No. Environments				12	12	5	5	5

[1] Abbreviations: ABI= Busch Agricultural Resources, MN = Minnesota Agricultural Experiment Station; ND = North Dakota State University Research Foundation, Ac or AAFC = Agriculture Canada or Agriculture and Agri-Food Canada

Table 9. Disease reactions[1] of barley varieties in multiple year comparisons (2017-2019).

Variety	DON[2]	Net Blotch[1]	Spot Blotch	Stem Rust[3]	Bacterial Leaf Streak
	---------- (1-9) ----------				
2-row					
AAC Synergy	7	5	2	4	4
AC Metcalfe	5	4	3	3	3
Conlon	3	6	5	3	5
ND Genesis	6	5	3	4	4
Pinnacle	6	6	3	5	4
6-row					
Lacey	8	5	2	4	4
Tradition	6	3	2	3	4

[1] Disease reactions measured on a scale from 1-9 where 1=resistant and 9=susceptible.
[2] Deoxynivalenol or vomitoxin associated with the disease Fusarium Head Blight.
[3] Data is for stem rust pathogen QCCJ. All lines were resistant to stem rust pathogen MCCF in years tested.

Table 10. Relative grain yield of barley varieties in Northern Minnesota locations in a single-year (2019) and multiple-year comparisons (2017-2019).

Variety	Crookston		Hallock		Oklee		Perley		Roseau		Stephen		Strathcona	
	2019	3 yr	2019	3 yr	2019	3 yr	2019	3 yr	2019	3 yr	2019	2 yr [2]	2019	2 yr [2]
2-row														
AAC Synergy	99	99	95	105	98	108	111	107	97	100	94	100	107	102
AC Metcalfe	93	85	98	96	95	93	87	91	100	96	96	95	110	98
Conlon	93	96	94	94	100	93	94	89	95	93	97	96	55	83
ND Genesis	109	102	120	101	108	107	108	100	103	99	103	99	116	106
Pinnacle	108	103	123	109	106	105	74	94	102	108	113	102	114	105
6-row														
Lacey	101	109	100	102	98	101	115	107	106	102	100	106	102	106
Tradition	98	105	70	93	107	103	111	111	97	101	97	103	96	101
Mean (bu/acre)	127	131	68	105	85	99	80	100	102	110	117	119	97	108
LSD (0.05)	8.8	6.8	37.6	12.6	7.4	14.0	14.2	14.7	18.0	11.5	12.7	7.4	10.9	19.8

Table 11. Relative grain yield of barley varieties in southern Minnesota locations in single-year (2019) and multiple-year comparisons (2017-2019).

Variety	Fergus Falls			Le Center		Morris			Rochester		St. Paul	
	2019	2 yr[1]		2019[1]		2019	3 yr		2019[1]		2019	3 yr
2-row												
AAC Synergy	93	98		111		123	107		102		111	113
AC Metcalfe	52	85		91		91	89		74		82	90
Conlon	81	77		117		36	68		75		53	59
ND Genesis	130	113		107		121	114		105		121	114
Pinnacle	110	110		72		125	110		108		109	100
6-row												
Celebration	107	107		104		112	111		118		117	115
Innovation	126	109		98		106	101		110		107	108
Mean (bu/acre)	41	72		78		66	58		76		59	83
LSD (0.05)	15.2	19.6		14.0		18.0	9.2		11.5		8.1	6.7

[1] Trial data is from 2019 only

Table 12. Relative grain yield of barley varieties in a single-year (2019) and multiple year comparisons (2017-2019).

Variety	State				North				South		
	2019	2 yr	3 yr		2019	2 yr	3 yr		2019	2 yr	3 yr
	-------(% of mean)------										
2-row											
AAC Synergy	103	104	104		100	103	103		109	107	107
AC Metcalfe	91	90	92		97	94	93		80	82	87
Conlon	84	86	87		89	94	92		74	67	73
ND Genesis	111	107	105		109	103	102		115	115	112
Pinnacle	105	105	104		106	105	104		103	105	104
6-row											
Lacey	106	106	106		103	103	104		111	115	111
Tradition	100	102	103		96	99	101		108	110	106
Mean (bu/acre)	83	92	97		96	108	110		64	66	72
LSD (0.05)	4.8	3.6	2.8		6.9	4.3	3.4		6.2	6.3	5.1
No. Environments	12	22	32		7	14	21		5	8	11

Table 13. Origin and agronomic characteristics of oat varieties in Minnesota in multiple-year comparisons (2017-2019).

Variety	Origin	Year of Release	Legal Status	Seed Color	Days to Heading	Plant Height	Straw Strength[4]	Test Weight	Grain Protein[5, 6]	Grain Oil [5, 6]
					(days)	(inches)	(1-9)	(lbs/bu)	(%)	(%)
Antigo	WI	2017	Pending	Yellow	54.4	90.4	5.4	38.3	14.4	5.0
Badger	WI	2010	PVP(94)	Yellow	54.2	85.1	5.1	34.5	13.3	4.1
Deon	MN	2014	PVP(94)	Yellow	58.7	99.2	6.0	35.5	12.8	4.6
Esker[1]	WI	2006	PVP(94)	White	58.6	92.0	4.1	35.2	14.2	4.4
Hayden	SD	2015	PVP(94)	White	59.2	100.0	7.9	36.8	12.8	5.3
Horsepower	SD	2012	PVP(94)	White	56.7	86.7	7.6	35.4	12.9	4.7
MN Pearl	MN	2018	Pending	White	59.7	103.5	5.4	35.5	12.6	6.0
Newburg	ND	2011	PVP(94)	White	59.8	110.0	8.6	34.4	12.5	5.0
Reins	IL	2016	PVP(94)	White	55.1	81.3	2.6	37.1	14.2	4.1
Rockford[1]	ND	2008	PVP(94)	White	63.0	103.7	6.4	36.2	13.3	6.0
Saber	IL	2010	PVP(94)	Yellow	54.8	87.2	5.8	35.8	14.4	4.1
Saddle	SD	2018	Pending	White	54.1	89.6	2.5	35.9	14.4	4.1
Shelby 427	SD	2011	PVP(94)	White	56.1	97.4	6.7	37.2	13.5	5.2
Streaker[2]	SD	2016	PVP(94)	Hulless	56.7	99.0	7.8	44.3	17.6	6.6
Sumo	SD	2017	Pending	White	53.6	92.1	4.3	36.6	15.0	3.8
Warrior[3]	SD	2019	Pending	White	57.5	86.1	4.2	35.1	-	-

[1] Line tested in 2017 and 2019
[2] Hulless oat
[3] Line tested in 2019 only
[4] 1 = resistant and 9 = susceptible
[5] Whole grain NIRS
[6] Trait measured in 2017 and 2018

Table 14. Disease characteristics of oat varieties.

Variety		Crown Rust,[8]	Loose Smut,[9]	BYDV [9]
Antigo[1]		4	7	8
Badger[2]		8	0	5
Deon[2]		3	0	4
Esker[3]		6	4	6
Hayden[2]		8	0	3
Horsepower[2]		9	9	8
MN Pearl[4]		7	0	7
Newburg[4]		7	14	4
Reins[5]		9	2	8
Rockford[3]		9	7	3
Saber[2]		8	16	7
Saddle[1]		5	5	5
Shelby 427[2]		8	2	8
Streaker[6]		7	0	3
Sumo[6]		5	0	9
Warrior[7]		2	2	--

[1] Line tested in 2017, 2018, and 2019 for Crown Rust and Smut, Line tested in 2016 for BYDV
[2] Line tested in 2017, 2018, and 2019 for Crown Rust and Smut; Line tested in 2015 for BYDV
[3] Line tested in 2017 and 2019 for Crown Rust and Smut; Line tested in 2015 for BYDV
[4] Line tested in 2017, 2018, and 2019 for Crown Rust and Smut; Line tested in 2015 and 2016 for BYDV
[5] Line tested in 2017, 2018, and 2019 for Crown Rust and Smut; Line tested in 2015 and 2018 for BYDV
[6] Line tested in 2017, 2018, and 2019 for Crown Rust and Smut; Line tested in 2018 for BYDV
[7] Line tested in 2019 for Crown Rust and Smut; Line not tested for BYDV
[8] Tested in 2017, 2018, and 2019 with a mixed race population of crown rust; 0 = most resistant, 9 = most susceptible
[9] Tested in 2017, 2018, and 2019; 0 = most resistant, 9 = most susceptible

Table 15. Relative grain yield of oat varieties in Minnesota in single-year (2019) and multiple-year comparisons (2017-2019).

Variety		**North**			**South**			**State**	
		2019	**3yr**		**2019**	**3yr**		**2019**	**3yr**
Antigo		93	91		105	106		101	99
Badger		99	100		94	99		96	99
Deon		106	108		104	107		105	107
Esker[1]		106	102		95	98		99	100
Hayden		106	111		102	100		103	106
Horsepower		110	109		97	94		102	102
MN Pearl		112	113		120	121		117	117
Newburg		100	101		94	96		96	100
Reins		94	98		103	106		100	101
Rockford[1]		106	103		72	78		84	91
Saber		106	104		100	105		102	104
Saddle		103	104		110	115		108	109
Shelby 427		88	96		99	94		95	95
Streaker[2]		87	78		66	68		73	72
Sumo		75	79		87	92		83	87
Warrior[3]		93	-		103	-		100	-
Mean (bu/acre)		112	138		118	104		116	116
LSD (0.1)		17	11		15	10		12	8

[1] Line tested in 2017 and 2019 [2] Hulless oat [3] Line tested in 2019 only

Table 16. Relative grain yield of oat varieties in Northern Minnesota locations in single-year (2019) and multiple-year comparisons (2017-2019).

Variety		Crookston			Roseau			Stephen			Northern Minnesota	
		2019	3yr		2019	3yr		2019	3yr		2019	3yr
Antigo		97	95		101	92		81	88		93	91
Badger		96	101		99	101		105	98		99	100
Deon		97	97		113	115		114	111		106	108
Esker[1]		114	122		100	89		99	98		106	102
Hayden		109	115		94	109		111	109		106	111
Horsepower		114	113		109	113		106	103		110	109
MN Pearl		112	106		113	121		110	109		112	113
Newburg		94	96		99	97		109	108		100	101
Reins		88	94		97	99		103	101		94	98
Rockford[1]		106	113		103	98		108	101		106	103
Saber		114	108		97	104		104	101		106	104
Saddle		104	101		101	105		102	106		103	104
Shelby 427		100	101		86	96		73	93		88	96
Streaker[2]		80	84		103	75		85	78		87	78
Sumo		55	67		99	86		85	82		75	79
Warrior[3]		96	-		88	-		92	-		93	-
Mean (bu/acre)		150	116		87	149		100	148		112	138
LSD (0.1)		29	16		13	21		14	18		17	11

[1] Line tested in 2017 and 2019
[2] Hulless oat
[3] Line tested in 2019 only

Table 17. Relative grain yield of oat varieties in Southern Minnesota locations in single-year (2019) and multiple-year comparisons (2017-2019).

Variety	Kimball		Lamberton		Le Center		Morris [4]		Rochester [4]		Waseca		Southern Minnesota	
	2019	3yr	2019	3yr	2019	3yr	2019	3yr	2019	3yr	2019	3yr	2019	3yr
Antigo	110	116	99	99	97	101	90	92	116	126	124	116	105	106
Badger	95	104	71	87	92	105	98	100	92	90	109	104	94	99
Deon	107	110	145	134	100	110	98	103	103	94	139	112	104	107
Esker[1]	128	98	74	95	81	64	96	97	121	127	94	130	95	98
Hayden	104	97	90	107	102	103	107	108	111	88	81	89	102	100
Horsepower	125	110	56	86	100	98	105	109	94	81	72	70	97	94
MN Pearl	121	120	139	127	124	130	116	105	108	116	132	132	120	121
Newburg	88	86	105	106	98	106	104	104	87	77	76	75	94	96
Reins	117	125	68	81	101	111	82	89	128	126	110	115	103	106
Rockford[1]	66	66	74	93	76	66	88	97	85	66	41	72	72	78
Saber	104	106	72	99	106	115	100	109	111	97	82	91	100	105
Saddle	107	117	100	104	116	120	105	107	107	132	122	119	110	115
Shelby 427	111	107	86	91	104	99	102	102	106	87	77	80	99	94
Streaker[2]	86	80	68	77	56	53	68	78	54	49	60	65	66	68
Sumo	76	92	107	93	92	85	79	88	81	109	91	94	87	92
Warrior[3]	109	-	125	-	97	-	118	-	70	-	114	-	103	-
Mean (bu/acre)	148	95	83	114	160	134	132	128	114	88	74	72	118	104
LSD (0.1)	41	26	15	17	22	17	22	16	22	40	11	12	15	10

[1] Line tested in 2017 and 2019
[2] Hulless oat
[3] Line tested in 2019 only
[4] Location evaluated in 2017 and 2019

North Dakota Hard Red Spring Wheat Variety Trial Results for 2019 and Selection Guide

Joel Ransom, Andrew Green, Senay Simsek, Andrew Friskop, Matt Breiland, Tim Friesen, Zhaohui Liu and Shaobin Zhong (NDSU Main Station); John Rickertsen (Hettinger Research Extension Center); Eric Eriksmoen (North Central Research Extension Center, Minot); Bryan Hanson (Langdon Research Extension Center); Glenn Martin (Dickinson Research Extension Center); Gautam Pradhan (Williston Research Extension Center); Mike Ostlie (Carrington Research Extension Center)

Hard red spring (HRS) wheat was planted on 6.7 million acres in 2019, up slightly from 2018. The average yield of spring wheat was 50 bushels/acre (bu/a), similar to 2018.

SY Ingmar was the most popular HRS wheat variety in 2019, occupying 20.6 percent of the planted acreage, followed by SY Valda (12.5), Bolles (5.0), SY Soren (4.7), Elgin-ND (4.2), Barlow (3.7), Faller (3.7), and Glenn (2-9). SY Ingmar, SY Soren and SY Valda were released by Syngenta/AgriPro. Bolles was released by the University of Minnesota. Barlow, Faller, Elgin-ND and Glenn are NDSU releases.

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, response 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 in multiple locations in 2018. The wheat protein data often are higher than obtained in actual production fields but can be used to compare relative 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 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 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 or 90 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 percent moisture, while protein content is reported at 12 percent 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. Also consider using the online variety selection tool at www.ag.ndsu.edu/varietyselectiontool/, which allows you to generate tables of data from research locations nearest your farm and make head-to-head comparisons of varieties of interest.

North Dakota State University Spring Wheat Tables #1 - 7 can be found on pages 79-86.

Table 1. North Dakota hard red spring wheat variety descriptions, agronomic traits, 2019.

				Reaction to Disease[4]							
Variety	**Agent or Origin[1]**	**Year Released**	**Height (inches)**	**Straw Strength[2]**	**Days to Head[3]**	**Stem Rust[5]**	**Leaf Rust**	**Stripe Rust**	**Tan Spot**	**Bact. Leaf Streak**	**Head Scab**
Ambush	DynaGro	2016	29	5	58	1	4	3	NA	6	5
Barlow	ND	2009	30	6	58	1	6	4	6	4	4
Bolles	MN	2015	29	4	62	2	3	5	4	7	5
Boost	SD	2016	30	5	62	1	4	3	8	2	5
Commander	**DynaGro**	**2019**	**28**	**6**	**59**	**NA**	**4**	**NA**	**NA**	**4**	**5**
CP3504	Croplan	2015	27	3	61	1	1	6	8	4	6
CP3530	Croplan	2015	31	5	61	1	2	8	6	5	5
CP3616	Croplan	2016	29	4	60	1	5	5	4	6	6
CP3888	Croplan	2017	28	4	60	NA	1	NA	NA	6	6
CP3910	**Croplan**	**2019**	**27**	**5**	**58**	**NA**	**1**	**NA**	**NA**	**8**	**6**
CP3915	**Croplan**	**2019**	**28**	**4**	**59**	**NA**	**1**	**NA**	**NA**	**4**	**5**
CP3939	**Croplan**	**2019**	**29**	**4**	**59**	**NA**	**3**	**NA**	**NA**	**6**	**6**
Elgin-ND	ND	2012	31	5	59	1	6	5	6	6	4
Faller	ND	2007	30	5	61	1	7	8	7	5	4
Glenn	ND	2005	30	4	58	1	6	4	6	4	4
Lang-MN	MN	2017	30	5	61	1	2	1	7	3	4
Lanning	MT	2017	26	3	60	NA	NA	NA	NA	8	6
LCS Breakaway	Limagrain	2011	26	5	58	1	3	6	4	6	6
LCS Cannon	Limagrain	2018	27	4	57	NA	7	NA	NA	7	6
LCS Rebel	Limagrain	2017	30	5	58	1	7	4	8	4	5
LCS Trigger	Limagrain	2016	29	5	64	1	1	2	6	3	4
Linkert	MN	2013	26	2	60	1	3	1	4	6	5
MN-Washburn	**MN**	**2019**	**27**	**3**	**60**	**NA**	**1**	**NA**	**NA**	**5**	**5**
Mott[6]	ND	2009	32	3	60	1	6	6	6	5	6
MS Barracuda	Meridian	2018	27	3	57	NA	2	NA	NA	7	6
MS Camaro	Meridian	2016	26	5	59	1	1	2	8	7	6
MS Chevelle	Meridian	2014	28	5	59	1	4	3	6	7	6
ND VitPro	ND	2016	29	3	59	1	4	3	7	3	4
Shelly	MN	2016	27	5	61	2	6	5	3	7	5
Surpass	SD	2016	28	5	58	1	4	6	8	4	5
SY 611CL2	**Syngenta/AgriPro**	**2019**	**27**	**5**	**59**	**NA**	**NA**	**NA**	**NA**	**6**	**5**
SY Ingmar	Syngenta/AgriPro	2014	28	3	60	1	3	6	6	5	5
SY Longmire[6]	**Syngenta/AgriPro**	**2019**	**28**	**5**	**60**	**NA**	**7**	**NA**	**NA**	**6**	**7**
SY McCloud	**Syngenta/AgriPro**	**2019**	**28**	**4**	**58**	**NA**	**5**	**NA**	**NA**	**6**	**5**
SY Rockford	Syngenta/AgriPro	2017	30	3	61	NA	NA	NA	NA	8	6

»

Table 1. *continued*

Variety	Agent or Origin[1]	Year Released	Height (inches)	Reaction to Disease[4]: Straw Strength[2]	Days to Head[3]	Stem Rust[5]	Leaf Rust	Stripe Rust	Tan Spot	Bact. Leaf Streak	Head Scab
SY Soren	Syngenta/AgriPro	2011	27	3	60	1	2	7	2	7	7
SY Valda	Syngenta/AgriPro	2015	27	4	60	1	2	7	6	6	5
TCG-Climax	21st Century Genetics	2017	29	2	64	1	6	3	8	5	5
TCG-Heartland	**21st Century Genetics**	**2019**	**27**	**5**	**58**	**NA**	**2**	**NA**	**NA**	**7**	**6**
TCG-Spitfire	21st Century Genetics	2015	29	4	62	1	5	4	8	4	6
TCG-Stalwart[6]	**21st Century Genetics**	**2019**	**28**	**4**	**59**	**NA**	**8**	**NA**	**NA**	**9**	**7**

[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.

[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 based on data from several locations in 2019.

[4] Disease reaction scores from 1-9, with 1 = resistant and 9 = very susceptible, NA = not available.

[5] Fargo stem rust nursery inoculated with Puccinia graminis f. sp. Tritici races TPMK, TMLK, RTQQ, QFCQ and QTHJ.

[6] Solid stemmed or semisolid stem, imparting resistance to sawfly.

Table 2. Yield of hard red spring wheat varieties grown at four locations in eastern North Dakota, 2017-2019.

	Carrington		Casselton		Langdon		Steele Co.		Avg. eastern N.D.	
Variety	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**2 Yr.**	**2019**	**2-3 Yr.**
	(bu/a)									
Ambush	45.7	59.3	61.7	69.6	76.4	78.6	56.0	68.6	59.9	69.0
Barlow	45.4	56.3	59.8	69.5	75.5	78.3	51.4	63.2	58.0	66.8
Bolles	54.0	57.5	56.5	72.7	72.5	76.1	57.7	66.6	60.2	68.2
Boost	47.6	58.2	62.6	72.6	74.8	80.5	67.5	75.3	63.1	71.6
Commander	50.8	--	70.4	--	79.8	--	60.5	--	65.4	--
CP3504	55.1	63.7	66.1	77.7	82.4	83.6	63.6	74.4	66.8	74.9
CP3530	52.9	61.0	70.4	77.0	78.3	85.4	57.9	73.9	64.9	74.3
CP3616	50.3	59.1	68.6	76.2	76.8	77.9	47.7	62.3	60.9	68.9
CP3888	48.7	--	72.1	--	81.5	--	52.7	66.5	63.8	--
CP3910	44.2	--	59.0	--	75.9	--	50.7	--	57.5	--
CP3915	42.9	--	65.5	--	77.5	--	63.9	--	62.4	--
CP3939	44.2	--	71.1	--	76.0	--	49.5	--	60.2	--
Elgin-ND	49.6	56.6	69.7	73.8	80.7	83.6	51.5	64.4	62.9	69.6
Faller	51.4	61.9	68.1	77.7	83.7	87.8	60.6	74.6	66.0	75.5
Glenn	43.8	53.3	56.1	66.4	74.7	73.9	51.9	61.2	56.6	63.7

»

Table 2. *continued*

	Carrington		Casselton		Langdon		Steele Co.		Avg. eastern N.D.	
Variety	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**2 Yr.**	**2019**	**2-3 Yr.**
	(bu/a)									
Lang-MN	46.9	58.9	67.2	72.8	77.0	77.9	56.0	66.4	61.8	69.0
LCS Breakaway	41.6	55.3	56.0	69.5	76.0	78.9	49.9	65.7	55.9	67.4
LCS Cannon	37.7	--	66.9	--	80.9	--	48.5	66.8	58.5	--
LCS Rebel	42.0	56.9	64.9	74.8	81.3	86.0	58.9	72.3	61.8	72.5
LCS Trigger	50.0	63.8	72.5	86.9	87.2	98.4	71.9	82.6	70.4	82.9
Linkert	50.1	56.9	62.6	69.8	69.3	69.4	51.1	62.4	58.3	64.6
MN Washburn	40.2	--	65.9	--	75.8	--	57.2	--	59.8	--
Mott	44.2	--	64.3	--	79.9	--	--	--	47.1	--
MS Barracuda	40.4	--	64.8	--	83.4	--	41.0	62.6	57.4	--
MS Camaro	43.3	52.7	63.5	68.6	82.2	75.2	40.2	57.5	57.3	63.5
MS Chevelle	51.3	63.0	67.2	76.4	84.9	88.5	51.0	67.1	63.6	73.7
ND VitPro	50.1	54.0	60.9	68.8	72.9	74.3	52.4	62.1	59.1	64.8
Shelly	41.1	60.5	70.6	78.9	82.1	83.9	49.5	67.3	60.8	72.6
Surpass	42.5	--	76.8	80.8	78.5	83.3	50.0	66.2	62.0	57.6
SY 611CL2	49.9	--	68.3	--	83.3	--	56.8	--	64.6	--
SY Ingmar	46.2	59.2	68.4	75.7	81.0	82.0	54.1	66.2	62.4	70.8
SY Longmire	47.8	--	67.7	--	78.7	--	55.4	--	62.4	--
SY McCloud	41.9	--	66.5	--	78.2	--	56.2	--	60.7	--
SY Rockford	53.7	--	65.7	--	81.0	--	25.3	51.7	56.4	--
SY Soren	50.4	58.6	64.8	72.4	77.9	77.9	47.9	61.3	60.2	67.6
SY Valda	54.0	64.3	69.1	78.5	80.2	88.4	61.6	75.4	66.2	76.6
TCG-Climax	43.5	57.8	58.6	67.3	69.2	74.5	54.0	67.9	56.3	66.9
TCG-Heartland	47.7	--	59.5	--	74.8	--	56.1	--	59.5	--
TCG-Spitfire	50.4	62.4	72.0	77.0	78.6	82.1	63.9	76.6	66.2	74.5
TCG-Stalwart	38.2	--	52.2	--	71.3	--	30.5	--	48.0	--
Mean	46.8	58.8	65.4	74.1	78.3	81.1	53.4	67.2	60.6	69.9
CV%	10.4	--	8.3	--	4.7	--	12.2	--	8.5	4.0
LSD 0.05	6.9	--	7.3	--	5.2	--	7.5	--	7.4	4.0
LSD 0.10	5.8	--	5.7	--	4.4	--	6.3	--	6.2	3.3

Table 3. Yield of hard red spring wheat varieties grown at five locations in western North Dakota, 2017-2019.

	Dickinson		Hettinger		Mandan		Minot		Williston		Avg. western N.D.	
Variety	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**
	-----(bu/a)-----											
Ambush	46.5	47.4	61.6	45.8	36.2	--	44.6	60.1	67.2	--	51.2	--
Barlow	45.2	47.8	66.3	48.8	34.4	32.2	46.2	58.9	59.6	46.7	50.3	46.9
Bolles	38.4	45.9	65.1	41.3	35.6	30.6	45.6	58.7	61.5	43.5	49.2	44.0
Boost	47.7	46.6	67.5	42.1	34.8	33.8	50.9	62.1	63.6	43.8	52.9	45.7
Commander	47.2	--	69.0	--	35.0	--	--	--	67.5	--	43.7	--
CP3504	53.9	53.0	70.0	46.9	43.7	--	49.7	62.2	69.4	--	57.3	--
CP3530	52.0	49.4	66.9	46.8	38.8	35.1	47.0	63.5	60.8	--	53.1	--
CP3616	50.6	50.8	62.8	46.1	36.8	--	45.3	58.3	64.5	--	52.0	--
CP3888	47.1	--	70.6	--	40.0	--	43.6	--	59.6	--	52.2	--
CP3910	51.0	--	68.4	--	33.6	--	8.5	--	67.5	--	45.8	--
CP3915	51.5	--	65.8	--	36.2	--	50.3	--	64.0	--	53.6	--
CP3939	51.8	--	65.0	--	34.0	--	44.9	--	58.6	--	50.9	--
Elgin-ND	47.3	47.9	68.2	50.1	38.7	35.0	50.6	61.4	71.2	53.1	55.2	49.5
Faller	51.2	52.6	71.8	50.5	42.1	--	58.0	69.9	64.5	47.8	57.5	--
Glenn	44.8	47.7	57.6	42.9	34.8	34.0	39.2	57.3	59.8	47.9	47.2	46.0
Lang-MN	51.2	49.4	68.7	47.8	40.0	37.5	50.6	58.4	62.8	43.3	54.7	47.3
Lanning	49.2	--	64.5	--	36.7	--	47.9	--	62.2	--	52.1	--
LCS Breakaway	41.0	41.1	67.5	44.1	34.1	--	42.5	51.3	61.9	46.8	49.4	--
LCS Cannon	47.3	--	63.5	--	37.1	--	43.1	--	60.8	--	50.4	--
LCS Rebel	48.9	47.5	63.7	46.8	36.8	--	48.3	56.5	68.3	48.4	53.2	--
LCS Trigger	47.1	52.4	70.0	54.9	41.7	38.0	54.9	67.1	68.1	50.1	56.4	52.5
Linkert	47.1	46.3	57.0	40.4	35.5	--	42.4	55.4	55.9	45.8	47.6	--
MN Washburn	48.6	--	64.7	--	35.4	--	47.3	--	58.3	--	50.9	--
Mott	42.7	44.2	62.8	43.6	40.0	34.4	49.2	56.0	63.5	--	51.6	35.6
MS Barracuda	36.8	--	66.9	--	34.7	--	51.8	--	61.4	--	50.3	--
MS Camaro	48.2	45.2	63.7	39.7	31.9	--	44.9	59.0	62.3	48.2	50.2	--
MS Chevelle	54.8	52.5	71.8	50.6	36.3	36.2	49.0	59.8	71.7	50.0	56.7	49.8
ND VitPro	--	--	61.5	43.8	36.9	33.4	39.1	50.5	60.5	48.4	48.4	44.3
Shelly	48.1	52.6	68.3	50.1	37.2	34.7	42.4	62.4	68.1	51.4	52.8	50.3
Surpass	45.8	48.8	67.4	44.4	41.9	36.9	39.0	52.7	69.9	50.8	52.8	46.7
SY 611CL2	49.8	--	68.7	46.8	40.7	--	47.1	--	69.3	--	55.1	--
SY Ingmar	46.8	48.5	73.8	--	33.0	36.3	37.0	55.7	67.2	45.6	51.6	37.2
SY Longmire	49.8	--	62.7	43.9	32.6	--	47.0	--	60.0	--	50.4	--
SY McCloud	46.2	--	69.0	--	32.5	--	41.0	--	65.7	--	50.9	--
SY Rockford	54.0	52.5	62.8	--	38.2	--	50.9	67.8	67.6	52.1	54.7	--
SY Soren	48.6	47.6	70.9	49.7	30.4	32.2	48.6	61.3	69.8	49.8	53.7	48.1
SY Valda	47.0	49.5	67.9	45.3	41.5	35.5	44.6	59.0	61.1	47.8	52.4	47.4
TCG-Climax	39.6	45.3	57.0	43.1	36.2	--	45.5	59.6	57.7	45.3	47.2	--
TCG-Heartland	43.9	--	65.5	--	30.9	--	49.5	--	61.3	61.3	50.2	--
TCG-Spitfire	52.6	51.3	69.4	48.6	38.5	37.0	49.8	66.5	68.9	53.3	55.8	51.3
TCG-Stalwart	48.2	--	59.8	--	26.6	--	48.2	--	66.0	66.0	49.8	--
Mean	47.6	48.6	66.0	46.1	36.1	34.5	47.0	59.7	64.3	49.5	51.7	46.4
CV %	8.1	--	7.1	--	7.6	--	13.7	--	7.0	--	8.5	5.1
LSD 0.05	5.4	--	6.6	--	3.8	--	10.4	--	7.3	--	5.5	3.1
LSD 0.10	4.5	--	5.5	--	3.2	--	8.7	--	6.1	--	4.6	2.6

Table 4. Protein at 12 percent moisture of hard red spring wheat varieties grown at nine locations in North Dakota, 2019.

Variety	Carrington	Casselton	Langdon	Steele Co.	Dickinson	Hettinger	Mandan	Minot	Williston	State Avg.
	(%)									
Ambush	15.4	15.8	14.9	15.6	17.5	15.4	12.4	16.3	14.9	15.3
Barlow	15.5	15.9	14.4	15.0	16.6	15.1	12.5	16.1	14.6	15.1
Bolles	17.4	17.5	15.3	16.0	18.7	15.8	12.8	17.9	16.7	16.5
Boost	15.4	14.8	14.2	14.6	16.4	14.6	12.3	15.9	15.0	14.8
Commander	14.7	15.2	13.7	14.7	16.6	14.7	12.9	15.3	15.2	14.8
CP3504	14.7	14.4	13.0	14.7	15.9	13.3	11.3	15.4	13.7	14.0
CP3530	15.0	15.1	14.2	15.9	15.7	14.5	12.3	15.6	14.5	14.8
CP3616	16.5	15.9	14.9	16.6	17.0	15.0	13.3	16.9	16.9	15.9
CP3888	15.5	15.5	14.0	15.4	16.4	14.5	12.3	16.6	15.5	15.1
CP3910	15.9	16.2	13.7	16.1	16.3	14.6	12.7	16.0	15.1	15.2
CP3915	14.5	15.3	14.3	15.1	17.0	15.2	12.2	15.1	15.9	15.0
CP3939	16.0	16.0	14.9	15.9	16.8	15.6	13.0	16.3	14.8	15.5
Elgin-ND	15.6	14.7	13.9	14.9	16.1	15.2	12.4	15.7	14.8	14.8
Faller	14.5	14.5	13.7	14.9	15.6	14.3	11.5	14.2	14.6	14.2
Glenn	15.8	15.6	15.0	15.6	16.9	15.4	12.3	16.1	14.5	15.2
Lang-MN	15.0	15.9	15.0	15.7	16.7	14.6	13.1	15.7	15.5	15.2
Lanning	--	--	--	--	17.5	16.0	13.0	16.6	15.5	--
LCS Breakaway	15.5	15.3	14.4	15.7	16.8	15.7	12.6	16.8	15.5	15.4
LCS Cannon	14.8	14.9	13.8	14.9	16.5	15.1	11.7	16.2	15.0	14.8
LCS Rebel	15.4	16.3	14.4	15.2	16.8	15.2	13.1	15.5	14.7	15.2
LCS Trigger	13.0	12.8	11.9	12.4	14.3	12.5	10.5	13.0	12.4	12.5
Linkert	16.4	15.4	15.1	16.1	17.1	16.7	13.8	17.6	15.8	16.0
MN Washburn	14.3	14.3	14.3	15.7	16.1	14.5	12.5	15.2	14.6	14.6
Mott	16.2	15.3	14.5	--	17.0	15.1	12.4	15.6	16.1	15.3
MS Barracuda	15.8	16.0	14.3	16.0	17.1	15.2	12.0	15.8	14.2	15.2
MS Camaro	15.3	15.5	14.4	15.7	17.0	15.1	13.5	16.1	16.5	15.4
MS Chevelle	14.0	14.6	12.6	14.7	15.7	13.7	11.6	14.4	13.7	13.9
ND VitPro	15.7	15.7	14.8	15.6	--	16.0	13.0	16.7	15.7	15.6
Shelly	14.2	14.8	13.5	14.9	16.0	14.3	11.9	15.8	13.8	14.4
Surpass	15.0	14.9	14.0	15.0	16.7	14.4	11.2	15.8	15.2	14.7
SY 611CL2	15.5	15.4	13.6	14.8	16.8	13.9	11.7	16.1	15.5	14.8
SY Ingmar	15.4	15.4	14.2	15.7	17.1	15.4	13.3	17.2	14.5	15.4
SY Longmire	15.7	14.9	14.0	14.6	16.7	14.4	12.8	16.4	15.6	15.0
SY McCloud	15.6	15.3	14.7	15.2	17.3	15.7	13.2	17.0	16.8	15.6
SY Rockford	15.2	15.4	13.9	16.4	16.2	14.2	12.3	15.8	14.7	14.9
SY Soren	16.1	15.7	14.4	15.8	17.7	15.3	13.0	16.1	16.2	15.6
SY Valda	14.7	15.1	13.0	14.4	16.0	13.9	11.8	15.0	14.3	14.2
TCG-Climax	16.6	16.5	15.9	5.8	17.6	15.6	13.1	16.6	17.0	15.0
TCG-Heartland	15.7	16.1	14.7	15.5	16.7	15.6	13.1	16.6	16.0	15.6
TCG-Spitfire	14.4	14.1	13.6	14.4	15.8	14.1	11.8	15.1	14.4	14.2
TCG-Stalwart	16.4	16.9	14.9	17.1	17.2	15.4	14.0	16.2	16.7	16.1
Mean	15.3	15.3	14.2	15.3	16.7	14.9	12.5	16.0	15.2	15.0
CV%	2.2	2.5	2.4	3.6	1.9	3.6	4.0	3.9	5.7	4.7
LSD 0.05	0.5	0.5	0.5	0.6	0.5	0.7	0.7	1.0	1.4	0.7
LSD 0.10	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.8	1.2	0.6

Table 5. Test weight of hard red spring wheat varieties grown at nine locations in North Dakota, 2019.

Variety	Carrington	Casselton	Langdon	Steele Co.	Dickinson	Hettinger	Mandan	Minot	Williston	State Avg.
	----------(lb/bu)----------									
Ambush	60.8	56.7	61.5	58.3	61.3	58.2	57.3	63.6	62.8	60.1
Barlow	60.3	56.7	62.3	55.3	61.1	58.8	57.0	63.9	62.6	59.8
Bolles	59.4	55.6	60.3	57.8	59.6	56.7	56.3	61.1	61.4	58.7
Boost	58.9	58.6	60.1	58.2	59.4	57.4	56.9	62.0	60.9	59.2
Commander	59.6	56.8	61.2	59.0	60.6	58.0	55.7	63.0	62.2	59.6
CP3504	58.5	56.5	59.5	56.4	59.3	56.3	56.4	61.3	60.6	58.3
CP3530	58.8	57.8	60.1	58.1	59.6	56.9	56.7	61.3	61.4	59.0
CP3616	59.6	55.4	60.3	55.4	59.6	56.7	55.4	61.3	61.6	58.4
CP3888	58.2	55.6	60.1	56.5	59.4	56.8	55.9	61.4	61.2	58.3
CP3910	58.8	53.4	60.9	56.0	61.5	59.0	55.9	63.6	62.5	59.1
CP3915	58.3	58.4	61.7	59.0	61.5	58.1	55.4	63.2	62.6	59.8
CP3939	59.9	55.3	61.5	56.8	60.6	56.7	54.8	61.5	62.7	58.9
Elgin-ND	59.0	56.6	60.7	56.5	59.5	56.9	56.4	62.2	61.7	58.8
Faller	60.1	56.5	60.4	58.2	59.4	56.9	56.1	61.0	60.7	58.8
Glenn	62.5	59.4	63.2	59.7	62.1	57.3	56.3	63.5	64.7	61.0
Lang-MN	60.8	57.4	61.4	59.1	60.9	58.1	56.8	62.7	61.8	59.9
Lanning	--	--	--	--	60.2	56.7	54.1	61.7	61.7	--
LCS Breakaway	60.7	57.4	62.1	58.0	61.6	58.6	56.5	63.4	63.1	60.2
LCS Cannon	60.0	57.7	61.8	54.0	61.6	59.2	56.8	63.7	62.6	59.7
LCS Rebel	60.4	58.1	61.7	58.3	61.0	58.0	56.5	63.2	63.0	60.0
LCS Trigger	58.7	57.3	60.5	59.4	59.6	57.9	57.5	62.4	62.1	59.5
Linkert	59.7	56.4	60.5	54.2	60.0	58.3	56.5	61.7	62.0	58.8
MN Washburn	57.7	58.6	60.7	57.5	59.4	57.2	54.5	62.1	61.7	58.8
Mott	59.5	57.1	60.7	--	60.3	57.2	56.8	61.3	61.9	59.1
MS Barracuda	59.5	54.7	61.3	54.7	60.1	57.7	55.8	62.2	61.9	58.7
MS Camaro	59.7	56.2	61.2	54.6	60.3	58.4	55.9	61.9	62.5	59.0
MS Chevelle	59.2	54.5	61.0	56.5	60.3	57.6	55.7	62.2	61.8	58.8
ND VitPro	61.2	59.0	63.0	59.1	--	57.3	54.4	62.8	64.0	60.2
Shelly	59.0	56.7	61.1	55.8	60.0	57.0	55.4	61.7	61.9	58.7
Surpass	58.9	56.6	60.5	58.3	60.0	57.0	56.4	61.2	61.1	58.9
SY 611CL2	60.4	56.8	62.3	57.6	61.0	59.0	57.4	64.2	63.3	60.2
SY Ingmar	59.9	57.8	61.5	59.0	61.4	58.8	56.2	63.4	62.6	60.1
SY Longmire	59.9	55.8	61.5	58.9	60.9	58.2	54.4	62.7	63.0	59.5
SY McCloud	61.1	58.0	61.8	58.4	61.1	58.2	56.8	63.1	63.2	60.2
SY Rockford	57.4	53.3	59.3	--	59.1	57.3	55.3	60.5	61.3	57.7
SY Soren	60.1	55.6	61.5	54.9	61.1	58.6	55.5	62.8	62.5	59.2
SY Valda	59.6	57.4	60.6	58.3	60.6	57.4	57.1	63.3	61.3	59.5
TCG-Climax	61.0	60.0	61.8	58.5	60.4	58.5	59.2	62.9	63.1	60.6
TCG-Heartland	60.8	57.4	61.9	59.5	60.9	58.1	54.9	63.5	63.5	60.1
TCG-Spitfire	57.9	56.8	60.2	57.2	59.5	56.5	55.1	62.7	61.8	58.6
TCG-Stalwart	55.7	51.7	59.5	50.6	59.1	56.0	51.1	60.8	60.8	56.1
Mean	59.6	56.9	61.2	57.3	60.5	57.7	56.2	62.4	62.1	59.3
CV%	1.4	1.5	0.8	2.9	0.6	1.2	1.7	0.6	0.5	1.5
LSD 0.05	1.1	1.1	0.7	1.9	0.5	1.0	1.3	0.6	0.5	0.9
LSD 0.10	0.9	0.9	0.6	1.6	0.5	0.8	1.1	0.5	0.4	0.7

Table 6. Quality data from 2018 eastern locations.

Variety	Test Weight[1]	Vitreous Kernels[2]	1,000 KWT[3]	Falling Number[4]	Wheat Protein[5]	Flour Extraction[6]	Farinograph Absorption[7]	Farinograph Stability[8]	Loaf Volume[9]
	(lb/bu)	(%)	(gram)	(seconds)	(%)	(%)	(%)	(minutes)	(cubic cm)
Ambush	64.5	97	38.2	414	14.9	67.2	64.4	10.3	1,069
Barlow	64.3	96	35.3	370	14.8	69.7	68.3	8.5	999
Bolles	62.8	97	36.8	419	16.1	65.6	67.4	20.1	1,101
Boost	62.4	97	36.1	424	15.0	66.9	67.3	7.0	1,001
CP3504	63.2	98	37.2	437	14.5	68.9	66.4	7.1	1,006
CP3530	63.3	98	37.5	417	14.4	67.0	66.4	6.9	1,014
CP3616	63.1	98	36.5	412	15.6	68.1	67.0	8.9	996
CP3888	63.3	96	35.4	414	14.6	69.1	65.6	7.4	1,011
Elgin-ND	62.8	95	34.7	414	14.9	67.4	67.5	9.0	1,019
Faller	63.3	97	38.6	410	14.4	68.9	64.8	9.8	1,014
Glenn	64.5	98	34.3	371	15.3	66.4	65.9	10.5	1,051
Lang-MN	64.4	98	32.5	416	14.5	69.1	65.9	8.9	964
LCS Breakaway	65.0	92	37.8	421	14.9	66.7	67.0	7.0	978
LCS Cannon	65.1	95	36.1	403	14.8	70.5	65.4	8.1	1,021
LCS Rebel	64.8	98	39.0	407	15.0	70.1	67.2	7.8	1,053
LCS Trigger	63.7	97	33.7	441	12.7	69.4	66.9	6.4	803
Linkert	63.3	87	37.4	458	15.1	65.5	65.2	14.2	1,033
MN Washburn	62.6	96	34.0	384	14.6	70.9	62.2	10.8	1,008
MS Barracuda	64.1	93	39.4	412	14.9	68.9	66.7	8.1	1,013
MS Camaro	63.8	95	33.0	401	15.6	67.1	66.7	6.6	1,004
MS Chevelle	64.0	96	35.8	380	13.9	68.8	65.4	8.7	1,038
ND VitPro	64.8	98	36.3	412	15.4	69.5	66.4	7.6	1,041
Shelly	63.7	98	34.4	428	13.7	70.2	62.4	10.1	935
Surpass	63.3	81	32.7	371	14.4	68.7	62.9	7.3	1,025
SY Ingmar	63.4	97	34.6	408	15.1	69.7	63.9	7.9	1,050
SY Soren	63.7	97	32.5	422	14.8	68.8	65.1	6.6	1,024
SY Valda	63.9	98	35.6	382	13.9	68.9	64.5	5.4	934
TCG-Climax	65.2	98	32.0	260	15.1	67.9	64.7	9.7	963
TCG-Spitfire	63.5	95	39.5	393	13.5	65.6	65.9	8.3	961

[1] Test weight - Expressed in pounds (lbs) per bushel. A high test weight is desirable. A 58 lb test weight is required for a grade of U.S. No. 1.

[2] Vitreous kernels - Expressed as a percentage of seeds having a vitreous colored endosperm. A high percentage is desirable. US No. 1 DNS requires greater than 75 percent vitreous kernels.

[3] 1,000 KWT- estimate of weight of 1,000 seeds based on a clean 10g sample. Expressed in grams and used to approximate seed size.

[4] Falling Number- Expressed in seconds at a 14 percent moisture basis. It is used as an indicator of sprouting based on elevated enzyme activity. A high falling number is desirable, preferably greater than 400 seconds.

[5] Wheat Protein- measured by NIR at a 12 percent moisture basis. A high protein is desirable for baking quality.

[6] Flour Extraction- Percentage of milled flour recovered from cleaned and tempered wheat. A high flour extraction percentage is desirable.

[7] Farinograph Absorption- measured by NIR at a 14 percent moisture basis. A measure of dough water absorption, expressed as percent. A high absorption is desirable.

[8] Farinograph Stability- A measure of dough strength. It is expressed in minutes above the 500 Brabender unit line during mixing. A high stability is desirable.

[9] Loaf volume- The volume of the pup loaf of bread, expressed in cubic centimeters. A high volume is desirable.

Table 7. Quality data from 2018 western locations.

Variety	Test Weight[1]	Vitreous Kernels[2]	1,000 KWT[3]	Falling Number[4]	Wheat Protein[5]	Flour Extraction[6]	Farinograph Absorption[7]	Farinograph Stability[8]	Loaf Volume[9]
	(lb/bu)	(%)	(gram)	(seconds)	(%)	(%)	(%)	(minutes)	(cubic cm)
Ambush	64.2	97	36.8	398	14.8	68.1	64.1	10.0	1,005
Barlow	64.3	98	33.8	414	14.8	71.2	67.9	9.0	1,025
Bolles	63.0	97	36.5	431	16.6	68.0	67.5	17.3	1,095
Boost	62.5	97	36.4	414	15.0	68.7	67.1	7.7	1,021
CP3504	62.6	96	35.4	454	13.9	70.0	64.9	7.1	948
CP3530	62.0	95	34.5	445	14.3	68.2	65.4	8.2	996
CP3616	63.4	97	37.4	404	15.4	68.0	67.2	9.2	1,053
CP3888	63.0	94	36.2	450	14.8	68.9	65.6	8.4	1,016
Elgin-ND	62.9	97	33.3	377	14.7	69.1	67.5	6.6	1,013
Faller	64.0	99	38.7	397	14.2	71.2	66.8	6.6	1,021
Glenn	65.7	99	33.7	382	15.3	68.6	66.4	11.2	1,029
Lang-MN	64.4	98	33.6	386	15.2	68.4	66.5	7.5	968
Lanning	62.7	93	37.5	404	15.0	67.4	65.5	6.7	1,059
LCS Breakaway	64.5	96	37.0	414	15.6	69.3	66.0	7.1	966
LCS Cannon	64.7	94	33.0	373	14.2	70.2	65.0	9.9	953
LCS Rebel	64.5	98	36.7	405	14.7	70.7	66.0	10.5	1,006
LCS Trigger	62.1	99	31.2	454	13.0	69.6	65.8	7.5	816
Linkert	63.4	97	39.5	452	15.8	68.2	66.3	14.6	1,084
MN Washburn	63.1	98	32.8	405	14.3	71.6	62.2	11.8	953
MS Barracuda	63.4	97	38.1	451	15.6	69.4	66.2	8.5	1,026
MS Camaro	63.9	96	34.8	383	15.2	66.4	66.1	6.4	963
MS Chevelle	63.4	97	33.2	371	13.7	69.1	65.1	11.8	1,000
ND VitPro	65.1	99	35.8	409	15.0	69.0	66.1	7.9	990
Shelly	64.0	98	36.0	444	13.4	69.6	61.9	12.6	894
Surpass	62.8	98	31.3	381	14.9	68.0	62.1	8.5	1,008
SY Ingmar	64.1	97	33.5	414	14.1	71.5	63.8	10.0	989
SY Rockford	61.9	97	35.8	409	14.3	68.8	66.4	8.4	1,011
SY Soren	64.1	97	33.0	422	15.3	68.4	65.5	9.2	1,084
SY Valda	63.2	99	35.5	398	13.8	68.0	64.5	6.9	976
TCG-Climax	63.6	97	32.4	267	16.5	68.3	65.8	8.2	1,028
TCG-Spitfire	62.4	95	38.6	419	14.1	66.7	67.5	8.4	1,035

[1] Test weight - Expressed in pounds (lbs) per bushel. A high test weight is desirable. A 58 lb test weight is required for a grade of U.S. No. 1.

[2] Vitreous kernels - Expressed as a percentage of seeds having a vitreous colored endosperm. A high percentage is desirable. US No. 1 DNS requires greater than 75 percent vitreous kernels.

[3] 1,000 KWT- estimate of weight of 1,000 seeds based on a clean 10g sample. Expressed in grams and used to approximate seed size.

[4] Falling Number- Expressed in seconds at a 14 percent moisture basis. It is used as an indicator of sprouting based on elevated enzyme activity. A high falling number is desirable, preferably greater than 400 seconds.

[5] Wheat Protein- measured by NIR at a 12 percent moisture basis. A high protein is desirable for baking quality.

[6] Flour Extraction- Percentage of milled flour recovered from cleaned and tempered wheat. A high flour extraction percentage is desirable.

[7] Farinograph Absorption- measured by NIR at a 14 percent moisture basis. A measure of dough water absorption, expressed as percent. A high absorption is desirable.

[8] Farinograph Stability- A measure of dough strength. It is expressed in minutes above the 500 Brabender unit line during mixing. A high stability is desirable.

[9] Loaf volume- The volume of the pup loaf of bread, expressed in cubic centimeters. A high volume is desirable.

North Dakota Barley, Oat and Rye Variety Trial Results for 2019 and Selection Guide

Joel Ransom, Rich Horsley, Mike McMullen, Paul Schwarz and Andrew Friskop (NDSU Main Station); Blaine Schatz, Steve Zwinger and Mike Ostlie (Carrington Research Extension Center); Glenn Martin (Dickinson Research Extension Center); John Rickertsen (Hettinger Research Extension Center); Eric Eriksmoen (North Central Research Extension Center, Minot); Bryan Hanson (Langdon Research Extension Center); and Gautam Pradhan (Williston Research Extension Center)

Barley, oat and rye varieties currently grown in North Dakota are described in the following tables. Successful production of these crops depends on numerous factors, including selecting the right variety for a particular area. Characteristics to evaluate in selecting a variety are: yield potential in your area, test weight, straw strength, plant height, reaction to problematic diseases and maturity.

Selecting varieties with good quality also is important to maintain market recognition. Because malting barley usually is purchased on an identity-preserved basis, producers are encouraged to determine which barley varieties are being purchased by potential barley buyers before selecting a variety. When selecting a high-yielding and good-quality variety, use data that summarize several years and locations. Additional data from county sites are available at www.ag.ndsu.edu/varietytrials/ and from each Research Extension Center.

The agronomic data presented in this publication are from replicated research plots using experimental designs that enable the use of statistical analysis. The LSD (least significant difference) numbers beneath the columns in tables are derived from these statistical analyses and apply only to the numbers in the column in which they appear. Differences between two varieties exceeding the LSD value means that with 95 or 90 percent confidence (LSD probability 0.05 or 0.10), the higher-yielding variety has a significant yield advantage.

The abbreviation NS is used to indicate that no statistical difference occurs between varieties. 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 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 this publication only if no portion is deleted, if appropriate footnotes are given and if the order of the data is not rearranged.

North Dakota State University Barley, Oat and Rye Tables #1 - 10 can be found on pages 87-95.

Table 1. 2019 North Dakota barley variety descriptions.

					Rachilla					Reaction to Disease[6]			
			Year	Awn	Hair	Aleurone	Height	Days to	Straw	Stem	Spot-form	Spot	Net
Variety	Use[1]	Origin[2]	Released	Type [3]	Length[4]	Color	(inch)	Head	Strength[5]	Rust	Net Blotch	Blotch	Blotch
Six-rowed													
Lacey	M/F	MN	2000	S	S	White	30	58	4	8	4	3	7
Tradition	M/F	BARI	2003	S	L	White	30	58	3	8	6	3	7
Two-rowed													
AAC Connect	M/F	Canterra	2017	R	L	White	27	62	3	4	5	4	5
AAC Synergy	M/F	Syngenta	2015	R	L	White	27	63	5	4	3	4	4
ABI Balster	M/F	BARI	2015	R	L	White	27	64	6	NA	4	8	NA
Conlon[7]	M/F	ND	1996	S	L	White	27	57	7	8	4	6	3
Explorer	M	Secobra	NA	R	L	White	25	61	4	NA	NA	8	4
ND Genesis	M/F	ND	2015	S	L	White	29	61	5	8	4	4	6
Pinnacle	M/F	ND	2006	S	L	White	29	60	6	8	8	4	6

[1]M = malting; F = feed.
[2]BARI = Busch Agricultural Resources Inc.; MN = University of Minnesota; ND = North Dakota State University.
[3]R = rough; S = smooth.
[4]S = short; L = long.
[5]Straw Strength scores from 1-9, with 1 = strongest and 9 = weakest.
[6]Disease reaction scores from 1-9, with 1 = resistant and 9 = very susceptible, NA – not available.
[7]Lower DON accumulations than other varieties tested.

Table 2. Yield and test weight of barley varieties at three locations in eastern North Dakota, 2017-2019.

	Fargo			Carrington			Langdon			Avg. eastern N.D.		
	Test	Yield		Test	Yield		Test	Yield		Test	Yield	
Variety	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.
	(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		(lb/bu)	(bu/a)	
Six-rowed												
Lacey	49.9	66.4	92.0	43.4	76.5	95.0	48.9	124.3	130.5	47.4	89.1	105.8
Tradition	49.4	81.0	105.7	42.1	82.3	96.2	48.3	121.0	124.9	46.6	94.8	108.9
Two-rowed												
AAC Connect	49.1	74.4	--	43.4	64.6	--	49.7	120.1	--	47.4	86.4	--
AAC Synergy	50.2	74.6	102.8	43.1	60.0	96.9	50.1	122.5	133.4	47.8	85.7	111.0
ABI Balster	51.8	64.2	95.5	41.5	55.5	90.2	49.5	123.9	127.9	47.6	81.2	104.5
Conlon	51.9	63.5	86.4	44.3	50.2	80.0	51.0	109.8	99.5	49.1	74.5	88.6
Explorer	48.8	53.6	88.0	39.5	48.9	85.5	49.1	122.7	126.1	45.8	75.1	99.9
ND Genesis	50.8	79.6	104.1	41.4	50.9	81.3	48.7	123.2	130.6	47.0	84.6	105.3
Pinnacle	49.0	65.5	90.2	39.4	49.6	78.2	50.6	127.3	130.0	46.3	80.8	99.5
Mean	49.7	71.5	96.0	42.3	61.5	87.9	49.4	122.9	125.4	47.1	85.3	103.1
CV %	--	10.5	--	2.1	14.0	--	0.7	3.4	--	1.9	7.8	5.2
LSD 0.05	--	11.8	--	1.3	12.2	--	0.5	5.9	--	1.3	9.6	7.9
LSD 0.10	--	9.9	--	1.1	10.2	--	0.4	4.9	--	0.8	5.9	4.9

Table 3. Plump and protein of barley varieties at three locations in eastern North Dakota, 2019.

	Fargo		Carrington		Langdon		Avg. eastern N.D.	
Variety	Plump	Protein	Plump	Protein	Plump	Protein	Plump	Protein
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Six-rowed								
Lacey	86.9	13.7	83.4	12.1	95.0	12.7	88.4	12.8
Tradition	81.2	13.5	79.2	10.9	92.0	12.8	84.1	12.4
Two-rowed								
AAC Connect	78.8	11.8	80.4	10.8	97.0	13.1	85.4	11.9
AAC Synergy	89.2	11.9	90.9	10.1	97.0	12.4	92.4	11.5
ABI Balster	88.8	12.3	81.0	11.5	94.0	12.2	87.9	12.0
Conlon	95.1	13.5	83.3	11.0	98.0	13.0	92.1	12.5
Explorer	86.3	11.6	75.4	11.0	96.0	12.4	85.9	11.7
ND Genesis	94.0	10.9	78.3	11.1	97.0	11.3	89.8	11.1
Pinnacle	87.3	11.6	72.4	10.7	99.0	12.1	86.2	11.5
Mean	88.9	12.1	83.1	10.7	96.5	12.1	89.5	11.6
CV %	--	--	6.1	7.0	1.3	3.5	3.8	4.0
LSD 0.05	--	--	7.1	1.0	1.8	0.6	5.0	0.7
LSD 0.10	--	--	6.0	0.9	1.5	0.5	3.1	0.4

Table 4. Yield and test weight of barley varieties at four locations in western North Dakota, 2017-2019.

	Dickinson			Hettinger			Minot			Williston			Avg. western N.D.		
	Test	Yield		Test	Yield		Test	Yield		Test	Yield		Test	Yield	
Variety	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.
	(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		(lb/bu)	(bu/a)	
Six-rowed															
Lacey	49.4	70.3	80.7	47.6	101.7	74.0	48.7	96.8	86.3	52.9	85.6	62.8	49.7	88.6	76.0
Tradition	50.0	67.3	79.3	45.7	113.2	78.6	49.5	98.6	91.1	52.6	73.4	61.1	49.4	88.1	77.5
Two-rowed															
AAC Connect	48.5	73.7	--	46.7	109.8	--	48.5	114.7	--	51.8	95.2	--	48.9	98.4	--
AAC Synergy	49.0	73.8	87.5	47.2	117.4	82.6	47.7	106.6	93.2	52.2	75.7	66.6	49.0	93.4	82.5
ABI Balster	48.6	84.8	89.1	46.8	113.3	83.8	49.1	108.3	93.9	52.6	106.4	75.0	49.3	103.2	85.4
Conlon	52.0	60.7	62.1	48.1	89.0	62.9	49.5	105.5	86.6	54.1	92.6	62.0	50.9	86.9	68.4
Explorer	49.4	86.9	91.8	46.1	90.1	81.1	48.3	110.1	95.3	52.2	105.7	71.8	49.0	98.2	85.0
ND Genesis	50.0	69.1	84.3	48.2	124.7	85.0	46.8	109.6	95.1	52.6	109.5	74.4	49.4	103.2	84.7
Pinnacle	51.3	76.4	85.3	46.4	80.9	73.6	47.5	110.8	95.1	54.0	109.4	73.2	49.8	94.4	81.8
Mean	49.7	73.0	82.5	46.9	107.6	80.0	48.0	105.6	92.1	52.9	99.2	68.3	49.5	94.9	80.2
CV %	1.1	11.3	--	2.3	4.4	--	1.6	5.5	--	1.0	8.9	--	1.5	10.1	4.4
LSD 0.05	0.8	11.8	--	1.4	6.7	--	1.3	9.8	--	0.9	14.7	--	0.9	12.4	6.7
LSD 0.10	0.6	9.8	--	1.2	5.6	--	1.1	8.1	--	0.7	12.2	--	0.8	10.3	5.5

Table 5. Plump and protein of barley varieties at four locations in western North Dakota, 2019.

	Dickinson		Hettinger		Minot		Williston		Avg. western N.D.	
Variety	Plump	Protein	Plump	Protein	Plump	Protein	Plump	Protein	Plump	Protein
	------------------(%)------------------									
Six-rowed										
Lacey	88	16.3	95	13.8	98	11.6	88	11.9	92	13.4
Tradition	87	16.9	94	13.4	98	12.2	89	11.9	92	13.6
Two-Rowed										
AAC Connect	90	15.5	92	12.5	97	10.9	85	10.8	91	12.4
AAC Synergy	94	15.1	94	13.0	98	10.1	94	11.5	95	12.4
ABI Balster	89	16.1	90	13.2	98	10.2	87	10.1	91	12.4
Conlon	98	15.8	97	13.0	98	11.6	96	11.5	97	13.0
Explorer	93	15.2	91	13.1	97	10.8	89	9.1	93	12.1
ND Genesis	95	13.9	94	11.9	97	10.3	93	9.9	95	11.5
Pinnacle	97	14.8	93	12.1	98	9.3	96	10.0	96	11.6
Mean	94	15.0	94	12.6	98	10.5	92	10.7	94	12.5
CV %	1.7	1.6	3.1	4.3	0.5	6.1	1.5	6.4	2.2	3.7
LSD 0.05	3	0.4	3.0	0.8	1	1.1	2.2	1.1	2.6	0.6
LSD 0.10	2	0.3	2.5	0.6	1	0.9	1.8	0.9	2.2	0.5

Table 6. 2019 North Dakota oat variety descriptions.

							Reaction to Diseases				
		Year	Grain		Straw		Stem	Crown	Barley	Test	
Variety	Origin[1]	Released	Color	Height	Strength	Maturity[2]	Rust[3]	Rust[3]	Y.Dwf[4]	Weight	Protein[5]
AC Pinnacle	AAFC	1999	White	39	Med.	63	8	8	8	V.good	L
Beach	ND	2004	White	35	M.strg.	63	8	4	6	V.good	M
CDC Dancer	Sask.	2000	White	35	Strong	63	8	6	8	V.good	M
CDC Minstrel	Sask.	2006	White	34	M.strg.	64	8	8	8	Good	M
CS Camden	Canterra	2016	White	33	Strong	64	8	6	NA	Good	NA
Deon	MN	2013	Yellow	37	Strong	65	8	1	2	V.good	NA
Hayden	SD	2014	White	36	Med.	62	8	7	NA	V.good	NA
HiFi	ND	2001	White	35	Strong	63	4	8	2	Good	M
Hytest	SD	1986	White	38	M.strg.	62	8	6	8	V.good	H
Jury	ND	2012	White	34	M.strg.	64	1	8	4	V.good	M
Killdeer	ND	2000	White	32	Strong	63	8	6	4	Good	M
Leggett	AAFC	2005	White	33	Strong	63	3	1	8	Good	M
Newburg	ND	2011	White	38	Med.	62	1	8	4	Good	M
Otana	MT	1977	White	36	M.weak	63	8	8	8	V.good	M/L
Paul[6]	ND	1994	Hull-less	37	Strong	68	1	4	2	Good	H
Rockford	ND	2008	White	38	Strong	65	8	8	4	V.good	M
Souris	ND	2006	White	33	Strong	63	6	8	6	V.good	M
Stallion	SD	2006	White	34	Med.	64	8	3	NA	V.good	M
Warrior	SD	2018	White	32	Strong	62	NA	1	NA	V.good	M

[1] AAFC = Agriculture & Agri-Food Canada; MN = University of Minnesota; ND = North Dakota State University; SD = South Dakota State University; Sask. = University of Saskatchewan; MT = Montana State University.
[2] Days after planting.
[3] Disease reaction scores from 1-9, with 1 = resistant and 9 = very susceptible.
[4] Disease reaction scores from 1-9, with 1 = resistant and 9 = very susceptible, NA – not available.
[5] H = high; M = medium; L = low; NA = not available.
[6] Hull-less variety.

Table 7. Yield and test weight of oat varieties at five locations in eastern North Dakota, 2017-2019.

	Fargo		Casselton		Verona		Carrington			Langdon			Average Eastern N.D.	
	Test	Yield	Test	Yield	Test	Yield	Test	Yield		Test	Yield		Test	Yield
Variety	Wt.	2019	Wt.	2019	Wt.	2019	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.	Wt.	2019
	(lb/bu)	(bu/a)	(lb/bu)	(bu/a)	(lb/bu)	(bu/a)	(lb/bu)	-----(bu/a)-----		(lb/bu)	-----(bu/a)-----		(lb/bu)	(bu/a)
AC Pinnacle	36.9	70.8	35.3	53.2	32.4	48.1	32.6	121.6	122.7	38.9	151.1	175.3	35.2	89.0
Beach	38.9	121.7	41.7	102.4	40.6	73.9	34.6	114.0	110.6	40.6	151.6	172.1	39.3	112.7
CDC Dancer	37.6	111.6	38.7	59.2	36.9	51.8	33.7	126.6	128.6	39.5	188.5	187.7	37.3	107.5
CDC Minstrel	33.3	100.4	32.1	67.3	25.9	23.6	28.6	115.8	118.5	37.2	176.9	192.2	31.4	96.8
CS Camden	33.7	108.3	34.3	59.5	28.1	39.1	30.5	142.0	130.4	36.3	188.0	208.5	32.6	107.4
Deon	38.3	113.0	36.3	74.0	35.6	72.2	32.9	130.6	129.1	38.0	184.0	189.7	36.2	114.7
Hayden	37.7	76.9	38.6	76.4	29.3	30.6	35.6	133.9	126.1	40.3	176.8	180.0	36.3	98.9
HiFi	35.9	95.2	34.0	49.9	26.9	29.1	31.0	100.1	108.3	38.5	154.6	174.8	33.3	85.8
Hytest	39.4	109.6	41.5	89.7	37.8	52.6	36.3	111.7	117.4	40.5	159.5	146.8	39.1	104.6
Jury	34.3	72.2	34.7	68.8	28.3	37.0	29.3	111.3	118.6	37.6	191.8	191.8	32.8	96.2
Killdeer	33.5	78.8	35.5	64.8	26.6	40.0	29.4	111.6	120.0	38.0	185.3	189.7	32.6	96.1
Leggett	37.8	129.2	39.2	114.1	37.1	89.2	33.1	118.5	112.5	39.5	189.3	193.0	37.3	128.1
Newburg	34.6	77.6	32.9	32.1	29.4	54.8	30.8	117.6	116.4	37.8	167.0	174.6	33.1	89.8
Otana	32.7	65.2	33.1	66.6	25.6	24.6	27.5	96.0	113.1	39.5	175.4	184.1	31.7	85.6
Paul1	43.7	35.2	43.2	21.0	40.6	14.2	38.5	47.9	68.5	44.1	129.4	147.7	42.0	49.5
Rockford	35.4	60.3	32.1	43.4	26.2	25.9	30.9	107.7	115.9	40.4	167.6	179.0	33.0	81.0
Souris	36.4	87.7	34.9	59.6	27.8	21.8	31.4	105.4	112.3	38.5	166.2	173.5	33.8	88.1
Stallion	37.8	91.3	38.5	75.1	37.4	93.2	35.1	126.3	125.5	40.8	164.8	172.2	37.9	110.1
Warrior	36.8	127.5	37.8	99.0	37.3	104.0	33.2	130.3	--	38.7	162.7	--	36.8	124.7
Mean	37.4	112.9	38.2	83.3	34.7	66.0	33.2	115.1	116.4	39.2	169.5	179.6	35.4	98.2
CV %	3.1	17.4	2.3	16.0	4.0	22.2	4.2	9.0	--	1.1	4.1	--	5.4	15.8
LSD 0.05	1.9	31.8	1.7	26.7	2.3	23.6	2.0	14.5	--	0.7	11.5	--	2.4	19.6
LSD 0.10	1.6	26.5	1.4	22.3	1.9	19.7	1.7	12.1	--	0.6	9.6	--	2.0	16.4

[1] Hull-less varieties. When comparing yield of hull-less oat varieties with varieties with hulls, multiply the yield of the hull-less oats by 1.35 (the hull of a hulled kernel comprises 35 percent of the weight).

Table 8. Yield and test weight of oat varieties at four locations in western North Dakota, 2017-2019.

	Dickinson			Hettinger		
	Test	Yield		Test	Yield	
Variety	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.
	(lb/bu)	(bu/a)		(lb/bu)	(bu/a)	
AC Pinnacle	38.8	102.5	100.7	34.8	142.1	105.7
Beach	40.1	108.5	87.4	37.2	153.9	98.6
CDC Dancer	39.5	102.3	90.7	35.7	172.9	114.7
CDC Minstrel	37.6	127.5	101.2	33.3	183.6	116.6
CS Camden	36.5	102.4	95.4	32.3	173.9	120.4
Deon	38.6	149.8	107.1	34.8	160.6	107.1
Hayden	39.8	129.5	109.3	36.7	174.1	118.2
HiFi	38.0	118.0	99.0	35.4	161.7	104.4
Hytest	39.5	90.5	86.0	38.3	146.4	98.1
Jury	38.5	122.6	97.0	33.9	162.2	104.2
Killdeer	37.6	125.7	105.6	34.2	150.5	105.7
Leggett	39.1	97.9	88.1	35.2	160.5	108.6
Newburg	37.8	107.5	87.6	33.3	159.1	104.1
Otana	39.5	108.0	94.1	35.6	159.3	107.9
Paul[1]	43.5	87.5	71.0	40.3	105.5	72.5
Rockford	39.6	123.4	97.9	37.3	167.7	118.7
Souris	37.6	110.9	94.5	35.3	152.3	110.0
Stallion	40.4	113.7	100.2	36.4	144.9	99.9
Warrior	38.3	97.0	--	32.3	168.1	--
Mean	39.0	111.9	95.2	35.4	157.9	106.4
CV %	1.5	14.6	--	4.3	7.3	--
LSD 0.05	0.8	23.2	--	2.1	16.2	--
LSD 0.10	0.7	19.4	--	1.8	13.5	--

[1] Hull-less varieties. When comparing yield of hull-less oat varieties with varieties with hulls, multiply the yield of the hull-less oats by 1.35 (the hull of a hulled kernel is 35 percent of the weight).

Minot			Williston			Average Western N.D.		
Test	Yield		Test	Yield		Test	Yield	
Wt.	2019	3 Yr.	Wt.	2019	3 Yr.	Wt.	2019	3 Yr.
(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		(lb/bu)	(bu/a)	
37.3	128.0	136.3	44.8	166.3	107.6	38.9	134.7	112.6
39.7	118.7	136.5	45.3	138.0	92.6	40.6	129.8	103.8
36.5	115.1	125.4	44.6	186.1	111.5	39.1	144.1	110.6
36.2	123.8	129.1	42.7	172.8	104.1	37.4	151.9	112.8
34.5	126.4	136.0	40.5	195.0	113.4	36.0	149.4	116.3
37.3	117.9	126.6	43.4	176.7	109.4	38.5	151.3	112.6
38.1	123.9	139.5	44.6	176.3	106.7	39.8	150.9	118.4
36.6	117.6	127.6	43.5	164.0	101.3	38.4	140.3	108.1
37.9	119.4	125.2	45.7	127.1	78.3	40.3	120.9	96.9
38.2	114.5	117.9	42.2	183.5	112.2	38.2	145.7	107.8
38.3	113.1	119.8	42.2	194.7	113.5	38.1	146.0	111.1
36.2	122.3	132.4	43.9	190.7	112.2	38.6	142.9	110.3
38.6	116.5	109.6	43.7	147.7	99.4	38.3	132.7	100.2
38.5	99.7	116.5	42.7	171.0	106.5	39.1	134.5	106.2
42.7	82.4	95.2	51.8	120.1	72.7	44.6	98.9	77.9
38.4	121.6	124.3	45.0	184.6	106.3	40.1	149.3	111.8
38.0	102.9	118.9	44.2	162.2	100.0	38.8	132.1	105.8
36.6	125.7	132.0	42.9	156.6	97.0	39.1	135.2	107.3
36.5	120.5	--	43.4	166.0	--	37.6	137.9	--
37.7	116.3	124.9	44.1	167.3	102.5	39.0	138.3	107.2
2.3	8.0	--	1.4	10.8	--	2.0	7.6	5.2
1.4	14.8	--	1.0	28.8	--	1.0	13.4	7.2
1.2	12.4	--	0.8	24.1	--	0.8	11.2	6.0

Table 9. 2019 North Dakota winter rye variety descriptions.

Variety	Origin[1]	Year Released	Height (inches)	Straw Strength	Days to Flowering	Seed Color	Seed Size	Winter Hardiness
AC Hazlet	Canada	**2006**	**43**	**Good**	**152**	**Bl-grn.**	**Small**	**Good**
Aroostok	USDA	**1981**	**45**	**Fair**	**145**	**Tan**	**Small**	**V.good**
Bono[3]	KWS Germany	**2013**	**37**	**Good**	**151**	**Green**	**Med.**	**Good**
Brasetto[3]	KWS Germany	**2008**	**36**	**V.good**	**151**	**Bl-grn.**	**Large**	**Good**
Dacold	ND	**1989**	**42**	**Good**	**154**	**Bl-grn.**	**Med.**	**Good**
Hancock	WI	**1979**	**43**	**Good**	**149**	**Tan**	**Large**	**Fair[4]**
ND Dylan	ND	**2016**	**45**	**Good**	**150**	**Blue**	**Med.**	**V.good**
ND Gardner	ND	**2019**	**44**	**Fair**	**144**	**Bl-grn.**	**Small**	**V.good**
Rymin	MN	**1973**	**42**	**V.good**	**150**	**Grn-gray**	**Large**	**Fair[4]**
Spooner	WI	**1993**	**44**	**V.good**	**149**	**Tan**	**Large**	**Good**
Wheeler	MI	**1971**	**47**	**Fair**	**152**	**Tan**	**Large**	**Fair**

[1] ND = North Dakota State University; WI = University of Wisconsin; MN = University of Minnesota; MI = Michigan State University.
[3] Hybrid.
[4] Varieties with fair winter hardiness should not be seeded in bare soil.

Table 10. Yield and test weight of winter rye varieties at five locations in North Dakota, 2017-2019.

	Carrington			Carrington (organic)			Hettinger		
	Test	Seed Yield		Test	Seed Yield		Test	Seed Yield	
Variety	Wt.	2019	3-yr.	Wt.	2019	3-yr.	Wt.	2019	3-Yr.
	(lb/bu)	(bu/a)		(lb/bu)			(lb/bu)	(bu/a)	
AC Hazlet	50.8	53.0	61.3	52.1	68.5	74.5	53.3	68.6	64.6
Aroostok	49.6	32.3	38.3	50.7	53.8	48.9	52.1	54.1	45.0
Bono	50.2	60.7	--	51.8	83.9	--	55.5	98.2	--
Brasetto	47.6	46.4	71.6	49.8	61.7	76.6	53.1	89.9	82.1
Dacold	50.2	43.9	57.2	51.9	67.0	68.9	47.9	43.8	52.7
Hancock	50.6	43.8	54.5	51.2	53.9	63.8	51.0	47.0	47.6
ND Dylan	49.4	45.5	64.2	51.1	69.3	71.8	53.6	69.5	55.2
ND Gardner	49.7	42.3	--	51.3	57.8	--	52.9	61.7	50.5
Rymin	50.3	48.9	66.3	51.9	68.9	75.8	52.5	65.0	63.3
Spooner	49.3	44.6	50.1	50.4	60.6	59.1	53.1	63.2	52.4
Wheeler	46.3	9.8	15.3	44.8	20.6	22.2	52.0	27.9	34.8
Mean	49.5	42.8	53.2	50.6	60.5	62.4	52.5	62.6	54.8
CV %	0.9	16.0	--	0.9	11.7	--	2.3	6.9	--
LSD 0.05	0.7	9.9	--	0.7	10.2	--	1.7	6.2	--
LSD 0.10	0.6	8.2	--	0.6	8.5	--	1.4	5.2	--

Langdon			Minot			Average		
Test	Seed Yield		Test	Seed Yield		Test	Seed Yield	
Wt.	2019	3-Yr.	Wt.	2019	3-yr.	Wt.	2019	3-yr.
(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		(lb/bu)	(bu/a)	
55.7	71.8	78.0	57.4	75.1	69.6	53.9	67.4	69.6
53.8	53.2	53.8	56.4	59.1	42.6	52.5	50.5	45.7
54.8	89.7	--	57.5	105.6	--	54.0	87.6	--
53.6	82.6	103.2	56.1	101.5	--	52.0	76.4	83.2
54.7	58.8	66.4	57.5	76.9	59.4	52.4	58.1	60.9
53.5	44.3	59.7	57.1	62.5	59.2	52.7	50.3	57.0
54.8	71.7	79.1	57.2	77.3	65.1	53.2	66.7	67.1
54.4	55.8	64.0	56.3	65.0	54.0	52.9	56.5	54.9
55.2	65.9	76.2	57.2	75.7	69.4	53.4	64.9	70.2
54.5	61.2	61.9	56.1	60.5	51.2	52.7	58.0	54.9
50.2	22.2	37.9	52.7	30.0	31.4	49.2	22.1	28.3
54.1	61.6	68.0	56.5	71.7	55.8	52.6	59.9	56.7
1.2	11.7	--	1.8	6.4	--	2.0	10.2	7.8
1.0	10.4	--	1.8	7.8	--	1.2	7.1	5.2
0.8	8.6	--	1.5	6.5	--	1.0	5.9	4.4

North Dakota Durum Wheat Variety Trial Results for 2019 and Selection Guide

Joel Ransom, Elias Elias, Andrew Friskop, Tim Friesen, Zhaohui Liu, Shaobin Zhong and Frank Manthey (NDSU Main Station); Blaine Schatz and Mike Ostlie (Carrington Research Extension Center); Glenn Martin (Dickinson Research Extension Center); Bryan Hanson (Langdon Research Extension Center); John Rickertsen (Hettinger Research Extension Center); Eric Eriksmoen (North Central Research Extension Center, Minot); Gautam Pradhan (Williston Research Extension Center).

Durum was planted on 720,000 acres in North Dakota in 2019, down 3.5% from 2018. The average yield was 42 bushels per acre (bu/a), up slightly from 2018. The most commonly grown varieties in 2019 and the percent of the acreage they occupied were Joppa (30), Divide (21), Alkabo (8), Carpio (6), VT Peak (6) and Mountrail (5).

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% moisture, while protein content is reported at 12% 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 significant 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% 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% 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.

North Dakota State University Durum
Tables #1 - 5 can be found on pages 97-101.

Table 1. Descriptions and agronomic traits of durum wheat varieties grown in North Dakota, 2019.

						Reaction to Disease[5]				
	Agent or Origin[1]	Year Released	Height (inches)[2]	Straw Strength[3]	Days to Heading[4]	Stem Rust	Leaf Rust	Foliar Disease	Bact. Leaf Streak	Head Scab
AC Commander	Can.	2002	31	5	60	1	1	6	NA	NA
Alkabo	ND	2005	33	2	61	1	1	5	7	6
Alzada	WB	2004	28	6	59	1	1	8	NA	9
Ben	ND	1996	35	3	60	1	1	4	7	8
Carpio	ND	2012	34	5	63	1	1	5	6	5
CDC Verona	Can.	2010	32	4	61	1	1	4	NA	8
Divide	ND	2005	35	5	62	1	1	5	7	5
Grenora	ND	2005	32	5	60	1	1	5	7	6
Joppa	ND	2013	33	5	61	1	1	5	7	5
Lebsock	ND	1999	33	3	60	1	1	5	7	6
Maier	ND	1998	32	5	61	1	1	5	NA	8
Mountrail	ND	1998	34	5	62	1	1	5	7	8
ND Grano[6]	ND	2017	34	5	63	1	1	NA	7	6
ND Riveland[6]	ND	2017	34	4	61	1	1	NA	7	5
Pierce	ND	2001	32	5	61	1	1	6	7	8
Rugby	ND	1973	36	5	60	1	1	4	NA	8
Strongfield[6]	Can.	2004	34	6	62	1	1	6	NA	8
Tioga	ND	2010	29	4	61	1	1	5	7	6
VT Peak	Viterra	2010	25	6	61	NA	NA	NA	NA	NA

[1] Refers to agent or developer: Can. = Agriculture Canada, WB = Westbred, ND = North Dakota State University.
[2] Plant height was obtained from the average of six variety trials in 2018.
[3] 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.
[4] Days to Heading = the number of days from planting to head emergence from the boot. Averaged from several locations in 2018.
[5] Disease reaction scores from 1-9, with 1 = resistant and 9 = very susceptible. NA = Not adequately tested. Foliar Disease = reaction to tan spot and septoria leaf spot complex.
[6] Low cadmium accumulating variety.

Table 2. Durum wheat variety quality descriptions, milling and processing data averaged for five years (2014-2018) from drill strips (32 locations/year).

	Test	Vitreous	Large	Falling	Wheat	Gluten	Pasta	Spaghetti	Overall
Variety	**Weight**	**Kernels**	**Kernels**	**Number**	**Protein[1]**	**Index[2]**	**Color[3]**	**Firmness**	**Quality[4]**
	(lb/bu)	**(%)**	**(%)**	**(sec)**	**(%)**		**(1-12)**	**(g-cm)**	
Alkabo	61.4	80	56	400	13.6	44	8.7	3.8	good
Alzada	59.6	87	66	475	14.1	84	8.3	4.2	good
Carpio	61.4	77	63	456	13.6	91	8.6	4.0	good
Divide	61.0	84	56	447	13.8	71	8.4	3.9	good
Joppa	61.3	83	48	428	13.3	81	8.8	3.9	good
Maier	60.8	87	53	413	14.3	52	8.4	4.1	good
Mountrail	60.7	87	48	435	13.8	20	8.1	3.7	fair
ND Grano[5]	61.6	83	50	461	13.8	64	8.9	4.0	good
ND Riveland[5]	61.3	88	60	442	13.8	79	8.7	4.0	good
Strongfield	60.6	85	57	436	14.3	63	8.2	4.0	good
Tioga	60.9	83	61	401	13.7	73	8.4	4.0	good
Average	61.0	84	56	436	13.8	66	8.5	4.0	

For all numbered footnotes, refer to bottom of Table 3.

Table 3. Durum wheat variety quality descriptions, milling and processing data for 2018 at all locations from drill strips.

	Test	Vitreous	Large	Falling	Wheat	Gluten	Pasta	Spaghetti	Overall
Variety	**Weight**	**Kernels**	**Kernels**	**Number**	**Protein[1]**	**Index[2]**	**Color[3]**	**Firmness**	**Quality[4]**
	(lb/bu)	**(%)**	**(%)**	**(sec)**	**(%)**		**(1-12)**	**(g-cm)**	
Alkabo	62.1	87	67	478	14.1	22	7.9	4.0	good
Alzada	60.5	90	72	519	15.1	64	7.3	4.5	good
Carpio	62.4	83	74	532	14.2	79	7.6	4.1	good
Divide	61.9	87	68	540	14.5	50	7.5	3.8	good
Joppa	62.3	90	63	514	13.9	62	8.0	3.8	good
Maier	61.4	93	59	521	15.2	32	7.7	4.1	good
Mountrail	61.6	90	60	494	14.6	11	7.2	3.8	fair
ND Grano[5]	62.6	88	66	533	14.3	43	8.2	3.9	good
ND Riveland[5]	62.1	93	71	503	14.1	57	7.9	4.0	good
Strongfield	62.0	88	69	528	15.1	46	7.3	4.2	good
Tioga	62.0	89	72	498	14.3	48	7.5	4.1	good
Average	61.9	89	67	515	14.5	47	7.6	4.0	

[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] Low cadmium accumulating variety.

Table 4. Yield of durum wheat varieties at six Research Extension Centers in North Dakota, 2017-2019.

	Carrington		Langdon		Dickinson		Hettinger		Minot		Williston		Average	
Variety	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**	**2019**	**3 Yr.**
	-----(bu/a)-----													
AC Commander	34.7	45.1	64.7	69.8	53.6	44.3	57.5	44.3	45.7	55.2	63.4	42.6	53.3	50.2
Alkabo	37.1	45.9	66.5	73.5	46.8	47.3	73.6	48.1	40.3	61.0	63.0	42.0	54.5	53.0
Alzada	22.3	38.4	59.4	57.2	50.2	41.2	48.2	39.3	35.3	51.5	54.2	39.0	44.9	44.4
Ben	33.5	45.3	67.5	71.9	52.7	47.4	60.3	42.4	49.1	61.9	63.0	39.5	54.3	51.4
Carpio	50.5	51.4	69.7	81.4	47.0	46.0	63.7	47.4	52.4	69.0	59.8	40.2	57.2	55.9
CDC Verona	43.8	50.0	67.2	73.7	49.7	47.9	67.7	46.6	44.5	57.4	65.4	40.7	56.4	52.7
Divide	45.7	52.3	68.4	78.8	49.7	48.4	70.8	46.1	56.7	65.6	63.6	41.2	59.1	55.4
Grenora	38.6	50.9	70.1	78.5	51.5	47.5	67.9	46.5	44.2	60.1	67.6	40.6	56.6	54.0
Joppa	45.5	53.2	74.9	82.5	51.0	50.3	66.2	45.5	46.0	70.1	61.4	41.5	57.5	57.2
Lebsock	40.7	48.9	69.8	73.5	53.9	48.3	64.8	45.3	41.6	63.4	--	--	55.8	53.4
Maier	36.0	47.9	68.9	74.2	47.7	45.9	62.7	44.0	43.0	59.9	65.4	41.4	54.0	52.2
Mountrail	36.0	47.5	67.9	77.5	52.1	50.9	66.9	47.8	55.3	68.9	67.6	41.7	57.6	55.7
ND Grano	39.8	53.6	69.8	76.7	53.9	50.4	68.5	46.3	50.9	71.9	63.7	39.7	57.8	56.4
ND Riveland	53.2	55.0	71.4	80.2	45.8	46.1	73.0	48.9	36.5	62.7	68.5	41.4	58.1	55.7
Pierce	39.4	48.8	69.5	80.2	47.2	45.5	69.6	45.5	41.7	58.5	61.6	39.5	54.8	53.0
Rugby	39.4	47.3	62.7	69.5	44.5	46.5	59.8	41.8	30.4	55.8	64.4	38.9	50.2	50.0
Strongfield	42.6	49.1	63.5	70.4	49.8	48.0	67.0	48.2	48.5	53.3	63.4	41.9	55.8	51.8
Tioga	44.2	53.0	69.4	79.4	52.1	49.4	64.5	43.5	47.3	58.7	66.1	43.9	57.3	54.6
VT Peak	48.0	52.1	72.4	77.0	50.5	46.9	72.4	49.7	47.9	69.1	64.3	41.7	59.3	56.1
Mean	42.9	49.3	70.2	74.9	51.1	47.3	67.6	46.1	44.6	61.8	64.7	41.0	56.8	53.4
CV %	8.1	--	5.6	--	9.3	--	7.6	--	13.2	--	9.8	--	7.5	5.6
LSD 0.05	4.8	--	5.5	--	6.6	--	7.2	--	9.5	--	10.2	--	5.0	3.4
LSD 0.10	4.0	--	4.6	--	5.6	--	6.1	--	8.0	--	8.6	--	4.1	2.9

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

	Carrington		Langdon	Dickinson		Hettinger		Minot	
Variety	**Test Wt.**	**Protein**	**Test Wt.**	**Test Wt.**	**Protein**	**Test Wt.**	**Protein**	**Test Wt.**	**Protein**
	lb/bu	**%**	**lb/bu**	**lb/bu**	**%**	**lb/bu**	**%**	**lb/bu**	**%**
AC Commander	49.4	16.2	58.8	60.5	15.6	56.8	14.4	60.0	15.1
Alkabo	51.3	15.1	60.2	60.6	15.2	57.6	13.5	61.1	14.9
Alzada	48.3	16.0	58.7	59.9	15.5	54.9	14.4	59.6	15.4
Ben	50.3	16.0	60.7	60.6	15.4	58.0	14.5	60.9	15.8
Carpio	53.7	14.8	61.1	60.1	15.8	57.5	13.6	62.3	13.8
CDC Verona	53.9	16.1	60.2	60.0	16.3	57.4	14.6	60.3	16.5
Divide	53.6	15.6	59.9	60.6	15.2	58.4	13.8	62.3	15.2
Grenora	51.5	15.8	59.1	59.8	14.9	56.9	14.2	59.4	15.3
Joppa	52.7	15.0	60.9	60.4	14.5	58.3	12.9	61.8	15.1
Lebsock	52.4	15.8	61.1	61.0	15.1	58.1	13.4	63.1	15.2
Maier	51.8	16.4	60.9	60.4	15.8	57.2	14.8	60.4	16.7
Mountrail	49.4	15.8	58.5	60.3	15.9	57.9	13.2	61.8	14.2
ND Grano	51.8	15.4	60.7	60.8	15.1	56.9	13.5	61.2	15.1
ND Riveland	54.7	14.8	60.3	60.6	15.7	58.2	13.4	61.3	16.0
Pierce	52.4	15.2	60.9	61.3	15.1	59.2	13.8	60.5	15.2
Rugby	52.0	15.2	60.3	60.4	16.0	57.7	14.1	59.6	17.6
Strongfield	50.5	17.3	60.1	59.8	16.8	56.9	14.5	61.2	16.6
Tioga	52.1	14.6	60.5	60.4	15.1	58.0	13.6	59.2	15.9
VT Peak	54.0	15.7	61.7	61.0	15.4	59.2	14.1	62.3	15.4
Mean	52.4	15.5	60.5	60.5	15.5	57.8	13.9	60.6	15.6
CV %	1.9	3.0	0.8	0.9	2.6	1.3	4.2	2.1	5.0
LSD 0.05	1.4	0.7	0.7	0.8	0.6	1.1	0.8	2.1	1.3
LSD 0.10	1.2	0.5	0.6	0.6	0.5	0.9	0.7	1.7	1.1

Williston		Average	
Test Wt.	Protein	Test Wt.	Protein
lb/bu	%	lb/bu	%
61.6	17.2	57.9	15.7
62.5	16.1	58.9	14.9
61.3	16.9	57.1	15.6
62.9	16.6	58.9	15.7
62.1	16.5	59.5	14.9
61.0	17.2	58.8	16.1
62.1	16.6	59.5	15.3
61.4	15.8	58.0	15.2
62.0	15.8	59.4	14.6
--	--	58.8	15.2
62.3	16.9	58.8	16.1
61.9	16.4	58.3	15.1
62.6	16.6	59.0	15.1
61.7	16.6	59.5	15.3
62.4	16.6	59.5	15.2
62.3	16.3	58.7	15.8
61.9	17.4	58.4	16.5
62.6	15.5	58.8	14.9
63.1	16.8	60.2	15.5
62.1	16.6	59.0	15.4
0.5	4.7	1.3	3.0
0.5	1.3	0.9	0.6
0.4	1.1	0.8	0.5

NOTES

Minnesota Wheat Research
& Promotion Council
2600 Wheat Drive • Red Lake Falls, MN 56750
Ph: (218) 253-4311
www.mnwheat.org

University of Minnesota Extension
240 Coffey Hall • 1420 Eckles Ave.
St. Paul, MN 55108-6068
Ph: (612) 624-1222
www.extension.umn.edu

Minnesota Soybean Research
& Promotion Council
151 Saint Andrews Ct # 710
Mankato, MN 56001
Ph: (507) 388-1635   www.mnsoybean.com

The report of research projects are advised by the Small Grains Research & Communications Committee and funded in part by the Minnesota Wheat Checkoff. Sponsors that help fund this book are the Minnesota Wheat Research & Promotion Council, the University of Minnesota and Minnesota Soybean Research and Promotion Council.